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Research on the effect of enterprise financial flexibility on sustainable innovation

Zezhong Hao, Xiuwu Zhang*, Jiangying Wei

HQU: Huaqiao University xiamen, Fujian, China

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ABSTRACT

The innovation and development of enterprises are influenced by both internal management and external economic policy uncertainty. This study examines methods for enterprises to ensure the development of sustainable innovation under economic policy uncertainty. Specifically, this study examines the effect of national economic policy uncertainty as a threshold variable on enterprise financial flexibility in a sustainable innovation model using the micro data of non-financial companies in China's A-share market from 2007 to 2019. Through an empirical analysis of the mechanism of the effect of enterprise financial flexibility on innovation, this paper discusses the possible "adaptive effect" of financial flexibility under policy uncertainty. Using a threshold effect model, this study examines the coefficient change of the negative effect of enterprise financing constraints on sustainable innovation caused by fluctuations in economic policy uncertainty and records the threshold value of the economic policy uncertainty index. The results show that a rise in policy uncertainty has a negative impact on enterprise innovation, and enterprises can actively adjust their flexible financial reserve to gain an adaptive effect under the influence of policy uncertainty. The results indicate a simultaneous threshold effect based on economic policy uncertainty in a model of enterprise financing constraints and sustainable innovation. Accordingly, the economic policy uncertainty index can be divided into a "reasonable area" and "warning area," to indicate the need for enterprises to take countermeasures to deal with the fluctuations caused by government economic policies appropriately.

Introduction

China's total economic output in 2019 was close to 100 trillion yuan, accounting for 30% of the world's economic growth. In the loose international environment of the past few years, China has achieved rapid economic growth by introducing external technology and investing heavily in the traditional means of production, like human resources and capital. The development path of Chinese enterprises has gradually changed from relying on OEM production to relying on technological innovation, in line with the global trend of economic development. China has made remarkable achievements in research and development (R&D) investment and innovation. Since 2013, R&D funds have ranked second worldwide, and these R&D investments have proved rewarding. In 2019, the number of patent applications increased to the highest in the world. However, from the perspective of patent structure, Chinese patents are mainly low-value patents, and overall innovation and R&D ability still need improvement. Among patents, general patents are 93.57% and 51.04%, important patents are 6.27% and 42.56%, and core patents are 0.16% and 6.4% for China and the United States, respectively.

Currently, there are several development directions and challenges in the world, including the sharing economy, digitization, sustainable development, carbon emission control, and COVID-19, all of which require enterprises to adapt through innovation. The sharing economy is a new socio-economic trend that affects sustainable economic development and energy efficiency (Dabbous & Tarhini, 2021). Government initiatives are an important prerequisite for the sustainable business model innovation of domestic enterprises (Molina-Castillo, Sinkovics, & Sinkovics, 2021). Digital development will promote innovation in enterprises (Tiago, Gil, Stemberger, & Borges-Tiago, 2021). Furthermore, scholars have shown that public policy innovation will be based on sustainable development (Zartha, Lopez, & Acosta, 2020). Government directed policy transformations regarding digitization and COVID-19 will inevitably affect EPU, which will, in turn, affect sustainable innovation in enterprises.

The sustainable innovation development of start-ups must rely on social support (Bergmann & Utikal, 2021). Moreover, public policies will influence enterprises to change their innovation development at the micro level. An enterprise's awareness of its environmental

* Corresponding author.
E-mail address: zxwxz717@hqu.edu.cn (X. Zhang).

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responsibility affects its innovation performance (Liu, Chen, Ren, & Jin, 2021). A careful examination of the essence of corporate environmental responsibility will reveal that it is closely related to the policy guidance of the government and the international community. This proves that the government's policy uncertainty is related to enterprise innovation in the short term and affects the sustainable innovation of enterprises in the long term.

Previous research on enterprise innovation has focused mainly on the micro mechanisms of innovation. Hall, Moncada-Paternò-Castello, Montresor, & Vezzani (2016) discuss the impact of financing constraints on enterprise innovation activities. According to the enterprise core competence theory, it can be concluded that the knowledge and special abilities accumulated by the enterprise itself are its assets. Enterprises also enhance their ability for open innovation through information and communication technology (Adamides & Karacapilidis, 2020). Open innovation has a heterogeneous impact on enterprise performance (Moretti & Biancardi, 2020). Enterprises can absorb relevant knowledge to the greatest extent by designing open innovation strategies (Giusti, Alberti, & Belfanti, 2020).

Therefore, to improve innovation in enterprises, we should study external environmental factors and delve into their internal environments. In the case of resource constraints, enterprises should fully utilize their internal resources, open external financing channels, release financing constraints, and perform high-quality circular development of internal and external linkages. However, research on the impact of financial flexibility on enterprise innovation efficiency remains in its infancy. To fill this gap, this study discusses whether an enterprise's financial flexibility reserve can effectively coordinate internal and external resources, alleviate financing constraints, and provide sufficient financial support to improve the innovation ability of enterprises. It further examines whether the financial flexibility of enterprise reserves can have an adaptive effect and reduce the negative impact of uncertainty on enterprise innovation. Finally, this study examines the threshold effect of EPU on enterprise financing constraints and the enterprise sustainable innovation model to provide a reasonable policy fluctuation range for the government.

We use the micro data of non-financial companies in China's A-share market from 2007 to 2019 to explore the impact of EPU on enterprise innovation. First, we measure the innovation of listed companies from the perspective of uncertainty and gradual innovation. Subsequently, we explore the mechanism of financial flexibility promoting innovation by releasing financing constraints and enrich the "Financial Flexibility Organization Theory." We further report that, in the face of the impact of EPU, enterprises' active reserve of financial flexibility can ensure the sustainability of innovation activities. Finally, by establishing a threshold effect model, we study the coefficient change of the negative effect of financing constraints on sustainable innovation caused by the fluctuation of EPU, record the threshold value of the EPU index, and divide China's EPU index into reasonable and warning areas. We provide countermeasures for enterprises to deal with the fluctuations caused by their government's economic policies.

Literature review and the research hypotheses

Economic policy uncertainty and enterprise innovation

Knight (1921) was the first to explain the concept of uncertainty. Economic and social uncertainty comes mainly from frequent changes in policies. Although the problem of policy uncertainty has a long history, there is still no unified and authoritative method for measuring it. The government cultivates advantageous industries and improves the country's competitive advantage by implementing innovation-driven policies, but changes in economic policies are difficult to predict accurately. Existing studies have mainly focused on the election or replacement of officials (Bhattacharya, Hsu, Tian, & Xu, 2017), policy or newspaper text analysis (Baker, Bloom, & Davis, 2016), and special events (Li & Mao, 2018) to characterize policy uncertainty. Therefore, this study uses a text analysis method to construct the EPU index (Baker et al., 2016).

Existing studies on the impact of policy uncertainty mainly focus on the macro-economy (Baker, Bloom, & Davis, 2012; Fernández-Villaverde, Guerrón-Quintana, Kuester, & Rubio-Ramírez, 2015) and its impact on micro-enterprise behavior (Nodari, 2014; Zhang & Wang, 2016). Méndez-Picazo, Galindo-Martín, and Castaño- Martínez (2021) studied the impact of socio-cultural and economic factors on social sustainable innovation. Seddighi and Mathew (2020) studied the relationship between a company's core competitiveness innovation and its regional location. Regional policymakers have an important impact on enterprise innovation. However, decisions taken by policymakers in public affairs also affect the innovative behavior of entrepreneurs. This study holds that the Chinese government's policymaking will affect enterprise innovation across the country, making EPU an important variable in studying Chinese enterprise innovation .

Previous studies based on option theory and financing premium theory, combined with empirical research, conclude that EPU will inhibit enterprise innovation. According to the financing premium and information asymmetry theories, the capital market is not perfect, and there is financial friction. Information asymmetry in the market makes the external capital cost higher than the internal capital cost of enterprises, thus creating financing premiums. Increasing policy uncertainty and financing premiums push enterprises to postpone innovation investments. It was found that with the rise in policy uncertainty, the risk of the stock market increases, and the cost of raising funds from the stock market also rises. This leads to the problem of insufficient funds, with the result that enterprises choose to reduce investment in innovation R&D.

Innovation includes several aspects. It will be the source of enterprise competitive advantage—either by improving the methods and technologies that can produce new products or services or by improving existing products or services (Taques, Lopez, Basso, & Areal, 2021). The generation, storage, and application of knowledge have a significant positive impact on enterprise innovation (Ode & Ayavoo, 2020). Therefore, an enterprise's innovation activities can be regarded as real options. The real option theory posits two different theories to analyze enterprise innovation: waiting option theory and growth option theory. Based on these two theories, different scholars have drawn different conclusions. The waiting option theory holds that enterprises' innovation investment is a silent and irreversible cost. In the face of increasing policy uncertainty, enterprise managers choose to delay innovation investment to obtain the value of the waiting option. Therefore, based on this theory, some scholars conclude that uncertainty inhibits enterprise innovation behavior. In the face of uncertainty, banks and investors tend to reduce loans and increase loan interest rates to avoid the losses caused by risks, thus increasing the cost of external financing. However, internal financing is insufficient to support innovative R&D, thus reducing corresponding innovative projects Durnev (2010). Enterprises tend to delay investments to reduce the economic losses caused by uncertainty (Li & Yang, 2015).

From the perspective of growth option theory, the choice of enterprise innovation is based on the overall strategic level. In the face of economic fluctuations caused by uncertainty, enterprises tend to maintain their core competitiveness through innovation and avoid market elimination. When macro-policy uncertainty increases, enterprises face a severe business environment. To protect their market positions, enterprises choose to increase their innovation investment Aghion (2005). Drawing on previous research results, based on financing premiums, information asymmetry, and waiting option theories, this study shows that policy uncertainty has a negative

impact on enterprise innovation. Therefore, the following assumption is proposed:

H1. : The rise of EPU will inhibit enterprise innovation.

Financial flexibility and enterprise innovation

Saunila (2020) summarized the literature on the innovation ability of small and medium-sized enterprises (SMEs). This literature is considerably significant for the study of innovation by SMEs. On this basis, this study examines the relevant literature and summarizes the important factors affecting innovation by SMEs.

Enterprise management pursues the golden rule, "cash is king"; especially when the financial crisis broke out, bank credit was tight, enterprise financing was difficult, and many enterprises went bankrupt because they could not obtain effective external funds in time. In China's imperfect capital market, enterprises face greater financing constraints. It is particularly important to reserve appropriate financial flexibility to deal with adverse shocks and grasp investment opportunities.

The earliest financial flexibility theory came from research on the tax management of enterprise capital structures, which holds that future risks and opportunities coexist, and an enterprise must retain a certain financing capacity (Modigliani & Miller, 1963). As a new research field of financial management, the definition of financial flexibility has not been unanimously settled. Early scholars defined financial flexibility mainly from the perspective of managing cash flow Heath (1978). Subsequently, they began to define it from the perspective of the acquisition mode of financial flexibility (Higgins, 1992; Gilson & Warner, 1997), expanded it to the capital structure of enterprises, and emphasized the "prevention" and "response" attributes of financial flexibility. However, recent studies have focused more on the "utilization" attribute of financial flexibility from the perspective of financing cost. Enterprises that reserve financial flexibility can avoid falling into financial difficulties in the face of adverse shocks and raise funds at a low cost to seize investment opportunities effected by risk (Gamba & Triantis, 2008).

Domestic scholars have formed two views on the definition of financial flexibility. One school emphasizes the "prevention" and "utilization" attributes of financial flexibility from the perspective of financing (Ge & Zhan, 2008; Ning & Liu, 2011). Another school defines it from a broader perspective, such as financial management and corporate strategy (Zhao & Han, 2004; Shi & OuYang, 2006). Drawing on previous studies, we define financial flexibility as the ability of enterprises to hold certain excess cash and residual liabilities in a dynamic business environment to maintain the flexibility of market competition strategies. The existing empirical research on financial flexibility mainly focuses on the following aspects: the research on financial flexibility and enterprise value (Ferreire & Vilela, 2004); the relationship between environmental uncertainty and financial flexibility (Cummins & Nyman, 2004); the nature of property rights and financial flexibility (Yang & Zhang, 2008). As financial flexibility can affect investment and financing behavior, can it affect enterprise innovation activities? Currently, Chinese scholars have tried to analyze enterprise innovation from experience and found that improving financial flexibility significantly improves the innovation performance of high-tech enterprises (Zheng & Lei, 2018). Financial flexibility can reduce enterprise financing costs and improve innovation efficiency (Fan & Chen, 2018).

Most existing research on financial flexibility and enterprise innovation is divorced from financing constraints. Analyzing financial flexibility alone can promote investment in enterprise innovation. The financing constraint caused by incomplete markets is an important factor in the study of enterprise innovation investment. Financing constraints limit enterprises' innovation R&D investment to a certain extent. The enterprise's reserve financial flexibility can effectively and timely mobilize funds, grasp the investment opportunities effected by uncertainty, release financing constraints, and promote the improvement of enterprise innovation ability. Therefore, when analyzing the role of financial flexibility in promoting enterprise innovation and R&D, we must discuss financing constraints. Based on the adverse impact of the financial crisis, some scholars have verified that financial flexibility can alleviate financing constraints. Enterprises that have maintained financial flexibility for three consecutive years before the outbreak of the financial crisis can continue to maintain innovation and R&D investment in the face of impact, resulting in rapid growth in enterprise performance after the crisis (Wan & Sun, 2010). Thus, when implementing innovation projects, enterprises can adjust the financing constraints on enterprise innovation activities by storing financial flexibility and maintaining sustainable innovation under the constraint of limited resources. Therefore, the following hypothesis is proposed:

H2. : Financial flexibility can significantly affect enterprises' sustainable innovation by reducing financing constraints.

Economic policy uncertainty, enterprise self-regulation, financial flexibility, and enterprise innovation

Strategic management theory holds that enterprises do not passively accept the impact of uncertainty but actively adapt to the environment. To improve this adaptability, enterprises should maintain financial flexibility. Additionally, as a special long-term investment, innovation will eventually form intangible assets and generate future profits.

However, innovation involves a long R&D cycle and high risk. Innovation is long-term, unpredictable, and uncertain Hall (2000). In a demand-oriented market environment, the cycle of product renewal iteration is short, whereas the enterprise requires a long cycle from innovation R&D to product promotion. During this period, market demand changes significantly, which makes the successful implementation of enterprise innovation R&D uncertain. Among the relevant studies on financial flexibility and uncertainty, some regard financial flexibility as a value reserve to deal with current uncertainty and study the impact of reserve financial flexibility on future investment opportunities from the perspective of intertemporal dynamics (Fazzari, Hubbard, Petersen, Blinder, & Poterba, 1988; Almeida, Campello, & Weisbach, 2004).

Based on previous studies, we believe that financial flexibility comprises both cash and debt flexibility. Enterprises enhance their internal financing ability by increasing their cash holdings to alleviate the pressure of external financing and improve innovation investment. In the case of high policy uncertainty, enterprises with high financial flexibility will adjust their financial structures by reducing their liabilities (Gu & Zhou, 2018). Thus, this study proposes that in the face of rising policy uncertainty, enterprises that actively reserve financial flexibility can cope with the impact and realize long-term development by adjusting their resource structures. Thus, the third hypothesis is proposed.

H3. : In the face of rising EPU, enterprise financial flexibility can alleviate the impact of uncertainty on enterprise innovation by actively adjusting savings.

Enterprise financing constraints and enterprise innovation based on economic policy uncertainty threshold variables

Exploring the relationship between EPU and enterprise innovation, the results show that EPU significantly inhibits enterprise innovation; the higher the internal financing constraints, the stronger is the inhibition (Chen & Zhao, 2021). The Chinese government should provide tax incentives and financial subsidies to enterprises to help them innovate. China's EPU affects enterprise innovation by

impacting enterprise financing constraints. An analysis of enterprise heterogeneity indicates that government subsidies should target non-state-owned enterprises and SMEs (Deng & Zhang, 2021). It was found that when enterprise innovation is negatively affected by the rising uncertainty of economic policy, the Chinese government's industrial policy plays a positive regulatory role. This provides a new idea for the Chinese government to promote enterprise innovation in the context of economic policy fluctuations (Jiang & Wang, 2021). The dynamic relationship between the Chinese government and Chinese enterprises is stronger than that between other foreign governments and enterprises. In the process of building an innovative country in China, Chinese scholars have alleviated the dilemma of enterprise innovation and development caused by the uncertainty in economic policies from the perspective of the Chinese government.

Based on H3, which says that financial flexibility can alleviate the impact of uncertainty by promoting sustainable innovation, this study introduces China's EPU as the threshold variable. It examines how this EPU changes the threshold value of enterprise financing constraints acting on enterprise sustainable innovation intensity. By taking accurate policy information release measures, the Chinese government can bring the country's EPU within the most reasonable range to minimize the negative impact of China's EPU and enterprise financing constraints on enterprise sustainable innovation. Simultaneously, Chinese enterprises can determine the negative impact of financing constraints on sustainable innovation by predicting the uncertainty of current economic policies and adopting appropriate financial flexibility schemes to alleviate the negative impact of financing constraints on sustainable innovation. Thus, the next hypothesis is proposed.

H4. : The Chinese government can minimize the negative impact of enterprise financing constraints on enterprise sustainable innovation by stabilizing the uncertainty of economic policies within a reasonable range. By predicting the uncertainty index of current economic policies, enterprises can determine the negative impact of financing constraints on sustainable innovation and adopt appropriate financial flexibility schemes to alleviate the negative impact of financing constraints on sustainable innovation.

Research method

Economic policy uncertainty and enterprise innovation models

To study the impact of policy uncertainty on enterprise innovation, we constructed an econometric model as follows:

$$Innnov_{i,t} = \beta_0 + \beta_1 EPU_{i,t} + \gamma X_{i,t} + Industry + Year + \mu_i + \theta_t + \varepsilon_{i,t} \quad (1)$$

where ***i*** refers to the listed company, ***i,t*** is the year, and ***Innov$_{i,t}$*** refers to enterprise innovation, which is measured by the number of invention patent applications. Simultaneously, innovation is divided into "breakthrough innovation" and "progressive innovation" (Zhang and Liu, 2019). "Breakthrough innovation" is measured by ***Ln (Number of invention patent applications in the current year + 1)***, and "progressive innovation" is measured by ***Ln (Number of patent applications for utility model + Number of patent applications for design + 1)***. ***X*** represents a series of control variables. We selected enterprise debt ratio, enterprise growth, operating cash flow, enterprise scale, enterprise age, and equity concentration as control variables (Xiao, Lin, & Chen, 2020). Further, μ and θ are the fixed-effects at the enterprise and year levels respectively, and ε is the random perturbation term.

Moreover, EPU denotes the policy uncertainty index. The EPU index used in this model was newly constructed by Shangqin Lu and Yun Huang of Hong Kong Baptist University. It is based on newspapers printed by major cities in mainland China, including the following: Beijing Youth Daily, Guangzhou Daily, Liberation Daily, People's Daily (Overseas Edition), Shanghai Morning Post, Southern Metropolis Daily, Beijing Daily, and Tonight Wen Wei Po and Yangcheng Evening News. Additionally, while the data of the EPU index are monthly, the above model uses annual data. Therefore, the monthly EPU data were transformed into annual EPU data using the method of annual arithmetic average (Xiao et al., 2020).

Financial flexibility and enterprise innovation test models

To test the relationship between financial flexibility and enterprise innovation, we constructed the following model:

$$Innnov_{i,t} = \beta_0 + \beta_1 FF_{i,t-1} + \gamma X_{i,t} + Industry + Year + \mu_i + \theta_t + \varepsilon_{i,t} \quad (2)$$

Combined with the model structure, enterprise innovation is measured by dividing the increment of intangible assets by total assets at the beginning of the period (Ju, Lu, & Yu, 2013). The core variable ***FF*** represents an enterprise's financial flexibility. This study uses the multi-index comprehensive method to measure financial flexibility, which we equate as the sum of cash flexibility and debt flexibility. Cash flexibility reflects the excess cash reserves held by the enterprise, expressed by the enterprise's cash holding rate exceeding the average cash holding rate of the same industry. Debt flexibility reflects the enterprise's residual debt raising ability, which indicates the extent to which the enterprise's debt level is lower than the average debt level of the industry in the same period. *Debt flexibility = max* ***(0, average debt ratio of the same industry − debt ratio of the company)*** (DeAngelo & DeAngelo, 2007). Additionally, the core variable ***FF*** with a lag of one period was adopted to reduce endogenous interference, along with enterprise-level clustering.

Further, to test whether financial flexibility significantly affects enterprise innovation efficiency by releasing financing constraints, we adopt the intermediary factor effect model as follows:

$$KZ_{i,t-1} = \delta_0 + \delta_1 FF_{i,t-1} + \varphi X_{i,t-1} + Industry + Year + \mu_i + \theta_t + \varepsilon_{i,t} \quad (3)$$

$$Innnov_{i,t} = \theta_0 + \theta_1 FF_{i,t-1} + \theta_2 KZ_{i,t-1} + \tau X_{i,t} + Industry + Year + \mu_i + \theta_t + \varepsilon_{i,t} \quad (4)$$

We test the effectiveness of the financing constraint (***KZ***) as an intermediary factor using the Sobel intermediary factor test (Baron & Kenny, 1986). When financial flexibility has a significant impact on financing constraints, both financial flexibility and financing constraints have a significant impact on enterprise innovation. Through the ***SobelZ − value*** test, the coefficient $\beta 1$ in Eq. (2) is significantly greater than the coefficient $\theta 1$ in Eq. (4), and the financing constraint is an effective intermediary variable.

KZ is a financing constraint index that uses operating cash flow, *Tobin's Q*, asset liability ratio, dividend payment rate, and cash holding to represent the operating net cash flow, cash holding, cash distribution level, debt degree, and growth of the enterprise. The regression coefficient of each variable was calculated by ranking logistic regression, followed by a comprehensive ***KZ*** index (Kaplan & Zingales, 1997). The larger the ***KZ*** index, the greater are the financing constraints faced by the company.

Adaptive effect test model of financial flexibility

To test whether the financial flexibility of enterprises can make the strategic adjustment of "Changing Response" through the reserved assets in the face of EPU, so as to maintain the adequacy and continuity of innovation funds and improve the innovation performance of enterprises. This study takes the impact of economic policy uncertainty, ***EPU***, on enterprise financial flexibility as the starting point. Thus, it uses the ***2SLS*** model to establish a two-stage equation

for the impact of EPU and financial flexibility on enterprise innovation efficiency to avoid possible endogenous problems (Xiao et al., 2020). The EPU impact estimation model set in this study is shown in Eq. (5), from which the EPU impact (EPUshock) is estimated.

$$EPU_{i,\ t} - EPU_{i,\ t-1} = \tau_0 + \tau_1\left(EPU_{i,t-1} - EPU_{i,t-2}\right) + \tau_2\left(EPU_{i,t-2} - EPU_{i,t-3}\right) + e_{i,t} \quad (5)$$

where the estimated residual term $\boldsymbol{e_{i,t}}$ is the uncertainty impact corresponding to the uncertainty of economic policy (***EPUshock***).

Next, the uncertainty impact estimated by Eq. (5) is used (***EPUshock***) to estimate the first stage and the predicted value of financial flexibility according to the model (***FF****). The specific model is shown in Eq. (6):

$$FF^{*}_{i,t-1} = \delta_0 + \delta_1 EPU_{shock,t-1} + \delta_2 X_{i,t-1} + Industry + Year + \varepsilon_{i,t} \quad (6)$$

Finally, the predicted value of financial flexibility $\boldsymbol{FF*}$, as an instrumental variable, is introduced in Eq. (7) for the second-stage estimation to investigate the adaptive effect of enterprise financial flexibility on innovation under the impact of EPU. The specific estimation model is shown in Eq. (7):

$$Innnov_{i,t} = \beta_0 + \beta_1 FF^{*}_{i,t-1} + \gamma X_{i,t} + Industry + Year + \mu_i + \theta_t + \varepsilon_{i,t} \quad (7)$$

Threshold effect model with economic policy uncertainty as the threshold variable

The regulatory role of the Chinese government and internal operations of enterprises play an important role in sustainable innovation. Therefore, to understand the role of the internal operation of enterprises on their sustainable innovation ability, this study divides China's EPU index into reasonable and warning areas. Following this, the study provides countermeasures for enterprises to accurately deal with the fluctuations caused by the government's economic policies.

This study considers the uncertainty of economic policy as the threshold variable, studies the change in the negative impact coefficient of enterprise financing constraints on enterprise sustainable innovation using the threshold effect model, and records the threshold value of EPU. Based on the uncertainty of economic policy, a single-threshold effect model of enterprise financing constraints affecting enterprises' sustainable innovation is established:

$$SRD_{it} = \alpha_1 KZ_{it} IEPU_{it} \le \gamma + \alpha_2 KZ_{it} IEPU_{it} > \gamma + \beta_1 GROWTH_{it} + \beta_2 DEBT_{it} + \beta_3 CFO_{it} + \varepsilon_{it} \quad (8)$$

where ***SRD*** (the explained variable) is the enterprise's continuous innovation, which is expressed as the innovation level of company ***i*** in year ***t; KZ*** represents the explanatory variable of enterprise financing constraints affected by the threshold effect of EPU. Further, $\boldsymbol{I}(\cdot)$ is the indicative function; ***EPU*** is the threshold variable, indicating the uncertainty of economic policy; $\boldsymbol{\gamma}$ is the specific threshold value. Moreover, $\boldsymbol{\alpha 1.\alpha 2}$ is the intensity coefficient of enterprise financing constraints on enterprise sustainable innovation when $(EPU_{it} \le \gamma)$ and $(EPU_{it} > \gamma)$ are threshold variables, respectively. Furthermore, ***GROWTH, DEBT,*** and ***CFO*** are control variables, which are expressed as enterprise growth, enterprise debt ratio, and enterprise operating cash flow, respectively. Finally, $\varepsilon_{it} \sim \text{iid}(0,\ \sigma^2)$.

Additionally, based on the test results of the single-threshold effect model, the following dual-threshold effect model is considered:

$$SRD_{it} = \alpha_1 KZ_{it} IEPU_{it} \le \gamma_1 + \alpha_2 KZ_{it} I\gamma_1 < EPU_{it} \le \gamma_2 + \alpha_3 KZ_{it} IEPU_{it} > \gamma_2 + \beta_1 GROWTH_{it} + \beta_2 DEBT_{it} + \beta_3 CFO_{it} + \varepsilon_{it} \quad (9)$$

where $\boldsymbol{\alpha 1.\alpha 2.\alpha 3}$ are the intensity coefficients of corporate financing constraints on corporate sustainable innovation when the threshold variable value is equal to $(EPU_{it} \le \gamma_1) \cdot (\gamma_1 < EPU_{it} \le \gamma_2) \cdot (EPU_{it} > \gamma_2)$.

Sample selection

This study examines all the listed companies in China's Shanghai and Shenzhen A-share markets. The sample was selected from 2007 to 2019. The data are obtained from the CSMAR and Wind databases. Simultaneously, to ensure data quality, the samples of financial listed companies, samples processed by ST and PT, missing samples, and abnormal sample data with extreme values were removed. Thus, 22523 observation samples were obtained. The specific definitions and descriptive statistical results of the main variables in this study are shown in Table 1 below.

Results

Descriptive statistical analysis

Table 1 presents the descriptive statistics for the main variables. The mean value of enterprise sustainable innovation is 0.0077, and the standard deviation is 0.0255. This means that the increment in intangible assets of listed companies accounts for only 0.77% of the total assets. The level of sustainable innovation among the Chinese listed companies was relatively low. The mean value of innovation efficiency is 1.5804, and the standard deviation is 1.5293, indicating that there are significant differences in innovation efficiency among the sample enterprises. The mean value of financial flexibility is 0.09612, and the standard deviation is 0.2056. This indicates that the holding level of financial flexibility of the sample enterprises is low, and the financial flexibility of many listed companies is negative.

Table 1
Variable Definitions and Descriptive Statistics.

Variable name	Symbol	Variable definition	Average value	Standard deviation
Continuous innovation	SRD	Increment of intangible assets divided by total assets	0.0077	0.0255
Innovation efficiency	Innov	Natural logarithm of invention patent application plus 1	1.5804	1.5293
Financial flexibility	FF	Sum of cash flexibility and liability flexibility	0.0961	0.2056
Economic policy uncertainty	EPU	Arithmetic mean of monthly data of economic policy uncertainty	141.7636	13.6262
Enterprise debt ratio	Debt	Sum of current liabilities and long-term liabilities divided by total assets	0.2917	0.1938
Enterprise growth	Growth	Annual growth rate of main business income	7.0489	902.4765
Operating cash flow	CFO	Net cash flow from operating activities divided by total assets	0.0443	0.07875
Enterprise scale	Size	Natural logarithm of total assets plus 1	3.0959	0.0593
Enterprise age	Age	Year of observation minus year of listing	16.0589	5.5967
Ownership concentration	HHI5	Sum of squares of shareholding ratios of the top five shareholders	0.167	0.1194

Table 2
Panel Data Stability (Unit Root) Test.

Variable name	Enterprise financing constraints KZ	Economic policy uncertainty EPU	Enterprise growth GROWTH	Enterprise debt ratio DEBT	Operating cash flow CFO	Ownership concentration HHI5
LLC	-33.2063***	-61.2037***	-41.0063***	-5.5003***	-38.1428***	-1.8002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
IPS	-14.6888***	-14.3829***	-18.0611***	-9.7435***	-16.0154***	2.7237
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	0.9968
Fisher-ADF	-33.7781***	-15.1185***	-42.2784***	-25.5895***	-32.7734***	-12.6337***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: *, * *, and * * * indicate that the confidence levels of 10%, 5%, and 1% are significant.

Data stationarity test

Between model setting and parameter estimation, this study uses panel data, making it necessary to test the unit root of each panel data series. In this study, ***LLC, IPS***, and ***Fisher-ADF*** are used to test the stationarity of the panel data series. According to the unit root test results of the panel data series, as shown in Table 2, in addition to the ***IPS*** stationarity test of equity concentration, other variables in the model show stationarity under the homogeneous panel hypothesis test or the other two tests of the heterogeneous panel hypothesis. Therefore, we use each variable in the regression model.

Test results for the impact of policy uncertainty on innovation

In the empirical process, this study proves that the mixed OLS, fixed-effects, and random effects models all significantly prove that policy uncertainty has a negative effect on innovation. This proves the hypotheses proposed; therefore, this study lists the model estimation results using mixed ***OLS***, fixed-effects, and random effects regression models. Table 3 reports the test results of the impact of policy uncertainty on innovation. Columns (1) and (4) are the mixed OLS model results, columns (2) and (5) are the fixed-effect model results, and columns (3) and (6) are the random effect model results. The regression results in columns (1)–(3) show that the estimated coefficients of policy uncertainty are significantly negative, indicating that enterprises reduce breakthrough innovation in the face of the risks brought by policy uncertainty. The policy uncertainty coefficient in columns (4)–(6) is also negative, indicating that enterprises reduce incremental innovation. Comparing the estimated coefficients of columns (1) and (4), (2) and (5), as well as columns (3) and (6), it is found that the reduction of breakthrough innovation is greater than that of incremental innovation. This indicates that while breakthrough innovation has high returns, it also carries greater risks. Enterprises will tend to reduce breakthrough innovation in the face of large policy fluctuations to reduce the possible loss caused by risk.

Channel test results of financial flexibility affecting enterprise innovation

Basic model regression results

Table 4 reports the test results of the impact of enterprise financial flexibility on enterprise innovation efficiency. The regression results show that there is a significant positive relationship between enterprise financial flexibility and enterprise innovation efficiency—an improvement in enterprise financial flexibility improves enterprise innovation efficiency. It shows that the financial flexibility of enterprises can provide sufficient capital supply for innovation activities, jointly restrain the increase of financing and adjustment costs, and ensure the steady improvement of enterprise profits.

Financial flexibility affecting the channels of enterprise innovation

To deeply study the transmission mechanism of financial flexibility affecting enterprise innovation, we introduce the intermediary factor effect model for analysis and use the ***KZ*** index as the proxy variable of financing constraints. The regression results are reported in Table 5.

Column (1) of Table 5 reports the estimation results of Eq. (2) in the intermediary factor effect model. The regression coefficient of financial flexibility is 0.0064, significant at the 1% confidence level. Column (2) shows the estimation results of Eq. (3) in the intermediary factor effect model. The regression coefficient of financial

Table 3
Economic Policy Uncertainty and Enterprise Innovation.

	Breakthrough innovation			Incremental innovation		
	(1)	(2)	(3)	(4)	(5)	(6)
EPU_t	−0.0228***	−0.0189***	−0.17***	−0.0112****	−0.00644***	−0.3555***
	(0.0016)	(0.0014)	(0.0065)	(0.0018)	(0.0017)	(0.0079)
$Debt_t$	0.0142**	0.021***	0.0009	0.0202***	0.0171**	0.0163*
	(0.0034)	(0.0036)	(0.0018)	(0.0045)	(0.0078)	(0.0082)
$Growth_t$	−0.0000***	−0.0000***	−0.0000***	−0.0000**	−0.0000 ***	−0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
CFO_t	0.055**	0.0402***	0.0378***	0.0434**	0.0421***	0.04***
	(0.026)	(0.0048)	(0.0048)	(0.0024)	(0.0046)	(0.0056)
$Size_t$	0.3636***	0.3163***	03047***	0.3616***	0.3201***	0.311***
	(0.0249)	(0.0198)	(0.0256)	(0.0248)	(0.0199)	(0.026)
Age_t	−0.0481***	−0.036**	−0.5227****	−0.05***	−0.0391***	−1.1663***
	(0.0048)	(0.0041)	(0.0217)	(0.0053)	(0.0000)	(0.0262)
$HHI5_t$	0.6799***	−0.6644***	−0.7048***	−0.2345	−0.3978**	−0.543**
	(0.2253)	(0.1816)	(0.2212)	(0.2406)	(0.1819)	(0.2196)
Year	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Industry	*Yes*	*Yes*	–	*Yes*	*Yes*	–
R^2	0.1561	0.1859	0.186	0.1478	0.1848	0.1849
No.Obs	23,885	23,885	23,885	23,885	23,885	23,885

Note: *, * *, and * * * indicate that the confidence levels of 10%, 5%, and 1% are significant.

Table 4
Regression Results of Financial Flexibility Affecting Enterprise Innovation.

	Mixed OLS		Fixed effect		Random effect	
	(1)	(2)	(3)	(4)	(5)	(6)
FF_{t-1}	0.0065***	0.007***	0.0141***	0.0142***	0.0066***	0.0071***
	(0.0014)	(0.0014)	(0.0023)	(0.0023)	(0.0014)	(0.0014)
$Innnov_{t-1}$	0.126***	0.1076***	−0.0434	−0.0478	0.126***	0.1076****
	(0.0399)	(0.0414)	(0.0415)	(0.0416)	(0.04)	(0.0414)
$Debt_t$	0.001	0.0009	0.002	0.0036	0.001	0.0009
	(0.0015)	(0.0018)	(0.0032)	(0.0034)	(0.0015)	(0.0018)
$Growth_t$	0.0002**	0.0002***	−0.0006	−0.00005	0.0002**	0.0002**
	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0001)	(0.0001)
CFO_t	−0.0000	−0.0009	0.0003	0.0003	−0.0000	−0.0009
	(0.0033)	(0.0035)	(0.0045)	(0.0034)	(0.0033)	(0.0035)
$Size_t$	0.0003	0.0011***	0.1083***	0.1101***	0.0083	0.1076***
	(0.0002)	(0.0003)	(0.0253)	(0.0259)	(0.0055)	(0.0068)
Age_t	−0.0002***	−0.0002***	−0.0012***	−0.0011***	−0.0002**	−0.0002****
	(0.0000)	(0.0000)	(0.0002)	(0.0002)	(0.0000)	(0.0000)
$HHI5_t$	−0.0034*	−0.0038*	0.0124*	0.0112*	−0.0035*	−0.0038*
	(0.0021)	(0.0021)	(0.0067)	(0.0067)	(0.0021)	(0.0021)
Year	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*
Industry	*No*	*Yes*	*No*	–	*No*	*Yes*
R^2	0.025	0.044	0.019	0.02	0.217	0.231
No.Obs	11,136	11,136	11,136	11,136	11,136	11,136

Note: *, * *, and * * * indicate that the confidence levels of 10%, 5%, and 1% are significant.

flexibility on the ***KZ*** index of the intermediary factor financing constraints is -4.8461, which is significant at the 1% confidence level, indicating that enterprise reserve financial flexibility can alleviate financing constraints. Finally, when the intermediate factor financing constraint is added to Eq. (2) for testing, the estimated coefficient of financial flexibility is reduced to 0.0042, and the significance is also reduced. The ***KZ*** index of financing constraint as an intermediate factor is -0.0045, which is significant at the 5% confidence level. Additionally, the Z value of the Sobel test obtained from the model test is 0.0022, which is significant at the 5% confidence level, indicating that financial flexibility promotes enterprise innovation by alleviating financing constraints.

Endogenous test

Table 6 reports the test results of endogenous problems. There may be a reverse causal relationship between enterprise innovation and financial flexibility. This is because the awareness of innovation may urge enterprises to reserve more financial flexibility and ensure the adequacy of innovation funds to ensure the smooth implementation of innovation activities, resulting in a reverse causal relationship between the two. In this study, differential ***GMM*** and system ***GMM*** are used to test endogeneity. The correlation test between the (1) and (2) residual sequences and the noncorrelation test of the second-order sequence in Table 6 show that after controlling endogeneity, the hypothesis of enterprise innovation and financial flexibility remains valid.

Table 5
Test Results of Coordinated Innovation Effect of Financial Flexibility.

	Innnov (1)	KZ (2)	*Innnov* (3)
FF_{t-1}	0.0064***	−4.8461**	0.0042**
	(0.0014)	(0. 0805)	(0. 0806)
KZ_{t-1}			−0.0045**
			(0. 0806)
Controls			
Year and Industry			
R^2	0.056	0.405	0.061
No.Obs	9,669	9,669	9,669
Sobel Z − Test	0.0022***		
	(0. 0009)		

Note: *, * *, and * * * indicate that the confidence levels of 10%, 5%, and 1% are significant.

Robustness check

To test the reliability of the above results, this study tests robustness from three aspects. First, when other variables remain unchanged, *Tobin's Q* is added to describe enterprise innovation investment opportunities. These regression results are consistent with the above results, indicating their robustness. Second, the financial flexibility data are discretized. When the enterprise's financial flexibility is in the lower 1/3 quantile, the value is 0; when in the middle, the value is 1; in the higher 1/3 quantile, the value is 2. Regression analysis using discrete financial flexibility shows the results to be consistent (Xiao et al., 2020). Finally, the increment of invention patent applications is used as an alternative variable for continuous innovation for regression analysis, and the results are consistent with

Table 6
Endogeneity Test Results.

	Differential GMM (1)	System GMM (2)
FF_{t-1}	0.0186*	0.0184*
	(0.0104)	(0.0099)
$Innnov_{t-1}$	0.0993***	0.106***
	(0.0361)	(0.0362)
$Debt_t$	−0.0031	−0.0031
	(0.0043)	(0.0037)
$Growth_t$	−0.00017	−0.0001
	(0.00014)	(0.0001)
CFO_t	0.0068	0.0067
	(0. 008)	(0.0076)
$Size_t$	0.0107***	0.0087***
	(0.0021)	(0.0018)
Age_t	−0.0024***	−0.002***
	(0.0003)	(0.0003)
$HHI5_t$	0.0136	0.0134
	(0.0109)	(0.01)
Year	*Yes*	*Yes*
Industry	*Yes*	*Yes*
$AR(1)P-value$	0.0000	0.000
$AR(2)P-value$	0.5443	0.5932
No.Observation	9,363	9,363

Note: *, * *, and * * * indicate that the confidence levels of 10%, 5%, and 1% are significant.

Table 7
Test Results of Adaptive Effect of Financial Flexibility.

	(1) Phase I	(2) Phase II
$EPU_{shock,t-1}$	0.0063*** (0.0018)	
FF^{*}_{t-1}		0.0828*** (0.0353)
Controls	Yes	Yes
Year and Industry	Yes	Yes
No.Observation	8,346	8,346

Note: *, * *, and * * * indicate that the confidence levels of 10%, 5%, and 1% are significant.

the above. In conclusion, corporate financial flexibility has a positive impact on sustainable innovation, supporting Hypothesis 2.

Test results for the adaptive effect of financial flexibility

The uncertainty arising from frequent policy changes can impact the operation of enterprises. To test whether the financial flexibility of enterprise reserves can maintain the ability of sustainable innovation when the policy uncertainty increases. Table 7 reports the results of the model.

The first stage results in column (1) of Table 7 show that the estimated coefficient of impact caused by policy uncertainty is significantly positive at the 1% confidence level. The second stage results in column (2) show that the enterprise's financial flexibility is significantly positive at the 5% confidence level. This indicates that increasing policy uncertainty will lead an enterprise to increase financial flexibility, which, in turn, can maintain enterprise innovation and help cope with the losses caused by the uncertainty. This proves H3.

Model test of the threshold effect of economic policy uncertainty

The estimated value of the economic uncertainty threshold is γ when the likelihood ratio test statistic ***LR*** is zero. In Table 8, the values of γ^1 and γ^2 are 136.8201 and 141.1646, respectively. The 95% confidence interval for thresholds γ^1 and γ^2 comprise γ less than the critical value at the 5% significance level of the ***LR*** value.

We analyze the threshold characteristics of the impact of changes in enterprise financing constraints on enterprise sustainable innovation. Through the threshold effect model of EPU, the negative impact of enterprise financing constraint variables on enterprise sustainable innovation has threshold characteristics based on EPU. Table 9 shows three stages. ***Stage I***: When the uncertainty value of government economic policy is lower than 136.8201, enterprise financing constraints have a significant negative effect on enterprise sustainable innovation (-0.0015). ***Stage II***: When the uncertainty value of government economic policy is within the range of 136.8201 to 141.1646, the negative effect intensity of enterprise financing constraints on enterprise sustainable innovation increases significantly (-0.0037). ***Stage III***: When the uncertainty value of government economic policy exceeds 141.1646, the negative effect intensity of enterprise financing constraints on enterprise sustainable innovation decreases significantly (-0.0011) (Table 10).

Table 9
Threshold Estimates and Confidence Intervals of Economic Policy Uncertainty Threshold Effect Model.

	Threshold effect model of economic policy uncertainty	
	Estimated value	95% confidence interval
Threshold value $\hat{\gamma}_1$	136.8201	/125.0278, 155.7498/
Threshold value $\hat{\gamma}_2$	141.1646	/141.1646, 150.4743/

Table 10
Estimation Results of Economic Policy Uncertainty Threshold Effect Model.

Explanatory variable	Threshold effect model of economic policy uncertainty Double threshold
KZ_1	-0.0015*** (-3.2912)
KZ_2	-0.0037*** (-7.3279)
KZ_3	-0.0011*** (-3.3074)
HHI5	0.0183***(4.1358)
DEBT	0.0004* (1.8557)
CFO	-0.0198* (-1.8920)
$F-value$	F-stat=12.0088 Prob>F=0.0000
R^2	0.171

Note: *, * *, and * * * indicate that the confidence levels of 10%, 5%, and 1% are significant.

Table 11 shows the negative effects of EPU on enterprise innovation efficiency and the negative effects of EPU on enterprise financing constraints and enterprise sustainable innovation, combined with the empirical results of H1 and H4. The economic policy fluctuation range $EPU \leq 136.8201$ is categorized as the reasonable area. However, the economic policy fluctuation range is located in $136.8201 < EPU < 141.1646$ and $EPU \geq 141.1646$ and, thus, is categorized as the warning area of economic policy fluctuation. Although the EPU will have a negative effect on enterprises' innovation efficiency at the uncertainty range of $EPU \geq 141.1646$, it will not weaken the positive effect of enterprises alleviating financing constraints on sustainable innovation through financial flexibility.

H3 proves that enterprises can improve innovation efficiency by improving their financial flexibility and reducing their financing constraints. Through the threshold effect model test, this section proves that the existence of enterprise financing constraints has a negative effect on enterprise sustainable innovation. However, its negative effect intensity changes significantly with a change in the range of the EPU index. When the uncertainty index of economic policy is below 136.8201, the negative effect of enterprise financing constraints on sustainable innovation is small.

Therefore, adopting a normal financial flexibility scheme can improve an enterprise's innovation efficiency. When the uncertainty

Table 11
Zoning of Economic Policy Fluctuations.

Zoning of economic policy fluctuations	Fluctuation range of economic policy
Reasonable area	$EPU \leq 136.8201$
Warning area	$EPU \geq 141.1646$
	$136.8201 < EPU < 141.1646$

Table 8
Test of Economic Policy Uncertainty Threshold Effect Model.

Model	Threshold type test	F-statistic	P-value	Critical value		
				1%	5%	10%
Threshold effect model of economic policy uncertainty	Single threshold test	15.2504***	0.0000	6.8900	3.8749	2.5487
	Double threshold test	12.0088***	0.0000	5.3144	2.2310	1.9838

Note: *, * *, and * * * indicate that the confidence levels of 10%, 5%, and 1% are significant

index of economic policy is significantly enhanced above 136.8201, enterprises need to significantly improve financial flexibility to reduce financing constraints and alleviate the significant negative effect of financing constraints on sustainable innovation.

Discussion and conclusion

Through this research, we draw the following conclusions. First, the rise of the policy uncertainty index has a negative impact on enterprise innovation efficiency, and the decline of breakthrough innovation is greater. Second, the financial flexibility of enterprise savings can significantly improve the innovation ability of enterprises by releasing the negative impact of financing constraints. Third, when the impact of policy uncertainty increases, enterprises can actively reserve financial flexibility and maintain sufficient financial resources, which can reduce the negative impact of uncertainty, seize the opportunities brought by it, improve the innovation efficiency of enterprises, and enhance their core competitive advantage. Finally, China's EPU has a threshold effect in the model of enterprise financing constraints and enterprise sustainable innovation. China can promote sustainable innovation by reasonably adjusting the uncertainty of economic policy.

In view of the above conclusions, we forward four suggestions for companies. First, enterprises should be aware of reserve financial flexibility. While holding excess cash and maintaining a low debt ratio to obtain financial flexibility, enterprises should pay more attention to equity flexibility by regularly distributing dividends to shareholders. Second, enterprises should strengthen their governance and improve their internal control systems to reduce agency costs. Third, the Chinese government should accelerate the construction of the capital markets, deepen the financial system reforms, improve the credit rating system, broaden enterprise financing channels, and provide long-term and stable financial guarantees for enterprise innovation activities. Fourth, we determined the reasonable or warning fluctuation ranges of the EPU according to the results of the threshold effect. When the uncertainty index of economic policy is within a reasonable range, the negative impact of enterprise financing constraints on sustainable innovation is small. Therefore, adopting a normal financial flexibility scheme can improve enterprise innovation efficiency. When the uncertainty index of economic policy is significant in the warning zone, enterprises need to improve financial flexibility significantly to reduce financing constraints and alleviate the significant negative impact of financing constraints on sustainable innovation.

First, we discuss the negative impact of the rise of policy uncertainty index on enterprise innovation. Subsequently, when the policy uncertainty index rises, enterprises stimulate innovation potential by adjusting financial flexibility. Further, in the context of Chinese politics, we will study how the Chinese government adjusts the uncertainty index of economic policies and stimulates the innovation potential of enterprises through the release of economic policies.

Our study has certain limitations because China's unique economic system has a strong ability to adjust its economic policy index. However, owing to the rapid development of the world economy, other countries have gradually strengthened the regulatory role of the government in economic development. Therefore, our research provides a reference for enterprises affected by the epidemic and struggling with innovation.

Conflict of Interest

None.

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