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In the eyes of the beholder: The effect of participant diversity on perceived merits of collaborative innovations

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ABSTRACT

Technological innovations often involve collaboration among firms from diverse industries. Existing literature has largely viewed participant diversity as a conduit for non-redundant information or complementary resources, thereby affecting the *ex-post* outcomes of innovation projects. However, it is seldom examined how projects are initially evaluated during the resource competition stage. In this study, we develop a theory of diversity as a cognitive primer, asking how collaborators from diverse backgrounds may affect external reviewers' *ex-ante* evaluation of potential merits of an innovation project. We argue that there are two logics at work in the process of evaluating innovations: the logic of technological advancement and the logic of market value. When an innovation project involves firms from diverse industries, it may be perceived as having a fuzzier market identity, hence making it less appealing to reviewers who hold with the strong market value logic. However, the penalty associated with participant diversity should be less pronounced among reviewers who hold the technological advancement logic. We also expect the relationship between participant diversity and reviewers' ratings to be moderated by project novelty and fuzziness of technology category. We find support for our hypotheses with a sample of collaborative innovation projects funded by the Advanced Technology Program of the U.S. National Institute of Standards and Technology.

1. Introduction

Innovation and management scholars have increasingly emphasized the importance of collaborative innovation among firms from different domains (Ahuja, 2000; Davis and Eisenhardt, 2011; Powell et al., 1996). In particular, prior research has highlighted that heterogeneity of participants' functional, technological, or industry backgrounds may affect innovation outcomes. The central theme in this line of research is that collaborative innovations among participants with heterogeneous knowledge sources could help generate non-redundant information flows, stimulate meaningful debates (Eisenhardt, 1989), and pull together complementary resources and capabilities (Fleming et al., 2007; Mowery et al., 1998), thus leading to better innovation performance.

In this study, we contribute to this line of research by examining the role of participant diversity in innovation from a different perspective. Instead of focusing on how participant diversity may affect the *ex-post* outcomes of innovation projects through the process of collaboration, we ask how participant diversity is associated with the *ex-ante* perceptions of key audiences in the stage of evaluation—especially evaluations from external resource providers or expert reviewers. Organizations continuously make critical resource allocations among potential projects, and resource providers consistently face the difficult task of determining which projects are worth investing in. Yet, research has shown that evaluators' decisions are not always a function of objective merits of the focal project, but rather an outcome of complex social-cognitive processes (e.g., Hsu, 2006; Lamont, 2009; Rivera, 2015; Simcoe and Waguespack, 2011; Tan and Roberts, 2010; Zuckerman, 1999). Evaluators' perceptions may shape project selection and resource allocation, thereby influencing the amount of innovation exploration by organizations. Given that evaluation is an important step for essentially any innovative endeavor, it is surprising how little we know regarding the effect of participant diversity on *ex-ante* evaluations.

We believe that it is critical to ask what happens when multiple projects compete for resources and evaluators' attention for two reasons. First, an innovation project might be underfunded or dismissed if it does not receive favorable assessments from key audiences, and evaluators' *ex-ante* biases may thus shape organizations' innovation outcomes by underinvesting in promising innovation projects. Second, initial evaluation outcomes may also affect motivation and resource

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allocation during the actual developmental phase of a project and thereby shape *ex-post* realized collaborative innovation performance. By highlighting the role of participant diversity as a signal or cognitive primer in the evaluation of collaborative innovations, this study complements existing views of diversity as conduits of information or resources, and addresses an important gap in the literature.

In environments where external audiences lack adequate information to judge the intrinsic quality of an offer or candidate, they rely on external attributes of the focal offer or the organization's observable qualities as a signal to make a judgment (Spence, 1974). Such attributes may include a product's brand name and price (Dawar and Parker, 1994), a firm's status (Podolny, 1994), or an organization's partnership and alliance portfolio (Chang, 2004; Stuart et al., 1999). In the context of collaborative innovations in which the process is technically complex and the outcome is often highly uncertain, we expect that external reviewers will pay particular attention to externally observable traits or affiliations of innovation projects. The composition of the collaboration team should thus be associated with the project's perceived value or potential. Determining the type of composition that will be valued more favorably, however, depends upon the primary logic held by the evaluators.

As Utterback (1971: 77) points out, to qualify as an innovation, an idea has to be "carried far enough to begin to have an economic impact." In other words, an innovation concerns not just the creation of new things, but also the creation of new value from a market perspective. The evaluation of an innovation, therefore, inherently involves two different logics: the logic of technological advancement[1] and the logic of market value. The tension between technological advancement and market value is reflected in the divergence of different theoretical traditions, particularly when juxtaposing the mostly optimistic view of diversity in the innovation literature with cautions against diversity from the emerging literature of categorization in organization studies. While some innovation scholars have cautioned against potentially higher risk associated with highly innovative ideas that involve novel recombination (e.g., Wang et al., 2017), the innovation literature has largely suggested that technological advancement comes from recombining or reconfiguring preexisting diverse knowledge elements (Galunic and Rodan, 1998; Katila and Ahuja, 2002). Following this perspective, collaborative innovation projects that involve more diverse participants should be associated with higher evaluations for their technical potential. However, based on the ecological principle of allocation (Bogaert et al., 2010; McKendrick et al., 2003), the literature on categorization in organization studies stresses the importance of category coherence, and cautions that category fuzziness may reduce the perceived value of an offer (Hsu, 2006; Zuckerman, 1999). Although the focus of past categorization research has been on the focal offer's categorical purity or fuzziness, in this study we extend this insight to the composition of a collaboration team's diversity, and propose that participant diversity may cause confusion among the audience, thereby lowering the perceived value of the innovation project.

The evaluation of innovation projects with diverse participants thus poses an uneasy tension for management scholars. That is, the innovation literature mostly touts the importance of diversity in fostering new ideas, while the literature on categorization implies that pulling together a diverse team might be a risky move. Therefore, how participant diversity is associated with the *ex-ante* evaluation of a collaborative innovation is not only a question of empirical significance, but also a theoretical puzzle that has not yet been well understood. In fact, authors from a variety of disciplines have written about both the potential merits of interdisciplinary research and the difficulty in evaluating such work (Aboelela et al., 2007; Campbell, 2005; Naiman, 1999; Wang et al., 2017; Lamont et al., 2006). The implication from this line of research is that, while innovation involving diverse participants may potentially create greater technological or scientific breakthroughs, such efforts may also encounter hurdles in obtaining funding or being published in the first place.

In this paper, we attempt to contribute to our understanding of the diversity-innovation relationship by developing and testing a theoretical framework that explains why, and under what conditions, participant diversity is associated with the perceived merits of collaborative innovations in the eyes of external reviewers. Bringing together the literature of innovation, categorical imperative, and institutional logics, we argue that, while reviewers may discount diverse projects based on the categorical imperative thesis (Zuckerman, 1999), the strength of this "imperative" also depends on other contextual factors. Specifically, different evaluation logics—logics that stresses technological advancement versus those that emphasize market value—will invoke different reactions to participant diversity in innovation projects, and diverse projects will be associated with a greater "illegitimacy discount" when reviewers hold a stronger market-value logic. We also propose that the effect of project participant diversity on the evaluation of external reviewers should be contingent upon the novelty of the focal project, as well as the fuzziness of the technology category to which the project belongs.

We test our arguments with data on collaborative innovation projects funded by the Advanced Technology Program (ATP) at the U.S. National Institute of Standards and Technology (NIST). ATP was a federally funded, cost-sharing program designed to partner with the private sector to further the R&D of technologies that have the potential to provide significant benefits for the nation. ATP is an excellent context for addressing our questions for two reasons. First, ATP collected information on every funded proposal, including participating firms' industry affiliations and evaluation scores from both technical and business reviewers upon submission of proposals, which allows us to inspect the effects of participant diversity on *ex-ante* evaluations of collaborative innovations before these projects were carried out. Second, ATP's mission was to fund projects that were collaborative and innovative in nature, as well as the potential for commercialization and broad economic impacts. This setting constitutes an ideal context for examining the tension between a logic favoring technological advancement and one that emphasizes commercialization and market potential, as well as the theoretical debate about the perceived merits of collaborative innovations and problems of knowledge and expertise diversity among participating firms.

2. Participant diversity, evaluation logics, and perceived value of collaborative innovation

Management scholars have long been interested in the notion of diversity and its effects in various organizational contexts. Diversity, especially expertise- or knowledge-based diversity, has been argued as an important source of creativity and innovation (Hoffman and Maier, 1961). Scholars have examined how diversity of participating firms affects innovation outcomes and firm performance (e.g., Ahuja, 2000; Fitjar and Rodríguez-Pose, 2013; Fleming et al., 2007; Lee et al., 2015; Walsh et al., 2016). Although insightful, existing literature has primarily focused on the effect of participant diversity on *ex-post* performance (as opposed on *ex-ante* perceptions) of an innovation, and on the informational aspect (as opposed on the cognitive aspect) of potential mechanisms. However, recent research on category studies and institutional logics offers some important insights that may significantly advance our understanding of the role of participant diversity in innovation.

According to the categorical imperative thesis, categories are often durable elements of institutional environments. People use categories to make sense of the world (Zerubavel, 1997). If human perceptual capabilities are the hardware for sensemaking, categories constitute the

[1] By "technological advancement," we refer to not only physical technologies, but also to social technologies.

software, so to speak. Categories guide attention, providing the building blocks that people can use to structure and understand what is commonly viewed as real. A growing body of literature on categories and categorization has taken a cognitive and constructionist approach to explore the consequences of categorical incoherence. This line of research suggests that, because audiences and judges use categories to allocate their attention, not fitting into clear-cut categories risks being undervalued or even overlooked (Hsu, 2006; Hsu et al., 2009; Zuckerman, 1999). In capital markets, for example, organizations whose corporate portfolios span many unrelated industries earn an "illegitimacy discount," that is, a penalty for not fitting into established industry categories (Zuckerman, 2000). Similarly, in the world of films, movies that combine several genres receive lower critical evaluations than those more readily associated with a familiar genre (Hsu, 2006). Studies on online transactions find that eBay sellers who engage in multiple categories are less likely to complete a sale (Hsu et al., 2009), and individuals seeking to borrow money are less likely to get a loan if they belong to multiple categories (Leung and Sharkey, 2013). In the context of patenting, inventions attract more unanticipated, examiner-added citations when they cut across the boundaries of examiner specialization or build on prior arts from more volatile classes (Tan and Roberts, 2010). The primary argument behind this line of research is that boundary-spanning entities lack perceptual clarity; therefore, it is not only hard for the audience to make sense of the focal offer, but also difficult to identify a proper reference group and make meaningful comparisons. As a result, boundary-spanning or category-straddling often causes confusion among the audience, negatively affecting the perceived credibility and value of the focal offer (Hannan et al., 2007).

In our research context, although involving participants from different fields may generate certain informational benefits and hence positive expectations among audiences, it is also a risky move when the collaborating team spans established categorical boundaries such as industries. Industry classification is a highly institutionalized system that has normative and cognitive foundations (Ruef and Patterson, 2009). Industry boundaries constitute implicit assumptions about what count as appropriate activities and behaviors, agreements about proper market boundaries, and intuitive understandings of the "form" of a member firm in each industry category. Ruef and Patterson (2009) find that firms suffer from lower credit coverage and ratings when they straddle or violate institutionalized industry boundaries, which arguably lower the perceived legitimacy of those "hybrid" firms, and decrease their comprehensibility and credibility among credit correspondents. The implication is that innovations that involve participants from diverse industries might cause confusion and even suspicion among the audience and thus be harmful to the innovation's perceived coherence and value.

Recent studies on categories have started to move beyond the basic tenets of the categorical imperative thesis and direct attention to the boundary conditions of this proposition. For example, Pontikes (2012) finds that different types of audiences react differently to organizations that use ambiguous labels or straddle mulitple categories. Kennedy et al., (2010) argue that the consequence of category-blending largely depends on the currency of a focal category and the category being blended. Wry et al., (2014) find that startup firms are less likely to suffer the negative effects of blending or bridging multiple categories when the mixed categories are perceived as similar. These recent works suggest that, when inspecting the effect of participant diversity on the perceived value of collaborative innovation projects, it is important to consider contextual factors. In this study, we advance this line of research by including contextual factors at the institutional level, at the project level, and at the category level, and examine how they may moderate the relationship between participant diversity and evaluation of external reviewers. Specifically, we ask how the relationship between participant diversity and reviewers' perception may be moderated by the institutional logic held by external reviewers, novelty of a focal project, and the fuzziness of technology field to which the project belongs.

2.1. Institutional logic of external reviewers

Institutional logics of external reviewers represent an important contextual factor in the evaluation process (Lo and Kennedy, 2014). Viewed through the lens of an inter-institutional system, society is organized by several cornerstone institutions such as family, religion, democracy, state, market, profession, corporation, and community (Friedland and Alford, 1991). Each institutional order is associated with a unique set of "logics," defined as "assumptions and values, usually implicit, about how to interpret reality, what constitutes appropriate behavior, and how to succeed" (Thornton and Ocasio, 1999: 804). Logics represent a frame of reference that guides preconditions actors' sensemaking choices in categorizing the world, and infuses activity with meaning and value. Prior research has found that prevalent logic has a profound impact on actors' attitudes, behaviors, and their outcomes. For example, using data from 16 European countries, Luo (2007) finds that national institutional logic regarding an individual's role and power shape people's preferences for a new model of employee training.

Even within the same institutional order or context, there may exist multiple "logics," or the dominant logic may change over time, resulting in varying evaluation modes and behavioral outcomes. In the higher education publishing industry, for example, Thornton and Ocasio (1999) find that evolution in institutional logics changes the attention of top managers and determinants of executive succession. As the prevalent logic shifted from an editorial logic to market logic, executive attention was directed away from author-editor relationships and internal growth to resource competition and acquisition growth, while executive succession was determined more by market considerations than by internal organizational factors such as size and structure. In the finance industry, competing logics have been linked to variations in mutual fund practices (Lounsbury, 2007) and the varying patterns of acquisition and founding of local banks (Marquis and Lounsbury, 2007). In fact, one of the original insights of the institutional theory—both old and new—is that institutional environments are often pluralistic (Meyer and Rowan, 1977; Selznick, 1949). Recently scholars have also noted that it is not uncommon for an organization to face or even embody multiple institutional logics (Besharov and Smith, 2014; Kraatz and Block, 2008), which may result in heterogeneous responses to the same institutional pressure both within and across organizations (Greenwood et al., 2010; Greenwood et al., 2011; Pache and Santos, 2010, 2013).

In our context, two institutional logics are particularly prominent in the evaluation process: the logic of technological advancement and the logic of market value. However, these two logics do not always agree with each other. Prior research has shown that the most technologically advanced innovations are not necessarily the most commercially viable projects (Chiesa and Frattini, 2011). Such two logics are likely to invoke different reactions to an innovation project that involves a group of diverse participating firms. Since industry affiliations of participating firms in a project are one of the most visible project characteristics, and the industry categorization provides a baseline for comparison and sensemaking (Ruef and Patterson, 2009), here we focus on this particular aspect of participant diversity.

The logic of market value focuses on the commercial and market potential of a project, and the industry-based classification system is instrumental in guiding audience attention in valuation and evaluation decisions (Ruef and Patterson, 2009; Zuckerman, 1999, 2000, 2004). In examining how structural coherence of a stock affects its valuation in the market, Zuckerman (2004) notes that companies that straddle multiple industry categories occupy an ambiguous position and have a fuzzier identity, as well as incoherent stock. As such stocks are more likely to be subject to different audience interpretations and evaluation schemes, both their volume and volatility are higher. Extending this insight, a project that spans multiple industry categories also tends to have fuzzier boundaries. Under this situation, reviewers with market value logic may not only have a harder time categorizing projects with participating firms from different industry affiliations and finding suitable comparison groups when evaluating their market potential, they may also question the target market and whether the focal project is spread too thin. Both mechanisms will eventually result in lower ratings of such projects.

In contrast, the effect of categorical imperative may be less salient among reviewers with a stronger technological advancement logic. In general, there are two opposing forces when it comes to evaluating scientific and technological advancements. On the one hand, one of the prevalent beliefs in the world of R&D is that cross-fertilization of ideas facilitates novelty and creativity. Believing that inquiries combining multiple perspectives can generate insights that cannot be obtained through single-domain lenses, funding agencies such as the National Institutes of Health (NIH) and the National Science Foundation (NSF) have encouraged R&D efforts to cross traditional expertise and organizational boundaries through increased funding and specific programs (Jacobs and Frickel, 2009; Powell and Owen-Smith, 1998; Powell et al., 2005). Therefore, the logic of technological advancement should implicate a more tolerant view of projects involving participating firms from diverse disciplinary or industry backgrounds. Yet, on the other hand, authors in a variety of disciplines (e.g., Aboelela et al., 2007; Campbell, 2005; Lamont et al., 2006; Naiman, 1999; Wang et al., 2017) have documented the challenges in reviewing and evaluating cross-cutting research that aligns with the predictions of the categorical imperative thesis. There are several inter-related reasons for this. First, the reviewers may lack the expertise to adequately evaluate the full spectrum of knowledge embodied in research that crosses established boundaries. Second, such projects may have a hard time identifying the "right" audience for their intended contribution. Third, reviewers with a strong disciplinary focus may perceive boundary-spanning work as confusing and even illegitimate.

Together, these arguments suggest that, while the basic categorical imperative may still affect reviewers with a strong technological advancement logic in evaluating collaborative innovations that involve diverse participating firms, they may also be more likely to see the merits of such projects, in comparison to reviewers strongly influenced by a market value logic. The net effect for such reviewers is thus less clear. Therefore, we expect that the diversity in industry affiliations of participating firms should have a less noticeable effect for reviewers who draw on the logic of technological advancement in evaluating the project's technological strength. We thus offer the following hypothesis:

H1. *Innovation projects that involve participants from more diverse industries will be associated with lower evaluations from business reviewers that hold a market value logic in comparison to technical reviewers with a technological advancement logic.*

2.2. Project novelty

In H1, we propose that participant diversity of an innovation project will have a lower evaluation from business reviewers as opposed to technical reviewers. However, this relationship may depend upon project-level factors such as project novelty. Innovation projects vary in terms of their newness, ranging from simple improvements to existing products to radical "new to the world" products. Prior research has found that novelty is not a matter of "the more, the better;" a project that is too novel or radical may also be difficult to appreciate (e.g., Lo, 2015; Trapido, 2015). Rather than examining how project novelty may directly affect project evaluation, we focus on its moderating effect in regards to the relationship between participant diversity and project evaluation.

Prior research has shown that, when a task is unfamiliar or marks a new direction from past routines, discussion and debate over alternative perspectives is essential for team members to identify appropriate strategies, and leads to better outcomes (Fiol, 1994). The constructive discussion and debate required to accomplish such tasks depend on the availability of informational diversity—i.e., diversity along expertise or knowledge dimensions among participants (Jehn et al., 1999). For example, Jehn et al. (1999) find that projects that are more complex or novel benefit more from diverse knowledge and expertise of partnering members. It thus follows that for highly novel projects—projects that intend to result in technologies that significantly depart from a firm's or industry's existing products or processes—participant diversity should be perceived as being able to render more benefits. As a result, the negative effect of participant diversity on the evaluation by external reviewers should be attenuated for this type of innovation, even against the backdrop of a strong market value logic, because reviewers are likely to perceive a higher level of diversity as necessary or beneficial for highly innovative projects.

In contrast, participant diversity may have different associations with reviewer evaluations when project novelty is low (e.g., incremental innovations). Incremental innovations tend to meet the needs of existing customers and markets by expanding existing products and services and increasing the efficiency of existing distribution channels (Benner and Tushman, 2003; March 1991). Prior research suggests that when a task is relatively simple and well understood, project members tend to rely on standard procedures and routines to perform it (Gladstein, 1984; Jehn et al., 1999). As a result, it becomes unnecessary or even disruptive if project members engage in many debates about the task strategy, which is likely to happen if a project involves a highly diverse team. In other words, because low novelty may make highly diverse collaboration to be perceived as unnecessary, a diverse project with low novelty may lose credibility in terms of management and planning capacity, and could thus be perceived as unnecessarily increasing the proposed personnel and coordination expenses. Such an effect would be more pronounced among business reviewers, who tend to be more attentive to a proposal's projected costs and expenses. Accordingly, we propose that:

H2. *The relationship proposed in* H1 *will be attenuated by project novelty; that is, the hypothesized negative association between participant diversity and the evaluation of innovation projects from business reviewers with a strong market value logic will be positively moderated by the novelty of a focal project.*

2.3. Fuzziness of technology field

The tendency to discount an innovation with a fuzzy identity or proposed by a diverse team should be even more pronounced when the project also belongs to a fuzzy field. Scholars have investigated the consequences of lacking a collective consensus and identity at the aggregate levels (e.g., field, form, community, region, or population) and found that falling into a fuzzy category may negatively impact the perceived value of a focal offer (e.g., Negro et al., 2010; Romanelli and Khessina, 2005). The rationale is that category coherence serves as a basis for comparison (Zuckerman, 1999). Fuzziness at the category level not only interferes with the evaluation processes of individual offers, but also reduces the perceived legitimacy of the category as a whole. For example, Negro et al. (2010) show that widespread straddling among wine producers blurs the boundaries of a style category and diminishes its perceived merits, thus decreasing the appeal of all wines of a style. Bogaert et al. (2010) found that heterogeneity among Dutch accounting firms hinders the legitimation of the accounting profession as a new form, which in turn has a detrimental effect on individual firms.

In our research context, fields of research or technology categories vary along their perceived coherence among both insiders and outsiders (e.g., external reviewers). Some fields, such as advanced materials or nanotechnology, are interdisciplinary in nature and have attracted more heterogeneous participants perceived to be less coherent than others. In the case of nanotechnology, for example, the boundaries are extremely hard to define due to its multi- and interdisciplinary nature (Porter and Youtie, 2009), well as to the diversity of participants in this emergent field. Indeed, what counts as "nano" and how to use this label has been highly debated (Granqvist et al., 2013; Kaplan and Murray, 2010). In such fields, collective consensus is lacking and boundaries are fluid, and it is harder to comprehend and measure projects, compared with innovations falling within categories composed of homogeneous participants and clearly defined boundaries. Thus, the fuzziness of a field of research may reduce the perceived value of innovation projects within the field. This not only suggests that an innovation project belonging to different fields may be evaluated differently, but also implies that, even within the same field, the aforementioned category-level effect may change over time, because the boundaries of many fields in science and technology are dynamic and rarely static. For example, while chemistry has been a very established field, its boundaries are becoming fuzzier and have even started to merge with other fields such as electronics, photonics, transport, pharmaceutical materials, and bioengineering, due to recent advances.

While field fuzziness may make a focal innovation project harder to evaluate, it may also render some perceived merits to the project, especially in the world of science and technology. In fact, most inter- or multidisciplinary fields tend to be fuzzy fields, in the sense that they do not have rigid boundaries and are open to a variety of disciplines. Reviewers who appreciate interdisciplinary research may value such fields. Therefore, the main effect of category fuzziness may go both ways. Prior research implies that whether the fuzziness of a technology field is valued—and, if so, to what extent—largely depends on contextual factors, including the prevalent institutional logic (Lo and Kennedy, 2014) or evaluators' taste (Lamont, 2009). Such appreciation for inter- or multidisciplinary research may be stronger among reviewers holding a strong technological logic, but not necessarily among those with a strong market value logic. This thus suggests that the potential penalty associated with a fuzzy field would be stronger for reviewers with a strong market value logic.

When the dominant evaluation logic focuses on market value, field fuzziness may intensify the negative effect of participant diversity on *ex-ante* evaluation. That is, projects that involve a diverse group of participants and belong to a highly diverse field may face a double hurdle against a strong market value logic. That is, in addition to the challenge of evaluating the market potential of a project team with diverse participants, field fuzziness will add onto the difficulty on the reviewers' end. Therefore, we expect that the negative effect of participant diversity on the evaluation of an innovation project is likely to be stronger when the project belongs to a fuzzier field. This moderating effect should also be more pronounced among business reviewers, who may be more interested in finding clear market applications for the focal project than seeking technological advances via cross-cutting research.

H3. *The relationship proposed in* H1 *will be intensified by the fuzziness of the technology field to which a project belongs; that is, the hypothesized negative association between participant diversity and the evaluation of innovation projects from reviewers with a strong market value logic will be negatively moderated by the fuzziness of a technology field.*

3. Research setting and method

3.1. The advanced technology program

The Advanced Technology Program (ATP) was established by NIST in 1990 with the mission to bridge the gap between the research lab and the marketplace by providing seed funding for the development of broad-based, pre-competitive technologies with applications across industries. It was hoped that the program could "serve as a focal point for cooperation between the public and private sectors in the development of industrial technology" and stimulate prosperity through innovation (Schacht, 1999: 2). The program, however, became a target of debates and political attacks, partly due to the difficulty in measuring the dual mission of both developing commercially viable technologies and advancing the common goods through technological advancement. When the ATP was terminated in 2007, the federal government had spent over $1.6 billion, matched by $1.5 billion from the private sector.

ATP's funding priority was generally given to projects with the potential for yielding transformational results with wide-ranging implications. Upon reception of a proposal, reviewers were invited to conduct independent peer reviews and evaluate both the potential technical and commercial merits of the proposal. Each project typically had two to three technical and business reviewers, respectively. Technical reviewers were drawn from NIST technical staff, federal laboratories, and the broader scientific community; business reviewers were hired consultants with diverse expertise in business operations, venture capital, economics, and business development. In the process of assessing each proposal, the ATP examined both technical feasibility and economic potential. The main evaluation criteria for technical strength included degree of technical risk, feasibility, and quality of the R&D plan. The evaluation criteria for economic merit included potential of broad-based economic benefits, pathways to successful commercialization, and proposers' need for funding. The technical and economic merits each accounted for 50% in the review process (For details, see Appendix A on the ATP's selection process and evaluation criteria).

To better understand the processes and challenges involved in the project evaluation process, we conducted informal interviews with three ATP officers in 2008 and collected all the available assessment reports from the program. While these efforts were not part of the formal data collection, they helped us to gain a better understanding of the research context. Our qualitative evidence suggests that, although participant diversity in expertise and knowledge was believed to be valuable, these very same characteristics also increased uncertainty, often inducing confusion and frustration among reviewers required to evaluate the "true merits" of the proposed projects. As one officer commented, "sometimes reviewers just don't agree with each other, especially if the project involved multiple industries… for example, a civil infrastructure company might fall into the concrete/bridge repair industry, but its proposal has to do with remote sensor and monitoring, which would be categorized as microelectronics, and it may also have partners from the electronics industry. So we would have a hard time to decide who should be reviewing this proposal, and in the end we might get reviewers from both civil engineering and microelectronics, or even other areas, if the proposal had applications in other markets… as you can imagine, the reviewers may have had very different opinions about the potential of the proposal." In addition to tensions at the project level, similar tensions also resided at the field level, in the sense that proposals in fuzzy technology fields were regarded as more promising, but also more challenging, to evaluate: "there is greater potential with interdisciplinary technology areas, but in these fields you also have several competing ideas, and each may be using some different technologies or concepts, and all have their own advantages or problems, how do you know if you are betting on the right one?"

Although it was challenging for both technical and business reviewers to judge *ex ante* the potential of any innovation project, this task was particularly challenging when the focal project involved participants from multiple industries—especially when reviewers were asked to evaluate a project's potential market or commercialization pathway. According to an ATP document (NIST, 2004), when evaluating the "broad-based economic benefit" of a proposed project, business reviewers would look for elements that indicate "expected markets for the technology," including potential users of the technology, expected size of the markets for the technology in the immediate and more distant future, as well as the growth trends for those markets.

Other components used to evaluate a proposal's economic merits included "magnitude of impact," (i.e., the magnitude of the advantage enabled by this project in terms of its economic and business benefit), "sources of benefits" (i.e., how the proposing company(ies) and other stakeholders would benefit from the proposed technology), as well as the project's "pathway to commercialization" (i.e., a commercialization plan that would use existing markets or develop new markets to achieve the economic benefits). When evaluating a project that involved participating firms from multiple industries (as opposed to a single-firm project with firms all from the same industry), our qualitative evidence suggests that business reviewers may have had a harder time in evaluating the claimed market size, sources of benefits, magnitude of impact, and commercialization plan.

We used the survey data collected by the ATP to test our hypotheses. In 2002, the ATP's Economic Assessment Office collected information from all participating firms involved in funded projects on questions such as company background, key applications proposed in the projects, goals for collaboration, and so forth. Excluding projects and firms with missing information, the final sample included 113 joint projects awarded between 1991 and 2001. While joint projects only accounted for about 27% of all ATP-funded projects, we used these projects instead of single-firm projects for our analysis because of the theoretical focus and research question of this study. Yet, as we report later, we also conducted supplementary analyses for all funded proposals to verify that our results are robust when including single-firm proposals. The mean of collaborating firms per project was 5.4, while the maximum number of firms on a project was 18. Most of the joint projects involved firms from multiple industries with an average of 4.2 industries per project.

3.2. Measurement

3.2.1. Dependent variable

Ex-ante evaluation. We measured the *ex-ante* evaluation of an innovation project with each technical and business reviewer's quantitative rating of the proposal, a continuous measure that ranged from one to ten. The unit of analysis was the score that a particular reviewer gave to a project. Note that before 1999, reviewers were asked to use one to ten as the scale. From 1999 and beyond, the reviewers were asked to use zero to five as the scale. We rescaled the scores from 1999 and beyond to make the evaluations comparable to the scores before 1999 and also included a dummy variable to control for the potential effect of this change in the rating system. To test our hypotheses that reviewers with different logics will respond to participant diversity and the moderators differently, we separated the scores of technical reviewers from those of business reviewers.

3.2.2. Explanatory variables

Participant diversity refers to the diversity that concerned affiliations with knowledge or expertise domains among participating firms in a given project. We measured this variable with the heterogeneity of Standard Industrial Classification (SIC) affiliations among participating firms for two reasons. First, to test how participant diversity affects reviewer perceptions, we needed a classification schema that was highly salient to the reviewers. Industry background is a salient identity, and scholars have used the SIC code as a proxy for frames of reference (Benner and Tripsas, 2012; Ruef and Patterson, 2009; Zuckerman, 2000) and for expertise similarity and relatedness of diversification in prior research (e.g., Farjoun, 1994). External reviewers in our context were typically highly aware of and attentive to a firm's industrial affiliation. Second, ideally we wanted to use a classification schema that could invoke both the technological and the market logic. The concept of "industry" contains both production and business activities. Thus, when using industry affiliations as a frame of reference, both logics are relevant.

3.10 Following prior work (Bowen and Wiersema, 2005; Zhang et al., 2010), we used the Herfindahl Index (H) to measure the diversity of industry backgrounds of participating firms, or *participant diversity*, in an innovation project, as determined by the 4-digit SIC code of each participating firm's primary industry affiliation. Because a lower value of the Herfindahl Index (H) indicates a higher level of diversity, we used the inverse measure ($1/H$) to measure the level of participant diversity, so that a higher value indicates a greater diversity of participant industry background. We also tried alternative measures, such as (1-H) (also called the Blau Index), total entropy, and a straight count of SIC codes of participating firms, and obtained similar results. The correlations among these indices are also very high, between 0.88 and 0.96. For simplicity of presentation, we only report results using the inverse Herfindahl Index. There is an additional benefit associated with this measure: that is, with a simple mathematic transformation (subtracting one from $1/H$), one can attain the odds that two randomly selected firms from the sample will be of different industries, which offers a more intuitive interpretation (Kvålseth, 1991). Using the primary SIC codes of all participating firms on a collaborative project, this measure captured the diversity level of the expertise base of a project and is written as:

$$\textit{Diversity} = 1/\Sigma_1{}^n \text{ (SIC share }_i)^2,$$

where n is the number of industries associated with a project, and SIC share i stands for the proportion of firms belonging to the ith SIC code in a project.

Project novelty was measured as a continuous variable. The participating firms were asked the question, "To what extent would you say your project represents a new R&D direction for your industry or technology field?" (i.e., new to the industry or the field) Responses ranged from 1 to 4, from "not at all" to "a large extent." We collapsed the responses across all participating firms to obtain a project-level measure. We also used an alternative measure based on the question, "To what extent did the proposed project represent a new direction for your company?" (i.e., new to the company), and obtained similar results. Because the former measure better captures the radicalness of the project and is more likely to affect external reviewers' perception, we reported results with this measure in the paper.

Fuzziness of a technology field was measured to capture the diversity of sub-fields within a particular technology field in a given year at ATP. NIST categorized all proposals into five "technology groups," or fields, based on the nature of underlying technologies. The five fields are biotechnology, electronics, information technology, advanced materials and chemistry, and manufacturing. Each technology field is further divided into several subfields. For example, the "biotechnology" group consists of animal and plant biotechnology, bioinformatics, biomolecular and biomimetic materials, bioprocessing/biomedical engineering, and so forth, while the "information technology" field includes subfields such as cognitive systems, computer systems and software applications, design and testing systems, and image processing, among others. It is useful to think of the fuzziness of a field in terms of the composite categories (subfields) in a given year—conceptually, this captures the interdisciplinarity and perceived diversity of a focal field, and reviewers with different evaluation logics may thus react differently to the fuzziness of a field.

At ATP, a new subfield may have been added to a field if existing categories were not sufficient in reflecting the technology of new projects. Thus, the total number of subfields per field may have been expanded throughout the years, but in practice, some subfields may have had multiple or no awarded projects in a particular year. Given the dynamic nature of technology fields at ATP, we measured the fuzziness of a field based on the composition of awarded subfields in a given year—i.e., subfields appearing in the ATP award system. Mathematically, the method for computing field fuzziness is the same as project-level diversity (i.e., inverse Herfindahl Index):

$$\textit{Field fuzziness} = 1/\Sigma_1{}^n \text{ (Subfield share }_i)^2,$$

where n is the number of subfields in a technology field, and Subfield share $_i$ stands for the proportion of awarded projects belonging to the ith type of subfield. This index was updated yearly for all fields and lagged for one year in analyses.[2]

3.2.3. Control variables

We controlled for several variables to tease out possible alternative explanations. To account for the possibility that reviewer experience may make a difference in the evaluation, we controlled for whether a reviewer is a *first-time reviewer* for an ATP project. As previously mentioned, because the NIST changed its rating scale in 1999, we created a dummy variable, *1999 and onwards,* for projects that entered the 1999 competition and beyond. We also controlled for the *competition year* to count for possible heterogeneities in the reviewer pool or preferences across years. Because there might exist unobservable heterogeneities among technology fields, especially considering that NIST might have a funding preference or priority for some particular field over others, we needed to control any potential field-level effect in addition to the fuzziness measure. Therefore, we created four dummy variables (*biotechnology, electronics, information technology, advanced materials science*) and used manufacturing as the reference group. To account for the potential effect of resource inflows, we controlled for R&D costs shared by participating firms (the amount of costs that participating firms proposed to invest, in addition to the amount awarded by NIST) at both project level (logged *participant R&D*) and aggregate level (logged *total awardee R&D expenses in focal technology subfield* in the previous year). Given that firms with more past collaboration experience may be better at formulating and framing the proposed ideas, we also controlled for average *collaboration experience* of a team for each project. This was constructed by taking the mean value of participant responses to the question, “Prior to this JV project, how much experience with R&D collaborations across companies did your team members have?” To account for the fact that there was considerable within-project variation of our novelty measure, in the sense that whether an innovation is “new to the industry/field” inevitably varies by the industry affiliation of each participating firm, we also controlled for the *within-team standard deviation of novelty* measure for each project. In addition, we controlled for the *average scores* of *technical reviewers* received by the focal project in the analysis of business reviewers’ evaluation and included the *average scores of business reviewers* as a control for the analysis of technical reviewers’ evaluation. In an unreported analysis, we also controlled for the size of the team, as measured in a count of participating firms on a project. Due to the high correlations between team size and diversity, we decided not to include this control variable in our final models, but the results were similar with or without controlling for team size. Tables 1 and 2 offer the correlations and summary statistics for variables used in the analyses for business and technical reviewers, respectively.

3.3. Analysis strategy

We used OLS regression to test our hypotheses for both business and technical reviewers. The basic estimation equation of our analysis was the following:

$$Y = \beta_0 + \beta_1 X + \beta_2 XZ + \beta_3 Z + \beta_4 W,$$

where Y is the score that a particular reviewer gives to a project, X is participant diversity, Z represents the moderating variables—project novelty and field fuzziness—and W are control variables. Given that the dependent variable is bounded by one and ten, we also used the Tobit model as a robustness check, and the results were very similar (these

[2] Field fuzziness is determined based on the previous year's subfields, rather than all the awarded subfields tracing back to the first ATP year. This was done because many of these technology fields were fast-paced and field composition changed quickly, and the previous year’s subfields tend to be the most salient to the present year’s reviewers.

Table 1
Summary Statistics and Correlations of Variables for Business Reviewers.

		Mean	S. D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1)	Business review score	7.50	2.08															
(2)	First-time reviewer	0.04	0.19	0.06														
(3)	1999 & onwards	0.16	0.36	−0.03	−0.09													
(4)	Competition year	1996	2.65	0.04	−0.26*	0.65*												
(5)	Advanced materials science	0.29	0.46	−0.04	−0.04	−0.07	−0.08											
(6)	Biology	0.10	0.30	−0.15*	−0.07	0.01	−0.02	−0.22*										
(7)	Electronics	0.30	0.46	0.09	0.16*	0.08	0.13*	−0.43*	−0.22*									
(8)	Information technology	0.12	0.33	−0.02	0.00	−0.08	−0.02	−0.25*	−0.13*	−0.25*								
(9)	Total awardee R&D expenses in field	235.9	374.3	0.06	0.05	−0.24*	−0.17*	−0.25*	−0.14*	−0.16*	0.76*							
(10)	Participant R&D	15.45	0.72	0.03	0.12*	−0.05	−0.08	−0.19*	−0.01	0.07	0.29*	0.44*						
(11)	Average collaboration experience	2.73	0.55	−0.02	−0.10*	0.19*	0.21*	−0.10*	0.08	0.11*	−0.07	−0.10*	−0.14*					
(12)	Average technical review score	7.97	1.06	0.11*	−0.07	0.15*	0.14*	0.01	0.08	−0.02	−0.01	−0.08	0.11*	−0.05				
(13)	Within-team S. D. of project novelty	0.64	0.55	−0.02	−0.07	0.04	0.04	−0.11*	0.03	−0.00	0.06	0.06	−0.09	−0.17*	0.07			
(14)	Participant diversity	3.62	3.19	−0.01	0.25*	−0.14*	−0.19*	−0.23*	−0.16*	−0.03	0.23*	0.46*	0.38*	−0.12*	−0.13*	0.01		
(15)	Project novelty	3.28	0.61	0.02	0.00	0.15*	0.13*	0.06	0.00	−0.04	−0.08	−0.15*	0.04	0.18*	0.02	−0.66*	−0.09	
(16)	Field fuzziness	1.86	0.99	0.03	0.02	−0.29*	−0.32*	−0.26*	0.22*	−0.28*	0.67*	0.61*	0.16*	−0.08	−0.03	0.11*	0.14*	−0.12*

Significance level: *$p < 0.05$.

Table 2
Summary Statistics and Correlations of Variables for Technical Reviewers.

		Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1)	Technical review score	7.93	1.77															
(2)	First-time reviewer	0.26	0.44	−0.01														
(3)	1999 & onwards	0.15	0.36	0.04	−0.07													
(4)	Competition year	1996	2.62	0.05	−0.28*	0.65*												
(5)	Advanced materials science	0.28	0.45	0.02	−0.04	−0.04	−0.04											
(6)	Biology	0.09	0.28	0.05	−0.06	0.02	−0.03	−0.20*										
(7)	Electronics	0.31	0.46	−0.00	0.01	0.04	0.11*	−0.42*	−0.21*									
(8)	Information technology	0.14	0.35	0.01	−0.07	−0.07	−0.02	−0.26*	−0.13*	−0.27*								
(9)	Total awardee R&D expenses in field	266.5	409.4	−0.04	0.00	−0.25*	−0.16*	−0.28*	−0.14*	−0.18*	0.77*							
(10)	Participant R&D	15.49	0.72	0.06	0.02	−0.08	−0.09	−0.20*	−0.03	0.06	0.32*	0.46*						
(11)	Average collaboration experience	2.71	0.58	−0.04	−0.07	0.19*	0.19*	−0.13*	0.11*	0.08	−0.03	−0.06	−0.11*					
(12)	Average business review score	7.57	1.36	0.10*	0.07	0.01	0.10*	−0.06	−0.20*	0.13*	−0.04	0.05	0.05	0.00				
(13)	Within-team S. D. of project novelty	0.65	0.55	0.02	0.02	0.04	0.04	−0.13*	0.01	−0.02	0.08	0.10	−0.10	−0.20*	−0.05			
(14)	Participant diversity	3.62	3.18	−0.08	0.10*	−0.16*	−0.19*	−0.25*	−0.16*	−0.05	0.25*	0.47*	0.39*	−0.10*	−0.04	0.04		
(15)	Project novelty	3.27	0.62	0.00	−0.05	0.16*	0.13*	0.10*	0.04	−0.08	−0.09*	−0.17*	0.01	0.20*	0.00	−0.66*	−0.12*	
(16)	Field fuzziness	1.91	1.06	−0.01	−0.03	−0.29*	−0.33*	−0.28*	0.17*	−0.25*	0.69*	0.63*	0.20*	−0.03	0.01	0.12*	0.15*	−0.14*

Significance level: *$p < 0.05$.

results are available upon request).[3]

Since the unit of analysis is the individual reviewer's score, and the evaluations of the same reviewer may not be independent from one another, we opt for a robust cluster variance estimator to account for possible intra-cluster (within reviewer) correlations. We have also clustered observations within each project, within competition years, and within technology fields, and the patterns of results were all consistent. To reduce potential multicollinearity concerns, and to make the results more interpretable, we followed Aiken and West (1991) and mean-centered all the predictors and moderators before creating interaction terms. Variance inflation factor (VIF) tests confirmed that multicollinearity is not a threat in our models. The mean VIF of the full model for the business review analysis is 2.57; for the technical review analysis, the mean VIF is 2.47; and the maximum VIF score for any individual variable across all models is 5.26.

4. Results

Table 3 reports the results with business reviewers' evaluation as the dependent variable, while Table 4 presents the results with technical reviewers' evaluation as the dependent variable. Models in the two tables are identical. The significance levels of predicting and moderating variables are based on one-tailed tests. Comparing the coefficients of control variables in Table 3 with those in Table 4, we find several interesting observations. Among business reviewers, first-time reviewers tend to be more favorable in their ratings, while not much difference exists among the technical reviewers. Projects belonging to the fields of biotechnology and information technology generally receive lower ratings from business reviewers, as compared with the reference group (manufacturing). However, proposals belonging to these fields do not receive the same "penalty" from technical reviewers. Firms' proposed R&D expenses have a significantly positive effect on technical reviewers' evaluation, but not so much on business reviewers' evaluation. However, when it comes to resource inflows at the field level, business reviews tend to favor fields with more resources, which is not the case for technical reviewers. Lastly, projects that receive higher technical scores also tend to fare better in business reviews, and vice versa. These results tentatively suggest that, while important differences seem to exist between the market value logic and the technological advancement logic—at least based on the differential effects of control variables—technical scores also help predict business scores, and vice versa, suggesting that both sets of reviewers still hold some common evaluation criteria.

H1 states that participant diversity of an innovation project will be associated with lower evaluations from reviewers with the logic of market value compared to the logic of technological advancement. As shown in Model 2 of Table 3, participant diversity has a significantly negative relationship with business reviewers' evaluation ($b = -0.106$, $p < 0.05$). In Model 2 of Table 4, although participant diversity has a negative relationship with technical reviewers' evaluation, the relationship is not statistically significant. These results support H1, suggesting that participant diversity is more negatively related to review ratings when the primary evaluation logic focuses on market value. At the same time, the negative but non-significant coefficient of participant diversity among technical reviewers suggests that the

[3] We choose to use OLS as the main estimation model for two reasons. First, although it has been shown that the results from the Tobit model are usually similar to OLS estimates (Foster and Kalenkoski, 2013; Stewart, 2013), some recent studies have suggested that OLS appears to be a more robust method in handling various assumptions about the underlying processes generating the threshold values and produces less biased estimates than Tobit (Flood and Genadek, 2016; Gubler et al., 2016; Stewart, 2013). Second, the McFadden's pseudo R-squared from the Tobit model does not mean what R-squared means in OLS regression and should be interpreted with caution. A higher pseudo R-squared simply suggests an improvement from the null model to the fitted model and is useful in comparing the likelihood of different models, but not very helpful in explaining the variability explained by the model.

Table 3
OLS Regressions with Clustered SE: Evaluation by Business Reviewers.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
First-time reviewer	0.723	0.985**	0.985**	1.040**	0.973**	0.800	0.854*
	(0.457)	(0.472)	(0.475)	(0.469)	(0.487)	(0.498)	(0.491)
1999 & onwards	−0.334	−0.290	−0.289	−0.273	−0.297	−0.223	−0.185
	(0.442)	(0.441)	(0.437)	(0.438)	(0.443)	(0.439)	(0.435)
Competition year	0.096	0.082	0.082	0.100	0.081	0.089	0.112
	(0.071)	(0.073)	(0.074)	(0.073)	(0.074)	(0.073)	(0.073)
Advanced materials science	−0.467	−0.702**	−0.703**	−0.738**	−0.706**	−0.533*	−0.560*
	(0.288)	(0.304)	(0.307)	(0.306)	(0.305)	(0.318)	(0.320)
Biotechnology	−0.975**	−1.253**	−1.254***	−1.255***	−1.225**	−1.280**	−1.306***
	(0.483)	(0.483)	(0.478)	(0.473)	(0.508)	(0.490)	(0.483)
Electronics	−0.202	−0.395	−0.397	−0.401	−0.401	−0.275	−0.270
	(0.295)	(0.302)	(0.313)	(0.317)	(0.303)	(0.301)	(0.314)
Information Technology	−1.582**	−1.920***	−1.920***	−1.961***	−1.915**	−1.804**	−1.844**
	(0.670)	(0.724)	(0.726)	(0.711)	(0.733)	(0.746)	(0.728)
Awardee R&D expenses in focal category	0.001**	0.002**	0.002**	0.002***	0.002**	0.002**	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Participant R&D	−0.086	0.026	0.027	0.049	0.024	0.037	0.071
	(0.191)	(0.196)	(0.199)	(0.200)	(0.195)	(0.194)	(0.198)
Average collaboration experience	−0.341	−0.367	−0.367	−0.521*	−0.363	−0.307	−0.485*
	(0.286)	(0.281)	(0.281)	(0.279)	(0.281)	(0.264)	(0.265)
Average technical review score	0.293**	0.268**	0.268**	0.254**	0.274**	0.258**	0.236*
	(0.124)	(0.116)	(0.117)	(0.115)	(0.122)	(0.121)	(0.119)
Within-team S. D. of project novelty	−0.205	−0.204	−0.211	−0.373	−0.207	−0.216	−0.438
	(0.211)	(0.211)	(0.297)	(0.298)	(0.209)	(0.209)	(0.291)
Participant diversity		−0.106**	−0.106**	−0.092*	−0.107**	0.051	0.085
		(0.050)	(0.050)	(0.052)	(0.049)	(0.091)	(0.089)
Project novelty			−0.010	−0.038			−0.078
			(0.262)	(0.264)			(0.258)
Participant diversity x Project novelty				0.133**			0.158***
				(0.065)			(0.060)
Field fuzziness					−0.036	0.123	0.159
					(0.199)	(0.198)	(0.189)
Participant diversity x Field fuzziness						−0.087**	−0.097***
						(0.036)	(0.035)
Constant	7.832**	6.466*	6.457*	6.777**	6.495*	5.880*	6.136*
	(3.220)	(3.337)	(3.353)	(3.412)	(3.332)	(3.282)	(3.351)
Observations	333	333	333	333	333	333	333
R^2	0.075	0.089	0.089	0.098	0.089	0.107	0.119

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Two-tailed test.

categorical imperative might still be at work for these reviewers, although the tendency to discount diverse projects is less severe, possibly due to the moderating effect of a logic emphasizing technological advancement.

H2 states that project novelty will positively moderate the negative association between participant diversity and the evaluation of innovation projects from reviewers with a strong market value logic. We entered the variable "project novelty" into Model 3, and its interaction term with participant diversity in Model 4. Results in Model 4 of Table 3 support H2. As shown, while the main effect of project novelty does not seem to be significant for either set of reviewers, the interaction between participant diversity and project novelty has a significantly positive relationship with business reviewers' evaluation ($b = 0.133$, $p < 0.05$). However, in Model 4 of Table 4, the interaction has no significant relationship with technical reviewers' evaluation.

H3 predicts that fuzziness of a technology field will exacerbate the negative association between participant diversity and the evaluation of innovation projects from reviewers with a strong market value logic. We included the variable "field fuzziness" in Model 5. Interestingly, while this variable does not have a significant effect on business scores, technical reviewers respond positively to the fuzziness of a technology field. This perhaps is in line with the theorization that field fuzziness may be viewed favorably, especially for reviewers who appreciate interdisciplinary works. To test H3, we further entered the interaction between participant diversity and field fuzziness in Model 6. As shown in Table 3, this interaction term is significant and negatively related to business reviewers' evaluation ($b = -0.087$, $p < 0.05$). Based on Model 6 of Table 4, however, the interaction between participant diversity and category fuzziness has no significant relationship with technical reviewers' evaluation. These results thus lend support for H3. Model 7 in both tables reports the results of the full model based on business reviewers and on technical reviewers, respectively. As shown, H2 and H3 receive strong support in the sense that project novelty and field fuzziness both significantly moderate the effect of participant diversity for business reviewers though in different directions. Interestingly, as shown in Models 6 and 7 of Table 3, participant diversity actually has a slightly positive, albeit insignificant ($p > 0.10$), effect on business review scores once controlling for the moderating effect of field fuzziness. In other words, the "diversity penalty" is subdued once we have controlled for the moderating effects of field fuzziness.

To better interpret the moderating effects of project novelty and field fuzziness, we plotted the predicted reviewer scores at high and low levels of these moderators (one standard deviation above and below the mean) in Figs. 1 and 2, based on the results in Model 4 and Model 6 of Table 3, respectively. As shown in Fig. 1, at the lower level of project novelty, participant diversity has a salient negative relationship with business reviewer scores, but the relationship between participant diversity and business reviewer scores is attenuated at a higher level of project novelty, providing further support for H2.

Fig. 2 shows that at a higher level of field fuzziness, the relationship between participant diversity and business reviewer scores is drastically negative; yet, in a less fuzzy technology field, participant diversity appears to have a neutral relationship with business reviewer scores. Taking the observation from Fig. 2 and results reported in Tables 3 and 4 together, our findings suggest that the effect of participant diversity on reviewer evaluation is largely contingent upon contextual factors. A

Table 4
OLS Regressions with Clustered SE: Evaluation by Technical Reviewers.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
First-time reviewer	0.085	0.088	0.086	0.091	0.155	0.155	0.162
	(0.211)	(0.212)	(0.212)	(0.219)	(0.203)	(0.203)	(0.210)
1999 & onwards	0.025	0.041	0.055	0.057	0.068	0.075	0.091
	(0.357)	(0.359)	(0.356)	(0.357)	(0.361)	(0.362)	(0.359)
Competition year	0.024	0.019	0.021	0.022	0.026	0.027	0.032
	(0.054)	(0.054)	(0.055)	(0.055)	(0.055)	(0.055)	(0.056)
Advanced materials science	0.205	0.136	0.124	0.120	0.177	0.194	0.180
	(0.247)	(0.271)	(0.271)	(0.272)	(0.271)	(0.273)	(0.271)
Biotechnology	0.454	0.366	0.356	0.353	0.158	0.149	0.133
	(0.377)	(0.391)	(0.392)	(0.392)	(0.399)	(0.400)	(0.400)
Electronics	0.336	0.286	0.271	0.268	0.338	0.349	0.332
	(0.276)	(0.287)	(0.288)	(0.286)	(0.288)	(0.288)	(0.288)
Information Technology	0.796*	0.692	0.687	0.679	0.628	0.634	0.614
	(0.473)	(0.495)	(0.497)	(0.491)	(0.486)	(0.483)	(0.483)
Awardee R&D expenses in focal category	−0.001*	−0.001	−0.001	−0.001	−0.001**	−0.001**	−0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Participant R&D	0.223	0.254*	0.262*	0.264*	0.252*	0.252*	0.263*
	(0.141)	(0.149)	(0.151)	(0.152)	(0.148)	(0.148)	(0.153)
Average collaboration experience	−0.180	−0.190	−0.188	−0.200	−0.219	−0.214	−0.237
	(0.190)	(0.190)	(0.190)	(0.201)	(0.191)	(0.187)	(0.202)
Average business review score	0.169**	0.159**	0.157**	0.156**	0.164**	0.158**	0.151**
	(0.077)	(0.074)	(0.074)	(0.075)	(0.073)	(0.074)	(0.075)
Within-team S. D. of project novelty	0.112	0.109	0.052	0.038	0.135	0.135	0.057
	(0.179)	(0.179)	(0.236)	(0.252)	(0.179)	(0.179)	(0.255)
Participant diversity		−0.028	−0.030	−0.029	−0.007	0.009	0.014
		(0.040)	(0.040)	(0.040)	(0.042)	(0.072)	(0.070)
Project novelty			−0.083	−0.086			−0.079
			(0.227)	(0.226)			(0.227)
Participant diversity x Project novelty				0.010			0.021
				(0.066)			(0.064)
Field fuzziness					0.330**	0.347**	0.352**
					(0.151)	(0.154)	(0.153)
Participant diversity x Field fuzziness						−0.009	−0.011
						(0.035)	(0.035)
Constant	3.416	3.075	3.003	3.033	2.639	2.634	2.629
	(2.261)	(2.354)	(2.370)	(2.370)	(2.356)	(2.364)	(2.366)
Observations	370	370	370	370	370	370	370
R^2	0.040	0.041	0.042	0.042	0.060	0.061	0.061

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Two-tailed test.

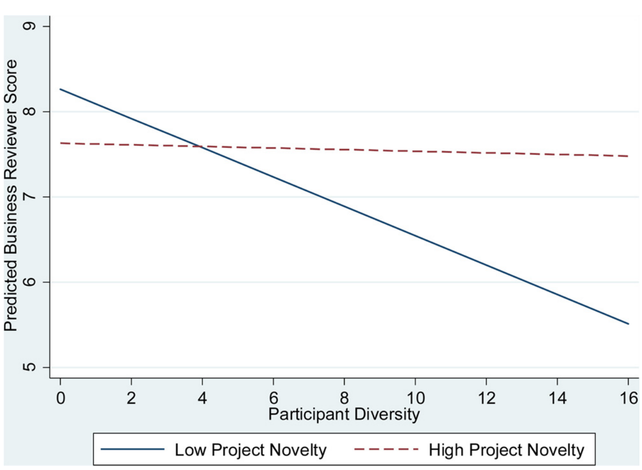

Fig. 1. Effect of participant diversity on predicted business review scores, by project novelty.

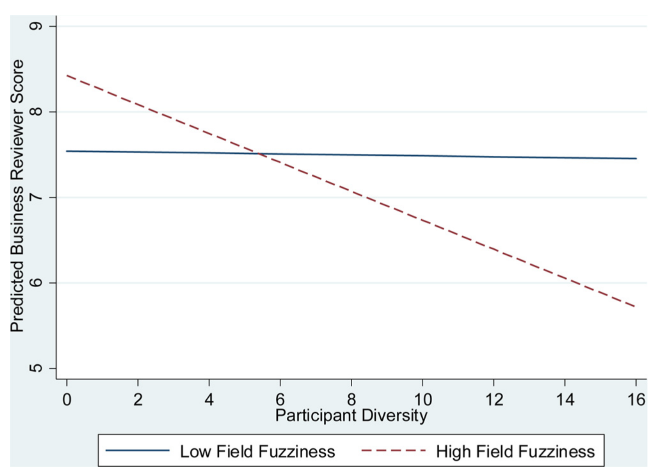

Fig. 2. Effect of participant diversity on predicted business review scores, by field fuzziness.

highly diverse project that *also* belongs to a fuzzy field is likely to be heavily discounted, especially for reviewers with a market value logic. However, for less fuzzy fields, participant diversity appears to have no statistically significant effect on reviewer evaluation.

The two sets of results are derived from two sets of reviewers and thus analogous to comparing the coefficients across two separately estimated groups. We therefore conducted a series of tests to compare whether the coefficients of our independent variable and the interaction terms were significantly different between the two groups. First, we followed the method suggested by Paternoster et al. (1998) to compare coefficients reported in Tables 3 and 4. For the main effect of the independent variable (participant diversity), the difference between coefficients from the two groups of reviewers is significant at the $p < 0.10$ level. For the moderators, we also calculated the z scores for the coefficients from the two groups of reviewers based on Models 2 and 4. The differences between coefficients of interaction terms between diversity and project novelty, as well as field fuzziness for the two reviewer groups, are significant at the $p < 0.10$ and $p < 0.05$ levels, respectively.

Second, we did an alternative test by combining evaluation scores from both sets of reviewers and used a dummy variable to indicate the reviewer type (business reviewer = 1). We then interacted this dummy variable with other predicting variables in the model. The interaction term of business reviewer dummy variable and participant diversity was significant and negative at 0.10 level (coefficient = −0.115, p = 0.096). We also performed the Wald test to determine whether the coefficients of business reviewer dummy variable, participant diversity, and their product were simultaneously equal to zero. The F statistic from this test is 3.29 and statistically significant, suggesting that the relationship between participant diversity and review scores does differ by the type of reviewers. Combining these results with those in Tables 3 and 4, we may tentatively conclude that, when evaluating collaborative projects involving diverse participants, business reviewers tend to react more negatively than technical reviewers, thus supporting H1.

We also conducted additional analysis on all funded projects (including single firm proposals) to verify that our results are valid across all proposals.[4] Consistent with the results in Table 3, we found that participant diversity has a negative effect on reviewer scores, and that the negative effect is only significant among business reviewers. Among technical reviewers, the coefficient of participant diversity was negative but non-significant. For the sake of space, we did not include results from these supplementary analyses but they are available upon request.

5. Discussion

Departing from prior research's focus on the performance effect of participant diversity in collaborative innovations, in this study we examine how participant diversity is associated with the perceived value of collaborative innovation projects by external reviewers. With a unique data set from the ATP, we find that an innovation project involving firms from a wide range of industries tends to receive lower ratings from external reviewers, and this basic tendency is moderated by evaluation logic at work, the novelty of the project, and the fuzziness of the technology field to which the project belongs. These results highlight the importance of viewing the composition of an innovation team not just as a conduit for facilitating information and resource flows, but also as a cognitive primer that may affect how an audience perceives a project. This echoes the observation in the literature of inter-organizational networks that networks and alliances are not only pipes for resources, they are also signals that convey social status and recognition (Gulati and Higgins, 2003). Given that the assessment of any offer starts from a categorization and comparison process (Zuckerman, 1999), which is based on collectively understood taxonomies and taken-for-granted classifications (Porac and Thomas, 1995; Zuckerman, 2004), we believe this inquiry to be of theoretical significance and practical importance.

By offering a new perspective on the role of participant diversity in innovation, our study makes two interrelated contributions to the innovation literature. Our first contribution lies in our inspection of *ex-ante* evaluation of collaborative innovations as opposed to their *ex-post* performance, a focus of most previous studies. We believe that *ex-ante* evaluation is an important outcome to consider in itself, because it is related to how well a proposed project is received and how many resources it can potentially mobilize (Foo et al., 2005). Given that resources are limited, and that *ex-ante* biases of evaluators may affect resource allocation among innovation projects, this study addresses an important gap in existing literature by linking participant diversity with reviewers' *ex-ante* evaluations. Also, if a project receives favorable reviews before it is even carried out, there may exist a self-fulfilling prophecy effect that will further affect the eventual outcome of the project.

Our second contribution lies in our attention to the socio-cognitive aspect underlying the diversity-innovation relationship. Prior research has mostly focused on how diversity may affect the dynamism and interactions among participants through information and resource exchange, as well as coordination costs (e.g., Ahuja, 2000; Kotha et al., 2013; Zahra and George, 2002). We complement this stream of research by proposing that categorical imperative may affect reviewers' perception of collaborative innovations among diverse participants. Our study thus echoes findings from the sociology literature on valuations that evaluators' decisions are ultimately a social-cognitive process, and that the outcome of judgment typically goes above and beyond the intrinsic quality or the content of the focal offer or candidate (e.g., Lamont, 2012; Zuckerman, 1999). This finding would apply even in contexts in which evidence-based evaluation is emphasized, such as science and technological fields (Azoulay et al., 2013; Lamont, 2012; Lo, 2015; Merton, 1968; Simcoe and Waguespack, 2011; Trapido, 2015).

The findings reported in this study also make two contributions to the category literature. First, past research has largely focused on the categorical coherence or clarity of the focal offer (Hsu, 2006; Zuckerman, 1999). In this research, we extend previous insights to the background affiliations and composition of collaborating teams behind the focal offer. Our results suggest that in highly uncertain contexts, even if the focal offer does not span multiple categories—as is the case in our context, in which each project is only assigned into one technology category—evaluators will still look for subtle signals as bases for their evaluations, such as participating firms' industry affiliations, the focal project's novelty, and the broader technology field's boundary clarity. Second, we bridge the literature on institutional logics and category research, showing that even within the same institutional order, there might exist multiple—sometimes incompatible— evaluation logics, and the reaction to category-spanning projects largely depends on the dominant logic at work. In doing so, we also join recent studies that aim to explore the boundary conditions of the categorical imperative (Lo and Kennedy, 2014; Pontikes, 2012; Wry et al., 2014), delineating under what conditions the preference for categorical purity is more or less of a constraint.

Practitioners will also find resh insights from this study. Collaborative innovation has gained currency in the world of R&D and is one of the most promising modes for discovering entrepreneurial opportunities. However, working with collaborators across industry boundaries also creates challenges. Besides the familiar lesson that multi-industry alliances can incur significant coordination costs, in this paper we show another reason for firms to be cautious when engaging in such collaborations. Understanding how evaluators think is critical to any business success (Hsu et al., 2012). Our findings suggest that the level of diversity of participants' background is associated with an audience's evaluation of a proposed project or a new venture, which may in turn be linked with resource acquisition. For example, how should a founding or advisory team be assembled? Is a diverse team beneficial for new ventures or entrepreneurs? Results from this study suggest that the answer not only hinges upon the nature of the product or underlying idea, it must also consider the general perceptions of the market category that the product competes in and the prevailing evaluation logic at work.

This paper has important policy implications as well. In our context, the ATP program emphasized collaboration from both public and private sectors, and thus the tension between market success and technological advancement was especially prominent. Yet, more broadly, the question of how innovation projects involving diverse participants are evaluated by policy makers is also of critical importance and has received little attention thus far. In the U.S., for example, even in government funding agencies such as the NSF or NIH, where basic research is valued more and market logic seems to play a trivial role,

[4] We thank an anonymous reviewer for suggesting the additional explorations.

economic impact is still considered as one of the important evaluation criteria. For instance, in the 2018 NSF budget request to Congress, Director France A. Córdova noted that, “The FY 2018 NSF budget request of $6.65 billion reflects NSF’s commitment to establishing clear priorities in areas of national importance and identifying the most innovative and promising research ideas that will yield the highest return on investment for the nation” (National Science Foundation, 2017). This quote implies that, besides technological advancement, there are also other logics in play, including the promotion of economic and other social progresses, but very few studies to date have systematically examined how government agencies make funding decisions during the review process, and how different logics interact to guide such decisions. While we did not study review processes at these funding agencies or agencies in other countries, we believe that our study has made an early, but crucial, step in this direction in the hope that more research will explore how multiple logics guide the allocation of government attention and resources in various domains.

It should also be fruitful to situate this study within the broader discussion regarding the value of boundary-spanning work. Although one should exercise caution when generalizing our findings to interdisciplinary research due to the fact that we did not directly test the effect of interdisciplinarity on evaluations, we believe that the results of this study have important implications for policy makers and scholars who are interested in the debates of the merits and challenges associated with interdisciplinary research. In the world of science, there has been a movement to increasingly embrace inter- and multidisciplinary work. For example, in 2008, the NIH formalized support of interdisciplinary research values by establishing the Exploratory Centers for Interdisciplinary Research. These centers are designed to remove “roadblocks to potential collaboration” across disciplines. However, does this trend mean that categorical imperative no longer matters? Our study suggests otherwise, echoing insights of scholars who indicate the difficulty of recognizing and evaluating cross-cutting research (e.g. Aboelela et al., 2007; Campbell, 2005). In fact, our results reveal that not only could participant diversity at project level be associated with discount from reviewers, but field-level diversity may also work as a double-edged sword. While reviewers may value an interdisciplinary field under some conditions, such benefits are not easy to reap, especially when the proposed idea involves a highly diverse team.

5.1. Limitations and future research

This study certainly has its limitations. First, we have only included awarded proposals in our analysis. Although NIST attempted to survey non-awardees in selected years, response rates from the unfunded applicants were not satisfactory. Also, information related to industry affiliations and technology categories are only available for awarded proposals. While we are not able to include non-awarded projects in our analysis, it would be interesting to see how differences or similarities between awardees and non-awardees inform the current study. Indeed, we consulted reports based on the applicants’ survey of the 1998 ATP competition (e.g., Feldman and Kelley, 2001). Apparently an applicant was more likely to receive the award if it had more business affiliations—i.e. connections with other for-profit companies.[5] However, a firm’s likelihood to obtain funding was not affected by whether it partnered with universities, nor was it affected by whether the proposal was a single-firm project or involved partnership with other organizations. These observations imply that although ATP encouraged collaborations, especially those between for-profit firms and universities, collaboration itself was not sufficient for a project to obtain funding. Moreover, the encouraged type of collaborations (between for-profit firms and universities) was not necessarily the type that would eventually become funded. Coupled with our findings, this may suggest that while ATP encouraged collaborations, collaborations were not necessarily rewarded in this context, especially those involving high levels of participant diversity (either in terms of institutional affiliations or industry backgrounds). Yet, given that we were not able to conduct full-fledged analyses of the complete pool of applicants, this speculation needs to be interpreted with caution, and more future research is needed.

With this limitation in mind, we believe that our findings and conclusions may have broader generalizability. Zuckerman (1999:1401) has noted that two stages of competition exist. In the first stage, the candidate has to fit into an existing category in order to be even considered; in the second stage, candidates should strive to differentiate themselves from all other legitimate offers in order to stand out. This suggests that category purity should be more critical during the initial screening stage. If this account holds, then the fact that we only examined the awarded projects may have made our study a stronger test of the categorical imperative thesis. Moreover, we believe that our setting allows us to make a unique contribution to the literature by shedding new insights into this two-stage model. Given that all of the studied proposals passed the initial screening and we continued to find a preference for categorical purity among business reviewers, our results suggest that the “imperative” may be at work even in the second stage. However, the strength of the “imperative” depends on other contextual factors, such as evaluation logics and the fuzziness of the entire category. These findings thus offer more a nuanced understanding of the relative importance of categorical purity in different evaluation stages.

An alternative explanation for our findings is that diverse teams may simply have produced projects of lower quality because of coordination problems or team conflicts, and hence the negative ratings by the reviewers have merely reflected the underlying inferior quality of such projects. However, the fact that we observe only negative associations between participant diversity and evaluations among business reviewers, but not technical reviewers, suggests that there is more to this intrinsic-quality argument. It seems implausible that diverse teams only produce intrinsically inferior projects on the commercialization aspect but not on the technological dimension. Moreover, the speculation that diverse collaboration would produce lower quality projects is inconsistent with findings of most prior research. For example, Walsh et al. (2016) found that heterogeneous collaborations are associated with higher quality inventions. Lucena and Roper (2016) found that diverse technology alliances typically increase a firm’s ambidexterity and absorptive capacity. In fact, in unreported *post-hoc* analyses, we found that participant diversity has a curvilinear relationship to two *ex-post* project outcomes: revenues generated and patents resulting from the project. While project outcomes can be affected by other factors and cannot be simply attributed to the quality of the proposal, these exploratory findings suggest that the association between participant diversity and project quality is not a straightforward, linear relationship. In fact, some recent research has also revealed that diversity along different dimensions and distance among collaborators have nuanced and non-linear effects on innovation outcomes (e.g., Aguiléra et al., 2012; Fitjar et al., 2016; Nooteboom et al., 2007).[6] While we did not find evidence for a curvilinear relationship between diversity and *ex-ante* review scores in our data, future research may want to explore whether participant diversity may have a curvilinear relationship with *ex-ante* evaluation outcomes in different contexts.

Another limitation of this study is that we only used participating

[5] Other noticeable differences include the following: compared to non-awardees, an applicant was more likely to receive funding if it had been more open in communicating its R&D strategy and findings, if the proposal involved new partners, and if the proposal represented a new technical area for the firm (i.e., if the project had not been included in the organization’s R&D portfolio in the previous two years.) See Feldman and Kelley (2001).

[6] We thank an anonymous reviewer for this point.

firms' SIC affiliation as a measure for participant diversity. Although we believe this is a satisfactory measure for our purpose, there are other dimensions of diversity, such as organizational type (e.g., public and private entities, research institutions and for-profit firms, and so forth.), specific capabilities, or technology portfolio. Moreover, some SIC codes may be closer to each other. Due to data limitations, we were not able to use such alternative measures or consider the distance or relatedness between each SIC code. Future research should explore whether the relatedness between SIC codes might moderate reviewers' perceptions, or whether diversity along other dimensions might induce different reactions from external reviewers.

While we focus on the relationship between participant diversity and *ex-ante* evaluation of a project, we believe it is also possible that this initial effect may trickle down and affect the *ex-post* performance outcome of the project, becoming a self-fulfilling prophecy. This may happen through two mechanisms: favorably evaluated projects may receive more resources, and participants on highly rated projects may have higher morale and motivation, thus translating into higher quality team effort. Such mechanisms are in addition to the well-established mechanisms in extant literature, such as informational benefits or collaboration costs. While it is beyond the scope of this paper, future research may want to explore and tease out our speculation.

In conclusion, to the best of our knowledge, this is the first empirical study that explicitly examines how external reviewers relate participant diversity to the perceived *ex-ante* value of collaborative innovations. Our findings can contribute to a better understanding of the diversity-innovation relationship and stimulate future research efforts on this interesting topic.

Appendix A. Selection Process and Evaluation Criteria of ATP

Proposals submitted to ATP are selected based on a peer-review process. Proposals will first go through an initial selection process held by a Source Evaluation Board (SEB); those that pass the initial screening would then be sent to expert technical and business reviewers outside of the SEB, who will conduct independent peer reviews. Outside technical reviewers are drawn from federal laboratories, and outside business/economics reviewers are hired consultants, with suitably diverse expertise in business operations, venture capital, economics, and business development. Proposals that are judged to have sufficient merit based on the established selection criteria receive further consideration and are referred to as semifinalist, which will then be invited to NIST/ATP for an oral review of their proposals. Semifinalist proposals are then ranked, and the Selecting Official selects funding recipients based on the ranking, the availability of funds, the adherence to ATP selection criteria, and the appropriate distribution of funds among technologies and their applications. To receive funding, a proposal has to be considered that it has scientific and technological merit and that the proposed technology has strong potential for broad-based economic benefits. Additionally, a proposal will not be funded if it (a) is product development rather than high-risk R&D, (b) does not display an appropriate level of commitment from the proposer, and (c) does not have adequate technical and commercialization plans.

Scientific and Technological Merit (50 percent). This selection criterion has three critical components: (1) Technical Innovation, (2) Technical Risk With Evidence of Scientific Feasibility, and (3) Technical Plan.

Proposals should provide a brief overview of information demonstrating their potential for scientific and technological merits; sample information include:

- Describe the technical barriers that prevent technical improvement in industry in this area.
- Describe the proposed solution to the identified problem and describe why it is innovative.
- Identify the measurable success criteria for the proposed technology development efforts.
- Discuss why the proposed solution has not previously been attempted or accomplished.
- Describe the technical challenges and assess the probability of success of the project approach(es).
- Demonstrate that the technical approach is feasible by documenting that there is a sound scientific and/or engineering foundation or rationale for the proposed approach.
- Provide appropriate interim and final milestones for each year of the technical plan and tie these to the metrics.

Potential for Broad-Based Economic Benefits (50 percent). This selection criterion has three critical components: (1) National Economic Benefits, (2) Need for ATP Funding, and (3) Pathway to Economic Benefits.

Proposals should provide a brief overview of information demonstrating potential for their economic merits; sample information include:

- Explain the business opportunity and identify the future users of the technology.
- Describe the economic significance of the project.
- Quantify the magnitude of the improvement over current technology. Discuss how successful commercialization will benefit the proposing company, customers, competitors, industry, and others.
- Describe the initial planned product incorporating the technology and the commercialization plan for bringing the technology into the marketplace.
- Describe how the proposing organization(s) will ensure that the technology will be broadly diffused.
- Explain the planned organizational structure for the project.
- Describe the experience and qualifications of the business staff who will work toward achieving the commercialization goals.

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