



OPEN Configurational impact of motivational factors on postdoctoral job satisfaction

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Postdoctoral researchers play a critical role in advancing global science, yet widespread job dissatisfaction threatens both their retention and research productivity. Although prior studies have identified discrete factors affecting postdoctoral job satisfaction, the complex, configurational relationships among them remain poorly understood. To bridge this gap, our study draws on Herzberg's Two-Factor Theory and employs fuzzy-set Qualitative Comparative Analysis (fsQCA) to explore how different configurations of key motivational factors jointly shape postdoctoral job satisfaction. Analyzing data from the 2023 *Nature* Global Postdoctoral Survey, we identified eight distinct configurational pathways—five associated with high satisfaction and three with low. These findings provide actionable evidence for institutions to tailor support strategies that better serve postdoctoral needs.

Keywords Postdoctoral researchers, Motivational factors, Job satisfaction, fsQCA

Postdoctoral researchers (PDRs), commonly referred to as “postdocs,” are individuals with extensive education, specialized skills, and significant productivity¹. They have played a pivotal role in advancing research, innovation, arts, culture, science, and policymaking worldwide^{2–4}. At the individual level, research has shown that engaging in postdoctoral positions could not only enhance the quantity of scientific contributions later in one's academic journey but also facilitate a stronger integration into global academic networks^{5,6}. In this context, the number of PDRs has grown substantially across various countries. Indeed, according to the National Science Foundation, the number of PDRs in science and engineering at U.S. universities rose by 4.9% in a single year, from 62,750 in 2022 to 65,850 in 2023 (National Center for Science and Engineering Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering).

Nevertheless, this rapid growth has coincided with a deepening career crisis within the postdoctoral workforce. According to the first global follow-up survey conducted by *Nature* in 2020, involving 7,670 PDRs across 93 countries, nearly 40% of participants planned to leave the scientific research community after one year of work⁷. The study highlighted that the global postdoctoral community is facing one of the most severe career crises in recent history, with declining job satisfaction identified as the primary driver of this trend. A more recent survey conducted by the US National Postdoctoral Association⁸ further confirmed that widespread dissatisfaction persists among US PDRs. Such an environment of low job satisfaction not only reduces scientific research output but also leads many PDRs to reconsider their career paths⁹, exacerbating high attrition rates^{10,11}. In the long run, this trend will inevitably impede national academic advancement and undermine the efficiency of scientific and technological innovation.

It is therefore essential to investigate the mechanisms that enhance postdoctoral job satisfaction to ensure the sustainable development of academia and support countries' sci-tech advancement. Existing research has identified multiple factors associated with postdoctoral job satisfaction, including the work itself, relationships with management and colleagues¹², income, independence in work¹³, peer support¹⁴, work-life balance¹⁵, institutional recognition¹⁶, and etc. While these findings have greatly advanced our understanding of the correlates of postdoctoral job satisfaction, most studies examined these factors in isolation or as net effects. Therefore, it is quite unclear which combinations of the previously identified factors better explain the obtained assessment outcome.

To address this gap, this study draws on Herzberg's Two-Factor Theory (1959) as a guiding framework to systematically identify the relevant factors and adopts a configurational approach using fuzzy-set Qualitative Comparative Analysis (fsQCA¹⁷) to explore how these factors combine to shape postdoctoral job satisfaction. In doing so, we aim to contribute to better explaining postdoctoral job satisfaction and offer empirical evidence to inform strategies for improving the postdoctoral experience and enhancing job fulfillment.

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Literature review and theoretical framework

Postdoctoral job satisfaction and its impact

There is currently no universal agreement among researchers on the definition of job satisfaction. One widely cited definition describes job satisfaction as “the degree to which people like their jobs” (18, p. 7). Scholars often conceptualize job satisfaction as a multidimensional construct, reflecting employees’ feelings toward various aspects of their work, including the work itself, payment, opportunities for promotion, and relationships with colleagues¹⁹. In recent years, this foundational concept from organizational behavior has been increasingly applied in educational research to examine postdoctoral job satisfaction. At its core, postdoctoral job satisfaction reflects how PDRs emotionally and cognitively evaluate their work experiences and professional roles²⁰.

Research on postdoctoral job satisfaction has been conducted over the years. As early as 1999, *Science* reported that PDRs were dissatisfied with work pressure and employment conditions²¹. More recent global postdoctoral surveys published by *Nature* found that approximately 60% of respondents were satisfied with their jobs in 2020, but this figure declined to 55% in 2023, indicating a downward trend in overall satisfaction²². Similarly, *Nature*’s 2021 Global Compensation and Satisfaction Survey revealed an average job satisfaction score of 2.43 out of 5—below the neutral midpoint—highlighting a general sense of dissatisfaction among PDRs²³. This growing dissatisfaction inevitably leads to negative consequences at the individual, institutional, and societal levels. Empirical studies have shown that PDRs with lower job satisfaction are more likely to experience mental health problems, particularly when dissatisfaction arises from poor work-family balance or unclear academic career prospects^{10,24}. Professionally, low job satisfaction among PDRs has been associated with reduced research productivity²⁵ and, in more severe cases, a heightened intention to leave academia (e.g. 26–28). This trend appears to be more pronounced among female PDRs, who tend to be more vulnerable to the negative impacts of dissatisfaction¹¹. At the societal level, these effects not only reduce future research outcomes at universities²⁵ but also result in a loss of personal investment and public resources allocated to postdoctoral training²⁹. Therefore, greater attention must be paid to improving postdoctoral job satisfaction.

Antecedents of postdoctoral job satisfaction

Postdoctoral job satisfaction is shaped by a range of complex and interrelated factors. Building on Herzberg’s two-factor theory, Hagedorn³⁰ categorized academic faculty job satisfaction into three broad domains: demographics, representing personal attributes, motivators and hygienes, referring to individual work experience; and environmental conditions, encompassing organizational and broader contextual influences.

Regarding demographic characteristics, studies have shown that factors such as gender, nationality, academic discipline, and the length of employment significantly influence postdoctoral job satisfaction. Female PDRs often report lower satisfaction due to more adverse working conditions and gender bias^{11,31}, while international PDRs tend to be less satisfied than their local counterparts³². Satisfaction also varies by academic disciplines, with PDRs in humanities and social sciences reporting lower levels than those in the hard sciences³². Additionally, extended periods in postdoctoral positions are associated with declining satisfaction, often reflecting concerns over job insecurity and limited career prospects^{33,34}.

When it comes to individual work-related factors, postdoctoral job satisfaction is influenced by both tangible factors, such as salary³⁵, and less tangible factors, such as opportunities for advancement and professional growth. Specifically, advancement opportunities are critical, as uncertainty about long-term academic prospects can lower PDRs’ job satisfaction³², while growth through skill development contributes positively to their satisfaction³⁶. A sense of responsibility, reflected in job autonomy, is another key driver, as PDRs who have control over their time and research focus reported higher levels of satisfaction^{24,37}. Similarly, PDRs who engage in work aligned with their personal interests are more likely to experience higher job satisfaction²⁰. A sense of achievement, derived from successfully meeting professional goals, can also enhance satisfaction³⁸. Finally, external recognition, particularly through journal publications, reinforces academic success and professional identity, thereby contributing to postdoctoral job satisfaction²⁵.

At the organizational and environmental level, postdoctoral job satisfaction is significantly influenced by institutional support, collegial relationships, and overall workplace climate. For instance, Scaffidi and Berman³⁹ found that PDRs report more positive experiences when they receive quality supervision, have opportunities for collaboration and networking, and work within a nurturing research environment. In addition, a positive collegial climate, characterized by supportive relationships with peers and colleagues, is powerfully associated with greater job satisfaction⁴⁰. Similarly, a generally positive working atmosphere has been identified as a key contributor to postdoctoral job satisfaction^{41,42}.

While the aforementioned research has identified various factors influencing postdoctoral job satisfaction, such relationships are often presented as symmetrical, linear, and unidirectional, with influencing factors treated as independent of one another. However, postdoctoral job satisfaction is likely shaped by complex combinations of multiple factors, which traditional variance-based methods may fail to fully capture⁴³. To address this, we employed fsQCA, a method designed to analyze complex combinations and interdependencies between various factors. By revealing asymmetric relationships, where the presence and absence of certain conditions lead to different outcomes, our study goes beyond prior studies, offering a novel explanation of postdoctoral job satisfaction.

Theoretical foundation and conceptual model

The Two-Factor Theory, developed by Herzberg and his colleagues^{44,45}, serves as a foundational framework for understanding job satisfaction. Recent studies have extended its application to academic settings, using it to define and categorize the factors that influence job satisfaction among PDRs⁴⁶. According to the theory, job satisfaction is shaped by two distinct sets of factors: motivators and hygiene factors. Herzberg emphasized that these two sets of factors are not opposites on a single continuum but operate independently. Motivators

relate to the content of the work and reflect employees' psychological needs—such as achievement, recognition, responsibility, meaningful work, opportunities for growth and advancement. Their presence increases satisfaction. In contrast, hygiene factors are tied to the work environment and reflect basic expectations—such as salary, job security, working conditions, company policies, interpersonal relations, and status. While their presence decreases dissatisfaction, they do not directly contribute to satisfaction^{44,47}.

Given that the aim of this study is to identify the factors that contribute to postdoctoral job satisfaction, we adopt Herzberg's classification and focus on the six core motivational dimensions: achievement, recognition, the work itself, responsibility, advancement, and growth. While other theories, such as Self-Determination Theory⁴⁸ and the Job Characteristics Model⁴⁹, also address intrinsic motivation, they focus more on the psychological mechanisms behind motivation. In contrast, Herzberg's framework provides a clear categorization of motivational factors that directly contribute to job satisfaction, making it more suitable for this study's focus. Building on this framework, we employed fsQCA to examine how different configurations of these key motivational factors jointly shape postdoctoral job satisfaction. It is important to note that the exploratory nature of fsQCA means this study seeks to identify different configurations of conditions rather than test linear hypotheses. Therefore, we do not propose traditional hypotheses but instead propose the core research question: *What configurations of motivators are associated with postdoctoral job satisfaction?* To guide this analysis, we present the following conceptual model (see Fig. 1).

Method

Ethics declarations

This study is based on the secondary analysis of publicly available data from the 2023 *Nature* Global Postdoctoral Survey, which was accessed from the Figshare repository on 7 May 2025. The dataset comprises fully anonymized and aggregated survey responses, and the authors had no access to any personally identifiable information at any stage of the analysis. All analyses were conducted in accordance with relevant ethical guidelines and regulations.

Sample

The data used in this study is derived from the *Nature* 2023 Postdocs Survey, which encompasses a wide range of information, including respondent profiles, salary and benefits, job satisfaction, and postdoctoral experiences, among other aspects. The global valid sample size comprises 3,838 respondents. Of these, 1,712 are European PDRs, representing 45% of the total sample. The remaining respondents are distributed across other regions, including North and Central America (38%), Asia (10%), Australasia (3%), Africa (2%), and South America (2%). In terms of disciplinary distribution, the majority of respondents are engaged in biomedical and clinical sciences (53%), followed by ecology and evolution (6%), chemistry (6%), healthcare (6%), agriculture and food (5%), engineering (5%), geology and environmental science (5%), physics (5%), and social sciences (5%). Regarding gender distribution, females constitute 51% of the sample, while males account for 47%. With regard to employment, 61% were working abroad, 48% had been PDRs for two years or less, and 4% were employed outside universities or research institutions. Overall, the survey sample is both extensive and representative, providing a robust foundation for analysis.

Variables

The survey instrument used a 7-point Likert scale, with response options ranging from 1 ("extremely dissatisfied") to 7 ("extremely satisfied"). The dependent variable, postdoctoral job satisfaction, was measured by the item: "How satisfied are you with your current postdoctoral work?" Guided by the Two-Factor Theory⁴⁴, which posited that the fulfillment of motivational factors can significantly enhance job satisfaction, this study selected independent variables from survey items reflecting such factors. These include advancement, the work itself, possibility of growth, responsibility, recognition, and achievement. Career advancement was assessed through the item "Career advancement opportunities." Work itself was measured by "My interest in the work," reflecting alignment between research tasks and intellectual motivation. Growth encompassed two dimensions: project-based development ("Opportunity to work on interesting projects") and formal skill acquisition ("Access to workplace-sponsored training and seminars"). Responsibility indicators included autonomy ("My

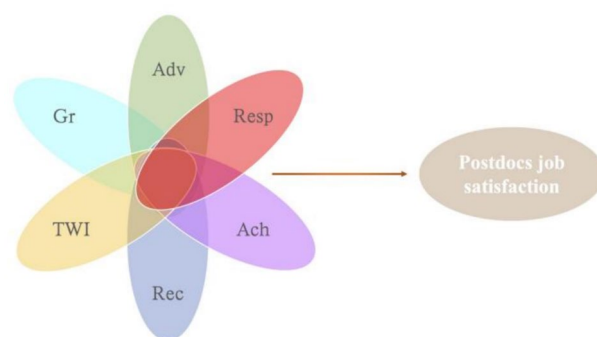


Fig. 1. The proposed configurational model; *Adv* Advancement, *Gr* Growth, *Resp* Responsibility, *TWI* The work itself, *Ach* Achievement, *Rec* Recognition.

degree of independence”) and agency (“Ability to influence decisions that affect you”). Recognition focused on performance acknowledgment through “Recognition for achievements,” while achievement captured intrinsic motivation via “Personal sense of accomplishment.”

Data analysis

This study adopted fsQCA, a method well-suited for examining complex configurations of constructs⁵⁰. Unlike traditional correlation-based quantitative methods, fsQCA focuses on how different combinations of antecedent conditions jointly influence an outcome, thereby emphasizing the synergistic effects among multiple influencing factors. A key feature of fsQCA is its ability to distinguish between core and peripheral conditions, where core conditions indicate a strong causal relationship with the outcome, while peripheral conditions exhibit a weaker causal link⁵¹. This configurational approach enables fsQCA to overcome certain limitations inherent in linear methods such as multiple regression analysis, particularly in capturing causal asymmetry. Given the multifaceted nature of factors influencing postdoctoral job satisfaction, as evidenced by prior literature, fsQCA was chosen in this study to identify specific combinations of necessary and sufficient conditions that contribute to PDRs’ overall job satisfaction.

Pre-processing

The fsQCA requires the calibration of raw data into a range of values between 0 and 1, where 1 signifies complete affiliation, 0 indicates complete disaffiliation, and values between 0 and 1 represent varying degrees of membership. This process involves defining three critical anchors for each variable: the full membership threshold, the full non-membership threshold, and the crossover point¹⁷. These anchors help determine whether a variable is included or excluded from a specific set⁵². In this study, the direct method¹⁷ was employed to address this calibration requirement. Researcher-specified qualitative anchors were used to identify the 5th percentile (minimum threshold), 95th percentile (maximum threshold), and 50th percentile (crossover point) values. Following the approach suggested by Ordanini et al.⁵³, three anchor points were established on a Likert 7-point scale: 6 for complete affiliation, 4 for the crossover point, and 2 for complete disaffiliation. Based on these calibrated fuzzy sets, necessary and sufficient condition analyses were then conducted. The results of these analyses are presented and discussed in the following section.

Results and findings

Necessity analysis

Prior to conducting the fsQCA configuration analysis, this study first examined whether each antecedent condition qualified as a necessary condition for the occurrence of the desired outcome. Consistency serves as an important indicator for assessing necessary conditions, where a value exceeding 0.9 signifies that the antecedent condition can be a necessary condition for the outcome variable¹⁷. Coverage, on the other hand, measures the extent to which the solution accounts for all causal relationships, with values ranging from 0 to 1. Higher coverage values indicate a more robust empirical explanation of the observed results⁵⁴.

As presented in Table 1, only The work itself (TWI) demonstrates consistency and coverage values of 0.934 (> 0.9) and 0.730 (> 0.5), respectively, meeting the thresholds for a necessary condition. This indicates that TWI qualifies as a necessary condition for high postdoctoral job satisfaction. To further validate this finding, we conducted an XY plot analysis. A necessary influence of X (TWI) on Y (postdoctoral job satisfaction) is confirmed when the consistency of $X \geq Y$ exceeds that of $X \leq Y$. The results show that the consistency of $X \geq Y$ (0.934) significantly surpasses that of $X \leq Y$ (0.730), solidifying TWI as an approximate necessary condition for high postdoctoral job satisfaction. In contrast, the consistency values for other antecedent conditions—Advancement (Adv), Growth (Gr), Responsibility (Resp), Achievement (Ach), and Recognition (Rec)—fall below the 0.9 threshold. This suggests that none of these conditions, whether at high or low levels, constitute

Condition variable	High job satisfaction		Low job satisfaction	
	Consistency	Coverage	Consistency	Coverage
Adv	0.614071	0.862695	0.347247	0.329014
~ Adv	0.522401	0.542681	0.855083	0.599082
Gr	0.880061	0.750224	0.653201	0.375545
~ Gr	0.267474	0.533497	0.565534	0.760757
TWI	0.933574	0.73018	0.703126	0.370896
~ TWI	0.195651	0.494236	0.488469	0.832196
Rec	0.802635	0.807783	0.519068	0.352321
~ Rec	0.356449	0.523569	0.716792	0.71008
Ach	0.835931	0.800834	0.545422	0.352405
~ Ach	0.324023	0.513828	0.691728	0.739802
Resp	0.858022	0.792593	0.580349	0.361559
~ Resp	0.308859	0.521827	0.667067	0.760104

Table 1. Necessity analysis of single condition variables. The symbol (~) indicates the absence of condition; Adv Advancement, Gr Growth, Resp Responsibility, TWI The work itself, Ach Achievement, Rec Recognition.

Antecedent conditions	High job satisfaction					Low job satisfaction		
	H1	H2	H3	H4	H5	L1	L2	L3
Adv	●	●	●		●	⊗	⊗	⊗
Gr	●	●	●	⊗	●		⊗	⊗
TWI	●	●	●	●		⊗		⊗
Rec	⊗			●	●	⊗	⊗	
Ach			●	●	●	⊗	⊗	⊗
Resp		●		●	●		⊗	⊗
Consistency	0.902	0.926	0.922	0.906	0.940	0.910	0.918	0.925
Raw coverage	0.192	0.542	0.533	0.173	0.487	0.374	0.367	0.312
Unique coverage	0.004	0.018	0.014	0.054	0.005	0.079	0.071	0.017
Solution consistency			0.896				0.900	
Solution coverage			0.627				0.462	

Table 2. Configurations for high and low postdoctoral job satisfaction. *Adv* Advancement, *Gr* Growth, *Resp* Responsibility, *TWI* The work itself, *Ach* Achievement, *Rec* Recognition; ● indicates the presence of core conditions, ● indicates the presence of peripheral conditions, ⊗ indicates the absence of core conditions, ⊗ indicates the absence of peripheral conditions, and “Blank” indicates “do not care”.

necessary conditions for high postdoctoral job satisfaction. Similarly, no single variable was identified as a necessary condition for low job satisfaction, indicating that no necessary conditions exist to produce the outcome of low postdoctoral job satisfaction.

Configuration construction

The sufficiency analysis of conditional configurations seeks to determine how different combinations of antecedent conditions contribute to the occurrence of the outcome⁵⁴. For this analysis, the consistency threshold cannot be lower than 0.9, the frequency threshold, which is sample-dependent, should be greater than 1 for large samples, and the PRI consistency threshold is recommended to be at least 0.75⁵². In this study, we set the consistency threshold at 0.9, the frequency threshold at 5, and the PRI consistency threshold at 0.75. Based on these parameters, the fsQCA analysis yields three types of solutions: complex, intermediate, and parsimonious. A condition is considered core if it is present in both the intermediate and parsimonious solutions, indicating a strong and stable causal relationship with the outcome. If a condition appears solely in the intermediate solution, it is deemed peripheral, playing a supplementary role. According to this, we identified five configurations linked to high job satisfaction and three configurations associated with low job satisfaction (see Table 2). All configurations exceeded the consistency threshold of 0.9, supporting that configurations H1, H2, H3, H4, and H5 are sufficient for high job satisfaction, while configurations L1, L2, and L3 are sufficient for low job satisfaction.

In detail, the results reveal two distinct groups of configurations that drive high job satisfaction among PDRs. (1) configuration H1 (*Adv* * *Gr* * *TWI* * ~*Rec*), H2 (*Adv* * *Gr* * *TWI* * *Resp*), H3 (*Adv* * *Gr* * *TWI* * *Ach*), and H5 (*Adv* * *Gr* * *Rec* * *Ach* * *Resp*) consistently identify advancement as the central driver of high job satisfaction among PDRs. However, advancement alone is insufficient and should be supplemented by other motivational factors. In fact, H2, which accounts for the largest proportion of high job satisfaction cases (54.2%), indicates that the combination of growth, responsibility, and meaningful work (the work itself) forms a strong foundation for high job satisfaction when paired with career advancement. Similarly, H3 explains a slightly smaller yet substantial share of satisfied PDRs, with a raw coverage of 53.3%, underscoring the reinforcing effect of achievement and growth opportunities alongside interesting work. In addition, H5 accounts for 48.7% of high job satisfaction cases and demonstrates that a comprehensive integration of advancement, growth, recognition, achievement, and responsibility creates a robust and well-rounded motivational framework. In contrast, H1 explains a smaller proportion of high job satisfaction cases (19.2%). This suggests that while career advancement

combined with growth and meaningful work can drive satisfaction even in the absence of recognition, this pathway is less observed among satisfied PDRs. The overall variations in raw coverage highlight that while career advancement is a critical driver, its combination with other motivational factors—particularly growth, responsibility, and meaningful work—produces a more consistent and widely observed pattern of high job satisfaction. (2) configuration H4 ($\sim\text{Gr} * \text{Rec} * \text{Resp} * \text{TWI} * \text{Ach}$) demonstrates that even in the absence of career growth opportunities, high job satisfaction can still be achieved through recognition and responsibility. This indicates a substitution effect, where recognition and responsibility compensate for the lack of career advancement, thereby driving satisfaction.

Furthermore, the analysis identifies two groups of configurations that contribute to low job satisfaction among PDRs. (1) configuration L1 ($\sim\text{TWI} * \sim\text{Rec} * \sim\text{Adv} * \sim\text{Ach}$) highlights that the absence of meaningful work (the work itself) and recognition are primary drivers of low job satisfaction. The lack of advancement and achievement as peripheral conditions exacerbates this effect, further diminishing postdoctoral job satisfaction levels. (2) configurations L2 ($\sim\text{Gr} * \sim\text{Ach} * \sim\text{Adv} * \sim\text{Rec} * \sim\text{Resp}$) and L3 ($\sim\text{Gr} * \sim\text{Ach} * \sim\text{Adv} * \sim\text{TWI} * \sim\text{Resp}$) reveal that the absence of personal accomplishment and professional growth significantly undermines job satisfaction. When combined with the lack of career development (advancement), meaningful work (the work itself), and responsibility, these deficiencies result in a significant loss of motivation, as evidenced in the low job satisfaction cases represented by L3.

Discussion

This study employed fsQCA to investigate how configurations of motivational factors, including advancement, growth, the work itself, responsibility, achievement, and recognition, contribute to postdoctoral job satisfaction. Although previous studies have identified these key determinants, they have generally failed to uncover the asymmetric relationships among them. Our fsQCA results demonstrate that postdoctoral job satisfaction stems not from single factors but from distinct, asymmetric combinations of various motivators. These findings provide institutions with clear, strategic directions for enhancing postdoctoral satisfaction. The key findings from the analysis are presented below.

Core drivers of high satisfaction

In the configurational paths for a high level of postdoctoral job satisfaction, advancement constantly emerged as a core condition in four of the five configurations (H1, H2, H3, H5). This suggests that access to career development and promotion opportunities plays a crucial role in shaping postdoctoral job satisfaction. This pattern is supported by empirical studies grounded in Self-Determination Theory, which show that when an individual's need for competence is fulfilled, their overall job satisfaction is likely to increase^{55,56}. In academic contexts, Bozeman and Gaughan⁴⁰ also found that access to promotion and tenure opportunities significantly increases satisfaction among university faculty.

Besides advancement as a core condition, other factors such as growth, responsibility, and achievement were identified as peripheral conditions contributing to postdoctoral job satisfaction. This finding confirms that postdoctoral job satisfaction does not result from a single factor but rather from configurations of multiple motivators. While advancement is crucial, it is insufficient by itself to ensure high job satisfaction; its impact is maximized when combined with additional reinforcing factors. For instance, the most frequently observed configurational pathway detected for postdoctoral job satisfaction is H2 ($\text{Adv} * \text{Gr} * \text{TWI} * \text{Resp}$), which suggests that PDRs who not only have access to career development and growth opportunities, but also show strong interest in their work and possess autonomy and control over their tasks, are more likely to report high satisfaction. This result echoes the findings of Marshall⁵⁷, who argued that the interplay between intrinsic motivators can create a positive feedback loop, where factors mutually reinforce one another, thereby strengthening job satisfaction among university research administrators.

Compensatory motivators when growth is limited

Also in the configurations for high job satisfaction, H4 ($\sim\text{Gr} * \text{Rec} * \text{Resp} * \text{TWI} * \text{Ach}$) with the presence of recognition and responsibility as core conditions in the absence of growth opportunities, indicates that when growth opportunities are lacking, job autonomy and sense of achievement serve as core compensatory conditions for maintaining high levels of job satisfaction among PDRs. This finding further underscores the importance of autonomy and recognition as key drivers of job satisfaction. Prior research has similarly highlighted the significance of social recognition, academic freedom, and participative decision-making in shaping satisfaction within academic settings^{58,59}.

Furthermore, achievement and the work itself serve as the peripheral conditions, suggesting that the nature of the work and professional accomplishments, when combined with the core conditions of recognition and responsibility, can help compensate for the lack of career development prospects, contributing to sustained satisfaction. This observation partially aligns with Chen's⁴⁶ findings, which highlight the importance of job attractiveness and job fulfillment, as well as the establishment of teacher grievance mechanisms and the reward system, in enhancing academic employees' job satisfaction.

Critical deficits undermine job satisfaction

Regarding the results for low job satisfaction, configuration L1 ($\sim\text{TWI} * \sim\text{Rec} * \sim\text{Adv} * \sim\text{Ach}$) suggests that PDRs experience a lower level of job satisfaction when they have little interest in their work, lack recognition, have limited growth opportunities, and feel a lack of achievement. In this configuration, both the work itself and recognition are identified as core conditions contributing to low postdoctoral job satisfaction. When PDRs engage in work that does not align with their interests or is not undertaken for skills development, they are more

likely to experience lower job satisfaction⁶⁰. Additionally, a lack of recognition for their achievements can lead PDRs to consider leaving academia, underscoring the importance of recognition in sustaining job satisfaction³⁷.

In configuration L2 (~Gr * ~Ach * ~Adv * ~Rec * ~Resp), the absence of growth and achievement as core conditions in the configuration is sufficient for low job satisfaction. Given the explicitly developmental nature of the postdoctoral position, PDRs typically have high growth need strength⁶⁰. Without sufficient opportunities for professional growth, they are likely to feel stagnant in their careers, leading to low satisfaction with the postdoctoral experience. Furthermore, the absence of a sense of achievement, namely, the inability to obtain grants and publish high-impact research, is also a main source of low satisfaction for PDRs¹⁰. In configuration L3 (~growth * ~achievement * ~advancement * ~the work itself * ~responsibility), growth and achievement again emerge as core conditions, while the absence of advancement, the work itself, and responsibility as peripheral conditions further exacerbate this situation. This suggests that, to effectively improve job satisfaction, institutions must not only meet PDRs' core needs for growth and achievement, but also strengthen career advancement opportunities, ensure meaningful and engaging work, and promote autonomy and responsibility in their roles.

Conclusion and implications

Drawing on Herzberg's Two-Factor Theory, this study employed fuzzy-set Qualitative Comparative Analysis (fsQCA) to explore how postdoctoral job satisfaction is shaped by the alternative configurations of six motivational factors: achievement, recognition, the work itself, responsibility, advancement, and growth. The results identified five configurations associated with high postdoctoral job satisfaction and three configurations linked to low satisfaction. Career advancement emerges as a core driver of high satisfaction, with its impact amplified when combined with other motivators such as growth opportunities, meaningful work, and responsibility. Second, recognition and responsibility function as compensatory core motivators that can sustain high satisfaction levels even when growth opportunities are constrained. Third, a lack of meaningful work and recognition constitutes a central pathway toward low satisfaction. Finally, the simultaneous absence of necessary conditions, growth, and achievement, together with the absence of peripheral factors such as advancement, meaningful work, and responsibility, further contributes to low satisfaction among PDRs.

These findings yielded a number of clear implications for enhancing postdoctoral job satisfaction. First and foremost, institutions should prioritize the development of transparent and structured career advancement pathways for PDRs, including clear criteria for promotion, transition-to-faculty tracks, and access to mentoring or networking opportunities. For PDRs on a defined advancement trajectory, institutions are encouraged to establish integrated career development programs that explicitly link promotion prospects with opportunities for professional growth, intellectually engaging work, and autonomy, thereby amplifying motivational outcomes. In contexts where growth opportunities are limited, creating an empowering work environment by granting PDRs greater intellectual autonomy and by providing regular recognition can serve as an effective compensatory mechanism to sustain their satisfaction. To prevent motivational decline, institutions should also ensure that postdoctoral roles are intellectually engaging and aligned with researchers' expertise, interests, and long-term goals. Recognition should extend beyond formal achievements like publications and grants to include ongoing efforts, such as collaboration, problem-solving, and mentoring junior colleagues. Finally, attention should be paid to the combined absence of core motivators (i.e., opportunities for growth and a sense of achievement) and supporting conditions (i.e., career advancement prospects, meaningful work, and autonomy). When several of these elements are lacking at once, it may indicate deeper organizational issues. Early identification of such patterns, followed by targeted interventions, is essential for maintaining engagement, motivation, and long-term satisfaction among PDRs.

Like many empirical studies, this research has its limitations. First, the data were based on self-reported questionnaires, which could potentially be influenced by social desirability bias, thereby affecting the accuracy of the findings. To enhance validity, future research could adopt a mixed-methods approach, such as combining self-reports with behavioral observations. Additionally, while this study identified key motivational drivers of postdoctoral job satisfaction based on the two-factor theory, the possibility of the interplay between other influencing factors and alternative configuration paths remains unexplored and needs to be analyzed in future research. Furthermore, future research could adopt longitudinal designs to examine the dynamic evolution of configurational pathways over time. In particular, applying time-series QCA to panel data would offer a promising approach for capturing how pathways to postdoctoral job satisfaction vary across different stages of the academic career.

Data availability

The datasets analyzed for this study can be found in the figshare repository: https://figshare.com/articles/dataset/Nature_Post-Doctoral_Survey_2023/24236875.

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Author contributions

XB conceptualized the study, analyzed the data, and drafted & revised the manuscript. XW discussed preliminary results with XB and provided feedback on the first and final draft of the manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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