VILNIUS TECH
Vilnius Gediminas Technical University

Journal of Business Economics and Management
ISSN 1611-1699 / eISSN 2029-4433
023 Volume 24 Issue 2: 315–335
https://doi.org/10.3846/jbem.2023.19047

PEER EFFECT OF CORPORATE R&D INNOVATION FROM THE PERSPECTIVE OF UNCERTAINTY

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Received 16 March 2023; accepted 25 April 2023

Abstract. Based on external uncertainty environment and R&D innovation wave background, this paper explores the impact of information noise caused by economic policy uncertainty and the peer effect on corporate R&D innovation activities, using the multiple regression method and the quarterly data of listed Chinese companies from 2010 to 2020, the influencing mechanism and boundary condition of economic policy uncertainty on the peer effect of corporate R&D were analyzed. Results show that there is a significant peer effect at the industry level in the R&D innovation behavior of corporates, with said effect and the uncertainty of economic policies both significantly stimulate the R&D innovation activities of corporates. The imitation learning path of peer effect is obviously targeted, and corporates in the same industry prioritize corporates with comparative advantages in the industry. Economic policy uncertainty and peer effect also present a certain selection effect on corporate R&D innovation, possibly further enabling corporates with better operating conditions to gain greater market share and gradually eliminate corporates with low R&D innovation ability. The conclusions help decision makers use the peer effect to implement incentive policies and optimize management.

Keywords: R&D innovation, peer effect, external uncertainty, imitation path, selection effect, corporate governance

JEL Classification: D81, G31, L23.

Introduction

The investment decision-making behaviors of corporates in uncertain external environments have always been the focus of field such as economics and finance. The turbulence of the current global political and economic structure and geopolitical and trade frictions have aggravated the economic uncertainty induced by COVID-19 in various global regions (Sorli-Pena & Parra-Gomez, 2020; Gao & Zhai, 2021). When it comes to economic policy uncertainty, the policies introduced by the government may affect the economy due to some

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unexpected reasons somewhere in the implementation process (Gulen & Ion, 2016; Hu & Gong, 2019; Imbruno, 2019) that may become sources of policy content adjustment, implementation changes, or other things.

Economic policy uncertainty affects larger macroeconomics (Handley & Limão, 2017; Shaikh, 2020; Gong et al., 2022) thus causing the decline of employment and output, impact the economic cycle, and trigger economic recession. Simultaneously, it will also have a significant effect on the behavior decision of microeconomic entities, thereby driving corporates to either strengthen or weaken their own investment motives to seek higher market profits or avoid market risks (Chen et al., 2018, 2019; Caldara et al., 2020). From the perspective of information economics, economic policy uncertainty increases the information noise in larger economic operation and development, reduces the transmission of effective information, and ultimately triggers the irrational decision-making behaviors of investors.

Due to the rising uncertainty of economic policies and other complicated shocks (Feng et al., 2022), the world's major economies have launched different countermeasures to ensure macroeconomic development and social and political stability. To cope with various shocks in macroeconomic development, micro-corporates have also started to cater to the new round of scientific and technological advancements and pursue further development by vigorously carrying out corporate R&D (Gao & Zhai, 2021; Saman, 2022) and innovation (Vrontis & Christofi, 2021; Dou et al., 2022). Peer effect also exists in the R&D innovation of corporates due to the inevitable mutual reference or learning behaviors with other corporates in their financial decision-making activities. The phenomenon is when individual behavior inside the social reference group becomes influenced by other individual behaviors in the group. It first appeared in fields such as education, sociology, and other related disciplines. Eventually, it was also further studied fields as finance and management, especially in corporate behavior.

When corporates are influenced by peer corporates in the same industry, the same region, or a certain comparable range in the process of decision-making and implementation, they tend to do behavioral convergence i.e., the peer effect. Peer effect also widely exists in all kinds of corporate activities, and has been found in areas such as the investment field of corporates (Chen & Cai, 2021), corporate violation, corporate merger and acquisition decision, corporate governance, and executive compensation.

For corporate managers and decision makers, referring to the behavior or activity information of peer corporates reduces their own decision-making costs to a certain extent, and also helps reduce the risk of decision failure (Chen & Ma, 2017). However, although peer effect plays a positive role in encouraging corporates themselves or similar corporates, it may also bring serious industrial problems such as over-agglomeration or lack of investment, or lead to negative consequences such as collective violation. Therefore, the emergence of peer effect in corporate decision-making behaviors also deepens the information loss caused by the rising economic policy uncertainty to some extent and thus aggravates the irrational behaviors of investors.

In existing literature on peer effect, the action mechanisms of peer effect's imitation path and selection effect have been usually ignored, despite them not being closely enough related to external factors. Here, it was logically clearly figured out that the peer effect stimulated corporates to carry out R&D innovation activities. Hence, the influence of economic policy

uncertainty on corporate R&D innovation was investigated, along with a detailed study on the imitation path and learning object of peer effect in corporate R&D innovation from the perspective of economic policy uncertainty. Theoretically, this study enriches the discussion regarding behavioral economics from the perspective of corporates. Practically, it also provides effective countermeasures for corporate managers to avoid investment over-agglomeration and also renders relevant suggestions for policy makers to effectively guide R&D investment activities in specific industries.

The possible marginal contributions of this study are as follows: (1) The existing study perspective on corporate' R&D innovation behaviors is generally based on single perspectives, and external factors such as economic policy uncertainty and internal factors such as corporate peer effect are rarely combined. This study explores the imitation motivation and path and improves the reference basis and theoretical logic of the imitation behavior in the peer group; (2) Given the current uncertainty in the global economy, this study reveals the imitation path of peer effect in corporate R&D innovation by studying the influences of economic uncertainty and peer effect on corporate R&D innovation behaviors; and (3) This study also discloses the selection effect of peer effect and provides a possible explanation conforming to economic intuition.

The remainder of this study is arranged as follows: In Section 1, the research hypotheses were proposed in a logical order through literature review and theoretical analysis of the causes and imitation paths of peer effect in corporate innovation investment activities. In Section 2, the data source, processing method, and the model used are introduced, and relevant variables are selected, accompanied by brief descriptive statistical analysis. In Section 3, the empirical results are analyzed, with robustness test and endogeneity test being performed after stepwise regression result analysis of the benchmark model. Given this, the selection effect of peer effect was probed into through further tests. Section 4 provides the current state of the discussion in which the relevant empirical results of peer effect are discussed based on the previous analysis, and the possible economic explanation is given accordingly. In the last Section, the research conclusions and enlightenments are presented.

1. Theoretical analysis and research hypothesis

1.1. Motivation analysis of peer effect in corporate innovation investment activities

The corporate investment activities are affected by many factors (Wang et al., 2021; Chen et al., 2022). Based on the information asymmetry theory, some factors, such as information leakage and noise in the market environment of corporates, make it very difficult for corporates to obtain complete and true market information. Therefore, when making management decisions, corporates will try to collect external information and then use internal information to facilitate the decision-making behavior, thereby "conforming to the Rational Man (homo economicus) Assumption the most". Usually, efforts are made to reduce the cost of decision-making and information collection and optimize the predictable decision-making results. To reduce the cost of external information collection and prevent themselves from bearing the consequences alone after decision failure, managers tend to refer to other individuals in the peer group of corporates and present similar investment trends (Li & Wang,

2022). Knowledge management is thus used as a part of business strategy (Aghamolla & Thakor, 2022; Mišević & Tomašević, 2021).

Given the limited information acquisition ability of micro-individuals, they tend to horizontally compare the decision results of other peer corporates in the similar period when referring to their own historical investment information. Naturally, there will be comparison and learning motivation, thereby leading to imitation behaviors (Cao et al., 2019). It is difficult for corporates to make a comprehensive and prudent analysis under the circumstances of strong market fluctuation, high information noise, and high cost of external information acquisition. Therefore, when making decisions with high risks and uncertain results, they are more inclined to refer to the behavior of peer corporates, aiming to evade risks as much as possible and obtain higher profits. Thus, the first hypothesis is forwarded herein:

Hypothesis 1: When other conditions are limited, the peer effect exists in R&D innovation investment activities of listed companies, which has an incentive effect on R&D innovation activities of listed companies.

1.2. Motivation analysis of economic policy uncertainty for R&D innovation

The policy system is crucial for corporate innovation activities (Naveed & Shabbir, 2022; Xiong et al., 2023). When the transmission of market information is blocked and economic policy uncertainty rises, corporates may tend to improve their R&D innovation behaviors to tackle more intense market competition. Innovative investment differs from other investments in its strong uncertainty and irreversibility, and its proportion in the overall expenditure of corporates is generally low, thus making it possible to be "motivated" by economic policy uncertainty (Li et al., 2021).

Corporate decisions are very dependent on the introduction of various economic policies (Lu et al., 2020; Pan & Yang, 2019; Xue et al., 2022), and economic policy uncertainty will, to some extent, affect the behavior of economic markets and economic entities (Baker et al., 2016; Gulen & Ion, 2016). Economic policy uncertainty will also generate a significant impact on corporate behaviors (Guo & Sun, 2021), thus affecting the willingness and decision-making of corporate R&D innovation (Gu et al., 2018), subsequently leading to a series of corporate R&D innovation behaviors. Therefore, when facing the risk of uncertainty, corporates often make and adjust their own decisions by referring to the decisions or information of peer corporates. From the perspective of managers, under the external environment with strong uncertainty, referring to the decision-making results of peer corporates helps in providing more convincing proof of legitimacy and protecting themselves from bearing decision-making risks along. Given this, the next hypothesis is forwarded:

Hypothesis 2: When other conditions are limited, economic policy uncertainty stimulates listed companies to implement R&D innovation activities.

1.3. Imitation mechanism of peer effect in corporate innovation investment activities

Peer effect is the phenomenon of learning and imitating the activities of peer corporates, and imitation objects are not selected randomly or blindly. Generally, peer effect is the results

of some rational choices of corporates, making imitators adopt certain screening strategies when choosing reference objects (Zhang et al., 2022). Also, corporates with an advanced management mode, large size, and higher return of investment in the industry will be taken as the main target of reference. Therefore, corporates occupying a dominant position are more likely to be listed as objects of reference and imitation, while relatively disadvantaged corporates are often not taken for reference too much (Leary & Roberts, 2014). This may be because corporates in a dominant position have more valuable inside information, and the market signals released by their innovative investment behaviors are thus more referential.

The effectiveness of decision results of corporates operating well in the industry can be found more easily by peer corporates, making them likelier to be the object of reference and imitation. If the R&D innovation data of such corporate are disclosed a lot, peer corporates will be motivated to increase the investment expenditure of the same type (Peng et al., 2020), thus seeking for equivalently high returns and profits. Meanwhile, the relevant data of corporates in a dominant position are actively disclosed or collected, which is easier for other companies to obtain and refer to. By and large, there are many dimensions and indicators in distinguishing corporates' position in the industry. In the current study, corporate size was selected as the division basis. Thus, another hypothesis is forwarded below:

Hypothesis 3: When other conditions are limited, when corporates carry out R&D and innovation activities, the larger corporates are imitated to a higher degree, and the smaller corporates are imitated to a lesser degree.

Given the national conditions in China, corporates are obviously divided according to their nature, which are generally two categories: state-owned corporates and non-state-owned corporates. According to the standards of the National Development and Reform Commission of China and the State-owned Assets Supervision and Administration Commission of the State Council of China, state-owned corporates include corporates with total state-owned shares ≤50%, and limited liability companies, joint stock companies or other economic organizations with state-owned shares ≥50%. Because of its equity nature, such corporates are generally regulated by the state and are managed by the government. Hence they may also have certain financing convenience and sensitivity to policy orientation. Therefore, the R&D and innovation activities of state-owned corporates in the market have more reference significance and value than those of non-state-owned corporates. This propels the fourth hypothesis in this study:

Hypothesis 4: When other conditions are limited, when corporates carry out independent innovation activities, state-owned corporates are imitated to a greater extent, while non-state-owned corporates are imitated to a lesser extent.

2. Methodology

2.1. Sample selection and data source

In this chapter, the common least squares multiple linear regression model is used to study the influence of peer effects on corporate R&D innovation under the environment of economic policy uncertainty. Since the economic policy uncertainty index exhibits significant seasonal characteristics, the quarterly data of Chinese listed companies from the first quarter

of 2010 to the fourth quarter of 2020 were selected and processed as follows: (1) The samples of financial companies were excluded; (2) ST and *ST samples were excluded; (3) Samples with missing financial data were excluded; (4) Industries with the number of companies not greater than 5 were excluded; (5) Continuous variables were winsorized (at 1% and 99% quantiles). Finally, the observed values of 12464 company-quarterly samples were acquired.

The financial data of this study derived from CSMAR and WIND databases. The industry classification standard was Guidelines for Industry Classification of Listed Companies.

2.2. Variable settings and description

Here, R&D investment (*Rd*) of sampled corporates was the explained variable, which was measured according to the methods commonly used in the existing literature. Following Hansen and Hill (1991), the ratio of R&D investment to current operating income of corporates was chosen as the measurement standard for R&D investment.

R&D investment of peer corporates (*Rd_peer*) was the main explanatory variable used herein. Following Peng et al. (2020), peer corporates were divided based on the second-level code of the manufacturing industry and the first-level code of other industries in accordance with the Guidelines for Industry Classification of Listed Companies (2012 edition). In Model (1), *Rd_peer* was measured by the calculated ratio of industry-quarterly R&D investment to operating income.

Here, economic policy uncertainty (*EPU*) served as the explanatory variable, which was measured using China's economic policy uncertainty index as compiled by Baker et al (2016). This index was obtained by retrieving some keywords after textual analysis of data from Hong Kong's South China Morning Post. See other control variables in the following Table 1.

Table 1. Variable definition

Type	Variables	Variable definition and description
Dependent variables	*Rd*	The innovation revenue ratio is used to measure the intensity of R&D innovation activities, which is the ratio of corporate R&D and innovation expenditure to corporate current operating revenue
Independent variables	*Rd_peer*	The average of the innovation revenue ratio of the industry where the corporate is located is used to measure the innovation investment level of the same group corporates, which is the average of R&D innovation expenditure/business income of the same group corporates
	EPU	China's economic policy uncertainty index (quarterly), to the monthly economic uncertainty index transformed $EPU = PUI_m + PUI_{m+1} + PUI_{m+2}$. Where, PUI is the monthly economic uncertainty index, and m is the month of the last month of the quarter. Considering the comparability of data in this study, EPU index is reduced to 1/100
Control variables	*Size*	Size of corporate, which is the logarithm of total assets of the corporate at the end of the period
	Lev	Corporate financial leverage, which is the recorded as asset-liability ratio, total liabilities/total assets at the end of the period
	Growth	Corporate growth ability, which is recorded at the growth rate of business revenue

End of Table 1

Type	Variables	Variable definition and description
	Ocf	Business operating cash flow, which is the net cash flow from business activities/total assets
	Cash	Corporate cash holdings, which is the corporate money fund holdings/ total assets
	Roa	Corporate return on total assets, which is the corporate net profit/total assets
	Ppe	Ratio of fixed assets of corporates, which is the net fixed assets/total assets
	Eastage	The duration of the corporate shall be recorded as the duration of the corporate +1
	Rta	Rate of return on corporate assets, EBIT/average total assets
	State	Set the dummy variable differentiated by the property rights of corporates, which is 1 for state-owned corporates and 0 for non-state-owned corporates

2.3. Model setting

(1) Basic regression model

Following Gulen and Ion (2016), the two-way fixed effect model with controlled time and individuals was adopted to investigate whether the peer effect existed in the R&D innovation activities of listed companies and whether their R&D innovation activities were affected by economic policy uncertainty. Therefore, the model (1) was constructed:

$$Rd_t = \beta_0 + \beta_1 Rd\_peer_{t-1} + \beta_2 Epu_{t-1} + \beta_3 Controls_{t-1} + \sum ID + \sum Q + \varepsilon_{t-1}. \quad (1)$$

In Model (1), the variable subscripts t and t-1 represent the current time and the lag time by one period, respectively. *ID* represents the fixed effect of controlled individual (corporates) while *Q* is the fixed effect of controlled time (quarter).

(2) Imitation path of corporate size difference

To explore the learning path of corporates imitating the investment behaviors of pee corporates, the following model was constructed, as suggested by Leary and Roberts (2014):

$$Rd_t\left(small\right) = \beta_0 + \beta_1 Rd\_largepeer_{t-1} + \beta_2 Epu_{t-1} + \beta_3 Controls_{t-1} + \sum ID + \sum Q + \varepsilon_{t-1}; \quad (2a)$$

$$Rd_t\left(large\right) = \beta_0 + \beta_1 Rd\_smallpeer_{t-1} + \beta_2 Epu_{t-1} + \beta_3 Controls_{t-1} + \sum ID + \sum Q + \varepsilon_{t-1}. \quad (2b)$$

This test divides peer corporates into two sub-sample groups: larger corporates and smaller corporates according to the median Size. In Model (2a), the main explanatory variable *Rd_largepeer* was replaced to express the R&D innovation intensity of large corporates. Meanwhile, in Model (2b), the main explanatory variable *Rd_smallpeer* was substituted to denote the R&D innovation intensity of small corporates. The meanings of other variables remain unchanged.

(3) Imitation path of corporate property rights difference

The following model was established to investigate the imitation path between corporates having varying nature of property rights:

$$Rd_t\left(private\right)=\beta_0+\beta_1 Rd\_statepeer_{t-1}+\beta_2 Epu_{t-1}+\beta_3 Controls_{t-1}+\sum ID+\sum Q+\varepsilon_{t-1};\quad (3a)$$

$$Rd_t\left(state\right)=\beta_0+\beta_1 Rd\_privatepeer_{t-1}+\beta_2 Epu_{t-1}+\beta_3 Controls_{t-1}+\sum ID+\sum Q+\varepsilon_{t-1}.\quad (3b)$$

This test divides peer corporates into two sub-sample groups: state-owned corporates and non-state-owned corporates according to the nature of the corporates (corporates with the share of state-owned stock right reaching ≥50% were state-owned corporates). In Model (3a), the main explanatory variable *Rd_statepeer* was used to represent the R&D innovation intensity of state-owned corporates in the same industry. Meanwhile, in Model (3b), the main explanatory variable *Rd_privatepeer* was adopted to represent the R&D innovation intensity of non-state-owned corporates in the same industry. The meanings of other variables remain unchanged.

2.4. Descriptive statistical results

Correlation coefficient analysis and VIF analysis are carried out to eliminate multicollinearity problems that may occur in variable selection. The results are shown in the Appendix and the values in parentheses are the VIF values of the continuous real variables.

According to the correlation analysis results, the absolute values of correlation coefficients among the variables selected in this study are all lower than 0.8, and most of them are less than 0.1. Therefore, there is basically no multicollinearity problem among the variables selected in this study. In addition, from the perspective of correlation coefficient, the main explanatory variable *Rd_peer* has a significant positive correlation with the explained variable Rd, and the EPU has a significant positive correlation with *Rd*, indicating that the same-group effect and economic policy uncertainty have an incentive effect on corporate R&D innovation, which is consistent with the expected results. Meanwhile this result shows that the correlation between explanatory variables is not strong, but they are highly correlated with explained variables, indicating that the selection of explanatory variables and control variables in this study is scientific and rigorous. VIF test results show that all individual factors and overall factors are less than 10, which also proves that there is no multicollinearity problem in variable selection in this study.

The descriptive statistical analysis results of variables are shown in the following Table 2.

Table 2. Descriptive statistical analysis results of variables (source: own calculations)

Variables	Obs.	mean	std	min	median	max
Rd	49875	0.050	0.050	0.000	0.035	0.270
Rd_peer	89803	0.150	0.790	0.000	0.044	7.540
Epu	127409	3.818	2.643	0.730	2.847	8.658

End of Table 2

Variables	Obs.	mean	std	min	median	max
Rta	114109	0.050	0.050	–0.110	0.038	0.230
State	127409	0.350	0.480	0.000	0.000	1.000
Size	114109	22.000	1.270	19.400	21.845	25.750
Lev	118876	0.410	0.210	0.040	0.397	0.950
Growth	107260	0.130	0.550	–0.780	0.041	3.220
Ocf	114108	0.030	0.070	–0.150	0.030	0.230
Cash	114108	0.190	0.150	0.000	0.147	1.000
Roa	118092	0.030	0.050	–0.110	0.023	0.210
Ppe	114106	0.220	0.160	0.000	0.187	0.710
Estage	126743	9.410	7.990	–4.000	8.000	27.000

According to the median of the main explanatory variables and the explained variables in the table, the average value of R&D innovation investment of corporates was 0.050, while the maximum value was 0.207 and the minimum value was 0. It shows that the index of R & D innovation investment has a significant rightward bias. These indicate great differences between selected corporate samples in the R&D investment decision. Moreover, from the company size and industry statistics, samples were selected within a large range, with certain scientific weight and robustness.

3. Results analysis

3.1. Basic regression analysis

(1) Full sample regression results

The results in Table 3 were obtained through stepwise regression of the samples and using the clustering standard controlled at the corporate level. Among them, Column (1) displays the regression result with only individual effect fixed in the absence of control variables, Column (2) exhibits the results under the two-way fixed effects, and Column (3) shows the regression results with two-way fixed effects (individual and quarterly-time) after adding the control variables. Results revealed that the regression coefficients of peer corporate R&D innovation activity intensity and economic policy uncertainty were positive at a very high significance level. This manifested the marked peer effect in listed companies' R&D innovation behaviors, which would promote the R&D innovation activities of corporates in the same industry.

Meanwhile, R&D innovation activities of corporates would also be stimulated by economic policy uncertainty. Both the significance level and symbol of the main explanatory variable in regression results of each column were unchanged, thus indicating that the above conclusions were rigorous.

Table 3. Full sample regression results (source: own calculations)

Variables	(1)	(2)	(3)
	Rd	*Rd*	*Rd*
Rd_peer	0.001*** (3.01)	0.001*** (3.03)	0.001*** (2.93)
Epu	0.001*** (8.99)	0.001*** (8.31)	0.001*** (8.00)
Rta			–0.012 (–1.29)
Size			–0.003** (–2.08)
Estage			0.000 (0.67)
Ppe			0.003 (0.63)
Lev			–0.019*** (–4.68)
Growth			–0.002*** (–7.58)
Ocf			0.002 (0.63)
Cash			0.004 (1.13)
Roa			–0.090*** (–9.24)
Constant	0.042*** (80.51)	0.040*** (75.40)	0.109*** (4.05)
Observations	35,500	35,500	82,803
R-squared	0.010	0.0376	0.056
ID FE	YES	YES	YES
Q FE	NO	YES	YES

Note: Figures in brackets are robust standard errors of regression coefficients; ***, ** and * represent the significance level of 1%, 5% and 10% respectively.

(2) Analysis of imitation path regression results based on corporate size difference

Following the classification of corporate size, corporates were grouped using the median of corporate size to test the difference in mutual influences between large and small corporates within the industry. For Models (3a) and (3b), the two-way fixed effect test was performed, with results listed in Table 4.

Columns (1) and (2) represent the regression results of small and large corporates, respectively. The estimated regression parameters of explanatory variables in both Models (2a) and (2b) were positive at a high significance level, thus manifesting mutual learning and imitation behaviors between differently sized corporates in the process of R&D investment. From estimated values, small corporates showed a stronger willingness to learn from and

refer to large corporates, although large corporates seemed less willing to learn from and refer to small corporates.

Table 4. Imitation path regression results based on corporate size difference (source: own calculations)

Variables	(1)	(2)
	Rd(small)	*Rd(large)*
Rd_largepeer	0.016** (2.50)	
Rd_smallpeer		0.000** (2.10)
Epu	0.001*** (7.43)	0.001*** (8.18)
Controls	Yes	Yes
Constant	0.010*** (4.82)	0.131*** (8.94)
Observations	15,160	16,460
R-squared	0.060	0.061
ID FE	YES	YES
Q FE	YES	YES

Note: Figures in brackets are robust standard errors of regression coefficients; ***, ** and * represent the significance level of 1%, 5% and 10% respectively. Limited by the length of this paper, the regression results of control variables are not shown in this table. If necessary, please send to the author for request.

(3) Analysis of imitation path regression results between state-owned corporates and non-state-owned corporates

Corporate samples were grouped based on the nature of their property rights to test the differences in the mutual influence between state-owned corporates and non-state-owned corporates in the industry. For Models (3a) and (3b), the two-way fixed effect test was adopted, with results listed in Table 5.

Columns (1) and (2) display the regression results of non-state-owned corporates and state-owned corporates. Notably, the estimated regression parameters of explanatory variables in Model (3a) were all positive at a certain significance level, but the result was not significant in Model (3b). This indicates that in R&D innovation activities, corporates likelier referred to the R&D innovation intensity of state-owned corporates, while that of non-state-owned corporates was not imitated as intensely.

Table 5. Imitation path regression results based on difference in the nature of property rights (source: own calculations)

Variables	(1)	(2)
	Rd(private)	*Rd(state)*
Rd_statepeer	0.024* (1.87)	

End of Table 5

Variables	(1)	(2)
	Rd(private)	*Rd(state)*
Rd_privatepeer		–0.000 (–1.60)
Epu	0.001*** (6.54)	0.000*** (3.98)
Controls	Yes	Yes
Constant	0.146*** (11.53)	0.115*** (7.91)
Observations	21,665	9,431
R-squared	0.070	0.058
ID FE	YES	YES
Q FE	YES	YES

Note: Figures in brackets are robust standard errors of regression coefficients; ***, ** and * represent the significance level of 1%, 5% and 10% respectively. Limited by the length of this paper, the regression results of control variables are not shown in this table. If necessary, please send to the author for request.

3.2. Robustness test and endogenous test

(1) Robustness test

The robustness test results are shown in Table 6: The measurement standard for the main explanatory variables was replaced to verify the robustness of the experiment. The variable was substituted using the industry-quarterly investment median *rd_medium* sampled corporates to test the original conclusions through two-way fixed effects following the original model, with results displayed in columns (1). Meanwhile, the test was conducted by combining the mixed Tobit model with left merge point of 0, and results were listed in columns (2). The regression symbols and significance levels of main explanatory variables were unchanged in the results obtained by both methods, and results were consistent with previous conclusions, thus indicating the robustness of conclusions herein.

Table 6. Robustness test (source: own calculations)

Variables	(1)	(2)
	Rd	*Rd*
Rd_peer	0.000*** (2.63)	0.003*** (11.98)
Epu	0.001*** (9.70)	0.001*** (8.54)
Controls	Yes	Yes
Constant	0.110*** (11.93)	0.138*** (28.20)
Observations	32,832	32,832

End of Table 6

Variables	(1)	(2)
	Rd	*Rd*
R-squared	0.057	
ID FE	YES	
Q FE	YES	

Note: Figures in brackets are robust standard errors of regression coefficients; ***, ** and * represent the significance level of 1%, 5% and 10% respectively. Limited by the length of this paper, the regression results of control variables are not shown in this table. If necessary, please send to the author for request.

(2) Endogeneity test

The endogeneity test results are shown in Table 7: Referring to Leary and Roberts (2014), the stock yield of corporates (Return) was chosen as the instrumental variable for the endogeneity test by using the two-stage least square method. The F value was 83.4412, without the problem of weak instrumental variables. The remaining results were displayed as follows: Here, the model settings were free from the serious endogeneity problem.

Table 7. Regression result based on two-stage least square method (source: own calculations)

Variables	(1)	(2)
	Rd_peer	*Rd*
Return	0.159*** (0.02)	
Epu	0.032*** (0.00)	–0.001*** (0.000)
Rd_peer		0.054*** (0.01)
Controls	Yes	Yes
Constant	0.397** (0.16)	0.129*** (0.01)
Observations	7,823	7,823
R-squared	0.044	

Note: Figures in brackets are robust standard errors of regression coefficients; ***, ** and * represent the significance level of 1%, 5% and 10% respectively. Limited by the length of this paper, the regression results of control variables are not shown in this table. If necessary, please send to the author for request.

3.3. Selection effect

(1) Selection effect based on corporate size difference

Differently sized corporates tend to make different decisions during R&D investment, hence the R&D investment activities of differently sized corporates are motivated to different degrees by both the peer effect and economic policy uncertainty. Hence, the study further inferred that corporate size was an internal factor influencing the incentive function of the peer effect between corporates and economic policy uncertainty.

The results are shown in Table 8: Two subsamples were respectively verified using Model (1) after overall samples were divided according to the median of Size. From the significance level and regression coefficients, a relatively significant regression result was obtained in the subsample group of small corporates. Meanwhile, the significance level of explanatory variables in the subsample group of large corporates was insufficient, indicating the peer effect affected the peer effect generated by the independent innovation activities of small corporates to a greater extent. The R&D innovation activities of differently sized corporates are thus aggravated by economic policy uncertainty, thereby generating a slightly greater influence on small corporates.

Table 8. Selection effect regression results based on corporate size difference (source: own calculations)

Variables	(1)	(2)
	Rd(small)	*Rd(large)*
Rd_peer	0.001** (1.99)	0.000 (1.26)
Epu	0.001*** (5.91)	0.001*** (7.03)
Controls	Yes	Yes
Constant	0.101* (1.71)	0.123*** (3.51)
Observations	15,654	16,913
R-squared	0.058	0.058
ID FE	YES	YES
Q FE	YES	YES

Note: Figures in brackets are robust standard errors of regression coefficients; ***, ** and * represent the significance level of 1%, 5% and 10% respectively. Limited by the length of this paper, the regression results of control variables are not shown in this table. If necessary, please send to the author for request.

(2) Selection effect based on corporate property rights difference

Policy changes will amplify the uncertainty of the economic environment and generate considerable impacts on investment decisions, risk taking, and other behaviors of micro-corporates. State-owned corporates are very sensitive to the policy orientation of the government. Therefore, compared with non-state-owned corporates, state-owned corporates are more likely to obtain prior information on policy changes, thus making financial arrangements for intertemporal R&D investment activities and reducing their defensive imitation motives.

The results are shown in Table 9: The two subsamples were respectively verified using Model (1) after the whole samples were divided based on the median of the nature of corporates' property rights (State). From the significance level and regression coefficients, regression results in the subsample group of non-state-owned corporates were relatively significant, while the significance level of explanatory variables in the state-owned subsample group was insufficient. This shows that the R&D investment activities of state-owned corporates were not evidently influenced by the peer effect which influenced non-state-owned corporates very markedly, thus conforming to the earlier expected hypothesis.

Table 9. Selection effect regression results based on difference in the nature of property right (source: own calculations)

Variables	(1)	(2)
	Rd(private)	*Rd(state)*
Rd_peer	0.001*** (3.47)	–0.001 (–0.84)
Epu	0.001*** (7.23)	0.000*** (3.81)
Controls	Yes	Yes
Constant	0.107*** (3.19)	0.098** (2.42)
Observations	23,228	9,677
R-squared	0.064	0.053
ID FE	YES	YES
Q FE	YES	YES

Note: Figures in brackets are robust standard errors of regression coefficients; ***, ** and * represent the significance level of 1%, 5% and 10% respectively. Limited by the length of this paper, the regression results of control variables are not shown in this table. If necessary, please send to the author for request.

4. Discussion

The scientific weight and rigorousness of this study were supported by empirical results, while also verifying the veracity of the proposed hypothesis. This meant that the peer effect with the industry as the division basis existed in the R&D innovation behaviors of corporates; this internal mechanism, together with the external impact from economic policy uncertainty, influences the R&D innovation activities of listed companies and generates different incentive functions on the R&D innovation activities of listed companies under different classification bases, specifically as follows:

First, results in Table 3 showed that the peer effect existed in the R&D and innovation activities of listed companies, and could stimulate such activities just as economic policy did, thus supporting Hypothesis 1 and 2 and coinciding with the conclusions of Atanassov et al. (2015) and Peng et al. (2020). This shows that corporates refer to, imitate, and learn from the behavior of corporates in the same industry when conducting R&D investment activities, with said behavior encouraging R&D innovation activities in the whole industry.

Corporates will also accelerate the development of R&D and innovation activities under the impact of economic policy uncertainty. This may be because listed companies will take relatively positive measures when facing the rising economic policy uncertainty, and conduct activities referencing the R&D investment strategies of peer corporates to gain advantages in industry competition. Simultaneously, it also shows that the peer effect has effectively promoted corporates to carry out R&D and innovation activities, which has a positive incentive effect on corporates in various industries to actively perform technological innovation.

Second, Table 4 reveals that one of the logical mechanisms for the peer effect of listed companies was that corporates in the same industry were more inclined to referring to and learning from the R&D innovation decisions of large corporates, while referring to and learning from the decisions of small corporates to a small extent, thus verifying Hypothesis 3. This reveals that for the imitation behavior in R&D investment activities, corporates selectively screened corporates with a business volume instead of blind imitation, thus presenting the learning characteristic of preferential reference.

This finding coincided with the research of Lu et al. (2017), indicating that when making R&D innovation decisions by reference to corporates in the same industry, listed companies tended to imitate large corporates in the industry to acquire more effective behavioral outcome out of managers' learning motivation and risk aversion. This also shows that when choosing reference objects, corporates would screen relatively advantaged corporates to pursue the behavioral outcome of "he who gets in contact with vermillion will become red".

Third, Table 5 shows that one of the logical mechanisms for the peer effect of listed companies was that corporates in the same industry would tend to referring to and learning from the R&D and innovation decisions of state-owned corporates, supporting Hypothesis 4 and coinciding with the study of Wan et al. (2016). Thus, considering the stronger policy sensitivity and information acquisition advantages of state-owned corporates, other corporates in the same industry would skew towards referring to the R&D innovation activities of such corporates, thus reducing the decision-making cost and realizing the "free ride" behavior by using favorable policy information.

Conversely, this also showed that the peer effect of corporates resulted from the avoidance of economic policy uncertainty. The noise interference of market information would aggravate the R&D innovation activities of corporates to avoid adverse consequences, such as the loss of market shares caused by inadequate innovation.

Fourth, Table 8 shows that the motivation of peer effect and economic policy on the R&D innovation activities of differently sized corporates presented a selection effect. Essentially, peer effect and uncertain impact stimulated small corporates more significantly, while the incentive effect on relatively large corporates was small, thus verifying Hypothesis 3 and coincides with the research of Tan and Zhang (2017). A possible economic explanation is that large corporates possess better management mode and operation architecture and are accompanied by a higher degree of irreversibility of their investments, thus leading to their smaller imitation motivation during R&D innovation activities. Moreover, they are less susceptible to economic policy uncertainty, but this is not the case for small corporates.

Last, Table 9 shows that the peer effect and economic policy uncertainty generated a more significant incentive effect on non-state-owned corporates and a smaller incentive effect on state-owned corporates. This verifies Hypothesis 4 and coincides with the research of Wan et al. (2016). To some extent, this explains the selection effect caused by the difference of corporate attributes: with certain advantages in obtaining policy information and more sensitive expectation for capturing policy trends, state-owned corporates show more accurate expectations of the impact of economic uncertainty. Hence, they are more rational and relatively advantaged when making decisions over R&D investment activities, thereby resulting in their weaker motivation to imitate and learn from other corporates. The incentive

effect of peer effect and economic policy uncertainty is also very evident on non-state-owned corporates as they generally do not have such advantages.

Conclusions and implications

Based on the quarterly panel data of listed companies in China during 2010–2020, the influences of the peer effect in listed companies' innovation investment and economic policy uncertainty on the R&D innovation activities of listed companies were explored. The following conclusions were drawn: (1) The peer effect widely exists in the R&D innovation activities of listed companies and motivates their R&D innovation activities; (2) Economic uncertainty stimulates the innovation investment activities of corporates; (3) In the simulation logic of peer effect, smaller corporates in the same industry make innovation investment decisions more by referencing the R&D innovation intensity of large corporates, while non-state-owned corporates are more inclined to decision-making by referring to the R&D innovation intensity of state-owned corporates; and (4) Economic policy uncertainty exerts a more promoting effect on non-state-owned corporates and small-scale corporates.

According to the abovementioned conclusions, the following policy suggestions are proposed: (1) the government and relevant institutions should ensure the long-term and steady implementation of policies when formulating economic policies. The impact of policy changes on economic fluctuations may lead to investment-driven behaviors of listed companies, which may reduce the operating efficiency of financial markets, or cause potential risks. Simultaneously, the government and relevant institutions should also improve the market mechanism, establish an efficient information disclosure and supervision mechanism, and prevent investors from blindly convergent investment behavior. While encouraging corporates to develop and innovate, they should also strengthen supervision measures to prevent market speculators from following suit behavior which subsequently cause abnormal market fluctuations and risks.

(2) The government and relevant departments can effectively use the peer effect of R&D innovation activities, issue a series of targeted policies to encourage and promote R&D innovation activities in target industries, encourage and promote the innovation activities of individual state-owned corporates, or even drive the whole industry to carry out R&D innovation through special support for the "leading" companies in the industry. The market should also be encouraged to build a perfect information disclosure mechanism and effectively transmit market information, thereby reducing the adverse consequences caused by blind imitation of corporates in the market and further effectively optimizing the quality and efficiency of market operation.

(3) Corporate managers must strengthen their own management ability, which enable the avoidance of blindly imitating investment decision-making behavior of other companies in the same industry to effectively avoid the losses caused by blind herding behaviors. By constructing a reasonable long-term learning mechanism, management's theoretical investment knowledge and practical experience are enriched and the internal incentive system of managers are optimized, thus alleviating the principal-agent problem and reducing the blind herding investment of corporates to better dig the potential opportunities in the market.

There are still some limitations found in this study. For example, peer corporates were not divided from the level of geographical space or other more levels. Only the data of Chinese listed companies were chosen, while the behaviors of non-listed small and medium-sized corporates and micro-corporates were not accordingly investigated. The suggestions obtained may thus be inapplicable to non-listed companies. Because the ultimate goal of this study is to solve such problems as the insufficient effective motivation of corporates' R&D innovation activities and excessive investment concentration, it is a direction worthy of deep investigation to analyze the peer effect in corporates' technology R&D innovation from the perspective of uncertainty in succeeding studies.

Funding

This study was supported by National Social Science Foundation of China (No. 22BJY251), Fundamental Research Funds for the Central Universities of Zhongnan University of Economics and Law (No. 2722023AK002) and Postgraduate Research Innovation Platform Project of Zhongnan University of Economics and Law (No. 202210564).

Author contributions

All authors have participated in the concept and design, analysis and interpretation of data,drafting or revising of the manuscript.

Disclosure statement

Authors do not have any competing financial, professional, or personal conflict of interests from other parties.

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APPENDIX

Correlation analysis

	Rd	*Rdp_peer*	*Epu*	*Rta*	*Size*	*Lev*	*Growth*	*Ocf*	*Cash*	*Roa*	*Ppe*	*Estage*	*State*	*Industry*	*Quarter*
Rd	1														
Rd_peer	0.068***	1													
Epu	0.008*	0.049***	1												
Rta	−0.052***	0	−0.006**	1											
Size	−0.008*	−0.034***	0.117***	−0.018***	1										
Lev	0.008*	−0.012***	−0.019***	−0.126***	−0.018***	1									
Growth	0	−0.00100	0	0	0.007**	0.002	1								
Ocf	−0.046***	−0.018***	0.034***	−0.750***	0.068***	−0.045***	0	1							
Cash	0.015***	0.037***	−0.102***	0.013***	−0.242***	−0.037***	−0.001	0.036***	1						
Roa	−0.048***	0	−0.00400	0.998***	−0.013***	−0.123***	0	−0.769***	0.009***	1					
Ppe	−0.00100	−0.038***	−0.083***	−0.011***	0.195***	0.029***	0.004	0.098***	−0.356***	−0.008***	1				
Estage	−0.013***	0.00500	0.073***	−0.00400	0.367***	0.068***	0.004	−0.018***	−0.254***	−0.007**	0.155***	1			
State	−0.007*	−0.026***	−0.098***	−0.007**	0.330***	0.034***	0	−0.005*	−0.118***	−0.007**	0.218***	0.438***	1		
Industry	−0.00600	−0.00500	0.007***	0.00500	−0.057***	0.016***	0.001	−0.054***	0.098***	0.00500	−0.212***	0.00200	0.053***	1	
Quarter	0	0.007**	0.077***	−0.00200	0.030***	−0.00300	0.005	−0.020***	−0.035***	0.014***	−0.006**	−0.139***	−0.051***	0.002	1
VIF value		(1.014)	(1.034)	(5.214)	(1.665)	(1.641)	(1.088)	(1.535)	(1.23)	(4.448)	(1.245)	(1.353)			