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Effects and Interactions of Researcher's Motivation and Personality in Promoting Interdisciplinary and Transdisciplinary Research

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Abstract: Motivation is one of the most important factors driving innovative activities such as interdisciplinary research (IDR) and transdisciplinary research (TDR) for the achievement of sustainable development goals (SDGs). While there has been progress in developing ex-post indicators to evaluate their performance, only a few trials have been conducted to explore how researchers' motivations are related to their proactive participation. To address this issue, this study empirically investigates the effect of researchers' personality traits on their attitudes toward IDR/TDR collaboration. A questionnaire survey of 228 researchers in the natural sciences, mathematics, engineering, and related interdisciplinary fields was used to test the hypotheses by regression analysis that included interaction terms. The results show that researchers' intrinsic motivation positively affects both IDR and TDR, while their extrinsic motivation mainly affects TDR. Furthermore, researchers' personality traits have a significant effect on interdisciplinary collaboration and regional/societal collaboration. These findings provide cues on how to effectively integrate knowledge of IDR/TDR and how to motivate and allocate researchers for successful TDR/IDR collaboration.

Keywords: sustainable development goals (SDGs); interdisciplinary research; transdisciplinary research; motivation; personality; R&D management

Citation: Katoh, S.; Aalbers, R.; Sengoku, S. Effects and Interactions of Researcher's Motivation and Personality in Promoting Interdisciplinary and Transdisciplinary Research. *Sustainability* **2021**, *13*, 12502. https://doi.org/10.3390/su132212502

Academic Editor: Ortwin Renn

Received: 29 September 2021
Accepted: 8 November 2021
Published: 12 November 2021

1. Introduction

1.1. Trends in Recent Scientific Research

Science involves complicated phenomena, and public research has a significant impact on research and development (R&D) in industries [1–3]. University–industry knowledge transfer has to bridge the gap between academic research and social implementation. Many studies have highlighted the relevance of collaborative research, contract research, consulting, and informal relationships [4–8]. Recent discussions reveal a complex stakeholder field, which involves policymakers and non-academic stakeholders, jointly leading R&D management [9–13]. Different stakeholders are indispensable in developing new scientific knowledge and technologies [14,15]. Collaboration with diverse stakeholders has led to the positioning of science as a more social problem-driven phenomenon [2,13,16]. The increasing complexity of science has increased the importance of collaboration and the personal traits required to partake in such social interactions (as organizational boundaries open up, these new collaboration patterns have direct implications for future transdisciplinary R&D). Accommodating expert users and professional R&D scientists at the forefront of science requires an understanding that extends beyond mere collaborative identification and structuring of problems to conducting these transdisciplinary interactions at a personal level [10]. Personality traits of researchers are essential in adhering to such collaborative requirements.

One study, using 19.9 million papers over five decades and 2.1 million patents, clearly shows that teams increasingly dominate solo authors in the production of knowledge [17].

An extensive literature review shows that there is a higher probability of team research leading to a novel combination of ideas than research by single authors [18]. Large and diverse teams are needed to achieve high-impact research results [19]. Relatedly, one study focused on the process of expanding teams understands the changes in team size that the data show over the past 50 years due to a combination of stable core teams and extended teams with fluid change [20]. At the same time, teams do not instantly become productive. Group membership entails invested time to establish trust, affective relations and a shared group identity before becoming effective catalysts to innovation [21,22]. However, some teams are more effective than others. For instance, collaborative routines need to develop and are more likely to appear among long-time members of a research team [10,23–25]. In balance, however, over the past decade, scientific activities have increasingly been conducted by teams, triggering a shift towards project-based organizations [26–28].

1.2. Interdisciplinary and Transdisciplinary Research

Owing to the increasing need to achieve sustainable development goals (SDGs), and consequently, the increasing complexity of science and social expectations, research on team science has developed using the framework of interdisciplinary research (IDR) and transdisciplinary research (TDR). Both definitions have been outlined in many studies. IDR is oriented towards common societal problems and integrating knowledge and methods from different disciplines [29]. TDR, in addition to the definition of IDR, is essential in involving non-academic stakeholders [30–34]. IDR/TDR is important because individual disciplines can offer only partial views of the issues at stake [35,36]. IDR/TDR is closely related to sustainability science in that it focuses on solving social problems, and an interdisciplinary/transdisciplinary approach is essential in shaping a sustainable society [37–40].

Both quantitative and qualitative approaches for evaluating IDR have been considered by scholars, and there seems to be a consensus, at least in terms of establishing evaluation methods for ex-post performance [41]. From a qualitative perspective, problems such as extensive task burden on evaluators and grantees as well as bias stemming from the evaluator's specialization and evaluation stance have been reported [42]. In addition, various qualitative studies have shown that peer review trends have negative biases in IDR [43–45]. From the quantitative perspective, IDR evaluation using the bibliometric method has been widely discussed [41,46]. Other studies have assessed the interdisciplinarity of researchers, research centers, and projects by analyzing research articles using a variety of indicators of diversity [47–50]. Conventional indicators such as impact factor and number of citations are used only in the context of monodisciplinary research (MDR) and are not fully applicable in the evaluation of IDR [51]. Macro-level analysis based on the Web of Science and Scopus category shows that the impact of research published in multidisciplinary journals on multiple subjects is lower than that of MDR [52]. Although there is a certain consensus that the existing indicators in IDR are not appropriate, studies based on more novel approaches have noted that IDR is associated with lower productivity expressed in terms of the number of articles but has a higher impact as assessed by the number of citations [53]. However, performance indicators, such as research papers and patents, are ex-post outputs that are obtained as a result of research, and these indicators have a fatal time lag in R&D management. Therefore, we believe that it is necessary to evaluate the factors that promote IDR, using indicators that can be observed in advance, for appropriate project management.

Some of the studies that provide a conceptual model of TDR that includes IDR in constructing a sustainable innovation ecosystem have made a significant academic contribution [40,54,55]. These studies focus on both science and society and understand that TDR cycles through three phases: problem transformation, interdisciplinary integration, and transdisciplinary integration. In TDR, the actual research, or co-creation of knowledge, occurs in interdisciplinary integration. While most research on TDR is based on qualitative analysis of organizational layers [39], a quantitative approach that focuses on

the relationship between the individual researcher and TDR is needed to provide a more coherent theory.

1.3. Study Objective

While there has been some progress in focusing on the organization itself to understand IDR/TDR, there has been only a preliminary examination of how the motivations and personalities of individual researchers relate to IDR/TDR. Team members may not always feel comfortable providing feedback to each other or be sufficiently motivated to work together to produce great ideas. Despite its relevance in risk-taking and creativity, the link between more common IDR/TDR orientation and intrinsic motivation has not been adequately clarified. Therefore, this study attempts to identify the interaction effect of motivation and personality, which form the base of a researcher's decision-making process, on IDR/TDR collaboration.

2. Theoretical Development

2.1. Factors Associated with IDR/TDR

2.1.1. Project Management Framework

Scientists decide on research problems to work on by balancing the tension between productive tradition and risky innovation [56]. For instance, biomedical chemistry is a science field where traditional strategies are common and risky innovation strategies are rare [57]. This problem primarily affects scientists' own careers and the careers of those reliant on them [51,58,59]. Empirical trends show that researchers are less motivated to engage in risky IDR/TDR activities early in their careers, as IDR/TDR has a high impact but reduces short-term productivity [36]. On the other hand, it has been noted that innovation-oriented researchers are motivated by a desire to bequeath a legacy and achieve a higher position in their respective field and that scientific awards and accolades appear to function as primary incentives in resisting conservative tendencies and encouraging better exploration [57].

Various studies have suggested the direction of evaluation and understanding of IDR/TDR projects. In one literature review, we argued that the evaluation framework for IDR/TDR should incorporate seven general principles: (a) variability of goals; (b) variability of criteria and indicators; (c) leveraging of integration; (d) interaction of social and cognitive factors in collaboration; (e) management, leadership, and coaching; (f) iteration in a comprehensive and transparent system; and (g) effectiveness and impact [60]. Similarly, studies that attempted to understand IDR and its integration process categorized it into three drivers (complexity, motivational factors, and an assumption of creative potential) and two barriers (institutional factors and differences in disciplinary traditions) [61]. In a qualitative analysis of five TDR projects, a Swedish research group found that process qualities, such as practitioner motivation and the perceived importance of the project, together with the breadth of perspectives, openness/flexibility of participants, and in-depth exchange of expertise and knowledge contribute to better output and outcomes, though the impact of TDR needed greater examination [62]. In addition, studies that quantitatively explored local government officials' (LGOs') preferences in the context of TDR found that collaboration preferences are influenced by LGOs' confidence that researchers can help solve problems, experience with researchers, the severity and type of problems occurring in the community, and partner trust [38].

2.1.2. Personal Traits

Approaches that focus on identifying the characteristics of individual interdisciplinary researchers also provide some useful suggestions. One study that analyzed the relationship between researcher characteristics and IDR collaboration based on 303 survey questionnaires showed that women researchers are more engaged in IDR collaboration, years of research experience is positively related to both MDR and IDR collaboration, and work experience in firms and government organizations increases IDR collaboration [63]. Although

this survey provides some definite results, it should be noted that their scope of collaboration was limited, there was no clear concept of TDR, and bias was included because more than half of the surveyed participants were PhD students and student assistants. A more comprehensive perspective deepens our understanding by organizing the transdisciplinary researcher into four dimensions: (a) an appreciation of an array of skills, characteristics, and personality traits aligned with a transdisciplinary attitude; (b) acceptance of the idea that transdisciplinary individuals are intellectual risk-takers and institutional transgressors; (c) insights into the nuances of transdisciplinary practice and attendant virtues; and (d) respect for the role of creative inquiry, cultural diversity, and cultural relativism [64].

These IDR/TDR-focused studies used a variety of data sources, including case studies, some using open communication environments, such as workshops, conferences, or meetings, while others used detailed surveys and interviews [39]. In addition, visualization techniques and tools such as mind maps, diagraming, and GIS tools were adopted for analyzing such data, while few studies used verification by a statistical approach or modeling.

Following the above discussion, this study focuses on the following four distinct IDR/TDR collaboration types: interdisciplinary, industry, government/local authority, and regional/societal collaboration. The influence of contextual factors such as demography, motivation, and personhood on these four types of collaboration also needs to be carefully considered [10]. Many studies have adopted a qualitative analysis centered on case studies, which increases the importance of connecting each study with an abstract dimension.

2.2. Motivation

Individual-level motivation is commonly regarded as fundamental to innovation. As such, it is believed that motivation positively influences the amount of transferred knowledge [65] and that low levels of motivation restrict knowledge transfer [66]. Intrinsic motivation is considered to encourage risk-taking and creativity, while extrinsic motivation introduces an external appeal in the search for the next creative idea [67]. Intrinsic motivation, the motivation to engage in a task owing to interest or enjoyment and not as a means to gain a reward, has been found to direct one's willingness to take risks, mediating the effect of intrinsic motivation on employee creativity [68]. Extrinsic motivation, by contrast, is the motivation to work in response to something apart from the work itself, such as a reward, recognition, or the dictates of other people [69].

These two motivations—intrinsic and extrinsic—are known to affect various activities and performances that matter to innovation at large. For example, one comprehensive review points out that people are most creative when they are motivated primarily by their interests, pleasures, satisfactions, and challenges in the work itself, that is, intrinsic motivation [70]. Extrinsic (expected organizational rewards, reciprocal benefits) and intrinsic (knowledge self-efficacy, enjoyment in helping others) motivation might explain how employees may be more engaged in IDR/TDR collaboration as the payoff can appeal to share with others. While intrinsic motivation is generally known to have a positive impact on performance and innovative knowledge sharing [71–73], extrinsic motivation is known for its negative impact and requires proper design and operation. Extrinsic rewards, such as money and promotions, generally have a direct and indirect positive impact on performance [74,75]. In addition, by properly designing incentives based on the employee's career stage, individual performance can be improved efficiently [76]. On the other hand, extrinsic motivation has also been shown to have an undermining effect [77]. In this study, the rewards were removed after the participants were rewarded for their voluntary activities. As a result, their activity was lower than what it was before the reward was provided. The undermining effect implies that rewards (i.e., extrinsic motivation) reduce intrinsic motivation. This effect is more likely to occur when the reward is tangible (e.g., money) rather than verbal and when a promise is made in advance. Moreover, a meta-analytic review shows that the effect is greater when the reward is performance-based and commensurate with the engagement [78,79].

Interest and curiosity are widely recognized in psychology as factors that cause or maintain intrinsic motivation. Interest is considered to promote learning and effort and has been empirically shown to be associated with academic achievement and knowledge acquisition [80–82]. Curiosity refers to the desire to acquire knowledge. It has been proposed that curiosity develops when one becomes aware of a gap between what one wants to know and one's current knowledge and expects that one can fill that gap [83]. Since curiosity only arises when there is a perceived gap in knowledge, interest is considered a broader concept [84]. They are also viewed as different in terms of persistence, as curiosity only lasts until the time the knowledge gap is filled, whereas interest has no such limitation and is often persistent [85].

2.3. Personality

Personality has long been a major topic of discussion in psychology and has been developed as a concept for answering the simple yet difficult question, "Who are you?" The American Psychological Association (APA) (American Psychological Association (APA). Available online: https://www.apa.org/topics/personality/ (Accessed 23 September 2021)) defines personality as "individual differences in characteristic patterns of thinking, feeling, and behaving," and many researchers have examined ways to understand and measure what makes some people different from others. The American psychologist Lewis Goldberg proposed the Big Five factors, which have become the most commonly-used construct in explaining personality since the 1990s. The Big Five is not a dichotomous variable but a conceptualization of spectrum characteristics and is composed of five factors: extraversion, agreeableness, conscientiousness, neuroticism, and openness to experiences.

The Big Five personality traits have been found to be associated with a variety of output and performance indicators. One cross-sectional study reported conscientiousness as being highly associated with college grade point average (GPA) and SAT scores [86]. Conscientiousness is found in all job performance criteria, while extraversion has been found to be an effective predictor in occupational groups, such as managers and sales personnel, where social interaction is important [87,88]. Similarly, research on personality traits related to job turnover has shown that neuroticism best predicts employees' intention to quit, whereas low agreeableness and low conscientiousness best predict the actual decision to quit [89]. Personality is also related to creativity, which is known to have a significant impact on performance [90,91].

2.4. Hypotheses

Some studies have pointed out qualitatively the relationship between researchers' motivation and IDR/TDR, but it has not been verified by a quantitative analysis [61,62]. A quantitative study has used, for example, three concepts of "gold" (financial rewards), "ribbon" (reputational/career rewards), and "puzzle" (intrinsic satisfaction) for analyzing scientists' motivation in pursuing commercial activities [92]. This study highlights the primacy of scientists' self-motivation and suggests that a proper explanation of their commercial behavior needs to consider a broader mix of motives. Therefore, our study extends the commonly held belief that both intrinsic and extrinsic motivation improve business activity. We consider that similar patterns will be replicated in researcher motivation and IDR/TDR activities and formulate the following hypothesis.

Hypothesis 1a (H1a). *Intrinsic motivation is positively associated with IDR/TDR collaborations.*

Hypothesis 1b (H1b). *Extrinsic motivation is positively associated with IDR/TDR collaborations.*

Figure 1 shows a conceptual summary of the following hypotheses. In the context of IDR/TDR, qualitative analysis has pointed out that personality and attitude are essential for becoming an interdisciplinary researcher [64,93]. Hence, we use a quantitative approach to test the hypothesis that a researcher's personality is related to IDR/TDR collaborations. As IDR/TDR includes a variety of collaborations, it is assumed that the corresponding

personality traits would differ depending on the type of collaboration. It would be preferable to propose hypotheses that are decomposed into individual personality traits, but in the context of IDR/TDR, there is not enough accumulated prior research. Therefore, we attempt to approach the hypotheses exploratory.

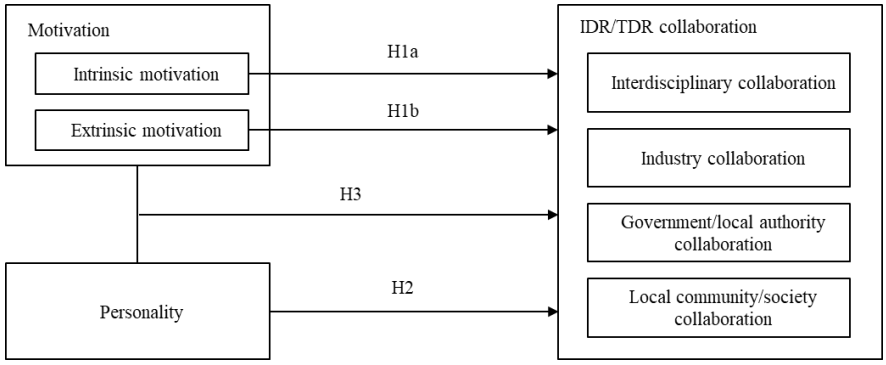


Figure 1. Conceptual summary of hypotheses.

Hypothesis 2 (H2). *The researcher's personality is related to IDR/TDR collaborations, and the corresponding personalities for each collaboration are different.*

Hypotheses 1 and 2 discuss the simple effect of a researcher's motivation and personality on IDR/TDR collaboration, but it is also important to examine the effect of these interactions because IDR/TDR involves complicated phenomena [36,60]. Through exploratory hypothesis testing, we attempt to answer one question that concerns many researchers and practitioners: Is there a best match between motivation and personality in promoting IDR/TDR?

Hypothesis 3 (H3). *Interaction between motivation and personality is related to IDR/TDR collaborations, and the corresponding interaction for each collaboration is different.*

3. Research Methods

3.1. Setting

To test these hypotheses, we conducted a web-based survey of natural science researchers in Japanese academia or public research institutions. We used the Macromill Inc. (Tokyo, Japan) survey panel, which is one of the largest panels in Japan, to select researchers who matched our focus. As it was an unspecified population, we took care to screen the respondents. Researchers were defined using three criteria: has an employment relationship with a university or public research institution; has published his/her work in a peer-reviewed journal; and primarily conducts research activities, that is, is not a research technician or research assistant. The scope of this survey is for researchers in the natural sciences (e.g., biology, medicine), mathematics, engineering, and related interdisciplinary fields. The respondents were screened using questions corresponding to these items, and we received 308 responses. However, it was assumed that there would be a certain amount of noise among the respondents. Therefore, we excluded the likely noisy respondents by asking them to respond to the screening questions again after we set up dummy questions. Finally, 228 valid responses were adopted as the dataset for hypothesis testing.

3.2. Measures

All the data required for the analysis in this study were obtained through a survey questionnaire. The details of the variables are presented below.

IDR/TDR collaborations. Based on the literature review, four self-assessment-based indicators were developed: one for IDR (interdisciplinary collaboration) and three for TDR

(industry collaboration, government/local authority collaboration, and regional/societal collaboration) [36,38,60,63,94]. The IDR activity (interdisciplinary collaboration) item is "I am actively working with researchers from different disciplines". TDR activity items include "I am actively conducting research through industry–academia collaboration"; "I am actively collaborating with government/local authorities"; and "I am actively collaborating at regional/societal level". The respondents answered on a 7-point Likert scale (1 = not at all, 7 = very much so).

Motivation. We designed the intrinsic and extrinsic motivation section based on the most prominent studies in motivation research on the Work Preference Inventory and personal psychology, which is closely related to the focus of this study [69,95]. The sample items include "I enjoy solving complex problems" and "I am strongly motivated by the money I can earn". The responses were on a 7-point Likert scale (1 = not at all, 7 = very much so). See Appendix A for details of the questions. Intrinsic and extrinsic motivation each consisted of 4 items, and the mean was used as a variable. We evaluated the reliability of Cronbach's alpha (intrinsic motivation: $\alpha = 0.90$, extrinsic motivation: $\alpha = 0.70$) by comparing it with similar studies [96,97]. As both values were above average, the motivational indicators were considered reasonable.

Personality. The present study was conducted using the Big Five personality framework, the most dominant framework used in personality research. We adopted the Ten-Item Personality Inventory (TIPI) as a convenient way to measure the Big Five traits [98]. Each item was assessed using a 7-point Likert scale, and the average of every two items was used as a Big Five variable.

Other variables. To test the constructed hypotheses, researchers' demographic information had to be made variable in the analysis. First, three basic demographic variables were adopted—age, job position, and education (degree). For age, the respondents' age was used as a variable. Position and education were quantified as a variable with four levels (4: Professor, 3: Associate professor, 2: Assistant professor and 1: Post-doc) and three levels (3: PhD, 2: Master, 1: Bachelor).

Second, it was necessary to consider the differences in the academic field to which the researcher belongs, so we introduced a variable related to the field. The categorization of academic fields was designed with reference to the standardized categorization of the Japan Society for the Promotion of Science (JSPS), the most popular organization in Japan that subsidizes public scientific research. The researchers were categorized into four domains (engineering; biology and agriculture; medicine, dentistry and pharmacy; and other sciences), with engineering as the baseline and the other three domains as dummy variables. The academic domain was selected as the one considered closest to their own research and therefore did not overlap with more than one domain.

Finally, the researcher's own research phase was assessed on a 7-point Likert scale. The concepts of IDR/TDR and basic-applied research are fundamentally different; however, they have been shown to have an association [94,99], and there is agreement that these studies should be evaluated by different policies [100]. As the researchers providing the responses could get confused between these concepts, we determined that it is appropriate to adopt the research phase as a control variable. This item was "How would you qualify your continuous research between 'pure basic research' (=1) and 'applied research' (=7)?" [99].

3.3. Analysis

First, we reviewed the profiles of 228 respondents to examine the validity of the study framework (Table 1). Job positions were widely distributed from senior positions, such as professor, to post-doctoral researchers. Although the majority are PhD holders, many other degrees were also identified. This distribution reflects the current scenario of science in Japan, which may be due to: (i) in fields such as medicine and dentistry, they can participate in academic research after obtaining the degree of a medical doctor; (ii) in the past, there have been cases of non-PhD graduates with significant work experience being appointed to

academic posts; and (iii) when employment is fixed-term or part-time, degree requirements might be reduced in some cases. Therefore, although the percentage of PhD holders is lower than expected, we conclude that the data set is acceptable for use in this study. After reviewing the basic respondent profile (Table 1) and descriptive statistics (Table 2), the hypotheses were tested using ordinary least squares (OLS) regression (Table 3).

Table 1. Profile of respondents.

	N	Ratio		N	Ratio
Age			Education		
Under 29	13	6%	PhD	124	54%
30–34	39	17%	Master	67	29%
35–39	31	14%	Bachelor	37	16%
40–44	33	14%			
45–49	37	16%	Specialization		
50–54	29	13%	Engineering	71	31%
50–59	20	9%	Biology and Agriculture	59	26%
Over 60	26	11%	Medicine and Dentistry and Pharmacy	49	21%
Position			Other Sciences	49	21%
Full professor	40	18%			
Associate professor	65	29%			
Assistant professor	65	29%			
Post-doc	58	25%			
			Total	228	100%

The following regression analysis was performed with the four self-assessed IDR/TDR indicators as the dependent variables, with control variables including a dummy for specialization; model of intrinsic and extrinsic motivation variables (Model 1a, 2a, 3a, 4a); Big Five personality model (Model 1b, 2b, 3b, 4b); a model that includes both motivations and the Big Five personality (Model 1c, 2c, 3c, 4c); the interaction model of intrinsic motivation and the Big Five personality (Model 1d, 2d, 3d, 4d); and the interaction model of extrinsic motivation and the Big Five personality (Model 1e, 2e, 3e, 4e). The variables of the interaction model were considered for the correlation between variables using mean-centering. From the histogram and normal P–P plot, we confirm that the residuals in all the regression models generally follow normal distribution. We also review the variance inflation factor (VIF) to assess the level of multicollinearity. Since the VIF values remain between 1.20 and 1.77 for all the models, we conclude that the risk of multicollinearity is very low. In general, multicollinearity within a model is suspected when the VIF is close to or greater than 10 [101]. Finally, simple slope analysis was performed on the interaction terms that showed significant differences at least 5% in the interaction models (Model 1d, 1e, 2d, 2e, 3d, 3e, 4d, 4e).

Table 2. Means, standard deviations, and correlations.

No.	Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
IDR/TDR collaboration																					
1	Interdisciplinary collaboration	4.10	1.45																		
2	Industry-academia collaboration	4.23	1.49	0.58 **																	
3	Collaboration with government/local authorities	4.02	1.64	0.44 **	0.65 **																
4	Collaboration with local community/society	4.00	1.56	0.44 **	0.50 **	0.72 **															
Control variables																					
5	Age	44.72	10.92	0.09	0.06	−0.04	−0.05														
6	Position	2.38	1.05	0.07	0.10	0.01	−0.02	0.28 **													
7	Education	2.38	0.75	0.20 **	0.03	−0.05	−0.11	0.25 **	0.45 **												
8	Basic-applied research	3.96	1.80	0.20 **	0.30 **	0.21 **	0.13	0.15 *	0.01	−0.03											
Specialization																					
9	Engineering	0.31	0.46	0.12	0.21 **	0.10	0.08	0.14 *	0.02	0.00	0.23 **										
10	Biology & Agriculture	0.26	0.44	0.02	−0.04	0.05	0.09	0.00	−0.11	−0.11	0.03	−0.40 **									
11	Medicine & Dentistry & Pharmacy	0.21	0.41	−0.08	−0.11	−0.09	−0.12	0.02	0.02	0.16 *	0.02	−0.35 **	−0.31 **								
12	Other Sciences	0.21	0.41	−0.07	−0.09	−0.08	−0.06	−0.18 **	0.07	−0.04	−0.31 **	−0.35 **	−0.31 **	−0.27 **							
Motivation																					
13	Intrinsic motivation	5.04	1.36	0.49 **	0.29 **	0.30 **	0.27 **	0.17 *	−0.04	0.20 **	0.13	0.07	−0.05	0.01	−0.03						
14	Extrinsic motivation	4.15	1.06	0.32 **	0.32 **	0.39 **	0.24 **	−0.04	−0.02	−0.07	0.23 **	0.12	−0.08	0.01	−0.07	0.31 **					
Personality																					
15	Extraversion	3.91	1.13	0.37 **	0.19 **	0.20 **	0.25 **	−0.06	0.04	−0.04	0.12	0.13	0.02	−0.11	−0.06	0.09	0.32 **				
16	Agreeableness	4.40	0.93	0.14 *	0.16 *	0.20 **	0.25 **	0.07	0.07	0.02	0.17 *	−0.04	0.06	0.04	−0.06	0.26 **	0.03	0.02			
17	Conscientiousness	4.54	1.06	0.35 **	0.19 **	0.19 **	0.20 **	0.18 **	0.04	0.15 *	0.24 **	−0.05	0.05	0.15 *	−0.15 *	0.37 **	0.06	0.22 **	0.38 **		
18	Neuroticism	4.26	0.92	0.06	0.00	0.05	0.02	0.16 *	0.11	0.09	0.12	0.07	−0.06	0.02	−0.04	0.18 **	−0.02	0.03	0.34 **	0.37 **	
19	Openness to Experiences	4.53	0.86	0.26 **	0.15 *	0.18 **	0.11	0.07	0.04	0.16 *	0.14 *	0.15 *	−0.02	−0.04	−0.11	0.40 **	0.06	0.14 *	0.10	0.38 **	0.30 **

$n = 228$; * $p < 0.05$, ** $p < 0.01$.

Table 3. Results of regression analysis for IDR/TDR collaboration.

Variables	Interdisciplinary Collaboration					Industry–Academia Collaboration				
	Model 1a	**Model 1b**	**Model 1c**	**Model 1d**	**Model 1e**	**Model 2a**	**Model 2b**	**Model 2c**	**Model 2d**	**Model 2e**
Control variables										
Age	−0.01	0.00	0.00	0.00	0.00	−0.01	0.00	−0.01	−0.01	0.00
Position	0.06	−0.06	0.04	0.05	0.05	0.21 *	0.15	0.20 *	0.23 *	0.20 *
Education	0.27 *	0.38 **	0.26 *	0.26 *	0.26 *	−0.07	−0.02	−0.07	−0.07	−0.06
Basic-applied research	0.08	0.08	0.06	0.07	0.06	0.18 **	0.19 **	0.16 **	0.17 **	0.16 **
Specialization										
Biology and Agriculture	0.05	−0.12	−0.01	−0.01	−0.02	−0.29	−0.48 †	−0.38	−0.35	−0.37
Medicine and Dentistry and Pharmacy	−0.41 †	−0.45 †	−0.40 †	−0.42 †	−0.41 †	−0.60 *	−0.67 *	−0.66 *	−0.66 *	−0.67 *
Other Sciences	−0.17	−0.03	−0.10	−0.07	−0.11	−0.34	−0.32	−0.34	−0.31	−0.17
Motivation										
Intrinsic motivation	0.43 **		0.38 **	0.36 **	0.37 **	0.24 **		0.19 *	0.21 *	0.15 †
Extrinsic motivation	0.25 **		0.16 †	0.14	0.16 †	0.28 **		0.26 **	0.23 *	0.31 **
Personality										
Extraversion		0.37 **	0.31 **	0.32 **	0.33 **		0.14	0.06	0.06	0.15
Agreeableness		0.10	−0.01	−0.01	0.00		0.20 †	0.14	0.12	0.20 †
Conscientiousness		0.32 **	0.24 *	0.24 *	0.22 *		0.16	0.12	0.14	0.06
Neuroticism		−0.19 †	−0.14	−0.14	−0.14		−0.25 *	−0.22 †	−0.24 *	−0.23 *
Openness to Experiences		0.19 †	0.00	0.04	0.00		0.13	0.03	0.07	0.06
Interaction										
IM × Extraversion				0.03					−0.02	
IM × Agreeableness				−0.07					0.04	
IM × Conscientiousness				−0.01					0.04	
IM × Neuroticism				0.01					−0.02	
IM × Openness to Experiences				−0.08					−0.17 *	
EM × Extraversion					0.06					0.03
EM × Agreeableness					−0.08					0.01
EM × Conscientiousness					0.01					−0.15
EM × Neuroticism					−0.01					0.07
EM × Openness to Experiences					−0.03					−0.22 *
R-squared	0.31	0.28	0.40	0.41	0.41	0.23	0.19	0.25	0.27	0.29
Adjusted *R*-squared	0.29	0.24	0.36	0.36	0.35	0.20	0.14	0.21	0.21	0.23
F	11.06 **	7.14 **	10.31 **	7.67 **	7.55 **	7.30 **	4.12 **	5.20 **	4.14 **	4.55 **

Table 3. *Cont.*

Variables	Collaboration with Government/Local Authorities					Collaboration with Local Community/Society				
	Model 3a	**Model 3b**	**Model 3c**	**Model 3d**	**Model 3e**	**Model 4a**	**Model 4b**	**Model 4c**	**Model 4d**	**Model 4e**
Control variables										
Age	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Position	0.15	0.06	0.11	0.14	0.13	0.16	0.04	0.11	0.12	0.12
Education	−0.17	−0.13	−0.15	−0.17	−0.15	−0.33 *	−0.22	−0.29 †	−0.31 *	−0.29 †
Basic-applied research	0.10	0.12 †	0.07	0.07	0.06	0.04	0.03	0.01	0.02	0.00
Specialization										
Biology and Agriculture	0.14	−0.07	0.07	0.02	0.10	0.16	−0.04	0.04	0.01	0.07
Medicine and Dentistry and Pharmacy	−0.37	−0.41	−0.41	−0.37	−0.36	−0.42	−0.50 †	−0.48 †	−0.45	−0.45
Other Sciences	−0.24	−0.20	−0.22	−0.20	−0.06	−0.29	−0.24	−0.28	−0.24	−0.15
Motivation										
Intrinsic motivation	0.28 **		0.18 *	0.22 *	0.19 *	0.32 **		0.24 **	0.24 **	0.25 **
Extrinsic motivation	0.44 **		0.46 **	0.35 **	0.45 **	0.19 †		0.15	0.06	0.16
Personality										
Extraversion		0.18 †	0.05	−0.02	0.09		0.25 **	0.20 *	0.15	0.24 *
Agreeableness		0.30 *	0.23 †	0.14	0.22 †		0.40 **	0.32 **	0.25 *	0.32 **
Conscientiousness		0.12	0.09	0.12	0.05		0.18	0.13	0.14	0.12
Neuroticism		−0.14	−0.09	−0.12	−0.06		−0.20	−0.16	−0.16	−0.14
Openness to Experiences		0.23 †	0.13	0.17	0.13		0.09	−0.03	0.03	−0.03
Interaction										
IM × Extraversion				0.14 †					0.15 *	
IM × Agreeableness				0.27 **					0.18 *	
IM × Conscientiousness				−0.04					−0.08	
IM × Neuroticism				−0.08					−0.09	
IM × Openness to Experiences				−0.15					−0.14	
EM × Extraversion					−0.05					−0.06
EM × Agreeableness					0.08					0.09
EM × Conscientiousness					−0.26 *					−0.18 †
EM × Neuroticism					0.06					−0.04
EM × Openness to Experiences					0.06					0.00
R-squared	0.23	0.14	0.25	0.31	0.28	0.16	0.17	0.22	0.27	0.24
Adjusted *R*-squared	0.19	0.09	0.20	0.25	0.21	0.12	0.12	0.17	0.20	0.17
F	7.08 **	2.85 **	5.09 **	4.96 **	4.22 **	4.49 **	3.64 **	4.29 **	4.06 **	3.49 **

Note. IM, Intrinsic motivation; EM, Extrinsic motivation; n = 228. Partial regression coefficient (B) is reported. † $p < 0.10$. * $p < 0.05$, ** $p < 0.01$.

4. Results

Table 2 reports the Pearson's correlations of all the variables. The four IDR/TDR collaborations are correlated with each other ($p < 0.01$). Age, position, and education are also found to be correlated with each other. Older age is associated with a higher position and higher degree ($p < 0.01$). Most of the motivation and personality items are not correlated with the specialization expressed by the dummy variables, indicating that they are not influenced by the academic domain. The correlations between the two motivations and the Big Five traits are clearly differentiated. That is, intrinsic motivation is correlated with agreeableness, conscientiousness, neuroticism, and openness to experience, while extrinsic motivation is correlated with extraversion only ($p < 0.01$). The maximum value of these correlations is $r = 0.40$, showing loose positive relationships.

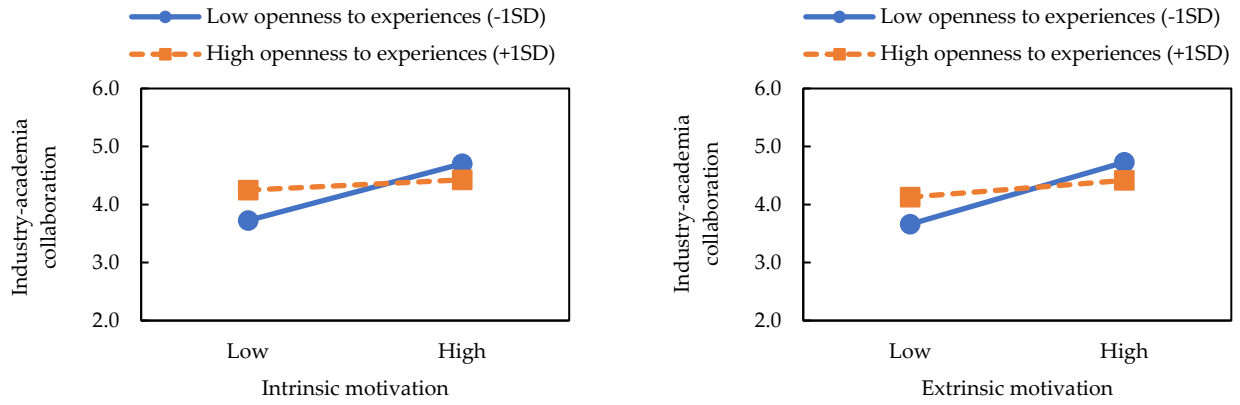
Table 3 summarizes the OLS regression results for IDR/TDR collaboration. The following points are noted regarding the relationship between researcher demographics and IDR/TDR collaboration activities. Firstly, researchers with a PhD had higher IDR collaboration scores. Secondly, researchers engaged in applied research had higher scores for industry collaboration, and lastly, researchers in the field of medicine, dentistry and pharmacy had lower scores for industry collaboration than researchers in the field of engineering.

For Hypotheses 1a and 1b, in models 1a, 2a, 3a, and 4a, intrinsic and extrinsic motivations have significant positive relationships with all four IDR/TDR collaborations, except the relationship between regional/societal collaboration and extrinsic motivation. In the models where personality was introduced (models 1c, 2c, 3c, and 4c), the significant relationship between IDR/TDR collaborations and motivation changes. While intrinsic motivation continues to have a significant relationship with all IDR/TDR collaborations, extrinsic motivation has a significant relationship with industry collaboration and government/local authority collaboration, but its relationship with interdisciplinary collaboration and regional/societal collaboration is not explicit. Intrinsic motivation seems to be more important in promoting IDR/TDR activities than extrinsic motivation in terms of having a significant relationship with a wide range of IDR/TDR collaborations. Thus, Hypotheses 1a and 1b are supported.

To verify Hypothesis 2, we analyze the relationship between the four IDR/TDR collaborations and the Big Five personality traits. First, interdisciplinary collaboration has a significant positive relationship with extraversion and conscientiousness (Models 1b and 1c). Second, industry collaboration is negatively related to neuroticism and government/local authority collaboration is positively related to agreeableness (Models 2b and 3b), but the relationship is not significant in the model that includes motivation, where it remained at the 10% level (Models 2c and 3c). Third, regional/societal collaboration has a significant positive relationship with extraversion and agreeableness (Models 4b and 4c). Although interdisciplinary collaboration and regional/societal collaboration are found to be related to personality, industry collaboration and government/local authority collaboration have a weak or no relationship with it. The corresponding personalities for each collaboration are also different, and Hypothesis 2 is supported.

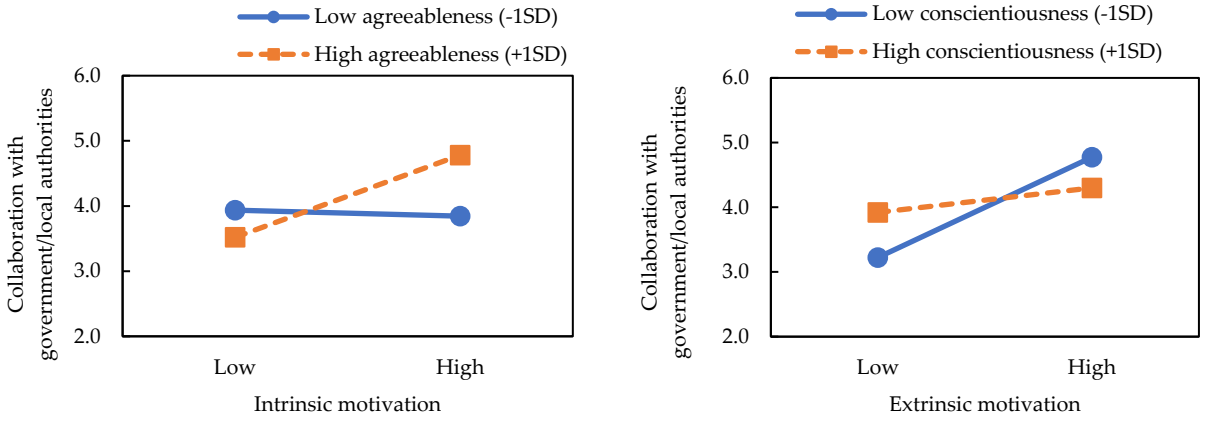
For Hypothesis 3, the interaction between motivation and personality, there are significant differences in six items at the 5% or 1% levels (Model 1d, 1e, 2d, 2e, 3d, 3e, 4d, 4e). There is no significant interaction effect in the model with interdisciplinary collaboration as an independent variable, but there are significant interaction effects on two items in each of the other three TDR indicators. Figures 2–4 display these six significant interactions. Figure 2 shows that when there is low openness to experience, intrinsic and extrinsic motivation have a more sensitive effect on the orientation of industry collaboration. Figure 3 describes interactions in collaboration with government/local authorities. Interestingly, intrinsic motivation has a negative impact on collaboration with these authorities when agreeableness is low. Although intrinsic motivation is generally known to have a positive impact on a broad range of performance indicators, this result suggests that it might have no or a negative impact under some conditions. Finally, Figure 4 shows that extraversion

and agreeableness amplify the positive effect of intrinsic motivation on the enhancement of regional/societal collaboration. In summary, there is no interaction effect for interdisciplinary collaboration, but the other three TDR collaboration indicators support Hypothesis 3.



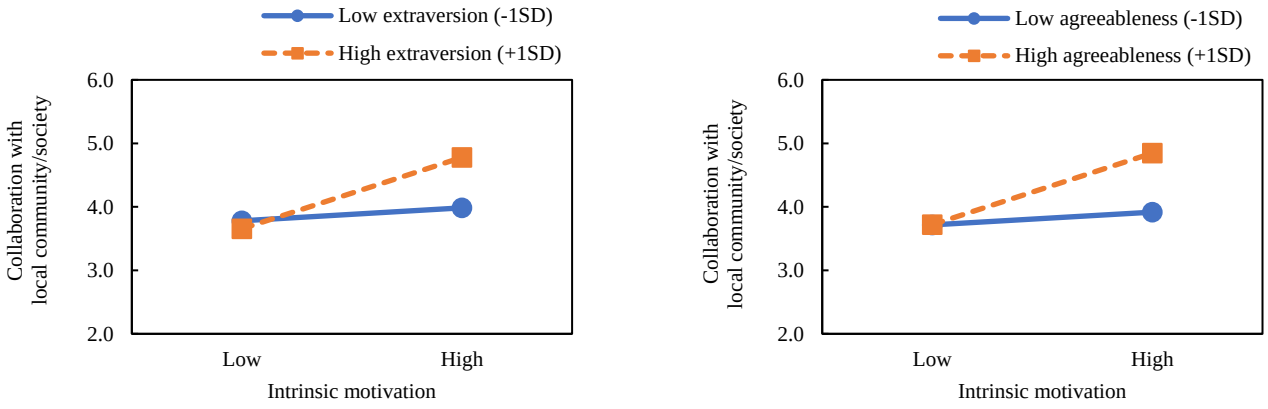
(**a**) Interaction of intrinsic motivation and openness to experiences (**b**) Interaction of extrinsic motivation and openness to experiences

Figure 2. Interaction of motivation and personality (in industry–academia collaboration).



(**a**) Interaction of intrinsic motivation and agreeableness (**b**) Interaction of extrinsic motivation and conscientiousness

Figure 3. Interaction of motivation and personality (in government/local authority collaboration).



(**a**) Interaction of intrinsic motivation and extraversion (**b**) Interaction of intrinsic motivation and agreeableness

Figure 4. Interaction of motivation and personality (in local community/society collaboration).

5. Discussion

5.1. Researcher's Motivation and Personality to the Type of IDR/TDR Collaboration

Intrinsic motivation has a consistently positive effect on IDR/TDR collaboration, as indicated by Hypothesis 1a. Consistent with previous analyses showing that intrinsic motivation has a positive effect on normal research activities, the results indicate that it has a broader effect [70,102]. Although the goal of IDR/TDR is to solve a social problem, the results of this study suggest that it is necessary to link intrinsic motivation with the researcher's interest and curiosity to achieve this goal. Conversely, as shown in the verification based on Hypothesis 1b, a strong relationship is found between extrinsic motivation and industry collaboration or government/local authority collaboration especially. These collaborations are an important process in the social implementation of science, but when the process is unlikely to generate interest and curiosity in the researcher, extrinsic motivations such as rewards and recognition may facilitate it. Extrinsic motivation is likely to facilitate performance in a behavioral task in situations where financial rewards are expected in advance through intellectual property or ventures [103].

Based on the findings of previous studies and the present results, we discuss the motivation management requirements for IDR/TDR projects. First, project managers should carefully consider whether the project goals and actions stimulate the intrinsic motivation of researchers. These points may suggest the importance of staffing (researcher team building); managers should be aware of how to generate knowledge integration among stakeholders, which is crucial in IDR/TDR. Second, extrinsic motivation will work effectively in those tasks where intrinsic motivation for a researcher is unlikely to take place, especially those coordinating relationships with external stakeholders, such as the industry and government. We claim that designing policies to enhance and maintain these motivations is key to the initial success of IDR/TDR projects.

The testing of Hypothesis 2 supports that researcher personality is associated with a particular type of collaboration. The results of the analysis indicate extraversion and conscientiousness facilitate collaboration with researchers from different academic disciplines. The first step in IDR collaboration is to have an interest in fields beyond one's own academic field. In addition, conscientiousness may be an important factor in building trustworthy relationships between researchers in different fields. In other words, extraversion and conscientiousness will facilitate communication and build trust with researchers from different disciplines. Communication and trust are essential in maximizing performance by teams [104].

Industry collaboration is negatively related to the researcher's neuroticism. We consider that this is only because researchers have psychological barriers to industry–academia collaboration. Therefore, we believe that a discussion of the inhibiting factors is more important than promoting industry–academia collaboration [105]. Moreover, regional/societal collaboration is associated with extraversion and agreeableness. It is reasonable to expect that these personality traits will be shown when natural science researchers are interested in society and have contact with nonacademic actors.

However, the above results show that there was no personality trait associated with all four IDR/TDR collaborations. In other words, this means that the researcher's personality as a promoting factor differs depending on the type of collaboration. Particularly in TDR projects, where co-creation with external stakeholders is essential, it is important to discuss the type and quality of the expected collaboration and design the project accordingly.

5.2. Interrelation of Researchers' Motivation and Personality

Although it is dangerous to assert the effect of the interaction based only on the results of testing Hypothesis 3, it would be appropriate to assume that there is at least some interaction between motivation and personality trait that promotes or inhibits TDR collaboration. For example, researchers with higher scores on a particular trait have a lesser impact of motivation on their respective TDR collaboration (Figures 2 and 3). There are traits (extraversion and agreeableness) that increase the positive impact of intrinsic moti-

vation in regional/societal collaboration (Figure 4). However, even when considering the effects of interactions, team building and incentive design stimulate the intrinsic/extrinsic motivation of members in TDR projects.

The negative effects of intrinsic motivation also need to be discussed. It is commonly accepted that intrinsic motivation generally has a positive effect on performance [70,106]. In the present study, intrinsic motivation has a small negative impact on government/local authority collaboration when researchers' agreeableness is low. In the case of collaborative research involving non-academic actors with strict norms, team harmony is important, and any behavior that violates it may have a negative impact on overall performance. While this point may have a high academic novelty, this is only a speculative point and only generates a new hypothesis.

5.3. Limitation and Future Perspective

Finally, we refer to the limitations of this study. First, this analysis is based on a limited sample set (N = 228) and requires a more detailed examination of the robustness of these results. Second, there are limitations to this method. The IDR/TDR collaboration indicator, which is a dependent variable, is a scale based on researchers' self-assessment; a more objective indicator should be used. However, in IDR/TDR projects, there is no singular recipe for successful cooperation, and the styles are also diverse [107]. Therefore, it is essential to develop indicators that can be evaluated from multiple perspectives that can be used practically. Third, the present analysis is limited to the evaluation of individuals at a single point in time and does not consider the influence of others or changes over time. There should be further indicator development and additional validation to establish a more comprehensive IDR/TDR project management methodology.

6. Conclusions

This study analyzes the factors necessary to promote IDR/TDR by focusing on researchers' motivation and personality traits. The main results of the analysis are as follows. First, intrinsic and extrinsic motivations have significant positive relationships with all four IDR/TDR collaborations, except the relationship between regional/societal collaboration and extrinsic motivation. Second, interdisciplinary collaboration and regional/societal collaboration have a strong relationship with personality traits. Third, three types of TDR collaboration (industry collaboration, government/local authority collaboration, regional/societal collaboration) have significant interaction effects of specific motivation and personality traits.

After reviewing the validity of the results of the analysis, a discussion was held from the perspective of IDR/TDR project management. In IDR/TDR projects, it is important that the researcher's intrinsic motivation (i.e., interest and curiosity) is linked to the goals of IDR/TDR, and extrinsic motivation (i.e., reward and recognition) works effectively in those tasks where intrinsic motivation is less likely to develop. IDR/TDR project managers must also consider the breakdown of the collaborations that may be important to the success of the project. We conclude that the motivation given to individual researchers and the team structure needs to be rearranged depending on the quality of the collaboration. As a point of scholarly novelty, we also note the possibility that intrinsic motivation could have a negative effect under some conditions. However, this requires a more detailed validation.

Author Contributions: Conceptualization, S.K. and S.S.; methodology, S.K.; software, S.K.; validation, S.K.; formal analysis, S.K.; investigation, S.K. and S.S.; resources, S.K. and S.S.; data curation, S.K.; writing—original draft preparation, S.K.; writing—review and editing, S.K., R.A., and S.S.; visualization, S.K.; supervision, R.A. and S.S.; project administration, S.S.; funding acquisition, S.K. and S.S. All authors have read and agreed to the published version of the manuscript.

Funding: The present study was financially supported by the Center of Innovation Program from the Japan Science and Technology Agency, JST (grant no. JPMJCE1305 and JY250226C).

Acknowledgments: We thank Hiromichi Kimura and Kazunori Kataoka of Kawasaki Institute of Industrial Promotion for providing information and advice. We thank the two anonymous reviewers for their contributions to improving the manuscript. Our gratitude is extended to each of the parties listed above.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Survey Questions (Intrinsic and Extrinsic Motivation).

Intrinsic motivation (4 items) (α = 0.90)
I enjoy trying to solve complex problems
The more difficult the problem, the more I enjoy trying to solve it
I enjoy creating new procedures for work/research tasks
Most of the driving force for my actions is curiosity
Extrinsic motivation (4 items) (α = 0.70)
I am strongly motivated by the money I can earn. ("Money" means your own income, not research expenses)
I am keenly aware of the promotion goals I have for myself
I am strongly motivated by the recognition I can earn from other people
I am keenly aware of the income goals I have for myself

Note. These items were answered on 7-point Likert scale (1 = not at all, 7 = very much so).

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