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Perceived Innovation Environment and Research Resilience among Scientific and Technological Researchers: Psychological Mechanisms and Boundary Conditions

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ABSTRACT: Background: The mental health challenges facing scientific and technological researchers, together with increasing demands for innovation performance, underscore the importance of research resilience, which helps protect mental health and sustain innovation performance. Accordingly, drawing on conservation of resources theory, social cognitive theory, and cognitive appraisal theory, this study investigated how perceived innovation environment may contribute to research resilience through the two candidate indirect pathways of research self-efficacy and anxiety and examined the moderating role of perceived fault-tolerant environment. **Methods:** A cross-sectional survey was conducted among 310 scientific and technological researchers working in Beijing (47.1% women; $Mean_{age} = 33.445$ years, $standard\ deviation = 5.126$ years). **Results:** First, perceived innovation environment was positively associated with research resilience ($b = 0.390$, $p < 0.001$). Second, research self-efficacy and anxiety mediated this association. Specifically, the indirect effect through research self-efficacy was significant ($indirect\ effect = 0.113$, 95% confidence interval $[0.018, 0.234]$) as was the indirect effect through anxiety ($indirect\ effect = 0.116$, 95% confidence interval $[0.006, 0.282]$). Third, perceived fault-tolerant environment moderated both second-stage paths. The index of moderated mediation was significant for the research self-efficacy pathway ($index = -0.113$, 95% confidence interval $[-0.240, -0.023]$) and the anxiety pathway ($index = 0.092$, 95% confidence interval $[0.021, 0.204]$). **Conclusions:** These findings clarify how perceived innovation environment is associated with research resilience through two distinct pathways: a cognitive pathway through research self-efficacy and an affective pathway through reduced anxiety. They also suggest that efforts to promote researchers' research resilience should combine research self-efficacy development and anxiety management with careful consideration of the differential moderating role of perceived fault-tolerant environment.

KEYWORDS: Perceived innovation environment; research resilience; research self-efficacy; anxiety; perceived fault-tolerant environment

1 Introduction

Mental health problems among scientific and technological researchers have emerged as a pressing concern internationally. Recent meta-analytic evidence indicates that nearly one in three early-career researchers report elevated psychological distress, with depressive and anxiety symptoms each affecting approximately 30% [1]. Across disciplines and cultural backgrounds, substantial evidence has documented elevated rates of depression and psychological distress. A survey of the planetary science community found that the severity of depressive symptoms exceeded that of the general population of the United

States [2]. Among mental health researchers themselves, another study reported that 13.4% of respondents met the threshold for severe psychological distress, and 23.7% of a subsample reported suicidal ideation since commencing their academic careers [3]. The situation in China appears particularly severe. A nationwide cross-sectional study of Chinese researchers found that 60.1% reported depressive symptoms, with approximately one in six reporting self-harm or suicidal ideation [4]. Somatic symptoms are also common among Chinese postgraduates, with a large cross-sectional study reporting such symptoms in 38.4% of medical and nonmedical postgraduates [5]. Beyond documenting the prevalence of these problems, emerging evidence suggests that features of the research environment may contribute to researchers' psychological functioning. Among postdoctoral researchers, for example, longer working hours, frequent overtime, and job insecurity have been associated with greater mental health problems [6]. Against this background, research resilience, defined as the capacity to persevere, adaptively cope, and recover from research-related setbacks [7–9], has emerged as a protective factor against these mental health challenges.

Research resilience is associated with both improved mental health and enhanced research performance [7–10]. A meta-analytic review revealed that protective factors, including resilience, predict positive achievement and adjustment outcomes [8]. In engineering, resilience theory has been positioned as a framework for understanding how individuals overcome adversity related to research and life [9]. Identifying the antecedents of research resilience is therefore important. Previous studies have focused predominantly on individual-level antecedents of research resilience, such as research stressors, passion, and research self-efficacy [10–12]. However, contextual resources, as perceived by researchers, may also shape research resilience. The innovation environment, encompassing innovation platforms, research funding, the scientific and technological talent pool, intellectual property protection, and talent policy support, has been linked to technological-talent agglomeration and scientific researchers' innovative behavior at the regional level [13,14]. Nevertheless, whether researchers' perceived innovation environment is associated with their research resilience, and through which psychological processes such an association may occur, remain insufficiently understood.

More specifically, the existing literature leaves three important gaps. First, prior studies have predominantly examined innovation environments at the firm or provincial level, with limited attention to the urban context in which researchers work. City-level innovation environments exhibit substantial variation across urban centers and directly shape the experiences of researchers working within them [13,15]. While research has demonstrated that urban innovation-oriented policies influence talent inflow and innovation performance [16,17], the role of researchers' perceived city-level innovation environment in their research resilience has not been tested. Without such evidence, policymakers lack an empirical basis for designing urban talent development environments that enhance research resilience.

Second, the psychological mechanisms linking perceived innovation environment to research resilience remain unclear. Two plausible mediating pathways exist. The cognitive pathway, operating via research self-efficacy, reflects researchers' confidence in their capacity to perform research-related tasks [18]. Perceiving the innovation environment as favorable may signal resource availability and institutional endorsement, thereby strengthening researchers' confidence in their ability to overcome challenges. The affective pathway, operating through anxiety, reflects the affective distress associated with research demands [19]. Perceiving the innovation environment as favorable may reduce uncertainty and performance pressure, thereby lowering anxiety levels that otherwise deplete research resilience. Examining these pathways together might clarify the psychological transformation mechanisms linking perceived innovation environment to individual psychological outcomes, by showing how a favorable perceived innovation environment is

associated with higher research self-efficacy as a cognitive resource and lower anxiety as an affective state, both of which are associated with greater research resilience.

Third, the boundary conditions governing these second-stage associations remain unclear. Perceived innovation environment primarily captures structural, resource-based, and institutional support, whereas perceived fault-tolerant environment captures the normative climate surrounding failure. Specifically, perceived fault-tolerant environment is defined as the extent to which researchers perceive that their local research environment tolerates failures arising from genuine attempts to innovate, encourages experimentation, and treats errors as opportunities for learning [20,21]. It may moderate the associations of research self-efficacy and anxiety with research resilience. If so, it is necessary to combine resource- and climate-based strategies for supporting researchers.

To address these three gaps, the present study aimed to examine (a) the predictive role of perceived innovation environment in research resilience; (b) the mediating roles of research self-efficacy (the cognitive pathway) and anxiety (the affective pathway) in this relationship; and (c) the moderating role of perceived fault-tolerant environment in these mediating mechanisms. We tested this conceptual model among scientific and technological researchers in Beijing. Beijing provides a particularly relevant empirical context because, as China's capital and one of its major high-level talent hubs, it has been designated as an International Science and Technology Innovation Center and hosts many of China's leading universities, research institutes, and scientific and technological researchers [22]. Its innovation ecosystem is characterized by a high concentration of talent policies, research funding, and innovation platforms [23]. At the same time, researchers working in such a highly competitive environment face substantial demands related to research performance, innovation outcomes, and, in some contexts, publication and funding competition that may heighten psychological strain [5]. This coexistence of abundant innovation resources and acute psychological demands makes Beijing a theoretically informative setting in which to examine how perceived innovation environment relates to research resilience and under what psychological and contextual conditions these associations emerge. In the following sections, we drew on conservation of resources theory, social cognitive theory, and cognitive appraisal theory to hypothesize the direct association between perceived innovation environment and research resilience, the mediating roles of research self-efficacy and anxiety, and the moderating role of perceived fault-tolerant environment.

1.1 Research Resilience and Perceived Innovation Environment

Before examining the association between perceived innovation environment and research resilience, it is necessary to clarify how research resilience resembles and differs from psychological resilience. The two constructs share two inseparable core elements: adversity, which involves risk or hardship that threatens effective functioning, and positive adaptation, which involves maintaining or regaining effective functioning despite such adversity [24]. Psychological resilience, when conceptualized as a general capacity, is domain-general and may relate to mental health and work performance across populations, whereas research resilience is domain-specific and may therefore be more directly relevant to scientific and technological researchers' mental health and innovation performance [7,25]. Although recent studies have identified individual-level protective factors for research resilience [7,25], institutional and socioecological perspectives emphasize that resilience may be shaped by environmental factors [26,27], making perceived innovation environment a theoretically salient contextual factor for the research resilience of scientific and technological researchers.

Perceived innovation environment refers to researchers' appraisal of whether the innovation system provides sufficient infrastructure, funding, platforms, incentives, administrative support, and legal protec-

tions. Prior research has linked favorable perceptions of regional environment to regional commitment and intention to stay, and perceived innovative environments to creative performance [28,29]. According to conservation of resources theory, a supportive innovation environment can function as a resource caravan passageway that facilitates the acquisition, protection, and investment of valued resources [30–32]. More specifically, the innovation environment can be regarded as a type of extrinsic resource, while research resilience represents a typical intrinsic resource. From this perspective, extrinsic resources can effectively foster the accumulation of the intrinsic resources [30–32]. When researchers perceive the innovation environment as supportive, they should be better able to sustain effort and adapt positively when adversity threatens their resources. Accordingly, we hypothesized:

H1: *Perceived innovation environment would be positively associated with research resilience.*

1.2 The Mediating Role of Research Self-Efficacy

Social cognitive theory conceptualizes human functioning as the reciprocal interplay of environmental conditions, personal factors, and behavior, while recognizing that sociostructural conditions influence action through proximal psychological mechanisms such as self-efficacy [33,34]. Perceived innovation environment captures researchers' appraisals of resources and opportunity structures, including infrastructure, research and development investment, commercialization platforms, incentives, administrative efficiency, and legal protections [13–16]. A favorably perceived environment may strengthen research self-efficacy by affording mastery opportunities, reducing avoidable impediments, and facilitating successful task performance. Consistent with this account, prior studies have found that research self-efficacy is strongly contingent upon research training environment and supervisory support [35–37]. Accordingly, we hypothesized:

H2: *Perceived innovation environment would be positively related to research self-efficacy.*

Social cognitive theory further identifies self-efficacy as a foundation of agency that shapes goal commitment, effort, perseverance, and cognitive and affective responses to adversity [33,34,38]. Researchers with stronger research self-efficacy should be more likely to remain task focused when research stalls, findings are inconclusive, or technical difficulties arise; to revise ineffective strategies; and to sustain effort rather than interpret setbacks as evidence of inadequate ability. More directly, a study of 396 doctoral students found that research self-efficacy was positively associated with research resilience and mediated the associations of challenge and hindrance research stressors with research resilience [10]. Research self-efficacy may therefore support research resilience by sustaining purposeful effort, adaptive problem solving, and proactive coping under research-related adversity. Accordingly, we hypothesized:

H3: *Research self-efficacy would be positively related to research resilience.*

Integrating these arguments, perceived innovation environment is expected to foster research self-efficacy, which may enable researchers to sustain effort, adapt strategies, and recover from setbacks, thereby strengthening research resilience. Accordingly, we hypothesized:

H4: *Research self-efficacy would mediate the positive relationship between perceived innovation environment and research resilience.*

1.3 The Mediating Role of Anxiety

Anxiety, an anticipatory emotion characterized by apprehension, worry, and tension, has been documented among scientific and technological researchers [1–3]. Cognitive appraisal theory holds that anxiety arises from relational appraisals of whether environmental conditions threaten personally valued goals and whether available coping resources are sufficient [39,40]. A less favorable perceived innovation environment may signal that inadequate research infrastructure, investment, incentives, administrative support, or legal protections could obstruct research goals. Researchers may therefore appraise research demands as threatening, difficult, uncertain, and insufficiently controllable. This appraisal profile is consistently associated with anxiety [41,42]. Conversely, a favorable perceived innovation environment should promote appraisals of goal conduciveness, predictability, and control, thereby reducing anxiety.

H5: *Perceived innovation environment would be negatively associated with anxiety.*

Cognitive appraisal theory characterizes anxiety as an anticipatory response to uncertain threat, coupled with low control and no clear course of action [40,41]. Its characteristic action tendency is avoidance or escape [40]. In research settings, this pattern may impede engagement with setbacks, sustained effort, strategy adjustment, and recovery, all of which are central to research resilience. Longitudinal studies of university students found that anxiety symptoms or broader mental ill-being predicted lower resilience [43,44]. These studies assessed general resilience rather than research resilience, but they provide prospective evidence that anxiety may impair adaptation to adversity.

H6: *Anxiety would be negatively associated with research resilience.*

Lower anxiety may therefore partly account for the positive association between perceived innovation environment and research resilience. Thus, we proposed the following hypothesis.

H7: *Anxiety would mediate the relationship between perceived innovation environment and research resilience, such that perceived innovation environment enhances research resilience by reducing anxiety.*

1.4 The Moderating Role of Perceived Fault-Tolerant Environment

Conservation of resources theory describes resource caravan passageways as conditions that foster or constrain resource creation and maintenance [31]. Perceived fault-tolerant environment signals a supportive passageway that limits disproportionate penalties for failed innovation attempts and facilitates correction and learning [45,46]. Research self-efficacy is a personal resource [47]. A resource-substitution account suggests personal resources become more consequential when contextual resources serving similar functions are scarce [32]. Researchers should therefore rely more on research self-efficacy when perceived fault-tolerant environment is low, whereas contextual protection may partly compensate at higher levels.

H8: *Perceived fault-tolerant environment would moderate the positive association between research self-efficacy and research resilience, such that the association would be stronger at lower levels of perceived fault-tolerant environment.*

The resource investment principle holds that recovery and gain require investment [30]. Anxiety can divert attention from error correction and learning [45]. Higher levels of perceived fault-tolerant environment expand opportunities for discussing unsuccessful attempts, revising strategies, and continuing

experimentation, but using these opportunities requires attentional and emotional resources. Researchers with lower anxiety should capitalize on this passageway more effectively than those with higher anxiety, widening the resilience gap.

H9: *Perceived fault-tolerant environment would moderate the negative association between anxiety and research resilience, such that the association would be stronger at higher levels of perceived fault-tolerant environment.*

These arguments yield two moderated mediation hypotheses.

H10: *The positive indirect association between perceived innovation environment and research resilience through research self-efficacy would be stronger at lower levels of perceived fault-tolerant environment.*

H11: *The positive indirect association between perceived innovation environment and research resilience through lower anxiety would be stronger at higher levels of perceived fault-tolerant environment.*

The proposed model is shown in Fig. 1.

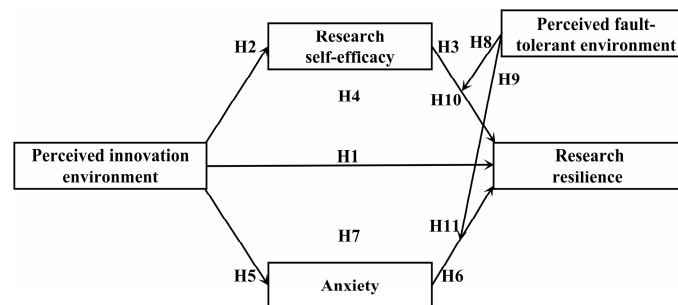


Figure 1: Conceptual model of the proposed association between perceived innovation environment and research resilience, including research self-efficacy and anxiety as psychological pathways and perceived fault-tolerant environment as the boundary condition.

2 Methods

2.1 Participants

Before recruitment, an *a priori* power analysis was conducted using G*Power 3.1.9.7 [48]. Based on the mean effect size reported for social psychological research ($r = 0.21$) [49], the analysis indicated that a minimum of 175 participants was required to detect a Pearson correlation of $r = 0.21$ using a two-tailed test with $\alpha = 0.05$ and 80% power. Because the planned analyses involved multiple hypothesis tests, the target sample size was conservatively set at 300. Participants were subsequently recruited through Credamo (<https://www.credamo.com>), an online survey platform in China, from late March to early April 2024. To reduce the risk of invalid participation associated with compensated online recruitment, a two-stage screening procedure was implemented. First, during recruitment, Credamo's prescreening system restricted questionnaire access to individuals whose registered information indicated that (a) they were located in Beijing and (b) they held a full-time position involving research and development (R&D)-related activities. Only participants who met these prescreening criteria were able to access the questionnaire. Second, during questionnaire completion, participants' actual Internet Protocol (IP) addresses were recorded, and participants were asked to report their job function and type of employing organization. These sources of information were used to cross-check participants' geographical location and professional background.

In this study, scientific and technological researchers were operationally defined as individuals whose primary work involved research, technological development, or other R&D-related activities within their organizations. This definition was intended to focus on individuals engaged in substantive research and development activities rather than technology-related occupations that do not involve research or innovation activities. Participants received 20 Chinese yuan (CNY), equivalent to approximately 2.77 United States dollars (USD) at the exchange rate prevailing during data collection, as compensation for completing the questionnaire.

A total of 313 participants completed the questionnaire. Following the prespecified screening procedure, participant eligibility was further assessed based on the recruitment criteria, recorded IP information, and reported occupational characteristics. In addition, an attention check was included to assess response attentiveness. Three participants failed the attention check and were excluded, leaving a final sample of 310 participants. The final sample included participants from 13 administrative districts and 11 science-and-technology-related industry sectors in Beijing. Of the participants, 92.9% were aged 39 years or younger ($Mean_{age} = 33.445$, $standard\ deviation\ [SD] = 5.126$). Their disciplinary backgrounds were natural sciences (41.3%), engineering (53.9%), agricultural sciences (0.6%), medical sciences (2.6%), and other disciplines (1.6%). Under China's professional-rank system, 30.0% had no professional title or held a junior rank, 54.5% held an intermediate rank, and 15.5% held an associate-senior or full-senior rank. Regarding research experience, 77.4% reported up to 10 years, 19.7% reported 11–15 years, and 2.9% reported more than 15 years. Regarding industry sector, 60.6% worked in scientific research and technical services, 25.5% in information transmission, software, and information technology services, and 13.9% in other sectors (for additional participant characteristics, see Table 1).

Table 1: Participant characteristics ($N = 310$).

Variable	Category	<i>n</i>	%
Gender	Men	164	52.9
	Women	146	47.1
Age	<30 years	63	20.3
	30–39 years	225	72.6
	≥40 years	22	7.1
Education	Bachelor's degree or lower	45	14.5
	Master's degree	253	81.6
	Doctoral degree	12	3.9
Type of employing organization	Higher education institution	15	4.8
	Research institute	185	59.7
	Business enterprise	110	35.5
Primary research and development activity	Basic research	81	26.1
	Applied research	114	36.8
	Experimental development	73	23.5
	Mixed research and development activities	42	13.5
Primary job function	Research	295	95.2
	Research management	15	4.8
Subjective socioeconomic status	Scores 1–3	14	4.5
	Scores 4–7	289	93.2
	Scores 8–10	7	2.3

Table 1: *Cont.*

Variable	Category	<i>n</i>	%
Monthly personal income (CNY)	<10,000	18	5.8
	10,000–19,999	174	56.1
	20,000–29,999	89	28.7
	≥30,000	29	9.4

Note. *N* = total sample size; *n* = number of participants in each category; % = percentage; CNY = Chinese yuan; < = less than; ≥ = greater than or equal to. Percentages may not total 100% because of rounding.

2.2 Procedure and Measures

The study involving human participants was reviewed and approved by the Research Ethics Committee at Capital University of Economics and Business (Approval No. CUEB-REC-2024-0023). All participants provided informed consent before completing the anonymous online questionnaire. They were informed that (a) the study examined research personnel's work-related attitudes and experiences and (b) their anonymous responses would be kept confidential and used solely for research purposes. Measures originally developed in English, including the research resilience and research self-efficacy scales, were adapted into Chinese using a standardized translation and back-translation procedure. A graduate with a degree in English prepared the Chinese versions, which were independently back-translated into English by another graduate with the same academic background. The back-translations were compared with the original measures, and any discrepancies were resolved through discussion.

2.2.1 Perceived Innovation Environment

Perceived innovation environment was assessed using nine items adapted and contextualized from indicators included in an urban talent development environment index [50]. The items assessed respondents' perceptions of Beijing's innovation infrastructure, technology commercialization platforms, research and development investment, innovation incentives, administrative processes, and legal and intellectual property protections. The nine items were: (a) Beijing's key laboratories have reached internationally advanced standards. (b) The number of national-level technology business incubators in Beijing is sufficient to effectively support the development of technology-based small and medium-sized enterprises. (c) Beijing's industrial technology innovation alliances provide an effective platform for the commercialization of scientific and technological achievements. (d) The number of new-type research and development institutions in Beijing is sufficient to support the research and development of frontier technologies. (e) Beijing's research and development expenditure intensity is sufficient to support the development of key technologies. (f) Beijing provides sufficiently strong incentives for patents arising from scientific and technological innovation. (g) Beijing's administrative approval procedures for research projects, such as funding applications and equipment procurement, are streamlined and transparent. (h) Beijing's regulations protecting the rights and interests of scientific and technological personnel, such as those governing the ownership of scientific and technological achievements, are clear and reasonable. (i) The available channels for enforcing intellectual property rights in Beijing, such as litigation and arbitration, are accessible and efficient. Each item was rated on a six-point scale (1 = strongly disagree; 6 = strongly agree). Item scores were averaged, with higher scores indicating a more favorable perception of the innovation environment ($\alpha = 0.799$; $\omega = 0.799$).

2.2.2 Research Resilience

Research resilience was assessed using the four-item measure employed by Zhu and Hou [10], which was informed by previous research on academic resilience [51]. This measure assessed respondents'

persistence in the face of research-related difficulties, maintenance of standards and goals despite setbacks, positive appraisal of research-related pressure, and continued effort in the absence of timely help or support. A sample item was “When I encounter difficulties in my research that might cause most people to give up, I continue to persevere”. Responses were rated on a six-point scale (1 = strongly disagree; 6 = strongly agree). Item scores were averaged, with higher scores indicating greater research resilience ($\alpha = 0.664$; $\omega = 0.668$). The four-item Research Resilience Scale yielded modest reliability estimates, which might be partly because of its small number of items.

2.2.3 Research Self-Efficacy

Research self-efficacy was assessed using the three-item Research Self-Efficacy Scale developed by Zhang et al. [52], drawing on prior work on academic self-efficacy [53]. The scale assessed respondents’ confidence in their ability to perform research work. A sample item was “I am confident in my ability to perform research work effectively”. Participants responded on a six-point scale (1 = strongly disagree; 6 = strongly agree), with higher mean scores indicating greater research self-efficacy ($\alpha = 0.608$; $\omega = 0.611$). The Research Self-Efficacy Scale yielded modest reliability estimates, which may be partly because of its brevity.

2.2.4 Anxiety

Anxiety was assessed using the brief Chinese version of the Self-Rating Anxiety Scale [54–56]. The ten-item scale assessed both psychological manifestations of anxiety, including tension, fear, and panic, and somatic manifestations, including fatigue, dizziness, pain, and gastrointestinal discomfort. A sample item was “I feel more nervous and anxious than usual”. Participants indicated how frequently each statement applied to them on a four-point scale (1 = none or a little of the time; 2 = some of the time; 3 = a good part of the time; 4 = most or all of the time). Three positively worded items were reverse-scored, after which the item scores were averaged, with higher scores indicating more frequent anxiety symptoms ($\alpha = 0.903$; $\omega = 0.906$).

2.2.5 Perceived Fault-Tolerant Environment

Perceived fault-tolerant environment was measured using five items adapted from the Organizational Fault-Tolerant Climate Scale [46]. The items assessed the extent to which respondents perceived Beijing’s research environment as permitting exploration and trial and error, tolerating innovation-related failure, and limiting disproportionate penalties or career costs associated with unsuccessful innovation attempts. A sample item was “In Beijing’s research environment, I am not excessively penalized for failures resulting from attempts to innovate”. Responses were recorded on a six-point scale (1 = strongly disagree; 6 = strongly agree). Item scores were averaged, with higher scores indicating greater perceived tolerance for failure in the research environment ($\alpha = 0.784$; $\omega = 0.782$).

2.2.6 Control Variables

Gender, age, education, type of employing organization, primary job function, primary research and development activity, monthly personal income, and subjective socioeconomic status were included as controls in all regression, mediation, moderation, and moderated mediation models. Gender was coded 1 = men and 0 = women. Education was represented by two dummy variables for master’s and doctoral degrees, with a bachelor’s degree or lower as the reference category. Type of employing organization was coded 1 = higher education institution or research institute and 0 = business enterprise. Primary job

function was coded 1 = research and 0 = research management. Primary research and development activity was coded 1 = basic research and 0 = applied research, experimental development, or mixed research and development activities. Monthly personal income was coded from 1 to 4, representing Chinese yuan (CNY) 0–9999, CNY 10,000–19,999, CNY 20,000–29,999, and CNY 30,000 or above, respectively. Subjective socioeconomic status was assessed using the MacArthur Scale of Subjective Social Status [57], on which participants rated their perceived social standing on a 10-rung ladder ranging from 1 (lowest) to 10 (highest). Age and subjective socioeconomic status were treated as continuous variables.

2.3 Data Analysis

Primary analyses were conducted using SPSS Statistics 32 (Statistical Package for the Social Sciences; International Business Machines Corporation, Armonk, New York, United States of America) and PROCESS macro version 5.0 [58]. Confirmatory factor analyses were conducted using Mplus 9, as described in Section 3.2. First, Harman's single-factor test was conducted using an unrotated principal component analysis of all measurement items to examine common method bias. Second, multiple regression analyses were conducted to examine the direct relationships and the regression paths involved in the mediation models. Subsequently, the mediating roles of research self-efficacy and anxiety were examined using the PROCESS macro (Model 4) [58]. The indirect effect, estimated using 5000 percentile bootstrap samples and a 95% bootstrap confidence interval (95% CI), was considered significant if its 95% CI excluded zero. Then the moderating role of perceived fault-tolerant environment was examined using PROCESS Model 1 [58]. Separate models were estimated for the interactions between research self-efficacy and perceived fault-tolerant environment and between anxiety and perceived fault-tolerant environment. Continuous variables involved in interaction terms were mean-centered before the interaction terms were constructed. Significant interaction effects were interpreted using simple slope analyses at low and high perceived fault-tolerant environment, operationalized as one standard deviation (SD) below and above the mean [59]. Subsequently, the model 14 of the PROCESS macro [58] was used to test the second-stage moderated mediation models. Conditional indirect effects of perceived innovation environment on research resilience via research self-efficacy and anxiety were estimated at low and high perceived fault-tolerant environment. All statistical tests were two-tailed, with statistical significance set at $p < 0.05$.

3 Results

3.1 Common Method Bias Test

Harman's single-factor test showed that five components had eigenvalues greater than 1, of which the first component accounted for 33.0% of the total variance, below the more stringent threshold of 40.0%. Under this criterion, the test did not indicate pronounced common method bias.

3.2 Descriptive Statistics and Correlations

Means, SDs, and correlations are shown in Table 2. Perceived innovation environment was positively correlated with research self-efficacy ($r = 0.485$, $p < 0.001$) and research resilience ($r = 0.473$, $p < 0.001$), and negatively correlated with anxiety ($r = -0.563$, $p < 0.001$). Research self-efficacy was positively correlated with research resilience ($r = 0.521$, $p < 0.001$). Anxiety was negatively correlated with research resilience ($r = -0.466$, $p < 0.001$). Perceived fault-tolerant environment was positively correlated with research self-efficacy ($r = 0.455$, $p < 0.001$) and research resilience ($r = 0.443$, $p < 0.001$), and negatively correlated with anxiety ($r = -0.590$, $p < 0.001$).

Table 2: Descriptive statistics and correlations ($N = 310$).

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Gender ^a	—	—	—												
2 Age	33.445	5.126	0.212***	—											
3 Education: master's degree ^b	—	—	−0.014	0.061	—										
4 Education: doctoral degree ^b	—	—	−0.112*	−0.109	−0.423***	—									
5 Type of employing organization ^c	—	—	0.084	0.242***	0.205***	0.044	—								
6 Primary job function ^d	—	—	−0.002	0.040	0.359***	0.045	0.241***	—							
7 Primary research and development activity ^e	—	—	0.002	−0.095	0.017	0.147**	0.088	0.100	—						
8 Monthly personal income ^f	—	—	0.042	0.100	0.211***	−0.045	−0.148**	0.066	−0.057	—					
9 Subjective socioeconomic status	6.023	1.059	0.014	0.183**	0.168**	−0.020	0.213***	0.019	−0.075	0.269***	—				
10 Perceived innovation environment	4.377	0.518	0.079	0.087	0.131*	−0.133*	0.254***	−0.013	0.022	0.089	0.489***	—			
11 Research resilience	4.975	0.623	0.113*	0.165**	0.165**	−0.079	0.311***	−0.027	−0.012	0.059	0.389***	0.473***	—		
12 Research self-efficacy	4.917	0.639	0.148**	0.185**	0.221***	−0.158**	0.330***	0.018	−0.049	0.082	0.416***	0.485***	0.521***	—	
13 Anxiety	1.380	0.444	−0.034	−0.122*	−0.493***	0.284***	−0.289***	−0.227***	0.004	−0.254***	−0.536***	−0.563***	−0.466***	−0.492***	—
14 Perceived fault-tolerant environment	4.768	0.728	0.046	0.088	0.268***	−0.318***	0.291***	0.052	−0.004	0.135*	0.434***	0.713***	0.443***	0.455***	−0.590***

Note. N = total sample size; SD = standard deviation; CNY = Chinese yuan. Values in the correlation matrix are Pearson correlation coefficients. ^aGender: 1 = men; 0 = women.

^bEducation was represented by two indicators: master's degree and doctoral degree, each coded 1 for the specified category and 0 otherwise. ^cType of employing organization: 1 = higher education institution or research institute; 0 = business enterprise. ^dPrimary job function: 1 = research; 0 = research management. ^ePrimary research and development activity: 1 = basic research; 0 = applied research, experimental development, or mixed research and development activities. ^fMonthly personal income: 1 = CNY 0–9999; 2 = CNY 10,000–19,999; 3 = CNY 20,000–29,999; 4 = CNY 30,000 and higher. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. All tests are two-tailed.

In addition, there was a strong positive correlation between perceived innovation environment and perceived fault-tolerant environment ($r = 0.713$, $p < 0.001$; Table 2). To assess the discriminant validity of these two constructs, one-factor and correlated two-factor confirmatory factor analysis models were estimated in Mplus 9 using robust maximum likelihood estimation (MLR). Both models used the same six continuous indicators: three three-item parcels for perceived innovation environment, and two two-item parcels and one single item for perceived fault-tolerant environment. Model fit was evaluated using the scaled chi-square statistic (χ^2), comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). The correlated two-factor model fitted the data well (scaled $\chi^2(8) = 9.972$, $p = 0.27$, CFI = 0.998, TLI = 0.996, RMSEA = 0.028, SRMR = 0.018) and provided a better fit than the one-factor model (scaled $\chi^2(9) = 36.052$, $p < 0.001$, CFI = 0.973, TLI = 0.954, RMSEA = 0.098, SRMR = 0.034). An approximate MLR-scaled chi-square difference comparison favored the two-factor model ($\Delta\chi^2(1) = 23.390$, $p < 0.001$). These findings provided evidence for the discriminant validity of these two constructs.

3.3 The Association between Perceived Innovation Environment and Research Resilience and the Mediating Role of Research Self-Efficacy

As shown in Table 3, perceived innovation environment significantly predicted research resilience ($b = 0.390$, $p < 0.001$), supporting **H1**. Perceived innovation environment also positively predicted research self-efficacy ($b = 0.382$, $p < 0.001$), supporting **H2**. When perceived innovation environment and research self-efficacy were entered simultaneously, both remained significant predictors of research resilience ($b = 0.277$, $p < 0.001$ for perceived innovation environment; $b = 0.297$, $p < 0.001$ for research self-efficacy). This significant positive association between research self-efficacy and research resilience supported **H3**. Furthermore, the indirect effect through research self-efficacy (*indirect effect* = 0.113, 95% CI [0.018, 0.234]) was significant, supporting **H4**.

Table 3: Regression models testing the predictive role of perceived innovation environment on research resilience and the mediating role of research self-efficacy ($N = 310$).

Predictor	Research Resilience	Research Self-Efficacy	Research Resilience
	Model 1	Model 2	Model 3
Constant	2.456*** (0.358)	2.192*** (0.356)	1.805*** (0.364)
<i>Control variables</i>			
Gender	0.079 (0.062) [1.075]	0.117 (0.062) [1.075]	0.045 (0.060) [1.088]
Age	0.006 (0.006) [1.171]	0.005 (0.006) [1.171]	0.004 (0.006) [1.174]
Education: master's degree	0.172 (0.099) [1.653]	0.182 (0.099) [1.653]	0.118 (0.096) [1.672]
Education: doctoral degree	0.076 (0.185) [1.423]	−0.165 (0.184) [1.423]	0.125 (0.177) [1.427]

Table 3: *Cont.*

Predictor	Research Resilience	Research Self-Efficacy	Research Resilience
	Model 1	Model 2	Model 3
Type of employing organization	0.232** (0.073) [1.364]	0.254*** (0.073) [1.364]	0.156* (0.071) [1.419]
Primary job function	−0.315* (0.157) [1.263]	−0.185 (0.156) [1.263]	−0.260 (0.150) [1.268]
Primary research and development activity	−0.017 (0.070) [1.063]	−0.062 (0.070) [1.063]	0.001 (0.067) [1.066]
Monthly personal income	−0.009 (0.045) [1.221]	−0.001 (0.045) [1.221]	−0.009 (0.043) [1.221]
Subjective socioeconomic status	0.099** (0.035) [1.505]	0.116*** (0.035) [1.505]	0.065 (0.034) [1.562]
<i>Focal variables</i>			
Perceived innovation environment	0.390*** (0.069) [1.415]	0.382*** (0.068) [1.415]	0.277*** (0.069) [1.562]
Research self-efficacy			0.297*** (0.056) [1.534]
R^2	0.308	0.348	0.369
$F(df1, df2)$	13.327*** (10, 299)	15.960*** (10, 299)	15.823*** (11, 298)

Note. Unstandardized coefficients are reported, standard errors in parentheses, and variance inflation factors (VIFs) in square brackets. N = total sample size; CNY = Chinese yuan; R^2 = coefficient of determination; F = overall model F statistic; $df1$ and $df2$ = numerator and denominator degrees of freedom, respectively. For the F statistics, the values in parentheses are $df1$ and $df2$. Categorical coding: Gender (1 = men; 0 = women); Education (two dummy variables for master's and doctoral degrees; reference category = bachelor's degree or lower); Type of employing organization (1 = higher education institution or research institute; 0 = business enterprise); Primary job function (1 = research; 0 = research management); Primary research and development activity (1 = basic research; 0 = applied research, experimental development, or mixed research and development activities); Monthly personal income (1 = CNY 0–9,999; 2 = CNY 10,000–19,999; 3 = CNY 20,000–29,999; 4 = CNY 30,000 and higher). * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

3.4 The Mediating Role of Anxiety

As shown in Table 4 (Models 1–2), perceived innovation environment negatively predicted anxiety ($b = -0.299$, $p < 0.001$), supporting **H5**. When perceived innovation environment and anxiety were entered simultaneously, perceived innovation environment remained a significant positive predictor of research resilience ($b = 0.275$, $p < 0.001$), while anxiety was a significant negative predictor ($b = -0.386$, $p < 0.001$), supporting **H6**. The bootstrap analysis further supported the positive indirect effect of perceived innovation environment on research resilience through anxiety (*indirect effect* = 0.116, 95% CI [0.006, 0.282]), supporting **H7**.

Table 4: Regression models testing the mediating role of anxiety and the moderating role of perceived fault-tolerant environment on the associations of research self-efficacy and anxiety with research resilience ($N = 310$).

Predictor	Anxiety		Research Resilience		
	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	3.966*** (0.197)	3.989*** (0.537)	4.558*** (0.277)	4.745*** (0.317)	4.573*** (0.460)
<i>Control variables</i>					
Gender	0.013 (0.034) [1.075]	0.084 (0.061) [1.076]	0.090 (0.058) [1.102]	0.093 (0.061) [1.074]	0.082 (0.056) [1.108]
Age	0.002 (0.003) [1.171]	0.007 (0.006) [1.172]	0.006 (0.006) [1.180]	0.006 (0.006) [1.179]	0.005 (0.006) [1.183]
Education: master's degree	-0.312*** (0.055) [1.653]	0.051 (0.102) [1.832]	0.077 (0.092) [1.672]	-0.028 (0.104) [1.915]	-0.079 (0.096) [1.956]
Education: doctoral degree	0.291** (0.102) [1.423]	0.189 (0.184) [1.462]	0.178 (0.179) [1.568]	0.228 (0.193) [1.628]	0.056 (0.178) [1.673]
Type of employing organization	-0.078 (0.040) [1.364]	0.202** (0.072) [1.381]	0.153* (0.070) [1.464]	0.174* (0.073) [1.426]	0.134* (0.067) [1.470]
Primary job function	-0.222* (0.086) [1.263]	-0.401* (0.155) [1.290]	-0.307* (0.145) [1.268]	-0.452** (0.154) [1.280]	-0.378** (0.142) [1.306]
Primary research and development activity	-0.009 (0.039) [1.063]	-0.020 (0.069) [1.064]	0.020 (0.065) [1.065]	-0.004 (0.069) [1.067]	0.029 (0.063) [1.076]
Monthly personal income	-0.057* (0.025) [1.221]	-0.031 (0.044) [1.243]	-0.018 (0.041) [1.229]	-0.050 (0.044) [1.243]	-0.034 (0.040) [1.253]
Subjective socioeconomic status	-0.116*** (0.019) [1.505]	0.055 (0.036) [1.689]	0.066* (0.032) [1.497]	0.063 (0.035) [1.643]	0.023 (0.033) [1.724]
<i>Focal variables</i>					
Perceived innovation environment	-0.299*** (0.038) [1.415]	0.275*** (0.074) [1.708]			0.103 (0.082) [2.542]
Research self-efficacy			0.179** (0.059) [1.847]		0.121* (0.058) [1.935]
Anxiety		-0.386*** (0.103) [2.409]		-0.530*** (0.111) [2.836]	-0.420*** (0.105) [3.050]
Perceived fault-tolerant environment			0.119* (0.050) [1.761]	0.255*** (0.062) [2.386]	0.142* (0.064) [3.093]

Table 4: Cont.

Predictor	Anxiety		Research Resilience		
	Model 1	Model 2	Model 3	Model 4	Model 5
Research self-efficacy × Perceived fault-tolerant environment			−0.266*** (0.052) [1.709]		−0.296*** (0.052) [1.838]
Anxiety × Perceived fault-tolerant environment				−0.197* (0.083) [2.619]	−0.308*** (0.078) [2.777]
R^2	0.585	0.340	0.417	0.346	0.464
$F(df1, df2)$	42.140*** (10, 299)	13.938*** (11, 298)	17.698*** (12, 297)	13.119*** (12, 297)	16.940*** (15, 294)

Note. Unstandardized coefficients are reported, standard errors in parentheses, and variance inflation factors (VIFs) in square brackets. N = total sample size; CNY = Chinese yuan; R^2 = coefficient of determination; F = overall model F statistic; $df1$ and $df2$ = numerator and denominator degrees of freedom, respectively. For the F statistics, the values in parentheses are $df1$ and $df2$. The multiplication sign (×) denotes an interaction term. Categorical coding: Gender (1 = men; 0 = women); Education (two dummy variables for master's and doctoral degrees; reference category = bachelor's degree or lower); Type of employing organization (1 = higher education institution or research institute; 0 = business enterprise); Primary job function (1 = research; 0 = research management); Primary research and development activity (1 = basic research; 0 = applied research, experimental development, or mixed research and development activities); Monthly personal income (1 = CNY 0–9,999; 2 = CNY 10,000–19,999; 3 = CNY 20,000–29,999; 4 = CNY 30,000 and higher). * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

3.5 The Moderating Role of Perceived Fault-Tolerant Environment

As shown in Table 4 (Model 3), the interaction between research self-efficacy and perceived fault-tolerant environment significantly and negatively predicted research resilience ($b = -0.266$, $p < 0.001$). This result indicates that the positive association between research self-efficacy and research resilience was weaker when perceived fault-tolerant environment was higher (Fig. 2A). Simple slope analyses showed that research self-efficacy had a significant and positive association with research resilience at lower levels of perceived fault-tolerant environment (*simple slope* = 0.373, *standard error* [SE] = 0.054, $p < 0.001$), whereas the association was not significant at higher levels of perceived fault-tolerant environment (*simple slope* = -0.014 , $SE = 0.083$, $p = 0.86$). Thus, **H8** was supported.

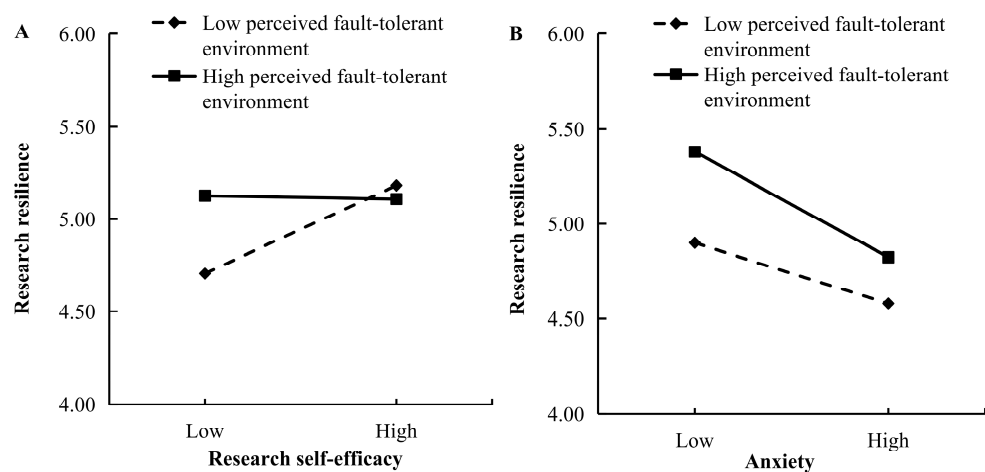


Figure 2: Moderating effect of perceived fault-tolerant environment on the relation between research self-efficacy and research resilience (A) and on the relation between anxiety and research resilience (B). Low, mean -1 SD; high, mean $+1$ SD.

Furthermore, as shown in Table 4 (Model 4) and Fig. 2B, the interaction between anxiety and perceived fault-tolerant environment negatively predicted research resilience ($b = -0.197$, $p = 0.02$). Simple slope analyses indicated that the negative role of anxiety in research resilience was significant but weaker at lower levels of perceived fault-tolerant environment (*simple slope* = -0.387 , $SE = 0.101$, $p < 0.001$), while this negative role was significant and stronger at higher levels of perceived fault-tolerant environment (*simple slope* = -0.674 , $SE = 0.147$, $p < 0.001$). Thus, **H9** was supported.

3.6 The Moderated Mediation Model

The second-stage moderated mediation hypotheses were tested using Model 14 of the PROCESS macro for conditional process analysis. To account simultaneously for the independent variable and the parallel mediator, the moderated mediation effects were estimated using the full model specification (Table 4, Model 5), which included perceived innovation environment, research self-efficacy, anxiety, perceived fault-tolerant environment, and both interaction terms. In this comprehensive model, both interaction effects remained significant (research self-efficacy $\times$ perceived fault-tolerant environment: $b = -0.296$, $p < 0.001$; anxiety $\times$ perceived fault-tolerant environment: $b = -0.308$, $p < 0.001$), providing further support for **H8** and **H9**, respectively. As shown in Table 5, for the mediating role of research self-efficacy, the indirect effect of perceived innovation environment on research resilience through research self-efficacy was significant at low perceived fault-tolerant environment (*indirect effect* = 0.128 , 95% CI [0.031 , 0.256]) but not under high perceived fault-tolerant environment (*indirect effect* = -0.036 , 95% CI [-0.160 , 0.048]). More importantly, the index of moderated mediation was significant (index = -0.113 , 95% CI [-0.240 , -0.023]), indicating that the indirect association through research self-efficacy weakened as perceived fault-tolerant environment increased. Thus, **H10** was supported. For the mediating role of anxiety, the indirect effect through anxiety was not significant under low perceived fault-tolerant environment (*indirect effect* = 0.059 , 95% CI [-0.031 , 0.180]) but was significant under high perceived fault-tolerant environment (*indirect effect* = 0.193 , 95% CI [0.053 , 0.421]). The index of moderated mediation was also significant (index = 0.092 , 95% CI [0.021 , 0.204]), indicating that the positive indirect association through lower anxiety strengthened as perceived fault-tolerant environment increased. Therefore, **H11** was supported. Across the regression models reported in Tables 3 and 4, variance inflation factor (VIF) values ranged from 1.063 to 3.093, with those for the interaction terms ranging from 1.709 to 2.777, providing no indication of pronounced multicollinearity.

Table 5: Results of moderated mediation analysis ($N = 310$).

Indirect Pathway	Moderator: Perceived Fault-Tolerant Environment	Conditional Indirect Effect	BootSE	95% CI
Perceived innovation environment → Research self-efficacy → Research resilience	Low (-1 SD)	0.128	0.058	[0.031, 0.256]
	High ($+1$ SD)	-0.036	0.052	[-0.160 , 0.048]
	Index of moderated mediation	-0.113	0.055	[-0.240 , -0.023]
Perceived innovation environment → Anxiety → Research resilience	Low (-1 SD)	0.059	0.054	[-0.031 , 0.180]
	High ($+1$ SD)	0.193	0.095	[0.053, 0.421]
	Index of moderated mediation	0.092	0.047	[0.021, 0.204]

Note. N = total sample size; BootSE = bootstrap standard error; CI = confidence interval; SD = standard deviation. Low and high perceived fault-tolerant environment correspond to one SD below and above the mean, respectively. Conditional indirect effects and the indices of moderated mediation were estimated using 5000 percentile bootstrap samples with 95% confidence intervals.

3.7 Exploratory Analyses of Individual Differences

To examine whether the association between perceived innovation environment and research resilience varied by gender, age, or type of employing organization, three exploratory moderation models were

estimated using Model 1 of the PROCESS macro for regression-based moderation analysis. Perceived innovation environment was specified as the predictor and research resilience as the outcome, with each individual characteristic examined separately as the moderator and the remaining control variables retained as covariates. None of the interactions involving gender ($b = 0.044$, $SE = 0.119$, $p = 0.71$), age ($b = -0.004$, $SE = 0.008$, $p = 0.60$), or type of employing organization ($b = 0.154$, $SE = 0.126$, $p = 0.23$) was significant. These findings provided no evidence that the association between perceived innovation environment and research resilience varied across the three individual characteristics examined.

4 Discussion

4.1 Theoretical Implications

The positive association between perceived innovation environment and research resilience accords with socioecological perspectives that situate resilience across individual, interpersonal, organizational, community, and policy contexts [27]. Prior research linked regional and perceived innovation environments to regional commitment, intention to stay, and creative performance [28,29]. The present association extends that literature by connecting perceived innovation environment with research resilience, a domain-specific capacity related to scientific and technological researchers' mental health and innovation performance under research adversity. From the perspective of conservation of resources theory, this finding supports a resource-accumulation account where a favorable innovation environment might provide external resources that facilitate the development and preservation of researchers' internal adaptive resources, thereby contributing to greater resilience [30–32]. Exploratory moderation analyses further showed that this association did not significantly vary by gender, age, or type of employing organization. Although exploratory, these findings suggest that, within the present sample, the association was not contingent upon these individual characteristics. Altogether, these findings move beyond individual-level approaches by situating research resilience within the talent-development environment and highlighting the broader relevance of contextual resources for fostering research resilience.

A central theoretical contribution of this study lies in clarifying the psychological transformation mechanisms linking perceived innovation environment to individual psychological outcomes. The mediating roles of research self-efficacy and anxiety indicate two complementary pathways, cognitive and affective, through which perceived innovation environment is associated with research resilience. The research self-efficacy finding accords with social cognitive theory [33,34] and evidence linking research self-efficacy with research resilience among doctoral students [10]. Although scientific and technological researchers have been studied less extensively than doctoral researchers, they face serious mental health risks [1–5]; documenting this relationship broadens its relevance beyond research training. The findings extend efficacy-based accounts of resilient adaptation [38] by situating research self-efficacy within a sequence linking perceived innovation environment to positive adaptation under research adversity. The anxiety finding likewise accords with cognitive appraisal theory [39–42] and evidence linking anxiety with lower general resilience [43,44]. By identifying this association for research resilience and relating anxiety to perceived innovation environment, the study extends prior work from general adaptation to researchers' capacity to persist, adjust strategies, and recover from research-specific setbacks. Taken together, these findings extend the literature beyond the direct association between perceived innovation environment and research resilience by identifying research self-efficacy and anxiety as distinct cognitive and affective pathways underlying this association. This integration links contextual and individual levels of analysis and provides a more differentiated account of how perceived innovation environment is related to research resilience.

The results clarify when research self-efficacy and anxiety relate to research resilience. First, the positive association between research self-efficacy and research resilience accords with doctoral-student evidence [10] and efficacy-based accounts of resilient adaptation [38]. The stronger association at lower levels of perceived fault-tolerant environment identifies the latter as a boundary condition. Conservation of resources theory emphasizes that environmental passageways shape resource maintenance [31], while resource-substitution reasoning predicts that personal resources gain importance when alternatives are limited [32]. Second, anxiety's negative association with research resilience accords with cognitive appraisal theory and anxiety-resilience findings [39–41,43], whereas its greater strength at higher levels of perceived fault-tolerant environment identifies a boundary condition. At lower levels of perceived fault-tolerant environment, penalties may broadly constrain adaptation; under such a common external constraint, differences in anxiety may be less consequential for research resilience. As that constraint recedes at higher levels of perceived fault-tolerant environment, researchers have greater opportunities to learn from unsuccessful attempts, revise strategies, and continue experimentation. The extent to which researchers can capitalize on these opportunities may then depend more strongly on anxiety, making anxiety more strongly associated with researchers' persistence and recovery [20,21,45,46]. This pattern extends anxiety-resilience evidence by identifying when anxiety connects perceived innovation environment with research resilience. Importantly, this interaction should not be interpreted as indicating that a more fault-tolerant environment is psychologically harmful. Rather, perceived fault-tolerant environment may reduce external constraints on adaptation, thereby making individual differences in anxiety more consequential for whether researchers can capitalize on available learning opportunities.

4.2 Practical Implications

The practical implications of these findings can be considered at two levels: context-specific implications for Beijing and broader principles that may be relevant to other research-intensive regions. In Beijing, the findings suggest that policymakers could consider further improving Beijing's innovation environment and ensuring researchers can understand, access, and use its provisions [13–16,50]. Policymakers could publish clear eligibility criteria and decision schedules for research funding, shared facilities, and technology commercialization platforms, because accessible regional innovation conditions support scientific and technological talent retention, innovative behavior, and urban innovation performance [13–16]. Building on this, policymakers could consider streamlining grant administration, equipment procurement, and project reporting and monitor processing times, thereby making objective improvements more readily perceived and used [15,16,50]. Relevant research management authorities could consider issuing coordinated guidance on ownership, patent incentives, researchers' rights, and enforcement procedures [13,14,28,50]. These authorities can also consult researchers regularly to identify and remedy gaps between formal policies and perceived accessibility [13,14,28,50]. More fundamentally, improvements in perceived innovation environment could be paired with efforts to strengthen perceived fault-tolerant environment. Universities, research institutes, and business enterprises can distinguish good-faith unsuccessful innovation attempts from negligence or misconduct and use developmental reviews to identify lessons, corrective actions, and opportunities for renewed experimentation [20,21,45]. Research leaders could apply these standards consistently and explain how unsuccessful attempts are evaluated, because credible error-management practices promote the discussion of errors, learning, and innovative behavior [20,45,46]. Beyond Beijing, the broader implication is that regional innovation systems may benefit from attending not only to the formal provision of research resources but also to researchers' perceived accessibility and usability of those resources and to the normative climate surrounding research failure. The specific policy instruments will

necessarily vary across regions, but this combination of resource provision, resource accessibility, and support for learning from good-faith failure may provide a useful framework for adapting innovation policies to different institutional contexts. However, it should be noted that these recommendations are preliminary insights rather than concrete policy directives.

Mental health support may likewise benefit from a context-sensitive rather than uniform approach. When perceived fault-tolerant environment is lower, research management authorities could incorporate training designed to strengthen research self-efficacy and research resilience, alongside research and psychological literacy, into their talent-development programs [33,34]. These programs can consider combining challenging research exercises with credible peer demonstrations and feedback, which represent sources of research self-efficacy [33,34]. Universities, research institutes, and business enterprises could reinforce this preparation through methods workshops, structured mentoring, and supervised practice [60]. When perceived fault-tolerant environment is higher, universities, research institutes, and business enterprises could consider prioritizing anxiety reduction through employee assistance programs (EAPs) [61]. Such programs could integrate confidential assessment and counseling with digital mindfulness training, thereby combining responsive and preventive mental health services [61,62]. Evidence supports voluntary, confidential EAP services [61] and digital mindfulness for reducing anxiety in a randomized workplace trial [62]. For other regions, these findings suggest that authorities and research organizations should consider the local research climate and researchers' psychological needs when designing support programs rather than directly reproducing Beijing-specific arrangements. In particular, the relative salience of research self-efficacy and anxiety might differ depending on how researchers perceive the local tolerance for innovation-related failure. Nevertheless, these policy suggestions are provisional and should be systematically evaluated before broader implementation.

4.3 Limitations and Future Directions

Several limitations should be noted. First, the cross-sectional design cannot establish temporal order or causality, so the observed mediation patterns should not be interpreted as causal mechanisms. If the longitudinal data of scientific and technological researchers are available, future research could profitably use a three-wave design, assessing perceived innovation environment and perceived fault-tolerant environment at Time 1, research self-efficacy and anxiety at Time 2, and research resilience at Time 3. This temporal separation would permit examination of the sequence of relationships. Second, participants were scientific and technological researchers working in Beijing. Beijing is an appropriate research setting because it has a high concentration of research institutions and scientific and technological innovation activities, but the generalizability of the findings requires examination. Although the sample included researchers from different organizational settings, including research institutes, enterprises, and higher education institutions, doctoral-degree holders represented a relatively small proportion of participants. Therefore, further research is needed to examine whether the observed associations can be replicated among research populations with different educational backgrounds and career stages, particularly those with a higher proportion of doctoral-level researchers. Accordingly, the broader implications proposed above should be understood as potentially transferable principles rather than established cross-regional effects or policy prescriptions. Future studies could replicate this research in other scientific and technological innovation contexts. Third, all focal variables were measured using self-reports, which may be influenced by recall bias and subjective judgment. If feasible, future research could benefit from incorporating multisource data, such as peer or supervisor assessments of research resilience, alongside researchers' self-reports.

5 Conclusions

Mental health challenges among scientific and technological researchers and increasing demands for innovation underscore the importance of environmental and individual antecedents of research resilience, which may protect mental health and sustain innovation. Drawing on conservation of resources theory, social cognitive theory, and cognitive appraisal theory, the study examined perceived innovation environment in relation to research resilience through research self-efficacy and anxiety, with perceived fault-tolerant environment as a boundary condition among 310 scientific and technological researchers. The primary findings are summarized as follows. First, perceived innovation environment was positively associated with research resilience. Second, a more favorable perceived innovation environment was associated with higher research self-efficacy and lower anxiety; both were associated with greater research resilience. Third, perceived fault-tolerant environment moderated both associations. Research self-efficacy was more strongly associated with research resilience at lower levels of perceived fault-tolerant environment, whereas anxiety had a stronger negative association with research resilience at higher levels of perceived fault-tolerant environment. Mediation was evident through research self-efficacy at lower levels of perceived fault-tolerant environment and through anxiety at higher levels of perceived fault-tolerant environment.

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