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Examining the Factors Behind the Success and Sustainability of China's Creative Research Group: An Extension of the Teamwork Quality Model

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Abstract: The Creative Research Group (CRG) is the special high-level scientific and innovation team funded by the National Natural Science Foundation of China to promote basic research at the frontiers of science. In general, there are problems of "structure anomie" and "cooperation inefficiency" in the operations and teamwork dynamics within the nationwide CRG project. By extending and developing the two-stage teamwork quality model, this study aims to depict and analyze the impact factors behind the success and sustainability of the Creative Research Group (SSCRG), and reveal the relationships among them. Herein, rationality of team structure (ROTS) is used to describe the rationality of team formation and structure collocation, teamwork quality (TWQ) is used to describe the process of team members' integration and cooperation, and SSCRG includes team performance, personal success and team comprehensive impacts. The results show that ROTS and TWQ have different influences on SSCRG, while TWQ is the key mediation factor between ROTS and SSCRG. In summary, the model built describes the complex phenomena and relationships in the teamwork of the CRG, and helps us to understand and solve the problems of structure and cooperation. Although the limitations lie in the specific samples and research methods, the extension and migration of classical models and theories would help to further deepen such research and contribute to the governance and development of such innovation teams.

Keywords: creative research group; teamwork quality; team structure; success and sustainability; innovation team; China

1. Introduction

Although basic research in China has made considerable progress, there is still a gap in its overall strength compared with major developed countries, according to the report of the National Natural Science Foundation of China (NSFC) and the "NSFC Strategic Plan for 2016–2020 (The 13th Five-Year Plan of NSFC)". It has been claimed that, "Firstly, there are few significant original achievements with international influence and there is a lack of the ability to create important new disciplines and directions; secondly, there is a shortage of world-class scientists leading the scientific trends and the environment for the growth of young talent needs to be improved; thirdly, the role of basic research in promoting economic and social development and safeguarding national security needs to be enhanced [1]." The lack of major original achievements and the top talent team has become a key factor restricting the development of basic research and the construction of an innovative country in China. Original achievements are achieved by scientific researchers, so the key is to pay attention to the training of scientific researchers and top teams. Yang Wei, the former director of the NSFC wrote in the journal *Nature* in 2016 that China should pay more attention to basic research and improving

the quality of basic research should be the focus of China's efforts to promote national innovation [2]. In terms of innovation, policy and institutional arrangements are particularly important: China is paying greater attention to the development of basic research and the cultivation of young talent as the core of its innovation-driven development strategy. The projects funded by relevant government departments include the Innovation Team Project of the Ministry of Education, the Innovation Team Project of Chinese Academy of Sciences, and the Creative Research Group (CRG) Project of the NSFC. The most representative innovation team project in the field of basic research field is the CRG Project funded by the NSFC.

As one of the most important talent projects under NSFC, as well as the most representative innovation team project leading basic research, the CRG Project undertakes the important missions in breaking through the frontiers of basic research and training top talent teams. According to the situation notifications and project management measures of NSFC, the CRG project supports outstanding young and middle-aged scientists as academic leaders and the backbone of research to carry out innovative research around an important research direction, and cultivate and foster research groups that occupy a place at the forefront of international science [3].

In early 2016, at the annual performance evaluation meeting of the NSFC, which was co-hosted by the National Center for Science and Technology Evaluation (NCSTE) and the NSFC, experts from different departments of the NSFC who have participated in the CRG project and experts from relevant scientific research management departments peer-reviewed and evaluated the CRG project as whole. In addition to affirming the outstanding achievements of the CRG project in cultivating leading talents, enhancing teamwork and concentrating on solving major scientific problems, the experts also found and summarized some common problems: firstly, there is "collusion" and "patchwork" in the application and team structure of the CRG Project. The composition of some teams is not based on the combination of research needs, but rather based on seniority and titles, which subsequently restricts the development of potential youth teams. Secondly, the main participants of the CRG project are often at odds with each other, and an effective teamwork mechanism has not been formed. How to carry out in-depth cooperative research around common goals, genuinely solve one or two important frontier scientific problems, achieve influential results, cultivate outstanding talents, and establish a sustainable team all remain major challenges at present.

Although CRG is an innovation team with Chinese characteristics, there are many similarities between it and other innovative teams in terms of the team cooperation and further development. Existing classical team theories and models are exploited by some scholars for studying and explaining the cooperation and structural problems of the CRG [4]. For the problems of "structure anomie" of CRG projects, there are some classical studies on team structure for team performance and team success [5–7]. A good team structure is the prerequisite and important factor for team development. For the problems of "cooperation inefficiency" of CRG projects, few studies are directly related. However, the impacts of teamwork on team performance, personal success, project success, team success and sustainability have been widely studied in the field of organizational science and technological innovation [5–8]. Since the 21st century, many studies have combined economics, sociology, organizational behavior and psychology to develop theories for explaining or predicting teamwork, team performance and team success and sustainability [9–17].

The theoretical model of teamwork quality (TWQ) is often used to study the relationship between teamwork factors and team performance, team members' personal success, team success and sustainability, including the research and evaluation of a research and development (R&D) team in enterprises [8,12–16], medical care teams [18,19], learning groups in education [20], and agile team research in software development [21,22]. However, although previous studies have used the TWQ model to explain the relationship between teamwork and different teams, few studies have examined high-level research and innovation teams, especially those working in the frontier areas of basic research and in innovative groups funded by government funds. At the same time, in the relevant literature, many studies have examined scientific research organizations and teamwork [22–26], but

few have used the TWQ model to analyze the impact of team structure and teamwork on a team's success and sustainability.

Teamwork quality is directly related to "cooperation inefficiency" [8,12–16], and team members' collocation and rationality are directly related to the "structure anomie" [23–25]. In this study, the related research on team structure is included in terms of the extension of the TWQ model. Besides, the problems of "structure anomie" and "cooperation inefficiency" encountered by CRG in its development are explored and discussed. We use the extended model to analyze the empirical data, and to understand the teamwork factors related to the success and sustainability of the project team. Although the CRG is a high-level scientific research and innovation team with Chinese characteristics, this study is of great significance to developing related theories and the TWQ model, as applied to scientific research cooperation and basic research. The implications of this study could be taken into consideration during the development and evaluation of policies related to science and technology, as well as when considering how to improve the structure and teamwork quality of scientific research teams, thus contributing to the CRG to achieve high-level personnel training and major scientific breakthroughs.

2. Literature Review

Many studies have demonstrated the impacts of TWQ on team performance, project success, team success and sustainability [8,12–17]. What are the specific contents that affect TWQ, and what is its specific and extended theoretical model of TWQ when predicting the success and sustainability of the Creative Research Group (SSCRG)? Based on previous studies and the current state of the CRG, we propose the theoretical model of the extended version of teamwork quality, which takes TWQ, the rationality of team structure (ROTS), and SSCRG as its main constructs and impact factors.

2.1. Teamwork Quality (TWQ)

Hoegl and Gemuenden (2001) developed and constructed the theoretical model of TWQ, which is a comprehensive conceptual model of teamwork that has been highly recognized in academia [8]. In order to better measure and analyze the nature of teamwork and open the "black box" of its dynamics, combined previous research and practical research, Hoegl and others have subdivided TWQ into six important dimensions or variables: communication, coordination, balance of member contributions, mutual support, effort and cohesion [8]. Based on an empirical analysis of the survey data, it has been concluded that TWQ is positively related to team performance, the personal success of team members, and project success [8]. For many years, Hoegl and his collaborators continued to publish research on teamwork and TWQ-related factors in important journals such as *Organization Science*, *Research Policy* and so on [12–17]. By using the TWQ model, Hoegl and Proserpio discussed the relationship between team members' proximity and team performance [12]; Hoegl, Weinkauf, and Gemuenden's study provided support for the hypotheses predicting positive relationships between interteam coordination, project commitment, and teamwork quality [13]. Hoegl and Parboteeah investigated how team autonomy is related to teamwork quality [14], analyzed the influence of the teamwork quality on creativity-relevant skills [15], and made a theoretical extension and hypothetical analysis of the team reflexivity [16]. Hoegl, Ernst and Proserpio discussed the important role of high-quality team cooperation and team leaders in team performance [17]. Based on the TWQ model, the above studies explore the relationships between teamwork-related factors of R&D and innovation team by adding a new variable or factor or expanding the model to a certain extent. This deserves to be learned and expanded by innovation teams in universities and research institutions, especially the CRG.

TWQ is an important factor or mediating variable for studying the rationality of team structure and team integration in forming cooperation mechanisms and their impact on team performance, team success and sustainability. It has been gaining more and more traction in the academic community [18–22]. Goebel, Guo and Wood explored how medical experts work together in

interdisciplinary teams to achieve a good quality of collaboration [18]. Thomas, Williams and Reichman discussed the communications and teamwork in neonatal resuscitation [19]. Cureu and Pluut explored the mediating role of teamwork quality between learning group composition differences and cognitive complexity [20]. Lindsjørn and co-workers studied the impact of team cooperation quality on many factors (learning and work satisfaction, team performance) in software development teams [21]. Freire and co-workers, based on Bayesian network models and case studies, argued that teamwork quality is critical to the success of agile teams [22]. These above research works are also representatives of TWQ's mutating and migrating to different fields. Meanwhile, research has begun to apply the TWQ model to the research and innovation team to explore the team cooperation mechanism of the CRG [4]. As shown in Figure 1, Hoegl and co-workers developed the TWQ model to analyze the related factors of teamwork and team success [8,12–17].

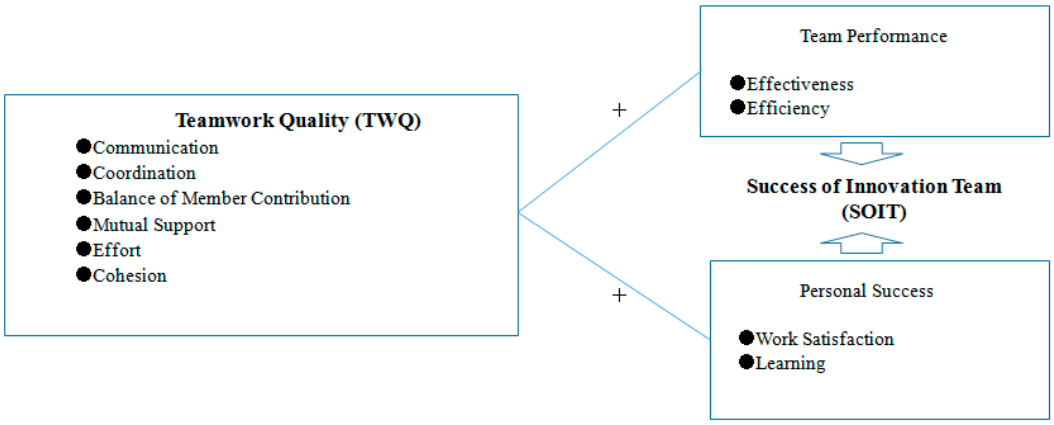

Figure 1. The teamwork quality (TWQ) model developed by Hoegl and co-workers.

Hoegl and Gemuenden's TWQ model mainly focuses on the teamwork of innovation teams [8]. The CRG is a typical scientific research and innovation team in the basic research field with Chinese characteristics [4]. It is of great relevance to use the TWQ model, which specializes in analyzing the innovation in team cooperation, to carry out this research. In recent years, the TWQ model has been gradually expanded to innovative team research in various fields. The theoretical model used in the research of the teamwork in innovation teams is either a simple causal hypothesis model [9,10], or a variant and extension based on the TWQ model [12–17]. In this paper, we apply the TWQ model to the CRG in China, using the same six dimensions as well as other internal cooperation factors that are specific to the CRG. Our criteria and basis for judging the degree of TWQ is whether the internal cooperation in CRG teams has achieved communication, coordination, balance of member contributions, mutual support, effort and cohesion, and whether effective information (including communication, coordination, etc.), incentive compatibility (including contribution balance, mutual support, etc.) have also been achieved.

2.2. Success and Sustainability of the Creative Research Group (SSCRG)

The success and sustainability of project teams reflect many components, and are also the result of teamwork development. Previous scholars have distinguished and summarized two general kinds of results: task-related results (e.g., task completion quality, degree of compliance with budget and plan, etc.) and human-related results (e.g., team members' satisfaction, personal success, team feasibility, stability, continuity, team cooperation quality, mechanism, etc.) [8,12–17]. Based on the research of Hoegl and others, we believe that the CRG has the dual attributes of talent cultivation and frontier exploration, and so the success and sustainability of a project team should include team performance and personal success.

For sustainability, Cheng and Zhang believed that the sustainability of innovation teams included the ongoing operation of the team, guarantee of the team members' benefit, the sustainable innovation of the team and other factors [26]. Some studies demonstrated that the sustainability of innovation teams is directly related to team composition, team member's communication, cooperation, integration and other factors directly related to the teamwork quality and team structure. In this context, teamwork quality and team structure are two important factors influencing sustainability [26–28]. Compared to team success at the static level, team sustainability is more focused on dynamic level considerations. In this study, we combine team success with sustainability as an important construct (SSCRG) that is influenced by ROTS and TWQ.

The CRG's comprehensive impact on science, technology, economy, and society is also a core goal of the project as whole. These are important indices that have been emphasized by the NCSTE and NSFC, and have been applied in the evaluation of science and technology. While many scholars are developing new ways to measure the academic impact of scholars or teams [29,30], they are also constantly expanding their evaluation of the comprehensive impacts of scholars, teams and scientific research results [31,32]. Wolf, Lindenthal and many scientists believed that the existing research evaluation focused on the scientific impact of research teams and research results, and should gradually extend the research evaluation to the comprehensive evaluation of scientists and their teams, taking into account the comprehensive impact of their activities and achievements on economic and social aspects [31]. Therefore, combined with the existing requirements for the evaluation of the comprehensive impact of CRG, and the research of relevant scholars, the theoretical model of TWQ is expanded here to include relevant elements of the SSCRG, which includes three variables in this paper: team performance, personal success, and comprehensive impacts (mainly, scientific and technological, economic, and social impacts. The SSCRG means the staged completion of the innovative project, the excellent evaluation of the project, the continuous operation of the team, the guarantee and possibility of the interests and benefits of team members, and the potential value and likelihood of continuous innovation, continuous growth and transition of the team in the future [4,8,12–17,23,26,31]. The criteria for our judgment and evaluation are whether the CRG has successfully completed their research project; achieved their research goals and the cultivation of talents and teams; whether the individual members of the team have grown and attained greater motivation as researchers; and whether the team has made an important impact on academia and beyond.

As shown in Figure 2, we developed a first-stage extension of the TWQ model for analyzing the impact factors of the SSCRG. On the basis of the TWQ model developed by Hoegl and his collaborators, we define SSCRG and point out that it includes team performance, personal success, and team comprehensive impacts.

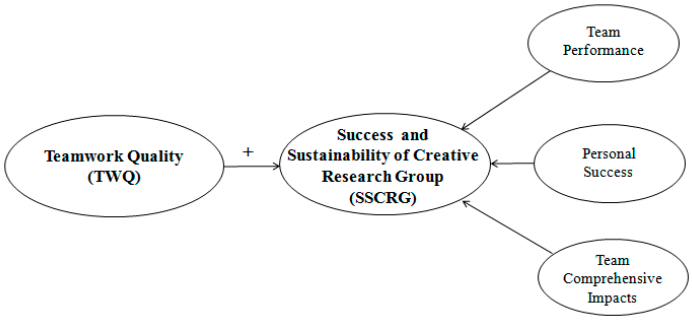

Figure 2. First-stage extended TWQ model for the analysis of impact factors of the Success and Sustainability of Creative Research Group (SSCRG).

2.2.1. Team Performance

Hoegl and his collaborators argued that team performance is reflected through effectiveness and efficiency. Team effectiveness refers to the degree to which the team meets the expectations of the

quality of the results. In the case of innovation research projects, effective performance usually implies meeting the pre-defined objective attributes and degrees of project operation and achievement, such as the functionality and robustness of results or products, the degree of final goal completion, and whether any major breakthroughs were made, etc. Team efficiency is achieved by adhering to the plan. For example, the degree to which tasks are completed according to budget and date is important; team effectiveness reflects the comparison between actual and expected results, while the efficiency evaluation is based on the comparison between actual and expected inputs [8].

The team performance of the CRG is evaluated based on the group's ability to complete the project on time, with products of good quality and of certain quantity; the ability to achieve the overall research goal; and whether it makes breakthroughs in the frontiers of certain basic research fields.

2.2.2. Personal Success

In addition to achieving performance goals, teams must work in ways that increase their ability to participate in future teamwork. Hoegl and his collaborators believe that satisfaction with team work will increase the enthusiasm of team members and their willingness to participate in projects now and in the future [8,14–16]. Denison et al. believe that the personal growth of members and the overall development of the team are mutually beneficial [33].

The personal success of the members of the CRG is a key component of the success of innovative group projects and team improvement. It includes not only the cultivation of graduate students, but also the growth and promotion of young and middle-aged scientists as the backbone of research, as well as the personal success of team leaders and other team members. Personal success, which is in line with the original intention of the establishment of the CRG Project, is also in line with the improvement and long-term development of the CRG from the team ability level down to the individual ability level.

2.2.3. Team Comprehensive Impacts (Scientific and Technological Impact and Economic, Social and Other Comprehensive Impacts)

Van Houten believes that academic influence is mainly reflected in how peers evaluate their academic research results, while the depth and breadth of academic influence can be reflected through research paper citations, which signifies how much the research is valued and recognized by others [34]. Mainstream research judges the academic influence of scholars or teams mainly through bibliometric methods and scientometrics [35–39]. Many studies use bibliometric methods to study the contribution and academic influence of scientists [35,36], while others use the methods of scientometrics and visual analysis to visualize the academic cooperation network and academic influence of scientists [37–39]. With the development of information technology and network technology in this new era, the academic and social influence of a scholar or research team can be reflected not only by traditional academic platforms and co-citation networks constructed from publications and patents, but also by quantifiable and assessable data on the Internet and social media, for example, through the use of altmetrics which has emerged in recent years [29,30].

Some scholars have discussed the importance of understanding and evaluating the comprehensive influence of scientific research work and a research team in a certain field, and have made up for the shortcomings of pure objective data and measurement methods solely by means of questionnaires and interviews [31]. Some scholars have also explored the economic and social impacts of teams and outcomes in terms of the transformation of scientific and technological achievements [32].

On 23 June 2016, the Ministry of Science and Technology of China officially abolished the appraisal method for scientific and technological achievements. The evaluation of scientific and technological achievements of related administrative departments at all levels was handed over to professional evaluation agencies by the entrusting party. This means that China is exploring and establishing a market-oriented evaluation mechanism for new scientific and technological achievements, and the evaluation of new scientific and technological achievements will be dominated by the market. The objective and fair evaluation of scientific, technological, economic and social value of scientific and

technological achievements by third-party professional evaluation institutions will help investors, partners and government recognize such achievements more quickly, and facilitate the smooth progress of technological transactions.

The NCSTE was commissioned by the NSFC Planning Bureau from 2015 to 2016 for the annual project performance evaluation and conducted the research and evaluation for the CRG project. In the project evaluation forms, questionnaires and even field interviews, the academic and economic and social impacts of the CRG were taken as important factors and evaluation indicators.

Therefore, team comprehensive impacts are an important evaluation standard for SSCRG, especially sustainability. Whether the team has an important academic impact and comprehensive impacts; whether the results have important scientific and technological, economic, social and cultural impacts. All these are the requirements for the sustainable development of the CRG in the new era, consistent with changes in the identification standards and expected scope of China's scientific and technological achievements.

2.3. Rationality of Team Structure (ROTS)

Some studies have shown that the rationality of the team structure can have a positive impact on the quality of teamwork, project success, team success and sustainability [40–42]. Stewart and Barrick believe that the rationality of the team structure has a positive impact on team performance, while the team structure also influences team performance through team self-leadership, teamwork mechanism, task complexity and other mediation factors [43]. Yang and Tang used the social network method to explore the relationship between team structure and team performance. They found that team structure is a key factor for quality performance. Team cohesion is positively related to overall performance and the rationality of team structure. Then, through the benign characteristics and cohesion factors of the group, cooperative networks and mechanisms are formed at different stages, which have an impact on team performance [44].

Balkundi and Harrison believe that teams with close relationships among members can better achieve goals, while teamwork timelines, membership familiarity, and relationship ties can moderate the relationship between team structure and team performance [45]. Some studies have shown that team structure does not necessarily have an absolute impact on the performance or success of the team. Team structure needs to be mediated or moderated by other variables or elements (such as a team cooperation mechanism, task complexity, team leadership, etc.) before it has an impact on team performance and overall project success [43,46].

Based on previous research, the rationality of team structure may have a direct or indirect positive impact on team performance, project success, team success and sustainability directly or indirectly. At the same time, it has also been found that on the basis of the rationality of team structure, the formation and development of cooperation and integration mechanism among team members also have an important influence on team performance and project success, team success and sustainability. Dynamic and process factors such as integration, communication, and mutual support among team members can be attributed to TWQ.

Therefore, the ROTS is closely related to the teamwork quality, team success and sustainability. The ROTS of the CRG means that the team structure and scale of the CRG is scientific and reasonable, and the distrubtion of age, background, education, title and posts range from prominent researchers to young researchers, graduate students and other members is reasonable. The group should have a strong collaborative foundation, strong likelihood of continuity and sustainability, and the potential to engage in high-level basic research and achieve cutting-edge breakthroughs.

Based on these descriptions of the role of TWQ and ROTS in SSCRG, combined with the previous research on TWQ and SSCRG by Hoegl and other scholars [8,12–17], the previous research on ROTS by Hoegl and Weinkauf [42] and Balkundi and Harrison [45], and the latest research on the CRG teamwork mechanism by Gao and Ding [4], this study proposes that the second-stage extension of the TWQ model includes ROTS. Using the previous model as a foundation, we added ROTS, a key factor

that has been shown to affect TWQ and SSCRG. As shown in Figure 3, TWQ and ROTS both may have a positive impact on SSCRG, and ROTS may have a positive impact on SSCRG. SSCRG consists of team performance, personal success and team comprehensive impacts. In this study, we analyze the possible positive impact of ROTS and TWQ on SSCRG and the possible impact of ROTS on TWQ.

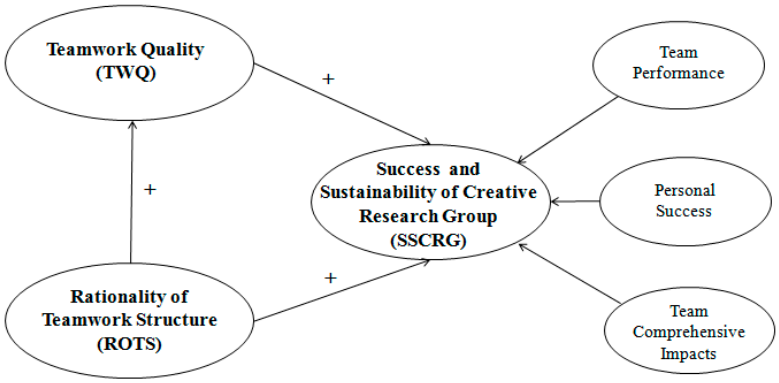

Figure 3. Second-stage extended TWQ model for the analysis of impact factors of SSCRG.

2.4. Hypotheses Development

Based on the extended TWQ theoretical model, this study divides the impact factors of the SSCRG into TWQ and ROTS.

TWQ includes communication, coordination, balance of member contributions, mutual support, effort and cohesion; ROTS means that the team structure and scale of the CRG is scientific and reasonable, and distribution of age, background, education, titles and posts range from leading figures in the field to young researchers, graduate students and other members.

According to the TWQ theoretical model, the direct and main determinant of SSCRG is TWQ. Literature on the R&D teams of commercial organizations and on team cooperation mechanisms in high-level scientific and innovation teams show that TWQ has an important impact on SSCRG. Therefore, we present the following hypotheses (summarized in Table 1):

Hypothesis 1. *TWQ has a positive impact on SSCRG.*

According to Hoegl et al.'s research and the actual status of the CRG, this study expects the rationality of the team structure (ROTS) to have an positive impact on the communication and integration of team members, and that factors such as communication and integration can be attributed to TWQ. This leads to our second hypothesis.

Hypothesis 2. *ROTS has a positive impact on TWQ.*

According to the research of Hoegl and Weinkauf, ROTS has a positive impact on team performance, project success, team success and sustainability. At the same time, other research has also shown that ROTS is related to team performance, the personal success of team members, team success and sustainability. Therefore, we hypothesize that ROTS is positively correlated with SSCRG.

Hypothesis 3. *ROTS has a positive impact on SSCRG.*

We summarize the research hypotheses with theoretical structural constructs and variables in Table 1 as follows.

Table 1. Research hypotheses.

Hypothesis	Path Direction
H1 TWQ has a positive impact on SSCRG	TWQ → SSCRG
H2 ROTS has a positive impact TWQ	ROTS → TWQ
H3 ROTS has a positive impact on SSCRG	ROTS → SSCRG

Note: ROTS = Rationality of Team Structure; SSCRG = Success and Sustainability of Creative Research Group; TWQ = Teamwork Quality.

3. Research Method

This study adopts the two-step approach proposed by Anderson and Gerbing to test the reliability and validity of model factors and to perform hypothesis testing and model fitting [47]. The number of valid samples for empirical analysis is 302, which are small and medium samples and mostly reflective the indicators we are interested in. Compared to the traditional structural equation model (SEM) analysis, our approach is more in line with partial least squares (PLS) analysis. PLS requirements for variable adaptability are more relaxed, and accuracy can also be maintained for a small sample size [48–53]. In addition, PLS can conform to normality, and put forward more relaxed stochastic requirements in other predictive models [52,53]. Therefore, we use PLS to carry out our main analysis, using the SmartPLS 2.0 software (www.smartpls.de) to test our research model. SmartPLS 2.0 is a very effective and widely-used analytical tool based on SEM [54].

Figure 4 below presents our research model, which is based on previous literature and the hypotheses we put forth in Table 1. This model is also constructed to examine the potential mediating role that TWQ might play between ROTS and SSCRG.

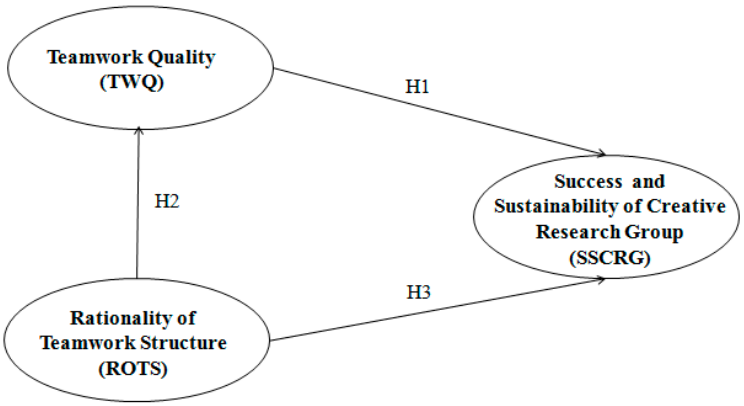

Figure 4. Schema of research model and hypotheses.

To ensure reliability and validity, the multi-item measures for each construct were developed, adjusted and revised mainly by referring to the state of the existing research and maturity scale, combined with the development status and unique characteristics of the CRG, as shown in Table 2.

Most of the questionnaires developed by previous scholars were written in English. Therefore, we entrusted two university professors in charge of English–Chinese translation training at the School of English at Hebei Foreign Studies University to translate them into Chinese, and entrusted two other member teachers from Hebei Translation Society to conduct a reverse translation to ensure that the translated versions of the two language questionnaires were accurate and consistent.

Then, the Chinese version of the questionnaires were tested among team members at Tsinghua University and Harbin Institute of Technology who had been or were currently undertaking CRG projects. Data processing and analysis were carried out to evaluate the operability and applicability of the questionnaire and scale, and then adjustments and revisions were made to ensure its reliability and validity. The main contents of the questionnaire were related to the specific measurement of each variable, item and construct. In the end, we selected 9 items for 3 constructs. For each

measurement item, the Likert scale was used with 1 being "complete inconsistency" to 7 being "complete consistency".

Table 2. Operational definition of constructs and measurement items.

Teamwork Quality (TWQ)	Source
Definition: It includes communication, coordination, balance of member contributions, mutual support, effort cohesion and other internal cooperation factors in the Creative Research Group (CRG). Our criteria and basis for judging the degree of TWQ is whether the team internal cooperation of CRG has achieved communication, coordination, balance of member contributions, mutual support, effort and cohesion, along with effective information (including communication, coordination), incentive compatibility (including contribution balance, mutual support).	Gao and Ding [4]; Hoegl and Gemuenden [8]; Hoegl and Proserpio [12]; Hoegl et al. [13,17]; Hoegl and Parboteeah [14–16]
TWQ 1. Whether there is frequent and efficient communication between team members and groups; whether tasks and work are reasonably and effectively allocated and completed; whether the team has a clear goal allocation, division and coordination of work, as well as abundant information and knowledge flow, to achieve effective information.	
TWQ 2. Whether the team is aware of the potential and contribution value of different members, so that they can effectively play their role and receive the appropriate incentives; whether team members support, cooperate and help each other as much as possible to make sure their incentives are compatible.	
TWQ 3. Whether the team members have done their best to complete the project; whether they have achieved an mental and action-oriented coordination under the agreed-upon concepts and paradigms; whether the team has cohesion, a healthy cooperation atmosphere, strong cohesion in practical work; whether scientific and technological resources represented by human resources have been effectively allocated and integrated.	
Rationality of Team Structure (ROTS)	
Definition: It means the team structure and scale of CRG is scientific and reasonable, and the distribution of age, background, education, titles and seniority ranging from leading figures to young researchers, graduate students and other members is scientific and reasonable. The team has a good foundation in research and cooperation, good continuity and sustainability, and the potential to engage in high-level basic research and achieve cutting-edge breakthroughs.	Hoegl [41]; Hoegl and Weinkauf K [42]; Stewart and Barrick [43]; Yang and Tang [44]; Balkundi and Harrison [45]; Keck [46]
ROTS 1. Whether the team structure and scale meet the requirements of the declared conditions and evaluation criteria of the CRG project.	
ROTS 2. Whether the age, background, education, professional titles, and seniority of the team members are reasonably distributed and fairly matched.	
ROTS 3. Whether the members represented by leading figures have a strong foundation in research and cooperation, good continuity and sustainability, high-level research cooperation ability and the potential to execute cutting-edge research and realize specific research goal.	
Success and Sustainability of CRG (SSCRG)	
Definition: It means the staged completion of the innovative project, the excellent evaluation of the project, the continuous operation of the team, the guarantee and possibility of the interests and benefits of team members, and the potential value and likelihood of continuous innovation, continuous growth and transition of the team in the future. It includes team performance, personal success, and the team's comprehensive impacts (scientific and technological, economic, social, and other comprehensive impacts).	Gao & Ding [4]; Hoegl & Gemuenden [8]; Hoegl & Proserpio [12]; Hoegl et al. [13,17]; Hoegl & Parboteeah [14–16]; Contractor [23]; Cheng & Zhang [26]; Wolf et al. [31]
SSCRG 1. Whether the CRG has successfully completed the project and achieved stipulated research goals and the cultivation of talent teams. Does it have the potential value and possibility of continuous innovation, continuous growth and transition of the team? What is the likelihood and evaluability of the team's future development and transition?	
SSCRG 2. In addition to the success and sustainability of the team, whether the individual members of the team have obtained corresponding satisfactory growth and motivation. Compared with other projects and teams, are the team's researchers satisfied with their personal growth, new honors and projects? Are team members given opportunities for future development, the guarantee and possibility of the interests and benefits?	
SSCRG 3. Whether the team has made an important academic impact and other comprehensive impact; whether the results have important scientific and technological value, as well as economic, social and cultural value. Whether the comprehensive impacts have been evaluated and recognized by scientific and technological evaluation institutions and third-party assessment institutions or other organizations.	

The release of the questionnaire and the development of interviews in this study benefited from the NCSTE being a third party that evaluated the annual performance of NSFC projects in 2016. Along with NCSTE staff, we conducted a performance evaluation and questionnaire survey on CRG projects, and sent questionnaires to CRG team leaders and members over a four-month period; 376 questionnaires were distributed and 302 valid questionnaires were collected. A preliminary descriptive statistical analysis of the respondents show that 212 were males, accounting for 70.20% of

the total; 90 were females, accounting for 29.80%; there were 196 team leaders and senior researchers, accounting for 64.90% of the total; 99 young researchers and graduate students, accounting for 32.78%; 7 other members, accounting for 2.32%; 10 members who were undergraduates and below, accounting for 3.31% of the total; 292 students at the master's level and above, accounting for 96.69%. Lastly, 258 members (85.43%) had worked in research for three years or less, while 44 members (14.57%) had worked for more than three years.

To reiterate, this study analyzed and expanded three dimensions of the theoretical model of TWQ: 3 dimensions of TWQ, 3 dimensions of ROTS, and 3 dimensions of SSCRG, which were mainly revised by Hoegl and Gemuenden [8] and Gao and Ding [4]. Table 2 summarizes the operational definitions of our measurement constructs, the items measured by the questionnaires, and the sources of our constructs and variables.

4. Results

According to Hair and other scholars, the factor loading in the research model we implement here should be at least above 0.5 [55]. Our results show that the standardized factor loading of variables such as TWQ, ROTS and SSCRG are at least above 0.8, which meet the criteria of structural validity. Composite reliability (CR) is used to measure internal consistency. According to research by Nunnally and Bernstein, CR values greater than 0.7 meet the requirements of model fidelity [56–58]. Table 3 shows that all CR values are greater than 0.8, which is high enough to meet the criteria of internal consistency. At the same time, internal consistency can also be tested by Cronbach's Alpha (α), which is generally greater than 0.6 [58,59].

Table 3. Reliability and convergent validity.

Construct	Items	Factor Loading	Cronbach's α	CR	AVE
Teamwork Quality (TWQ)	TWQ 1	0.871	0.764	0.864	0.681
	TWQ 2	0.896			
	TWQ 3	0.695			
Rationality of Team Structure (ROTS)	ROTS 1	0.825	0.744	0.854	0.661
	ROTS 2	0.814			
	ROTS 3	0.800			
Success and Sustainability of Creative Research Group (SSCRG)	SSCRG 1	0.841	0.811	0.887	0.725
	SSCRG 2	0.835			
	SSCRG 3	0.878			

Note: CR = Composite Reliability; AVE = Average Variance Extracted.

In contrast, the structural measurements in this study were based primarily on research at home and abroad, and were adopted and modified for our research purposes. The measures adopted are in line with the content validity standards, and thus, there is sufficient validity in the study.

To satisfy the test of discriminant validity, Fornell and Larcker suggested that the AVE (Average Variance Extracted) of each variable should be larger than the square of the correlation coefficient [58]. Table 4 shows that the square root of AVE (the diagonal numbers in the table which are bold and italicized) is larger than the correlation coefficient, that is, AVE values are larger than the square of correlation coefficients, which is in line with the test of discriminant validity in Fornell and Larcker's research.

Table 4. Correlation coefficients matrix and square roots of AVE.

	ROTS	SSCRG	TWQ
ROTS	***0.813***		
SSCRG	0.470	***0.851***	
TWQ	0.526	0.487	***0.825***

Note: ROTS = Rationality of Team Structure; SOCRG = Success and Sustainability of Creative Research Group; TWQ = Teamwork Quality. The diagonal bold and italic values are square roots of AVE, and the other values are correlation coefficients. It can be seen that the square roots of AVE are larger than the correlation coefficients, that is, AVE is larger than the square of correlation coefficients, so the discriminant validity exists.

Hypotheses Testing and Model Fitting

In this study, the bootstrapping method of PLS-SEM (Partial Least Squares-Structural Equation Model) was used to test for significance in our model. According to research by Hair et al., the number of repeated samplings combined with samples should be at least 500, and more than 1000 times would help achieve more stability [55]; the number of repeated sampling of 311 samples was set to 2000 times, and SmartPLS was used to calculate the model test and the significance test of path coefficient.

With a probability at 0.05 (confidence interval of 95%) and with deg_freedom set to 100, the T.INV.2T function in SmartPLS was used to calculate the significance criterion of the T-Value, which was 1983 in this confidence interval. If the T-Value is greater than 1983, the path coefficient is significant; similarly, the significance criteria for 99% and 99.9% confidence intervals are 2626 and 3390; at the same time, if the *p*-value is less than 0.05, it is significant, less than 0.01 means more significant, less than 0.001 means very significant [4,55,60,61]. As shown in Table 5, the standardized path coefficient and T-Value for TWQ and ROTS for SSCRG are 0.331 (T-Value = 5.819 > 3390) and 0.296 (T-Value = 5497 > 3390) respectively, and p-values are all less than 0.001. These results support hypotheses 1 and 3; that is, TWQ and ROTS have a positive impact on SSCRG. Similarly, our evidence also support hypothesis 2, since the path coefficient and positive correlation are highly significant; that is, ROTS is positively related to TWQ.

Table 5. Main analysis results.

Hypotheses		Standardized Path Coefficient	T-Value	Result
H1	TWQ→SSCRG	0.331 ***	5819	Supported
H2	ROTS→TWQ	0.526 ***	12.234	Supported
H3	ROTS→SSCRG	0.296 ***	5497	Supported

Note: ROTS = Rationality of Team Structure; SSCRG = Success and Sustainability of Creative Research Group; TWQ = Teamwork Quality. * *p*-value < 0.05; ** *p*-value < 0.01; *** *p*-value < 0.001.

This study uses three methods proposed by Sobel, Aroian and Goodman, respectively, to test the mediation effect of our model variables. When the z-value calculated by the three methods are greater than 2, the absolute value indicates that the mediation effect between variables is significant. The larger the z-value, the more significant the mediation effect is; otherwise, when the calculated *p*-value is less than 0.05, the mediation effect is significant. The smaller the p-value, the more significant the mediation effects [62–65]. In Table 6, we use the relationship among our three constructs, specifically, ROTS-TWQ-SSCRG, to predict and test the mediation effect of TWQ. The results of the mediation effect test show that the correlation coefficients exceed the critical value, and the mediation effect is highly significant (see Table 6 for more details).

Table 6. Mediation effect analysis.

Constructs of Measurement	Relationship of Constructs	T-Value	Sobel Test	Aroian Test	Goodman Test
ROTS-TWQ-SSCRG	ROTS-TWQ TWQ-SSCRG	12.234 5819	5255 ***	5241 ***	5269 ***

Note: ROTS = Rationality of Team Structure; SSCRG = Success and Sustainability of Creative Research Group; TWQ = Teamwork Quality. * *p*-value < 0.05; ** *p*-value < 0.01; *** *p*-value < 0.001.

5. Discussion and Conclusions

5.1. Research Findings

Firstly, it is clear that good TWQ and ROTS are important factors that have a positive impact on SSCRG. The validation of H1 and H2 imply that good TWQ and ROTS are positively correlated with SSCRG, and the impacts are significant. Meanwhile, the standardized path coefficients and T-Value

of H1 (TWQ→SSCRG) are 0.331 and 5819 respectively, which are larger than 0.296 and 5497 of H3 (ROTS→SSCRG), indicating that compared with ROTS, TWQ plays a greater role in SSCRG. While the standardized path coefficients and T-Value of H2 (ROTS→TWQ) are 0.526 and 12.234, ROTS turns out to have the most strong and significant impact on TWQ. This suggests that more attention should be paid to team formation and structural distributions.

Secondly, it is clear that TWQ is the key mediation construct between ROTS and SSCRG. After the verification of H2 (ROTS→TWQ) and H1 (TWQ→SSCRG), we found that ROTS is positively correlated with TWQ, and also that TWQ is positively correlated with SSCRG. At the same time, through the analysis of the mediation effect, it was found that the mediation effect of TWQ is highly significant in the "ROTS–TWQ–SSCRG" path, which emphasizes the key role of TWQ in the progress of the entire development of teamwork in the CRG project.

Combined with the development progress of the CRG project, the analysis above shows that having a reasonable team structure is not equivalent to the success and sustainability of the CRG; rather, there is a positive correlation. On the basis of a reasonable structure, the development and establishment of good teamwork quality and teamwork mechanism is the key to promote the success and sustainability of the CRG. In contrast, TWQ is particularly important and key, which is not only the direct influencing factor of SSCRG, but also an important mediation construct of ROTS and SSCRG. After TWQ's transition and mediation, the positive correlation between ROTS and SSCRG is more significant.

In addition, there is a need to focus on SSCRG, which means the staged completion of the innovative project, the excellent evaluation of the project, the continuous operation of the team, the guarantee and possibility of the interests and benefits of team members, the potential value and likelihood of continuous innovation, continuous growth and transition of the team in the future. It includes three variables: team performance, personal success, and comprehensive impacts (mainly, scientific and technological, economic, and social impacts). At this stage, we mostly evaluate and measure them through experts' scores and peer reviews. In the future, we hope to build more databases and evaluation index systems, and even use big data and artificial intelligence to evaluate their success and sustainability.

5.2. Implications for Project Management, Theoretical Contributions and Limitations of the Study

In recent years, many scholars have discussed the relationship between teamwork and factors related to team sustainability [11,26,66–68]. However, few studies have explored this relationship from the perspective of integrated teamwork-related factors, such as the relationship between static factors (rationality of team structure, ROTS), dynamic process factors (teamwork quality, TWQ), and team success and sustainability. Our paper attempted to fill this gap.

The main contribution of this study is (i) to extent the TWQ model by including ROTS, TWQ, and SSCRG, and (ii) to present its applications in analyzing and predicting the teamwork mechanism and team sustainability. We extend the analysis based on the TWQ model to the field of research and innovation teams, providing the possibility to further deepen and extend such analyses in the future.

Our research findings show that it is clear that ROTS and TWQ both have a positive impact on SSCRG, and TWQ's impact seems to be stronger, while ROTS has the strongest positive impact on TWQ. TWQ is the mediation factor between ROTS and SSCRG. This implies that team leaders and members alike should pay greater attention to ROTS and TWQ, especially in terms of team formation and structural distributions and how these factors may affect the growth and cohesion of the entire team. Only under the premise of a reasonable structure and strong cooperation qualities can a good team cooperation mechanism be established. Only then can the CRG project be successful, achieve research objectives, achieve scientific breakthroughs and innovations, cultivate high-level talent and teams, and achieve sustainable development. In fact, many factors related to teamwork quality, team structure, team success and sustainability in this study are not limited to CRG, but they share common

characteristics with many scientific research and innovation teams. In future, the applicability and promotion of such factors in similar teams would require further research and confirmation.

In general, the discovery and realization of high-level innovation require a better technology governance system and the cultivation of innovative talent teams. From the perspective of basic research projects and talent teams' ability to produce innovative research results, the NSFC needs to better play the role of a governing institution with "one body and two wings". That is to say, it should not only be the promoter of basic research and subversive innovation, but also play a role as the scientific and technological evaluator and discoverer. From the perspective of innovative talent teams, especially the CRG, these innovative talents and high-level teams are the implementers of innovation. The summary of teamwork rules and the construction and analysis of teamwork mechanisms can help them better achieve true team cooperation and successfully complete the project. It may also make it easier for managers from fund committees and other institutions to discover the rules of teamwork, the structure and the evolution mechanisms of a teamwork network, and the mutual relationships and action paths of various elements within teamwork dynamics. A well-defined teamwork mechanism design, as well as scientific and reasonable evaluation methods and systems, play an important role in promoting the development of innovation groups and their corresponding research.

Finally, the NSFC and experts in science and technology management should be reminded that the CRG is a unique frontier team undertaking basic research within China's science and technology system. Its future development and research should be combined with the reality of Chinese society in order to make greater progress in theoretical approaches and practical applications.

Although we have carried out some theoretical explorations and empirical studies on the teamwork of CRG and given some policy recommendations, our research still has many limitations, and further research is needed in the future. First, based on the existing extended model of teamwork quality and team success and sustainability relationship, we discuss teamwork in innovation groups. The theoretical framework and impact factors of our research have certain limitations; for example, we do not discuss the teamwork mechanisms of the CRG thoroughly enough. The second limitation is that the research methods are mostly based on questionnaires and semi-structured interviews, with certain subjectivity and limitations, and the sample size needs to be further expanded. This study is limited to a certain group of research projects. There is a need to examine teamwork in other types of high-level scientific research projects beyond those only in China, in order to conduct comparative studies in the future for scientists and research managers to have a reference for how to achieve scientific breakthroughs by adjusting teamwork dynmics. Future studies should combine more objective data with social network analysis methods, scientific measurements, structural equation models, peer reviews and other methods to conduct in-depth research on the cooperation mechanisms and sustainability of scientific research and innovation teams.

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