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Impact of Enterprise Research and Development Innovation on Brand Equity Value

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ABSTRACT

This article aimed to explore the impact of enterprise R&D (research and development) innovation on brand equity value, and deeply analyze the moderating role of monetary policy uncertainty in this relationship. In response to the difficulties in identifying the causal relationship between enterprise R&D innovation investment and brand equity, the lack of unified quantitative measurement standards for brand equity, and the unclear mechanism of the impact of monetary policy uncertainty on enterprise innovation behavior and brand equity, this article constructed a multiple regression model based on relevant data from Suning.com from 2010 to 2022, systematically analyzed the relationship between enterprise R&D innovation and brand equity value, and conducted in-depth analysis on the moderating variable of monetary policy uncertainty. By defining and quantifying R&D innovation investment, patent output, brand equity value, and monetary policy uncertainty, a multiple regression model was constructed to systematically analyze the impact of monetary policy uncertainty on the relationship between R&D innovation and brand equity value. The stability of the model was verified through model evaluation and residual analysis, and combined with methods such as significance analysis and multicollinearity diagnosis, it was demonstrated that both R&D innovation investment and patent output of enterprises can significantly enhance brand equity value, and monetary policy uncertainty can significantly suppress the value-added effect of R&D innovation investment and patent output on brand equity value.

1. INTRODUCTION

As the process of globalization continues to advance and market competition becomes increasingly fierce, enterprises are faced with unprecedented challenges and opportunities. To stand out in the competition, enterprises continuously invest large amounts of resources in research and development (R&D) innovation to enhance their competitiveness and market position. R&D innovation is seen as a critical factor for enterprises to achieve sustainable development and long-term growth. However, despite the increasing investment in R&D by enterprises year by year, how to effectively quantify the impact of these investments on brand equity value remains a major challenge in enterprise management and academic research. Specifically, the quantitative relationship between R&D investment and brand equity is complex and variable, involving the interaction of multiple variables and external factors. In addition, existing research often faces problems such as difficulty in data acquisition, complex variable measurement, and incomplete model construction when identifying the causal relationship between R&D innovation and brand equity. To address these issues, this article provides a systematic empirical analysis to deeply investigate the specific influence mechanism of enterprise R&D innovation on brand equity value. The purpose of this study is to reveal the direct and indirect effects of R&D investment and innovation patent output on brand equity value, and to

analyze the moderating role of monetary policy uncertainty in this process, providing scientific decision-making basis for enterprises in R&D investment and brand management.

This article proposes two main research hypotheses regarding this.

H1: Both R&D innovation investment and patent output of enterprises can significantly enhance brand equity value.

Specifically, the investment of enterprises in R&D not only includes R&D funds, but also R&D personnel, R&D facilities, and R&D projects. These investments can enhance the market competitiveness and popularity of the enterprise brand through improving product quality, launching new products, and improving production efficiency, thereby increasing the brand equity value.

H2: Monetary policy uncertainty significantly suppresses the value-added effect of R&D innovation investment and patent output on brand equity value.

In an uncertain economic environment, enterprises face increased risks and uncertainties, and may choose to reduce R&D investment to mitigate risks, leading to a weakening of the positive impact of R&D innovation on brand equity value.

This article aims to systematically explore the impact mechanism of enterprise R&D innovation on brand equity value, and reveal the moderating role of monetary policy uncertainty in this process. By establishing a multiple regression model and combining methods such as significance analysis, multicollinearity diagnosis, and residual analysis to conduct in-depth analysis of the model results, the two hypotheses proposed are scientifically validated.

2. RELATED WORK

In terms of enterprise R&D innovation, there have been many scholars who have conducted extensive research on the issue of enterprise R&D innovation. The R&D and innovation activities of enterprises are not only the key driving force for their survival and prosperous development (Jarle and Andreas, 2020; Papanastassiou et al., 2020; Pan et al., 2021), but also have a broad and far-reaching positive impact on the progress and sustainable development path of the whole socio-economic system (Kou et al., 2020; Xu et al., 2021; Hao et al., 2022). Researchers use different perspectives (Xie and Wang, 2020; Xiao et al., 2022; Roper and Turner, 2020) and fields (Lin et al., 2020; Zhong and Chen, 2024; Xia, 2024), combined with various research methods, to study enterprise R&D innovation (Wei et al., 2021; Antons et al., 2020; Tongtong and Xinhang, 2024). Li T (Li et al., 2021) sampled 1,221 non-financial listed enterprises in China from 2010 to 2019 and used a panel threshold model to analyze the threshold effect of financialization on enterprise R&D innovation. In order to investigate whether government behavior or enterprise investment can more effectively promote regional innovation performance, Zheng Y et al. (Zheng et al., 2021) empirically analyzed panel data from China from 2008 to 2016, examining the impact of high-tech enterprise recognition, enterprise R&D investment, and institutional environment on regional innovation performance. Scholars such as Shao S (Shao et al., 2020) summarized the impact of environmental regulation on enterprise innovation from various innovation perspectives.

Additionally, there are also large amounts of scholars to analyze the research related to brand equity value. The research includes the evaluation and processing of brand equity value (Gupta et al., 2020; He and Calder, 2020; Leite, 2024), as well as the study of the correlation and reliability of brand equity value (Chukurna, 2020; Hofmann et al., 2021; Park and Jang, 2021). By applying stakeholder theory, scholars such as Kim H G (Kim et al., 2021) studied how multiple dimensions of enterprise social responsibility have different impacts on global brand value, as well as the potential impact of enterprise size on the relationship between diversified enterprise social responsibility activities and global brand value. To study the factors that determine urban brand equity, Hanna G et al. (Hanna, 2020) conducted relevant analysis on urban brand equity based on a systematic literature review and successfully summarized the relevant factors that determine urban brand equity. To investigate how non-fungible tokens (NFTs) can bring value to brands,

scholars such as Colicev A (Colicev, 2023) demonstrated the enormous potential of NFTs to become independent brand equity by linking brand NFT strategies with the marketing funnel stage. In the research on innovation R&D and brand equity, He Q et al. (He et al., 2020) constructed a panel data model utilizing accounting data of Chinese listed enterprises from 2012 to 2017, providing new insights into the relationship between brand equity and enterprise level productivity, and indicating that brand equity has an essential role to play in China's future growth. However, the current research on the impact of enterprise R&D innovation on brand equity value (Andonova and Losada-Otalora, 2020; Paswan et al., 2021; Krasnikov and Jayachandran, 2022) is still low on issues such as the quantification of R&D investment and brand equity, and the identification of causal relationships. Therefore, this article explored the impact of enterprise R&D innovation on brand equity value, providing decision-making basis for enterprises in R&D investment and brand management.

3. DESIGN AND METHODS

3.1 Data Collection and Sample Selection

The study data comes from Suning.com's annual reports from 2010 to 2022 and other publicly available market research data. The collected data roughly includes R&D innovation investment data, education level data, patent application and disclosure data, patent type data, customer satisfaction data, and monetary authority balance sheet data.

Suning.com is an enterprise that occupies an important position in the Chinese retail market, and its annual report includes various situations of Suning.com throughout the year. Among them, the financial statements in the annual report provide detailed records of the enterprise's R&D expenditures, R&D personnel composition, and patent applications and disclosures for each year. In addition, the patent type data is sourced from iResearch Consulting; the customer satisfaction data is sourced from the China Customer Satisfaction Index Research Results Release Platform; the data of the monetary authority's balance sheet comes from the Investigation and Statistics Department of the People's Bank of China. These data not only cover Suning.com's R&D innovation activities, but also reflect the dynamic changes in its brand equity.

As a leading retail enterprise in China, Suning.com has strong representativeness in its practice of R&D innovation and brand building. Choosing Suning.com as a research sample can not only provide profound insights into large enterprises, but also help reveal the actual impact of R&D innovation on brand equity value in specific industries. The scale, industry status, and market influence of Suning.com make its data highly feasible and valuable for analyzing the relationship between R&D innovation and brand equity. In addition, by studying the data of Suning.com, experience and guidance can be provided for brand management and R&D strategies of similar enterprises.

3.2 Definition and Quantification of R&D Innovation Investment

R&D innovation investment means the resource investment made by enterprises to promote the growth and application of new products and technologies. This type of investment typically includes multiple aspects such as human resources, financial resources, and time. R&D innovation investment is the foundation of enterprise innovation activities, reflecting the degree of importance that enterprises attach to future development and the potential for enhancing competitiveness. It not only covers direct R&D expenses such as personnel salaries, equipment purchases, and material costs, but also includes indirect inputs such as the education background and work experience of R&D personnel.

In this study, R&D innovation investment is mainly quantified through two dimensions: R&D expenditure and R&D personnel education. In the R&D expenditure data of Suning.com from 2010 to 2022, the R&D expenditure data for 2022 is missing, so it is necessary to replace the missing values in the R&D expenditure data. Figure 1 shows the relevant data of R&D expenditure after replacing missing values.

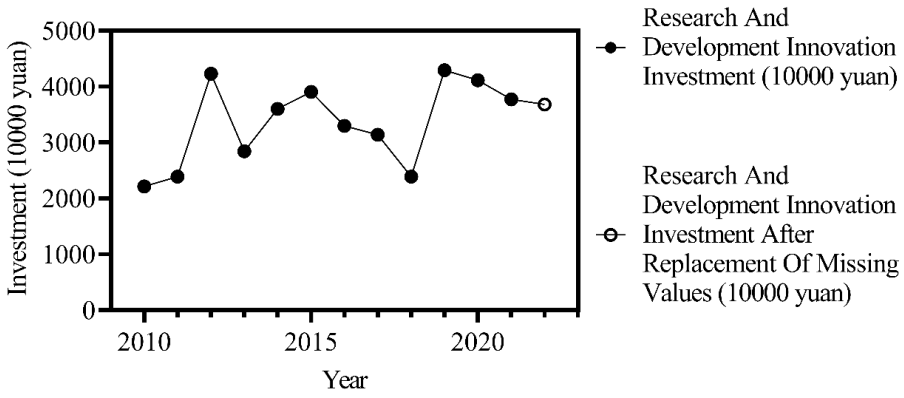

Figure 1. R&D expenditure data with missing values replaced

In Figure 1, the method used in the missing value replacement operation is the linear trend of neighboring points method, which is estimated by the least squares method (Maeng and Fryzlewicz, 2024; Qader et al., 2021; Chu et al., 2022). The hollow circle in Figure 1 refers to the R&D expenditure data replaced by the linear trend method using adjacent points. From Figure 1, it can be preliminarily learned that the R&D expenditure data of Suning.com shows certain fluctuations from 2010 to 2022, and the fluctuation amplitude is relatively large.

R&D expenditure directly reflects an enterprise's financial investment in innovation activities and is a core indicator for measuring an enterprise's R&D efforts. The educational background of R&D personnel reflects the enterprise's investment in talent, reflecting the professional level and innovation ability of the R&D team. Figure 2 shows the educational level of R&D personnel at Suning.com from 2010 to 2022.

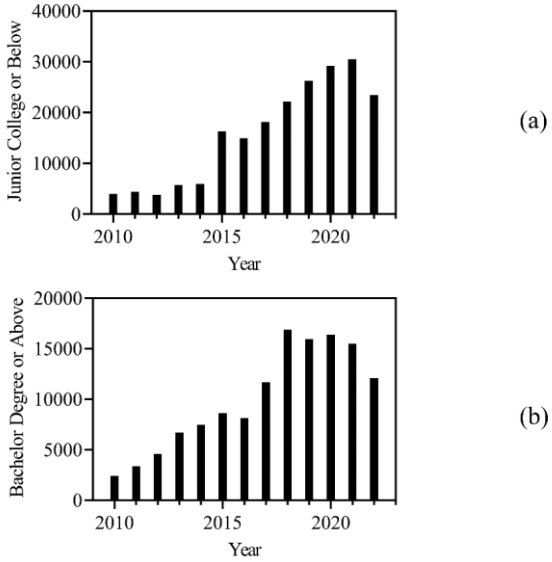

Figure 2. Education status of R&D personnel from 2010 to 2022

Figure 2 (a): R&D personnel with junior college degree or below from 2010 to 2022

Figure 2 (b): R&D personnel with bachelor's degree or above from 2010 to 2022

From Figures 2 (a) and (b), it can be preliminarily learned that the amount of R&D personnel at Suning.com has been continuously increasing from 2010 to 2022. However, the amount of R&D personnel with a bachelor's degree or above has shown a downward trend since 2020, while those with a junior college degree or below have shown a downward trend since 2021.

The education level of R&D personnel is quantified, with 1 representing researchers with a junior

college degree or below and 2 representing researchers with a bachelor's degree or above. The educational background of all researchers in a year is summed up and averaged to represent the average educational background for that year. The quantified educational background of Suning.com R&D personnel from 2010 to 2022 is shown in Table 1:

Table 1. Quantitative education status of R&D personnel

Year	Total Educational Background	Number of Research and Development Personnel	Average Educational Background
2010	8816	6398	1.38
2011	11123	7751	1.44
2012	12932	8364	1.55
2013	19149	12450	1.54
2014	20855	13391	1.56
2015	33572	24951	1.35
2016	31249	23102	1.35
2017	41484	29814	1.39
2018	55913	39031	1.43
2019	58154	42196	1.38
2020	61989	45598	1.36
2021	61540	46036	1.34
2022	47675	35583	1.34

Table 1 shows the quantified educational background of R&D personnel. It can be learned that after quantification, the educational background of the researchers has become numerical, which facilitates subsequent analysis. From the average education level, it can be preliminarily learned that the R&D personnel of Suning.com have fluctuated slightly from 2010 to 2022. Although the total education level and amount of R&D personnel are mostly on the rise, the change in average education level is not significant. In order to better use the educational background of researchers as a quantitative indicator of R&D innovation investment, the total educational background of R&D personnel is selected to quantify R&D innovation investment.

The comprehensive data obtained by standardizing the weighted method of R&D expenditure and the total education level of R&D personnel is utilized as R&D innovation investment data, and the formula is:

$$\rho_i = w_1 \cdot \frac{\vartheta_i - \mu_\vartheta}{\sigma_\vartheta} + w_2 \cdot \frac{\tau_i - \mu_\tau}{\sigma_\tau} (1)$$

Among them, ϑ_i represents the R&D expenditure in the i-th year; τ_i is the total educational level of R&D personnel in the i-th year; ρ_i is the investment in R&D innovation; w_1 and w_2 are corresponding weights. The setting of weights is based on expert opinions and practical experience.

The reason for choosing these two indicators as the basis for measuring R&D innovation investment is that R&D expenditure is a widely used measurement standard that can directly quantify the financial investment of enterprises in the innovation process; secondly, the total education level of R&D personnel can serve as an indirect indicator of innovation capability, and teams with higher education levels typically have stronger research capabilities and innovation potential.

3.3 Definition and Quantification of Patent Output

Patent output refers to the quantity and quality of patents obtained by an enterprise in its R&D activities. Patents, as a form of legal protection for innovative achievements, are a concrete manifestation of enterprise R&D innovation. Patent output can reflect the ability and achievements of enterprises in technological innovation, and is also an essential indicator for measuring the efficiency of enterprise innovation.

In this study, patent output is quantified by the amount of patent applications. Figure 3 shows the patent output of Suning.com from 2010 to 2022.

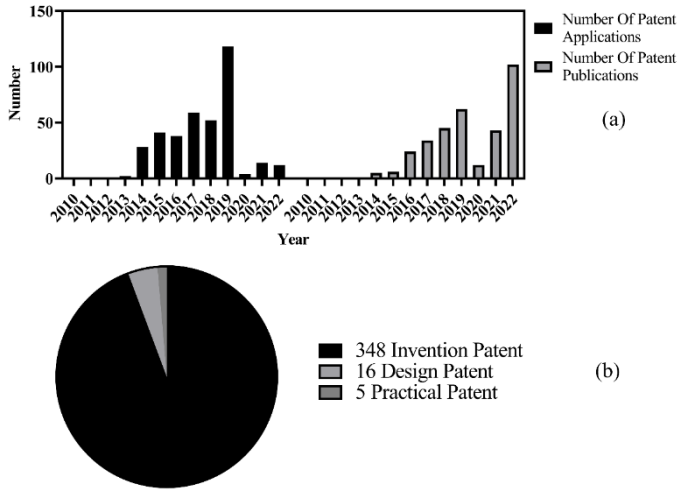

Figure 3. Patent data of Suning.com from 2010 to 2022

Figure 3 (a): Patent applications and public data of Suning.com from 2010 to 2022

Figure 3 (b): Patent type data of Suning.com from 2010 to 2022

Figures 3 (a) and (b) show the patent situation of Suning.com from 2010 to 2022. From Figure 3 (a), it can be preliminarily seen that the patent data of Suning.com shows a certain upward trend before 2019, reaching its peak in 2019, but begins to decrease significantly after 2019. From Figure 3 (b), it can be preliminarily seen that most of patents of Suning.com are invention patents, with 348 patents; secondly, there are 16 design patents.

The number of patents is the most intuitive and easily quantifiable indicator, which can directly reflect the innovation achievements of an enterprise during a certain period. The reason for choosing the number of patents as the measurement standard is that the number of patents is a universal standard for measuring the innovation achievements of enterprises, with strong operability and comparability; secondly, it can accurately reflect the efforts and achievements of enterprises in technological innovation. Although relying solely on the number of patents cannot fully reflect the quality of innovation, the process of obtaining patents usually involves strict examination, which can to some extent ensure their technological content and commercial value.

3.4 Definition and Quantification of Brand Equity Value

Brand equity value refers to the comprehensive performance and market value of a brand in the market, which includes multiple aspects such as brand awareness, reputation, loyalty, and market share. Brand equity is the intangible assets accumulated by enterprises through long-term market operations and brand building, and have important strategic significance. Enterprises with high brand equity value often have stronger market competitiveness and higher customer loyalty, which can occupy a favorable position in the market and achieve long-term profit growth. In this study, brand equity value is quantified through the indicator of customer satisfaction. In the platform for publishing research results on customer satisfaction index in China, only customer satisfaction data from Suning.com from 2012, 2013, and 2015-2022 are included. Therefore, it is necessary to replace missing values in the customer satisfaction data. The replacement method is consistent with the method of R&D expenditure data, using linear interpolation of neighboring points.

Customer satisfaction reflects consumers' overall perception and experience of a brand, and is a direct reflection of brand reputation and loyalty. Choosing customer satisfaction as the standard for measuring brand equity value is because customer satisfaction is the core indicator for measuring the relationship between a brand and consumers. High satisfaction means that the

brand has a good reputation and a loyal customer base in the market. In addition, customer satisfaction can intuitively reflect the actual performance of a brand in the market, with high credibility and representativeness.

3.5 Definition and Quantification of Monetary Policy Uncertainty

Monetary policy uncertainty refers to the economic environment uncertainty caused by changes in monetary policy, which may affect investment decisions and market expectations of enterprises. The uncertainty of monetary policy is usually related to factors such as interest rate adjustments by the central bank and changes in the balance sheet of monetary authorities, which have an impact on the financing costs, cash flow management, and market environment of enterprises. High monetary policy uncertainty typically means that businesses face greater risks and uncertainties when making long-term investment decisions, thereby inhibiting their R&D innovation investment and market expansion plans.

In this study, monetary policy uncertainty is quantified through the balance sheet of the Bank of China's monetary authority. The changes in the assets and liabilities of monetary authorities reflect the monetary policy orientation of central banks in different economic cycles, and their volatility can serve as a proxy indicator of monetary policy uncertainty. In addition, the total assets in the balance sheet of the monetary authority of Bank of China are equal to the total liabilities, because the main goal of the monetary authority of Bank of China is to maintain financial stability and regulate the money supply, and the structure and changes of its balance sheet are more influenced by monetary policy. This is also the main reason why the balance sheet of monetary authorities can quantify the uncertainty of monetary policy. Figure 4 shows the monetary authority asset liability data of Bank of China from 2010 to 2022.

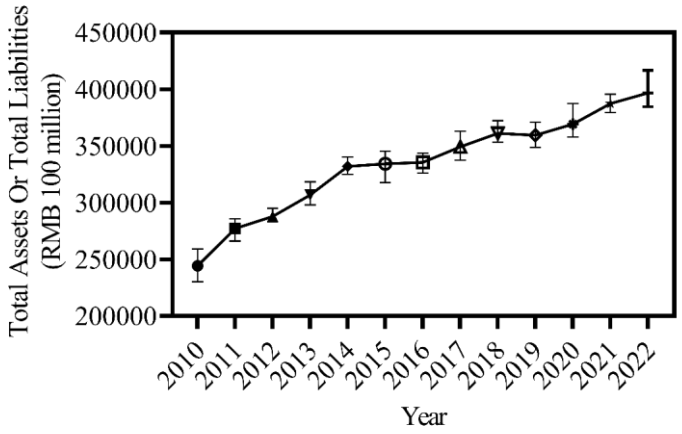

Figure 4. Asset and liability data of Bank of China monetary authority from 2010 to 2022

Based on Figure 4: from an overall trend perspective, the total assets or total liabilities of the monetary authorities are showing an upward trend, rising from around 25 trillion yuan in 2010 to around 40 trillion yuan in 2022. From an average perspective, the total assets or total liabilities of Bank of China also show an upward trend from 2010 to 2022. Although there is a slight decline in some years (such as 2019), the magnitude of the decline is not significant.

3.6 Quantitative analysis of control variables

The control variables in this study refer to those variables that may affect brand asset value and may be related to R&D innovation investment and patent output to some extent. There are three parts to selecting control variables, namely: enterprise size, macroeconomic environment, and market competition level. The size of the enterprise is quantified by its total assets and operating revenue, the degree of market competition is quantified by the number of enterprises in the same market, and the macroeconomic environment is quantified by the number of unemployed people and GDP (Gross Domestic Product). These data are respectively from the annual reports of the National Bureau of Statistics and Suning.com. Among them, the total assets

and operating revenue of Suning.com are shown in Figure 5:

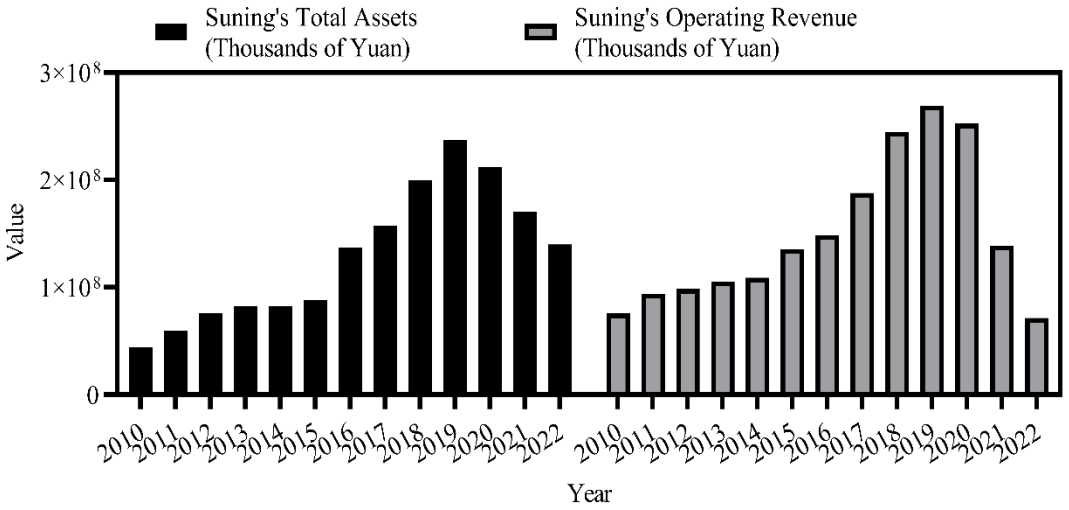

Figure 5: Total Assets and Operating Revenue of Suning.com

Figure 5 shows the total assets and total operating inputs of Suning.com from 2010 to 2022. From Figure 5 (left), it can be seen that the total assets of Suning.com have fluctuated to some extent between 2010 and 2022, with an upward trend from 2010 to 2019 and a gradual decline starting from 2020. From Figure 5 (right), it can be seen that Suning.com 'total operating revenue is similar to its total assets, both of which have been rising for a period of time before gradually starting to decline.

Figure 6 shows the correlation between the number of wholesale and retail enterprises, GDP, and unemployment.

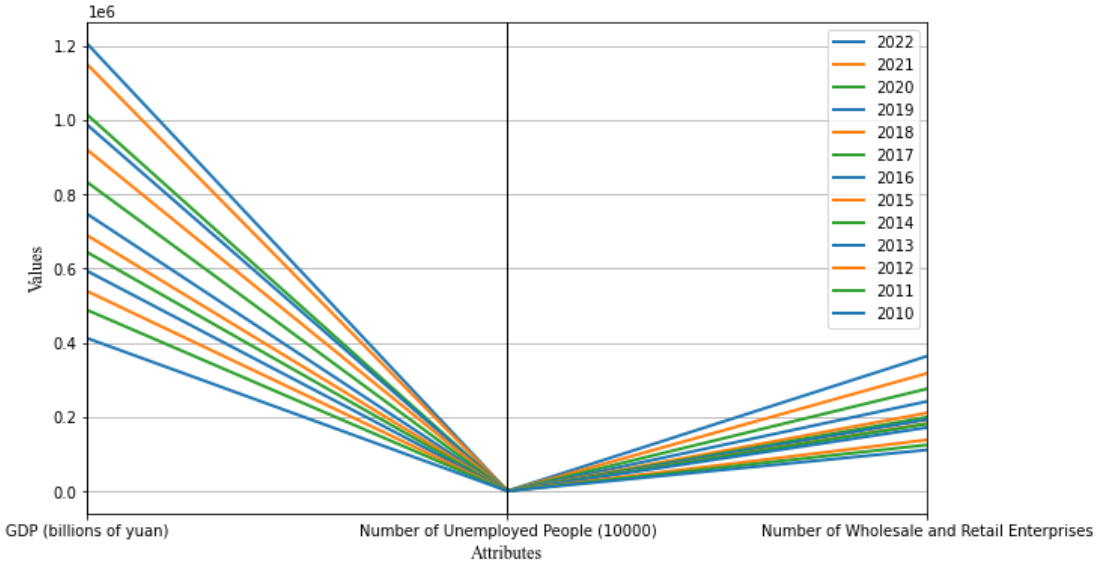

Figure 6: The number of wholesale and retail enterprises, GDP, and unemployment rate

Figure 6 is a parallel graph of the number of wholesale and retail enterprises, GDP, and unemployment. The horizontal axis represents GDP, unemployment, and wholesale and retail employment. It can be seen that the GDP from 2010 to 2022 has shown an upward trend year by year, while the number of unemployed people has not changed much between different years macroscopically. The intersection of the lines in the middle is more concentrated, and the number of wholesale and retail enterprises is similar to the trend of GDP, also showing an upward trend, but the overall growth rate is not as large as that of GDP.

3.7 Establishment of Regression Model

Regarding hypothesis 1: both R&D innovation investment and patent output of enterprises can significantly enhance brand equity value, and the following regression model is established:

$$Z_i = \alpha_0 + \alpha_1 \cdot \rho_i + \alpha_2 \cdot \varphi_i + \beta_1 \cdot S_i + \beta_2 \cdot C_i + \beta_3 \cdot E_i + \varepsilon_i (2)$$

Among them, Z_i represents the brand equity value in the i-th year; φ_i is the amount of patents in the i-th year; α_0 is a constant term; α_1 and α_2 are corresponding coefficients; ε_i is the error term; S_i is the scale of the enterprise; C_i is the degree of market competition; E_i is the macroeconomic environment; β_1, β_2, and β_3 are the corresponding coefficients, respectively.

Regarding hypothesis 2: monetary policy uncertainty significantly suppresses the value-added effect of R&D innovation investment and patent output on brand equity value, and the following regression model is established:

$$Z_j = \gamma_0 + \gamma_1 \cdot \rho_j + \gamma_2 \cdot \varphi_j + \gamma_3 (\rho_j \cdot \delta_j) + \gamma_4 (\varphi_j \cdot \delta_j) + \mu_1 \cdot S_i + \mu_2 \cdot C_i + \mu_3 \cdot E_i + \varepsilon_j (3)$$

Among them, δ_i represents monetary policy uncertainty; γ_0 is a constant term; μ_1, μ_2, and μ_3 are the corresponding coefficients, respectively.

4. DEMONSTRATIONS

4.1 Descriptive Statistics and Correlation

Descriptive statistics are conducted on R&D expenditures, R&D personnel education, R&D innovation investment, patent applications, customer satisfaction, and monetary authority asset liability data. The statistical findings are displayed in Table 2:

Table 2. Descriptive statistics of each data

Data Type	Minimum Value	Maximum Value	Mean Value	Standard Deviation
Research and Development Expenditure (Ten thousand RMB)	2213.00	4293.00	3374.54	727.09
Total Educational Background	8816.00	61989.00	35727.00	20025.44
Research and Development Innovation Investment	6835.10	44626.50	26021.26	14110.70
Number of Patent Applications	2.00	102.00	28.38	29.33
Customer Satisfaction	27.70	78.30	53.01	16.78
Total Assets or Total Liabilities (RMB 100 million)	244267.69	396678.77	333937.89	44554.46

The maximum, minimum, mean and standard deviation of each data can be observed from Table 2. Summarizing the data in Table 2: the standard deviation of R&D expenditure is 727.09, indicating that the R&D expenditure of Suning.com fluctuates within a narrow range, averaging around 33.7454 million RMB per year. This also suggests that Suning.com's R&D expenditure is relatively stable. The standard deviation of the total education level of R&D personnel is 20025.44, with a mean of 35727. Both the mean and standard deviation are at a relatively high level, and the difference between the maximum and minimum values is large, indicating that the R&D personnel of Suning.com are constantly changing with the increase of years. The R&D innovation investment is a comprehensive data of R&D expenditure and total education background, which has a minimum value of 6835.1, a maximum value of 44626.5, a mean value of 26021.26, and a standard deviation of 14110.7, indicating that Suning.com's R&D and innovation investment fluctuates significantly with the growth of years from 2010 to 2022. The number of patent applications ranges from the lowest 2 to the highest 102, with a mean of about 28 patent applications per year. However, the standard deviation is relatively large, indicating significant fluctuations in the amount of patent applications between years. In terms of customer satisfaction, the rating ranges

from 27.7 to 78.3, with a mean of 53.01 and a standard deviation of 16.78, indicating that there is some fluctuation in customer satisfaction between different years. In terms of total assets or total liabilities, in terms of standard deviation, the standard deviation is 4455.446 billion yuan. Although it is within a large range, the mean value is also within a large range, which is 33393.789 billion yuan. This indicates that monetary policy also fluctuates with annual changes.

All data are subjected to correlation analysis. The correlation coefficients of various data are illustrated in Figure 5:

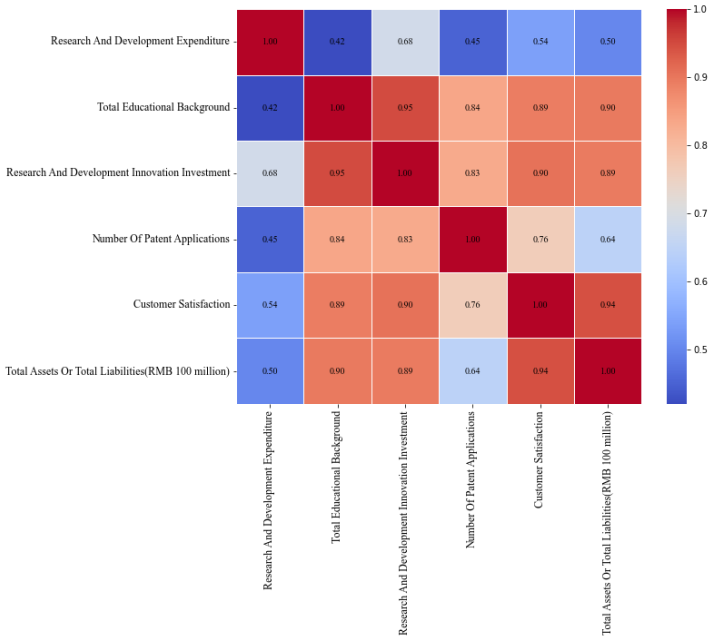

Figure 5. Correlation coefficients between various data

Figure 5 shows the correlation heatmap between six different data points. The color of each cell represents the degree of correlation between variables, with darker colors indicating greater correlation. Overall, there is a strong positive correlation between R&D expenditure, total education level of R&D personnel, R&D innovation investment, and customer satisfaction. In addition, it can be noted that R&D innovation investment is obtained through standardized weighting method based on R&D expenditure and total education of R&D personnel, and their correlations with customer satisfaction are 0.54, 0.89, and 0.9, respectively. It can be seen that after the integration of two data, the correlation between R&D innovation investment and customer satisfaction is higher, which also indicates that using the comprehensive data of R&D expenditure and total education background as a measure of R&D innovation investment has a good effect. In terms of total assets or total liabilities, their correlation with R&D innovation investment and customer satisfaction is also at a high level, at 0.89 and 0.94, respectively. In terms of patent application data, its correlation with total assets or total liabilities is 0.64, which is lower than other data but still at a relatively high level.

In addition, when conducting correlation analysis on control variables, it was found that there is a positive relationship between enterprise size and brand value, a positive relationship between macroeconomic environment and R&D innovation investment, and a positive relationship between market competition level and customer satisfaction. This is also why this article uses enterprise size, macroeconomic environment, and market competition level as control variables. Quantifying the control variables can more efficiently analyze the relationship between the independent and dependent variables.

4.2 Impact of R&D Innovation Investment and Innovation Patent Output on Brand Equity Value

Hypothesis 1 proposes that both R&D innovation investment and patent output of enterprises can

significantly enhance brand equity value. To verify hypothesis 1, R&D expenditure and patent application quantity are used as independent variables, and customer satisfaction is utilized as the dependent variable to quantify and verify the impact of R&D innovation investment and innovation patent output on brand equity value. Table 3 presents the correlation data between the significance test and collinearity diagnosis of the regression model for hypothesis 1.

Table 3. Regression model correlation coefficient data for hypothesis 1

Index	Indicator Symbol	Model Prediction Results	P-value	t-value	VIF
Research and Development Innovation Investment	ρ_i	$\alpha_1 > 0$	0.03	2.34	1.8
Patent Output	φ_i	$\alpha_2 > 0$	0.01	2.78	2.1

Table 3 shows the significance test results and multicollinearity index analysis of ρ_i and φ_i. It can be seen that both α_1 and α_2 are greater than 0, indicating a positive impact of R&D innovation investment and patent output on brand equity value. A P-value less than 0.05 means that there is significance between the independent and dependent variables. The P-value of ρ_i is less than 0.05, suggesting that at a significance level of 5%, the impact of ρ_i on the dependent variable is significant. This also suggests a significant correlation between R&D innovation investment and brand equity value; similarly, if the P-value of φ_i is less than 0.05, it means that at a significance level of 5%, the impact of patent output on brand equity value is significant. The t-value is used to test whether the regression coefficient is significantly different from 0. The larger the absolute value of the t-value indicates that the variable is less likely to be due to random error (generally, a t-value greater than 1.96 is considered significant). The t-values of ρ_i and φ_i are 2.34 and 2.78, respectively, indicating that the regression coefficients between R&D innovation investment and patent output are significant. Variance Inflation Factor (VIF) is an indicator utilized to detect multicollinearity, and the larger the VIF, the more severe the multicollinearity. It is generally accepted that a VIF less than 5 is not a serious multicollinearity problem, while a VIF greater than 5 indicates a serious multicollinearity problem. The VIFs of ρ_i and φ_i are 1.8 and 2.1, respectively, so the serious problem of multicollinearity between ρ_i and φ_i can be seen to be non-existent. It can be concluded from the data in Table 3 that both R&D innovation investment and patent output have a significant positive impact on brand equity value. Although there is some multicollinearity, the degree is relatively mild and does not cause serious effects.

4.3 Moderating Effect of Monetary Policy Uncertainty

Hypothesis 2 proposes that monetary policy uncertainty significantly suppresses the value-added effect of R&D innovation investment and patent output on brand equity value. The interaction term is applied to interact monetary policy uncertainty with R&D innovation investment and patent output, and a multiple regression model containing the interaction term is established. Table 4 contains the significance test and multicollinearity diagnosis results for the regression model of hypothesis 2.

Table 4. Significance and collinearity test results for hypothesis 2 regression model

Index	Indicator Symbol	Model Prediction Results	P-value	t-value	VIF
Research and Development Innovation Investment	ρ_j	$\gamma_1 > 0$	0.04	2.15	2.3
Patent Output	φ_j	$\gamma_2 > 0$	0.02	2.67	2.1

Interaction Term between Research and Development Innovation Investment and Monetary Policy Uncertainty	$(\rho_j \cdot \delta_j)$	$\gamma_3 < 0$	0.05	2.45	1.9
Interaction Term between Patent Output and Monetary Policy Uncertainty	$(\varphi_j \cdot \delta_j)$	$\gamma_4 < 0$	0.03	2.45	2.8

Table 4 shows the results of multicollinearity diagnosis and significance testing for the multiple regression model based on hypothesis 2. It can be seen that γ_1 and γ_2 are both greater than 0, indicating that R&D innovation investment and patent output have a positive impact on brand equity value, which is consistent with the conclusion in Table 3. Meanwhile, γ_3 and γ_4 are both less than 0, indicating that the cross term of R&D innovation investment and patent output with monetary policy uncertainty has a negative impact on brand equity value. The P-values of all four indicators are less than or equal to 0.05, and the t-values are greater than 1.96, indicating that all four indicators have significant effects on brand equity value. In terms of VIF, the VIFs of all four indicators are less than 5, indicating a relatively low degree of multicollinearity among the four indicators. The regression coefficient of the cross term between R&D innovation input and patent output and monetary policy uncertainty is less than 0, indicating that monetary policy uncertainty has a positive effect on suppressing the positive impact of R&D innovation input and patent output on brand equity value.

4.4 Experimental Discussion

The model evaluation and residual analysis are conducted on the multiple regression model constructed based on hypothesis 1 and hypothesis 2, and the findings are displayed in Table 5.

Table 5. Residual analysis and model evaluation results

Index	Multiple regression model for hypothesis 1	Multiple regression model for hypothesis 2
R^2	0.65	0.58
F-value	12.45	10.32
Residual Mean	0.12	0.36
Residual Variance	0.045	0.053
Durbin Watson Statistic	1.95	2.02

Table 5 presents the evaluation and residual analysis results of two multiple regression models for hypothesis 1 and hypothesis 2. It can be seen that the goodness of fit of the two models are 0.65 and 0.58, respectively, which are at a relatively high level. The F-value is utilized to measure the overall significance of the regression model, with larger F-values resulting in higher overall significance of the model. The F-values of the two models are 12.45 and 10.32, respectively, indicating that both models have high significance. In addition, the mean and variance of the residuals of both models are less than 1 and close to 0, indicating that the central trends of the two models are good and their predictive ability is also strong. For the Durbin Watson statistic, the value of Durbin Watson statistic is between 1.5 and 2.5, indicating that no serious autocorrelation exists in the residuals. The values of the two models are 1.95 and 2.02, both close to 2, indicating that there is no obvious positive autocorrelation in the residual sequence.

The following analysis results can be obtained by combining the data in Tables 3, 4, and 5.

Regarding hypothesis 1: the findings of the analysis show that R&D expenditures significantly and positively affect brand equity value, indicating that enterprises' investment in R&D can enhance the market performance of their brands. In addition, the regression coefficient of patent output is significantly positive, which means that an enterprise's patent output plays an important role in increasing brand value. Through further significance and residual analysis, the study shows that

enterprises can effectively improve brand equity value in both R&D innovation investment and patent output.

Regarding hypothesis 2: the analysis results indicate that the regression coefficient of the interaction term of monetary policy uncertainty is negative and significant, supporting the validity of hypothesis 2. This means that in situations where monetary policy uncertainty is high, the positive impact of R&D innovation investment and patent output on brand equity value is weakened.

5. CONCLUSIONS

This article explored the impact of enterprise R&D innovation on brand equity value and analyzed the moderating role of monetary policy uncertainty in this relationship. By collecting data from Suning.com from 2010 to 2022, this article defined and quantified key variables such as R&D innovation investment, patent output, and brand equity value, and constructed a multiple regression model for empirical analysis. The research results validated the hypothesis that R&D innovation investment and patent output significantly enhanced brand equity value, while also finding that monetary policy uncertainty suppressed this value-added effect. However, the model created in this article failed to completely eliminate potential external interference factors. In future research, richer sample data and more advanced multidimensional analysis methods should be applied to further investigate the impact of R&D innovation of different types of enterprises on brand equity value in different economic environments.

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