

# HOW DOES TMT HETEROGENEITY SHAPE CORPORATE INNOVATION? THE CONDITIONAL EFFECT OF UNCERTAINTY RISK PERCEPTION

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**Abstract:** Drawing on upper echelons theory and behavioral decision theory, this study examines how top management team (TMT) characteristics shape corporate innovation through firms' perceived uncertainty risk. Using a panel of Chinese A-share listed firms from 2013 to 2023, we find that perceived uncertainty risk significantly suppresses both innovation input and innovation output, suggesting that firms become less willing to commit resources to innovation when they perceive a higher level of external uncertainty. We further document substantial heterogeneity across TMT characteristics. Executives with higher educational attainment and R&D-related experience are associated with greater R&D investment and higher patent output, whereas older executive teams and those with stronger finance backgrounds tend to exhibit lower levels of innovation activity. Mediation analyses further reveal a partial mediating effect of perceived uncertainty risk in the relationship between selected TMT attributes and corporate innovation. Specifically, executive gender composition, educational attainment, and R&D experience promote innovation partly by reducing firms' perceived exposure to external uncertainty, thereby strengthening innovation incentives and improving patent outcomes. By contrast, the effects of executive age, overseas experience, and financial background do not operate through this uncertainty-perception channel. This study further extends upper echelons theory by identifying perceived uncertainty risk as a cognitive mechanism through which TMT characteristics influence innovation decisions. The findings offer practical implications for optimizing executive team composition, strengthening innovation resilience, and improving firms' strategic responses to uncertain external environments.

**Keywords:** Uncertainty perception; Top management team (TMT) characteristics; Corporate innovation; Upper echelons theory; Mediating effect

## 1 INTRODUCTION

Innovation is a fundamental source of firm competitiveness and a key driver of long-term economic growth. In recent years, however, firms have operated in an increasingly uncertain environment. Geopolitical tensions, trade frictions, supply-chain disruptions, and frequent policy adjustments across major economies have intensified global economic uncertainty. In China, the transition from high-speed growth to high-quality development has further increased the complexity of the business environment. Growth moderation, structural adjustment, and the gradual fading of earlier stimulus policies have jointly reshaped firms' operating conditions. These changes have made innovation decisions more difficult, as firms must allocate long-term, risky, and often irreversible innovation resources under heightened external uncertainty.

The effect of uncertainty on corporate innovation remains theoretically and empirically ambiguous. On the one hand, uncertainty may discourage innovation by increasing precautionary motives, weakening managerial confidence, and delaying irreversible investment. Since innovation projects are typically characterized by long investment horizons, high adjustment costs, and uncertain returns, firms facing greater uncertainty may reduce R&D expenditure or postpone innovation activities. On the other hand, uncertainty may also stimulate innovation by strengthening firms' incentives to search for new technologies, business models, and competitive advantages. Under external pressure, innovation may become a strategic response through which firms build flexibility, enhance resilience, and capture future growth opportunities. This tension suggests that the relationship between uncertainty and innovation is unlikely to be uniform across firms.

Existing studies have examined the relationship between uncertainty and corporate innovation from multiple perspectives, including industry heterogeneity, ownership structure, political connections, financing constraints, firm size, and leverage. The literature has generated two competing views: uncertainty may inhibit innovation by increasing risk and reducing firms' willingness to invest, or it may promote innovation by creating growth options and strategic incentives for technological upgrading [1-5]. While these studies provide important insights into the firm-level conditions under which uncertainty affects innovation, they tend to focus on observable organizational and financial characteristics. Less attention has been paid to the top management team (TMT), the group of decision-makers who interpret uncertainty, evaluate risk, and ultimately determine whether innovation resources should be committed. This omission may partly explain why prior studies have reached inconsistent conclusions.

Upper echelons theory provides a useful framework for addressing this gap. The theory argues that corporate strategic choices are shaped by executives' cognitive bases, values, experiences, and preferences. Because executives cannot

fully observe or process all information in uncertain environments, their demographic and professional characteristics become important proxies for how they interpret external conditions and make strategic decisions. Characteristics such as age, gender composition, educational attainment, overseas experience, financial work experience, and R&D-related experience may systematically influence executives' risk perception, information processing, and innovation orientation. As a result, firms exposed to similar external uncertainty may adopt markedly different innovation strategies depending on the composition and background of their TMTs.

This study introduces firm-level perceived uncertainty risk as a key cognitive mechanism linking TMT characteristics to corporate innovation. Following Knight's distinction between measurable risk and unmeasurable uncertainty [6], this study treats perceived uncertainty risk as a managerial-cognitive construct. External uncertainty does not affect innovation decisions mechanically; instead, its influence depends on how executives interpret, evaluate, and respond to uncertain conditions. Compared with macro-level uncertainty indicators, firm-level perceived uncertainty risk is closer to the actual decision-making process inside organizations. It helps explain why firms facing similar external conditions may differ substantially in their innovation responses.

By incorporating perceived uncertainty risk into the relationship between TMT characteristics and corporate innovation, this study develops an integrated analytical framework that connects executive heterogeneity, managerial cognition, and innovation decisions. This framework advances the literature in two ways. First, it shifts the analysis of uncertainty and innovation from external shocks to firms' internal interpretation of those shocks. Rather than treating uncertainty as a homogeneous exogenous condition, the study highlights the role of managerial cognition in transforming external uncertainty into firm-specific innovation decisions. Second, it extends upper echelons theory by identifying perceived uncertainty risk as a transmission channel through which TMT characteristics affect innovation. This perspective clarifies not only whether executive characteristics matter for innovation, but also how they matter.

Using a panel of Chinese A-share listed firms from 2013 to 2023, this study empirically examines the direct effects of TMT characteristics on corporate innovation and the mediating role of perceived uncertainty risk. Corporate innovation is measured from both the input and output dimensions, allowing us to distinguish firms' willingness to invest in innovation from their realized innovation outcomes. The empirical analysis investigates whether different TMT characteristics promote or inhibit innovation, and whether these effects operate through changes in firms' perceived uncertainty risk.

The findings provide evidence that perceived uncertainty risk significantly constrains corporate innovation. Firms with higher perceived uncertainty risk exhibit lower innovation input and weaker innovation output. The results further show that TMT characteristics have heterogeneous effects on innovation. Executives with higher educational attainment and R&D-related experience are more conducive to innovation, whereas older executive teams and those with stronger finance backgrounds tend to be associated with lower innovation activity. Mechanism tests indicate that perceived uncertainty risk partially mediates the effects of selected TMT characteristics on innovation, suggesting that managerial cognition is an important pathway through which executive composition shapes innovation decisions.

This study contributes to the literature on corporate innovation under uncertainty by revealing the managerial-cognitive mechanism behind firms' heterogeneous innovation responses. It also enriches upper echelons theory by demonstrating that TMT characteristics influence innovation not only through resource allocation preferences or strategic orientation, but also through the way executives perceive and interpret external uncertainty. The findings have practical implications for firms seeking to optimize executive team composition, strengthen innovation resilience, and improve strategic decision-making under uncertainty. They also offer policy implications for improving expectation management and designing innovation policies that account for firms' heterogeneous perceptions of external risks.

## 2 THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

### 2.1 Firm Uncertainty Risk Perception and Innovation

Prior studies have not reached a consensus on how economic and policy uncertainty affects corporate innovation. One line of research emphasizes the constraining effect of uncertainty. Drawing on theories of financing costs and financial frictions [7,8], the real-options logic of irreversible investment [9-11], and managerial risk aversion [12], these studies argue that uncertainty discourages innovation by raising external financing costs, increasing the value of waiting, and strengthening managers' tendency to avoid risky long-term projects. Because innovation investment is typically characterized by high sunk costs, long payback periods, and uncertain outcomes, heightened uncertainty may induce firms to reduce R&D expenditure or postpone innovation activities. A competing view suggests that uncertainty may instead stimulate innovation. From a growth-options perspective [13], uncertainty can increase the value of future opportunities. If the expected future benefits of innovation outweigh the returns from delaying investment, firms may respond to uncertainty by increasing investment in core technologies and accelerating strategic transformation [4,5,14].

A major source of these mixed findings lies in the way uncertainty has been measured. Much of the existing literature relies on macro-level uncertainty indicators, such as economic policy uncertainty indices [15], or on exogenous event shocks [16,17]. Although these measures are useful for capturing changes in the external environment, they implicitly assume that firms perceive and respond to macroeconomic uncertainty in a similar manner. Such an assumption may overlook substantial heterogeneity in firm-level risk perception and managerial interpretation [18].

Recent studies have therefore begun to measure uncertainty perception from a micro-firm perspective. Some studies use entrepreneur confidence indices or survey-based measures to capture expectations and perceived risks [19-21].

However, these measures often remain relatively aggregate in nature and may not fully reflect firm-specific perceptions. Another stream of research employs textual analysis of listed firms' annual reports, especially the "Management Discussion and Analysis" or risk-related sections, to extract firm-level uncertainty and risk perception [18,22-24]. This approach is better suited to capturing heterogeneity in how firms interpret their external environment.

Nevertheless, existing micro-level studies of risk perception have focused mainly on investment and financing behavior, financial asset allocation, and cash-flow risk. Relatively limited attention has been paid to innovation decisions from the perspective of firm-level perceived uncertainty risk. Although Yang et al. construct a firm development expectation index and find that it suppresses innovation output [25], their study does not directly examine perceived uncertainty risk as a managerial-cognitive mechanism. Therefore, whether firm-level perceived uncertainty risk inhibits or promotes corporate innovation remains an open empirical question.

Accordingly, we propose the following competing hypotheses:

*H1a: Firm uncertainty risk perception exerts a significant negative effect on innovation.*

*H1b: Firm uncertainty risk perception exerts a significant positive effect on innovation.*

## 2.2 Top Management Team Characteristics and Corporate Innovation

Another explanation for the mixed evidence on uncertainty and innovation lies in corporate heterogeneity. Prior studies show that the effect of uncertainty varies across firms with different financial, governance, and organizational characteristics. For example, the negative effect of economic uncertainty is more pronounced among firms with greater financing constraints, private ownership, political connections, higher innovation intensity, or exposure to regulated industries [2,3,26,27]. By contrast, the positive effect of uncertainty tends to be weaker in protected industries, highly diversified firms, firms with higher R&D efficiency, larger firms, and firms with higher leverage [4], but stronger in policy-sensitive industries, sectors with greater innovation difficulty, firms with lower financing constraints, firms with lower cash-flow levels, and firms receiving government subsidies [1,5,28]. These studies provide important evidence that firm heterogeneity matters. However, they primarily focus on industry, financial, or organizational characteristics, while paying insufficient attention to the top management team (TMT), the group that directly interprets environmental changes and makes innovation-related decisions.

Upper echelons theory provides a theoretical foundation for understanding how TMT characteristics influence corporate innovation. According to Hambrick and Mason [29], corporate strategic choices reflect the cognitive bases, values, experiences, and preferences of top executives. Under bounded rationality, executives cannot process all environmental information objectively and comprehensively. Instead, they interpret external conditions through their own demographic attributes, professional backgrounds, and cognitive frames. As a result, observable executive characteristics are frequently used as proxies for managerial cognition and preferences in studies of corporate strategic behavior [30-33].

Different TMT characteristics may shape innovation decisions in distinct ways. Age is closely related to executives' risk preferences, career horizons, and openness to change. Younger executives are generally more receptive to new technologies and emerging opportunities, and they may exhibit stronger risk-taking tendencies, thereby supporting R&D investment and exploratory innovation. Older executives, in contrast, may place greater emphasis on operational stability and risk control, leading to more conservative innovation strategies [34-37]. Gender composition may also influence innovation decisions by affecting team diversity, risk-taking structure, and decision-making quality. Prior research suggests that female executive participation may promote R&D expenditure and improve innovation output quality [38,39].

Educational attainment represents another important source of managerial cognition. Executives with higher levels of education tend to possess stronger abilities in information acquisition, knowledge integration, and complex problem solving. These capabilities are particularly important for innovation, which requires long-term commitment, technological judgment, and the ability to evaluate uncertain future returns. Therefore, higher executive education may provide stronger cognitive support for sustained innovation activities [36,40]. Professional experience further shapes executives' strategic orientation and resource integration capacity. Overseas experience can broaden executives' international vision, expose them to advanced management practices and technological frontiers, and enhance their ability to identify innovation opportunities in uncertain environments. Such experience may increase both innovation input and innovation output [41-43]. In addition, diverse professional backgrounds and generalist managerial experience may promote innovation by expanding executives' social networks, improving strategic flexibility, and strengthening opportunity recognition capabilities [44,45].

Accordingly, TMT characteristics are likely to exert heterogeneous effects on corporate innovation. The following hypothesis is proposed:

*H2: Top management team characteristics have significant heterogeneous effects on corporate innovation.*

## 2.3 TMT Characteristics, Uncertainty Perception, and Corporate Innovation Decisions

Upper echelons theory and behavioral decision perspectives suggest that corporate strategic decisions are not mechanical responses to external conditions. Rather, they are shaped by how top executives perceive, interpret, and evaluate the external environment [30,46]. In complex and uncertain contexts, executives' subjective cognition and risk perception may explain cross-firm differences in decision-making more effectively than objective environmental

conditions alone [47,48]. As behavioral corporate finance research has advanced, increasing attention has been paid to managers' subjective risk perception as a key mechanism linking external uncertainty to firm behavior [49].

Under frequent macro-policy adjustments and intensified external volatility, economic uncertainty does not directly determine corporate innovation decisions. Instead, its influence depends on how firms, through their TMTs, interpret external information and assess potential threats and opportunities. Firm-level perceived uncertainty risk therefore represents a managerial-cognitive channel through which external uncertainty is translated into innovation-related decisions. When perceived uncertainty risk is high, executives may become more cautious, reduce long-term investment, and postpone innovation projects. When perceived uncertainty risk is lower, they may be more willing to maintain R&D expenditure, explore new technologies, and support continuous innovation.

TMT characteristics are likely to shape this cognitive channel. Prior research shows that executives' demographic attributes and functional backgrounds systematically affect information acquisition, risk interpretation, and situational judgment, thereby generating heterogeneity in perceived risk intensity [50]. When facing similar external uncertainty shocks, different TMTs may form different assessments of the same environment and consequently make different innovation choices. Educational background, professional experience, R&D experience, overseas exposure, gender composition, age structure, and financial experience may all influence executives' cognitive frames and risk preferences.

Specifically, executives with higher educational attainment or R&D-related experience may have stronger information-processing capabilities, deeper technological expertise, and greater tolerance for uncertain innovation returns. They are therefore more likely to interpret external uncertainty as a signal of technological change, market restructuring, or strategic opportunity, thereby mitigating excessive risk concerns and sustaining innovation investment. Similarly, greater gender diversity within the TMT may enrich team-level cognition and improve decision quality, reducing overly conservative interpretations of uncertainty. By contrast, older executive teams or those with stronger financial backgrounds may be more sensitive to downside risk, short-term performance pressure, and capital preservation, which can amplify perceived uncertainty risk and weaken their willingness to commit resources to long-term innovation projects. Therefore, TMT characteristics may affect corporate innovation through both direct and indirect channels. Directly, they shape executives' strategic preferences, resource allocation priorities, and technological orientation. Indirectly, they influence how external uncertainty is cognitively interpreted, thereby shaping firm-level perceived uncertainty risk. This perceived risk, in turn, affects whether firms expand, maintain, reduce, or postpone innovation activities. Perceived uncertainty risk may therefore serve as a mediating mechanism linking TMT characteristics to corporate innovation decisions.

Accordingly, we propose the following hypothesis:

*H3: Firm uncertainty risk perception mediates the relationship between top management team characteristics and corporate innovation.*

### 3 RESEARCH DESIGN

#### 3.1 Sample and Data Sources

The financial and governance data used in this study are obtained from the Wind and CSMAR databases. Firm-level perceived uncertainty risk is constructed through text mining of listed firms' annual reports. The initial sample consists of Chinese A-share listed firms from 2013 to 2023. We exclude financial firms, firms designated as special treatment firms (ST/PT), insolvent firms, firms with no R&D investment during the sample period, and observations with missing key variables. Given substantial differences in innovation intensity across industries, we further restrict the sample to sectors with relatively active R&D activities, including Manufacturing (Category C), Information Transmission, Software and Information Technology Services (Category I), Scientific Research and Technical Services (Category M), and Water Conservancy, Environmental and Public Facilities Management (Category N). After applying these screening criteria, the final sample contains 24,328 firm-year observations. To mitigate the influence of outliers, all continuous variables are winsorized at the 1st and 99th percentiles.

#### 3.2 Variable Definitions

##### 3.2.1 Corporate innovation decisions (RD)

Corporate innovation is measured from both input and output dimensions. Innovation input captures firms' resource commitment to R&D and innovation activities, while innovation output reflects the realized outcomes of such activities, mainly in the form of patent applications and granted patents. Following prior literature, we use four indicators to measure corporate innovation: R&D expenditure scaled by total assets (RD1), R&D expenditure scaled by operating revenue (RD2), the number of patent applications (Patent1), and the number of granted patents (Patent2).

##### 3.2.2 Firm-level perceived uncertainty risk

The key explanatory and mediating variable in this study is firm-level perceived uncertainty risk. Following Nie et al. [22], we construct this measure using textual information from corporate annual reports. Specifically, we employ Python-based text processing and the Jieba word-segmentation tool to identify firms' perceived exposure to uncertainty. The construction procedure is as follows. First, we compile two keyword dictionaries: one related to economic policy and the other related to uncertainty. Sentences containing keywords from both dictionaries are identified as statements associated with perceived economic policy uncertainty. We focus on the "Discussion and Analysis of Operating

Conditions” section of annual reports, as this section provides management’s assessment of the firm’s operating environment and future risks. The firm-level perceived uncertainty risk measure is then calculated as the proportion of uncertainty-related sentences to the total number of sentences in this section.

### 3.2.3 Top management team characteristics (TMT)

We characterize top management team (TMT) characteristics along six dimensions: the average age of the TMT (AGE), the proportion of male executives (GENDER), average educational attainment (EDU), the proportion of executives with overseas experience (OVERSEAS), the proportion of executives with financial backgrounds (FINANCE), and the proportion of executives with R&D backgrounds (RESEARCH). These variables capture differences in managerial cognition, experience, and professional structure, allowing us to examine how TMT heterogeneity shapes corporate innovation decisions under uncertain policy environments. Detailed variable definitions are reported in Table 1.

### 3.2.4 Control variables (Controls)

Following existing studies, we control for a set of firm-level characteristics that may affect corporate innovation, including firm size, leverage, return on assets, firm age, the shareholding ratio of the largest shareholder, state ownership, and managerial shareholding. In the empirical analysis, we also control for year fixed effects and industry fixed effects to account for time-specific shocks and industry-level heterogeneity.

**Table 1** Variable Definitions

Type	Symbol	Variable Name	Definition
Dependent Variable	RD1	R&D Intensity (Assets)	R&D investment scaled by total assets (%)
	RD2	R&D Intensity (Revenue)	R&D investment scaled by operating revenue (%)
	Patent1	Patent Applications	The natural logarithm of the sum of invention patents, utility models, and design patent applications plus 1
	Patent2	Patent Grants	The natural logarithm of the sum of invention patents, utility models, and design patent grants plus 1
Mediating Variable	EPU	Economic Policy Uncertainty Perception	Drawing on the methodology of Nie et al. [22], this variable is constructed based on annual reports. It captures the frequency of sentences containing economic policy uncertainty keywords within the "Management Discussion and Analysis" (MD&A) section. The value is calculated as the ratio of the number of identified uncertainty-related statements to the total number of statements in the MD&A section.
Explanatory Variables (TMT)	AGE	Average Age of TMT	Natural logarithm of the average age of top management team members
	GENDER	Male Ratio in TMT	A binary variable where male executives are coded as 1 and female executives as 0. The mean value is taken to represent the gender ratio of the team.
	EDU	Average Education Level of TMT	Based on the highest educational degree attained (High school or below=1, Associate degree=2, Bachelor's degree=3, Master's degree=4, Doctorate or above=5). The mean value is taken to represent the team's average education level.
	OVERSEAS	Overseas Background Ratio in TMT	A binary variable where executives with overseas experience (residence or study abroad) are coded as 1 and others as 0. The mean value is taken to represent the proportion of overseas background.
	FINANCE	Finance Background Ratio in TMT	A binary variable where executives with a financial industry background are coded as 1 and others as 0. The mean value is taken to represent the proportion of financial background.
	RESEARCH	R&D Background Ratio in TMT	A binary variable where executives with R&D or technical backgrounds are coded as 1 and others as 0. The mean value is taken to represent the proportion of R&D background.
Control Variables	Size	Firm Size	Natural logarithm of total assets
	Lev	Leverage	Total liabilities divided by total assets at year-end
	ROA	Return on Assets	Net profit divided by the average balance of total assets
	FirmAGE	Firm Age	Natural logarithm of [Current year - Establishment year + 1]
	Top1	Largest Shareholder Ownership	Shareholding percentage of the largest shareholder
	SOE	State-Owned Enterprise	Dummy variable equal to 1 if the firm is state-owned, and 0 otherwise

Type	Symbol	Variable Name	Definition
	Mshare	Management Shareholding Ratio	Total shareholding of management divided by total shares outstanding

### 3.3 Regression Models

To address the research questions, we specify a set of regression models:

$$RD_{i,t} = \alpha_0 + \alpha_1 EPU_{i,t} + \Phi \sum Controls_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

$$RD_{i,t} = \beta_0 + \beta_1 TMT_{i,t-1} + \Phi \sum Controls_{i,t-1} + \varepsilon_{i,t} \quad (2)$$

$$EPU_{i,t} = \beta_0 + \beta_1 TMT_{i,t-1} + \Phi \sum Controls_{i,t-1} + \varepsilon_{i,t} \quad (3)$$

$$RD_{i,t} = \alpha_0 + \alpha_1 EPU_{i,t} + \alpha_2 TMT_{i,t-1} + \Phi \sum Controls_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

Model (1) examines the effect of firm-level perceived uncertainty risk (EPU) on corporate innovation. Model (2) tests the direct relationship between TMT characteristics and corporate innovation. Building on these baseline specifications, Models (2)–(4) adopt a stepwise mediation framework to examine the transmission channel of “TMT characteristics → perceived uncertainty risk → corporate innovation,” thereby identifying the mediating effect of perceived uncertainty risk. In the models,  $Controls_{i,t-1}$  denotes a vector of lagged firm-level control variables, including firm size and other relevant characteristics, and  $\varepsilon_{i,t}$  denotes the regression error term.

## 4 EMPIRICAL RESULTS

### 4.1 Descriptive Statistics

Table 2 reports the descriptive statistics for the main variables. Regarding innovation input, the average R&D intensity measured by R&D expenditure scaled by operating revenue (RD2) is 5.99%, while R&D expenditure scaled by total assets (RD1) averages 2.82%. In terms of innovation output, firms file an average of 21.63 patent applications and receive 18.77 patent grants per year. After the logarithmic transformation,  $(\ln(x+1))$ , the mean values of patent applications (Patent1) and patent grants (Patent2) are 3.12 and 2.93, respectively. The mean value of the perceived economic policy uncertainty index (EPU) is 2.08%, with a standard deviation of 1.82 percentage points, indicating substantial cross-sectional variation in firms’ perceived uncertainty risk during the sample period.

**Table 2** Descriptive Statistics

Variable	N	Mean	SD	p25	p50	p75	Min	Max
RD1	24328	2.8165	2.2491	1.4097	2.3502	3.5783	0.0000	14.9818
RD2	24328	5.9928	6.0941	2.9100	4.2894	6.8328	0.0000	52.2288
Patent1	24328	3.1191	1.5461	2.1972	3.2189	4.1431	0.0000	7.2056
Patent2	24328	2.9328	1.4834	1.9459	2.9957	3.9120	0.0000	6.7593
EPU	24328	2.0808	1.8245	0.7900	1.7100	2.9600	0.0000	15.9400
AGE	24328	3.8516	0.0837	3.7992	3.8562	3.9095	3.4657	4.1400
GENDER	24328	0.8278	0.1679	0.7500	0.8462	1.0000	0.0000	1.0000
EDU	24328	3.2507	0.5392	3.0000	3.2500	3.6250	1.0000	5.0000
OVERSEAS	24328	0.0691	0.1334	0.0000	0.0000	0.1176	0.0000	1.0000
FINANCE	24328	0.1639	0.1713	0.0000	0.1429	0.2500	0.0000	1.0000
RESEARCH	24328	0.2760	0.2222	0.1111	0.2500	0.4221	0.0000	1.0000
Size	24328	21.9737	1.1488	21.1455	21.8136	22.6101	19.5628	26.4523
Lev	24328	0.3720	0.1884	0.2182	0.3581	0.5094	0.0347	0.9268
ROA	24328	0.0481	0.0673	0.0176	0.0469	0.0824	-0.3750	0.2552
FirmAGE	24328	2.9024	0.3192	2.7081	2.9444	3.1355	1.6094	3.6109
Top1	24328	0.3261	0.1407	0.2183	0.3037	0.4162	0.0802	0.7578
SOE	24328	0.2562	0.4366	0.0000	0.0000	1.0000	0.0000	1.0000
Mshare	24328	0.1828	0.2108	0.0004	0.0787	0.3477	0.0000	0.7017

### 4.2 Uncertainty Risk Perception and Corporate Innovation

Table 3 reports the OLS estimation results for Model (1), which examines the effect of firm-level perceived uncertainty risk on corporate innovation. After controlling for industry and year fixed effects, the coefficients of EPU are significantly negative across all four innovation indicators, including RD1, RD2, Patent1, and Patent2. These results

indicate that perceived uncertainty risk significantly reduces both innovation input and innovation output. Therefore, Hypothesis 1a is supported. For the control variables, firm size and managerial ownership are positively associated with corporate innovation, whereas leverage, firm age, ownership concentration, and the SOE indicator are negatively associated with innovation input. These results are broadly consistent with prior studies.

**Table 3** Perceived Uncertainty Risk and Corporate Innovation Decisions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	RD1	RD1	RD2	RD2	Patent1	Patent1	Patent2	Patent2
EPU	-0.064*** [0.007]	-0.039*** [0.007]	-0.136*** [0.018]	-0.061*** [0.016]	-0.046*** [0.005]	-0.050*** [0.005]	-0.049*** [0.005]	-0.047*** [0.004]
Size	0.009 [0.016]	-0.040*** [0.015]	0.301*** [0.040]	0.190*** [0.037]	0.630*** [0.010]	0.622*** [0.009]	0.620*** [0.009]	0.598*** [0.008]
Lev	-1.105*** [0.106]	-0.681*** [0.097]	-10.044*** [0.317]	-8.931*** [0.282]	0.589*** [0.061]	0.247*** [0.056]	0.560*** [0.058]	0.257*** [0.053]
ROA	1.335*** [0.334]	2.548*** [0.314]	-12.265*** [0.955]	-8.836*** [0.902]	2.118*** [0.152]	2.010*** [0.139]	1.223*** [0.143]	1.286*** [0.132]
FirmAGE	-0.163*** [0.046]	-0.567*** [0.049]	-1.149*** [0.128]	-2.240*** [0.139]	-0.231*** [0.028]	-0.230*** [0.028]	-0.037 [0.027]	-0.196*** [0.027]
Top1	-1.573*** [0.100]	-0.565*** [0.089]	-5.717*** [0.257]	-3.023*** [0.226]	-0.173*** [0.065]	-0.108* [0.061]	-0.042 [0.062]	-0.034 [0.058]
SOE	-0.359*** [0.033]	-0.229*** [0.030]	-0.744*** [0.079]	-0.422*** [0.071]	0.089*** [0.022]	0.090*** [0.021]	-0.003 [0.021]	0.060*** [0.020]
Mshare	0.618*** [0.076]	0.176** [0.070]	1.806*** [0.197]	0.614*** [0.179]	0.669*** [0.046]	0.488*** [0.042]	0.682*** [0.044]	0.480*** [0.041]
Constant	4.060*** [0.328]	3.545*** [0.316]	9.051*** [0.801]	7.426*** [0.775]	-10.380*** [0.211]	-11.219*** [0.198]	-10.854*** [0.199]	-10.873*** [0.191]
N	24,328	24,328	24,328	24,328	24,328	24,328	24,328	24,328
Adj.R <sup>2</sup>	0.046	0.216	0.123	0.286	0.236	0.362	0.241	0.361
Industry FE	NO	YES	NO	YES	NO	YES	NO	YES
Year FE	NO	YES	NO	YES	NO	YES	NO	YES

**Note:** Standard errors are reported in brackets. \*, \*\*, and \*\*\* indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively.

### 4.3 TMT Characteristics and Corporate Innovation

Table 4 reports the OLS estimation results for Model (2), which examines the relationship between TMT characteristics and corporate innovation. For each of the six TMT characteristics, we estimate four regressions corresponding to the four innovation indicators. Table 4 summarizes the key coefficients from these 24 regressions; for brevity, the results for the control variables are omitted from the main text. The results indicate that TMT characteristics have heterogeneous implications for corporate innovation. Executive age (AGE) is not significantly associated with innovation input, but it is significantly and negatively related to both patent applications and patent grants at the 1% level. This pattern suggests that older TMTs may not necessarily reduce current R&D expenditure, but their more conservative strategic orientation may weaken the conversion of innovation resources into patent output.

**Table 4** TMT Characteristics and Corporate Innovation Decisions

	(1)	(2)	(3)	(4)
Variable	RD1	RD2	Patent1	Patent2
AGE	0.285* [0.171]	-0.632 [0.442]	-0.712*** [0.104]	-0.725*** [0.100]
Adj.R <sup>2</sup>	0.215	0.286	0.36	0.359
GENDER	0.208*** [0.079]	-0.592*** [0.205]	0.252*** [0.049]	0.192*** [0.047]
Adj.R <sup>2</sup>	0.215	0.286	0.359	0.358
EDU	0.727***	2.154***	0.180***	0.151***

	(1)	(2)	(3)	(4)
Variable	RD1	RD2	Patent1	Patent2
	[0.025]	[0.070]	[0.016]	[0.015]
Adj.R <sup>2</sup>	0.242	0.318	0.362	0.361
OVERSEAS	1.702***	4.928***	0.001	-0.064
	[0.125]	[0.370]	[0.062]	[0.061]
Adj.R <sup>2</sup>	0.225	0.297	0.358	0.358
FINANCE	-0.862***	-1.920***	-0.380***	-0.327***
	[0.077]	[0.194]	[0.050]	[0.047]
Adj.R <sup>2</sup>	0.219	0.289	0.36	0.359
RESEARCH	1.781***	5.680***	0.390***	0.291***
	[0.069]	[0.188]	[0.038]	[0.036]
Adj.R <sup>2</sup>	0.242	0.324	0.361	0.36
Controls	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

**Note:** Standard errors are reported in brackets. \*, \*\*, and \*\*\* indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively.

The proportion of male executives (GENDER) has no significant effect on R&D input, but it is positively associated with patent output. This result suggests that gender composition may affect the efficiency with which innovation resources are transformed into patentable outcomes, although it does not significantly change the scale of R&D investment. Average educational attainment (EDU) is significantly and positively associated with both innovation input and innovation output at the 1% level. Executives with higher educational attainment may have stronger information-processing capabilities, broader knowledge structures, and greater capacity to evaluate uncertain technological opportunities. These advantages enable them to support sustained R&D investment and facilitate the generation of innovation outcomes.

Overseas experience (OVERSEAS) significantly increases R&D input but does not significantly affect patent output. One possible interpretation, consistent with the managerial optimism perspective discussed by Amore et al. [51], is that overseas experience may strengthen executives' confidence in innovation opportunities and encourage greater R&D commitment, but such investment does not necessarily translate into immediate patent output. Financial background (FINANCE) is significantly and negatively associated with all innovation indicators. Executives with financial experience may place greater emphasis on short-term financial stability and risk control. Such preferences can reduce their willingness to support long-term and uncertain innovation projects, thereby constraining both innovation input and innovation output.

R&D background (RESEARCH) has a significant positive effect on both innovation input and innovation output. Executives with technical or R&D-related experience are more likely to understand the strategic value, technological feasibility, and development cycle of innovation activities. This expertise helps firms increase R&D investment and improve the transformation of innovation efforts into patent output. The results support Hypothesis 2, indicating that TMT characteristics significantly shape corporate innovation decisions. These findings suggest that executive cognition, professional experience, and risk preferences play distinct roles in shaping innovation resource allocation and the realization of innovation outcomes.

#### 4.4 Joint Effects and Mediation Tests

Table 5 reports the results for Model (4), which jointly includes perceived uncertainty risk and TMT characteristics in the regressions for corporate innovation. The results show that, after controlling for TMT characteristics, the coefficient of EPU remains significantly negative across all specifications. This confirms that the inhibitory effect of perceived uncertainty risk on corporate innovation is robust.

The coefficients of the TMT variables generally retain their original signs and significance levels after EPU is included. This suggests that TMT characteristics continue to play an important role in shaping innovation decisions even after accounting for firm-level perceived uncertainty risk. Specifically, TMTs with higher educational attainment and stronger R&D backgrounds may sustain innovation activities through stronger professional cognition and technological expertise. By contrast, executives with financial backgrounds may be more concerned about short-term financial risk, which weakens innovation incentives. Younger TMTs and teams with a higher proportion of male executives appear to be more strongly associated with patent output, while executives with overseas experience are more likely to increase R&D investment under uncertain environments.

**Table 5** Perceived Uncertainty risk, TMT Characteristics, and Corporate Innovation**Panel A. Age, gender, and edu**

Variable	RD1	RD2	Patent1	Patent2
EPU	-0.039*** [0.007]	-0.061*** [0.016]	-0.050*** [0.005]	-0.047*** [0.004]
AGE	0.291* [0.171]	-0.622 [0.442]	-0.704*** [0.104]	-0.717*** [0.099]
Adj.R <sup>2</sup>	0.216	0.286	0.363	0.362
EPU	-0.038*** [0.007]	-0.062*** [0.016]	-0.050*** [0.005]	-0.047*** [0.004]
GENDER	0.198** [0.079]	-0.609*** [0.205]	0.239*** [0.048]	0.179*** [0.047]
Adj.R <sup>2</sup>	0.216	0.287	0.362	0.361
EPU	-0.034*** [0.007]	-0.048*** [0.016]	-0.049*** [0.005]	-0.046*** [0.004]
EDU	0.725*** [0.025]	2.151*** [0.070]	0.176*** [0.016]	0.148*** [0.015]
Adj.R <sup>2</sup>	0.243	0.319	0.365	0.364
Controls	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

**Panel B. Overseas, finance, and research**

Variable	RD1	RD2	Patent1	Patent2
EPU	-0.039*** [0.007]	-0.061*** [0.016]	-0.050*** [0.005]	-0.047*** [0.004]
OVERSEAS	1.702*** [0.125]	4.928*** [0.370]	0.001 [0.062]	-0.064 [0.060]
Adj.R <sup>2</sup>	0.226	0.298	0.362	0.361
EPU	-0.038*** [0.007]	-0.060*** [0.016]	-0.050*** [0.005]	-0.047*** [0.004]
FINANCE	-0.861*** [0.077]	-1.918*** [0.194]	-0.378*** [0.050]	-0.326*** [0.047]
Adj.R <sup>2</sup>	0.22	0.289	0.363	0.362
EPU	-0.035*** [0.007]	-0.048*** [0.016]	-0.050*** [0.005]	-0.046*** [0.004]
RESEARCH	1.775*** [0.069]	5.672*** [0.188]	0.382*** [0.038]	0.284*** [0.036]
Adj.R <sup>2</sup>	0.243	0.324	0.364	0.363
Controls	YES	YES	YES	YES
Constant	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

**Note:** Standard errors are reported in brackets. \*, \*\*, and \*\*\* indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively.

Tables 6 and 7 further examine whether perceived uncertainty risk mediates the relationship between TMT characteristics and corporate innovation. Table 6 applies the stepwise mediation approach, corresponding to Models (2)–(4), to test the transmission mechanism of perceived uncertainty risk. Due to space constraints, the table reports only the results for the three TMT characteristics that exhibit significant mediation effects: executive gender composition (GENDER), educational attainment (EDU), and R&D background (RESEARCH).

In the second step of the mediation test, these three TMT characteristics are significantly and negatively associated with perceived uncertainty risk. This indicates that TMTs with a higher proportion of male executives, higher average educational attainment, and stronger R&D experience tend to perceive lower risks arising from external policy fluctuations. In the third step, after EPU is included in the innovation regressions, its coefficient remains significantly negative. Meanwhile, the direct coefficients of GENDER, EDU, and RESEARCH decline slightly but remain significantly positive. These results satisfy the conditions for partial mediation, suggesting that perceived uncertainty risk constitutes a cognitive transmission channel through which selected TMT characteristics influence corporate innovation.

**Table 6** Mediation Effect Test: Results of the Three-step Approach

**Panel A. Innovation input measured by RD1**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	RD1	EPU	RD1	RD1	EPU	RD1	RD1	EPU	RD1
EPU			-0.038***			-0.034***			-0.035***
			[0.012]			[0.012]			[0.012]
GENDER	0.208	-0.272**	0.198						
	[0.163]	[0.128]	[0.163]						
EDU				0.727***	-0.072*	0.725***			
				[0.053]	[0.039]	[0.053]			
RESEARCH							1.781***	-0.169*	1.775***
							[0.147]	[0.091]	[0.147]
Adj.R2	0.215	0.064	0.216	0.242	0.063	0.243	0.242	0.063	0.243

**Panel B. Innovation input measured by RD2**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	RD2	EPU	RD2	RD2	EPU	RD2	RD2	EPU	RD2
EPU			-0.062**			-0.048*			-0.048*
			[0.028]			[0.027]			[0.027]
GENDER	-0.592	-0.272**	-0.609						
	[0.382]	[0.128]	[0.382]						
EDU				2.154***	-0.072*	2.151***			
				[0.132]	[0.039]	[0.132]			
RESEARCH							5.680***	-0.169*	5.672***
							[0.361]	[0.091]	[0.362]
Adj.R2	0.286	0.064	0.287	0.318	0.063	0.319	0.324	0.063	0.324

**Panel C. Patent applications (Patent1)**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent1	EPU	Patent1	Patent1	EPU	Patent1	Patent1	EPU	Patent1
EPU			-0.050***			-0.049***			-0.050***
			[0.008]			[0.008]			[0.008]
GENDER	0.252***	-0.272**	0.239***						
	[0.092]	[0.128]	[0.092]						
EDU				0.180***	-0.072*	0.176***			
				[0.032]	[0.039]	[0.031]			
RESEARCH							0.390***	-0.169*	0.382***
							[0.075]	[0.091]	[0.075]
Adj.R2	0.359	0.064	0.362	0.362	0.063	0.365	0.361	0.063	0.364

**Panel D. Patent grants (Patent2)**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent2	EPU	Patent2	Patent2	EPU	Patent2	Patent2	EPU	Patent2
EPU			-0.047***			-0.046***			-0.046***
			[0.007]			[0.007]			[0.007]
GENDER	0.192**	-0.272**	0.179**						
	[0.089]	[0.128]	[0.089]						

EDU				0.151***	-0.072*	0.148***			
				[0.031]	[0.039]	[0.031]			
RESEARCH							0.291***	-0.169*	0.284***
							[0.073]	[0.091]	[0.073]
Adj.R2	0.358	0.064	0.361	0.361	0.063	0.364	0.36	0.063	0.363

**Note:** Standard errors are reported in brackets. \*, \*\*, and \*\*\* indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively.

Specifically, executives with higher educational attainment and R&D expertise may have stronger capabilities in information interpretation and risk assessment. They are more likely to view external policy volatility as manageable rather than as a reason to reduce R&D investment, thereby alleviating the dampening effect of uncertainty on innovation. By contrast, for executive age (AGE), overseas experience (OVERSEAS), and financial background (FINANCE), neither the second-step coefficients nor the Sobel statistics reach conventional significance levels. This suggests that the effects of these characteristics on corporate innovation do not operate through the mediating channel of perceived uncertainty risk. Instead, their effects may arise mainly through direct channels, such as resource access, governance preferences, strategic orientation, or risk attitudes.

Table 7 further employs the Sobel test and Bootstrap resampling with 1,000 replications to verify the robustness of mediating effects. The indirect effects of GENDER, EDU, and RESEARCH yield Sobel Z-statistics exceeding the critical value, with corresponding p-values below 0.05. In addition, the 95% Bootstrap confidence intervals do not include zero, confirming that perceived uncertainty risk plays a significant partial mediating role between these three TMT characteristics and corporate innovation.

**Table 7** Mediation Effect Test: Sobel Test and Bootstrap Method

**Panel A. RD1**

TMT	Indirect effect	Sobel Z	Sobel p-value	95% CI lower	95% CI upper	Significant
AGE	-0.0063	-1.0882	0.2765	-0.0177	0.0051	0
GENDER	0.0104	3.1523	0.0016	0.0039	0.0169	1
EDU	0.0025	2.6908	0.0071	0.0007	0.0043	1
OVERSEAS	0	-0.0108	0.9914	-0.0066	0.0065	0
FINANCE	-0.0013	-0.4968	0.6193	-0.0065	0.0039	0
RESEARCH	0.0058	2.6284	0.0086	0.0015	0.0102	1

**Panel B. RD2**

TMT	Indirect effect	Sobel Z	Sobel p-value	95% CI lower	95% CI upper	Significant
AGE	-0.0099	-1.052	0.293	-0.0283	0.0085	0
GENDER	0.017	2.544	0.011	0.0039	0.0301	1
EDU	0.0035	2.044	0.041	0.0001	0.0068	1
OVERSEAS	-0.0001	-0.011	0.995	-0.0104	0.0103	0
FINANCE	-0.0021	-0.492	0.623	-0.0062	0.0061	0
RESEARCH	0.008	2.051	0.04	0.0002	0.0159	1

**Panel C. Patent1**

TMT	Indirect effect	Sobel Z	Sobel p-value	95% CI lower	95% CI upper	Significant
AGE	-0.0082	-1.059	0.289	-0.0226	0.0063	0
GENDER	0.0136	3.707	0	0.0064	0.0208	1
EDU	0.0036	3.169	0.002	0.0013	0.0058	1
OVERSEAS	0	-0.011	0.995	-0.0086	0.0085	0
FINANCE	-0.0017	-0.498	0.618	-0.0084	0.005	0
RESEARCH	0.0084	3.083	0.002	0.0029	0.0138	1

**Panel D. Patent2**

TMT	Indirect effect	Sobel Z	Sobel p-value	95% CI lower	95% CI upper	Significant
AGE	-0.0076	-1.056	0.291	-0.0212	0.0059	0
GENDER	0.0127	3.691	0	0.006	0.0195	1
EDU	0.0033	3.105	0.002	0.0012	0.0054	1
OVERSEAS	0	-0.011	0.995	-0.0081	0.008	0
FINANCE	-0.0016	-0.498	0.618	-0.0079	0.0048	0

TMT	Indirect effect	Sobel Z	Sobel p-value	95% CI lower	95% CI upper	Significant
RESEARCH	0.0079	3.029	0.002	0.0027	0.013	1

**Note:** Bootstrap confidence intervals are based on 1,000 replications. "Significant" equals 1 when the 95% bootstrap confidence interval excludes zero, and 0 otherwise.

These results indicate that TMT characteristics influence corporate innovation through heterogeneous mechanisms. Gender composition, educational attainment, and R&D background affect innovation partly through a cognitive reshaping channel: they reduce firms' perceived threats from the external environment and thereby facilitate innovation decisions. By contrast, age, overseas experience, and financial background primarily exert direct effects. These findings support Hypothesis 3 and clarify the boundary conditions under which perceived uncertainty risk serves as a mediator between TMT characteristics and corporate innovation.

#### 4.5 Endogeneity Test

To address potential endogeneity concerns arising from omitted variables and reverse causality, we employ a two-stage least squares (2SLS) instrumental-variable approach. Following related studies, we construct two instruments for firm-level perceived uncertainty risk: the one-period lag of perceived economic policy uncertainty (L.EPU) and the average EPU of peer firms in the same industry and region, excluding the focal firm itself (Peer\_EPU). The relevance and validity of the instruments are assessed using standard diagnostic tests.

Table 8 reports the 2SLS estimation results. The coefficients of EPU remain significantly negative across all specifications and are broadly consistent with the baseline estimates in both sign and magnitude. These results suggest that the negative association between perceived uncertainty risk and corporate innovation is unlikely to be driven solely by omitted-variable bias or reverse causality. Collectively, the instrumental-variable evidence provides further support for the robustness of our main findings.

**Table 8** Endogeneity Test using the Instrumental-variable Method

**Panel A. RD1 and RD2**

Variable	RD1			RD2		
	EPU	L.EPU	Peer_EPU	EPU	L.EPU	Peer_EPU
EPU	-0.032*** [0.007]	-0.050*** [0.011]	-0.393*** [0.050]	-0.042*** [0.016]	-0.043 [0.028]	-0.580*** [0.112]
AGE	-0.152 [0.170]	-0.144 [0.170]	-0.064 [0.177]	-1.617*** [0.430]	-1.604*** [0.431]	-1.499*** [0.437]
GENDER	0.055 [0.077]	0.057 [0.078]	-0.04 [0.083]	-1.025*** [0.199]	-1.012*** [0.200]	-1.163*** [0.206]
EDU	0.557*** [0.025]	0.556*** [0.025]	0.534*** [0.026]	1.586*** [0.066]	1.592*** [0.066]	1.550*** [0.067]
OVERSEAS	1.087*** [0.121]	1.093*** [0.121]	1.081*** [0.123]	2.938*** [0.345]	2.948*** [0.346]	2.887*** [0.340]
FINANCE	-0.695*** [0.078]	-0.691*** [0.079]	-0.687*** [0.082]	-1.372*** [0.192]	-1.376*** [0.193]	-1.351*** [0.194]
RESEARCH	1.339*** [0.069]	1.336*** [0.070]	1.294*** [0.072]	4.673*** [0.181]	4.676*** [0.181]	4.606*** [0.184]
Constant	2.998*** [0.654]	2.956*** [0.655]	2.790*** [0.681]	10.243*** [1.627]	10.156*** [1.630]	10.017*** [1.652]
Observations	24,328	24,216	24,323	24,328	24,216	24,323
Adj.R <sup>2</sup>	0.267	0.267	0.187	0.351	0.352	0.327
Controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

**Panel B. Patent1 and Patent2**

Variable	Patent1			Patent2		
	EPU	L.EPU	Peer_EPU	EPU	L.EPU	Peer_EPU
EPU	-0.048*** [0.005]	-0.073*** [0.008]	-0.200*** [0.035]	-0.045*** [0.004]	-0.077*** [0.007]	-0.202*** [0.034]
AGE	-0.890*** [0.105]	-0.882*** [0.105]	-0.849*** [0.108]	-0.860*** [0.101]	-0.852*** [0.101]	-0.818*** [0.104]
GENDER	0.236*** [0.049]	0.230*** [0.049]	0.193*** [0.051]	0.184*** [0.047]	0.172*** [0.047]	0.140*** [0.049]
EDU	0.161*** [0.017]	0.161*** [0.017]	0.151*** [0.017]	0.141*** [0.016]	0.140*** [0.016]	0.131*** [0.016]
OVERSEAS	-0.117* [0.064]	-0.122* [0.064]	-0.104 [0.065]	-0.162*** [0.062]	-0.166*** [0.062]	-0.153** [0.064]
FINANCE	-0.373*** [0.051]	-0.371*** [0.051]	-0.373*** [0.052]	-0.334*** [0.049]	-0.333*** [0.049]	-0.334*** [0.049]
RESEARCH	0.266*** [0.040]	0.265*** [0.040]	0.247*** [0.041]	0.189*** [0.038]	0.187*** [0.038]	0.169*** [0.039]
Constant	-8.600*** [0.418]	-8.645*** [0.418]	-8.710*** [0.426]	-8.278*** [0.399]	-8.309*** [0.400]	-8.393*** [0.409]
Observations	24,328	24,216	24,323	24,328	24,216	24,323
Adj.R <sup>2</sup>	0.371	0.37	0.341	0.369	0.367	0.334
Controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

**Note:** Standard errors are reported in brackets. \*, \*\*, and \*\*\* indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. L.EPU is the one-period lag of EPU; Peer\_EPU is the average EPU of other firms in the same industry and region.

## 5 CONCLUSIONS AND IMPLICATIONS

Drawing on upper echelons theory and behavioral decision perspectives, this study examines the relationships among firm-level perceived uncertainty risk, top management team (TMT) characteristics, and corporate innovation. Using a sample of Chinese A-share listed firms, we find that perceived uncertainty risk significantly constrains corporate innovation. Firms with stronger perceptions of external policy uncertainty reduce both innovation input and innovation output, indicating that heightened perceived risk weakens firms' willingness to undertake long-term and uncertain innovation activities.

The results further show that TMT characteristics have heterogeneous effects on corporate innovation. Higher executive educational attainment and stronger R&D backgrounds are positively associated with both innovation input and innovation output, suggesting that knowledge accumulation and technological expertise are important managerial resources for innovation. By contrast, financial backgrounds are negatively associated with all innovation indicators, implying that executives with stronger financial experience may place greater emphasis on short-term stability, risk control, and investment payoffs. Overseas experience mainly promotes innovation input but does not significantly improve patent output, while executive age has no significant effect on R&D investment but significantly reduces patent output. In addition, a higher proportion of male executives is associated with greater patent output. These findings suggest that different executive attributes affect distinct stages of the innovation process.

Mechanism tests show that perceived uncertainty risk plays a significant partial mediating role between selected TMT characteristics and corporate innovation. Specifically, executive gender composition, educational attainment, and R&D background affect innovation not only directly, but also indirectly by reducing firms' perceived exposure to external uncertainty. In contrast, the effects of executive age, overseas experience, and financial background do not operate through the perceived-uncertainty channel. These results indicate that corporate innovation decisions are jointly shaped by external environmental perceptions and internal managerial attributes. Perceived uncertainty risk serves as an important cognitive mechanism linking TMT characteristics to corporate innovation behavior.

This study contributes to the literature in two ways. First, it extends the study of uncertainty and corporate innovation by shifting attention from external uncertainty shocks to firms' subjective perceptions of uncertainty. This perspective helps explain why firms exposed to similar external conditions may make different innovation decisions. Second, it enriches upper echelons theory by identifying perceived uncertainty risk as a managerial-cognitive pathway through which TMT characteristics influence innovation. The findings provide evidence that executive characteristics matter not

only because they shape resource allocation preferences, but also because they influence how firms interpret and respond to uncertain external environments.

The findings also have practical implications. For firms, optimizing TMT structure is important for sustaining innovation under uncertainty. Improving executives' educational attainment and increasing the presence of managers with R&D expertise can strengthen firms' capabilities in information interpretation, risk assessment, and technological judgment, thereby helping firms maintain innovation investment under uncertain conditions. At the same time, firms should be aware that excessive emphasis on financial stability and short-term risk control may weaken innovation incentives. For policymakers, the results suggest that policy uncertainty affects innovation not only through objective external conditions, but also through firms' perceptions and expectations. Therefore, when formulating and adjusting economic policies, governments should strengthen policy transparency, improve communication mechanisms, and stabilize market expectations. A more predictable policy environment can reduce firms' perceived uncertainty risk, encourage long-term innovation investment, and support the broader goals of innovation-driven and high-quality development.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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