

Innovation Rhythm and Enterprise Value: Threshold Effect Based on Rhythm and Moderation Effect of Supply Chain

Sun Zheng^{1,*} and Xie Wenyu²

¹ International Business School, Guangdong University of Finance & Economics, Guangzhou, China

² School of Economics and Finance, South China University of Technology, Guangzhou, China

Email: sz18607683637@163.com (S.Z.); xiewy0618@163.com (X.W.Y.)

*Corresponding author

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Abstract—In recent years, against the backdrop of fluctuations in the international economic situation and rapid technological iteration, innovation has become a key focus for enterprises to maintain competitiveness. However, the management of innovation rhythm is often overlooked, and the impact of innovation rhythm on enterprise value is still rarely explored by scholars. Therefore, the article selects Chinese A-share listed companies from 2019 to 2022 as research samples to conduct in-depth research on the mechanism and path of the impact of innovation rhythm on corporate value. After a series of empirical analyses, the following conclusions were drawn: (1) A stable rhythm of innovation will enhance the value of enterprises; (2) When supply chain coordination is at a high level, the stability of innovation rhythm will enhance its promoting effect on enterprise value; (3) There is a threshold effect between innovation rhythm and enterprise value. Before the threshold, the stability of innovation rhythm will reduce the value of the enterprise, but its negative impact is not significant; After the threshold, the positive impact of innovation rhythm on enterprise value is significant, and the stability of innovation rhythm will significantly promote the growth of enterprise value.

Keywords—innovation rhythm, enterprise value, supply chain coordination, moderation effect, threshold effect

I. INTRODUCTION

Currently, in the context of global economic fluctuations and rapid technological iteration, innovation has become the key for enterprises to maintain their competitive advantage. The innovation activities of enterprises often have the characteristics of high risk and high investment, and successful innovation is often seen as a process that requires continuous accumulation. On this basis, the sustainability of enterprise innovation becomes the key to whether innovation can succeed. Enterprises that can steadily promote the rhythm of innovation can often rely on their achievements to obtain more external resources, thereby promoting the enhancement of their enterprise value. Furthermore, as an indispensable part of the economic entity, enterprises are an important force in optimizing the allocation of social resources, driving regional development, and promoting social progress. Enterprise innovation is often the key to achieving these goals. Therefore, based on the input-output analysis theory, the article focuses on the relationship between the rhythm of enterprise innovation and enterprise value, in order to reveal the inherent connection and mutual influence mechanism between the two, and provide useful references for relevant theories and enterprise practices.

II. THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

A. Innovative Rhythm

Based on previous research, the issue of rhythm has been

examined by many scholars, such as the rhythm of internationalization (Chen *et al.*, 2016), the rhythm of change (Klärner and Raisch, 2013), and the rhythm of regional introduction of FDI (Wang *et al.*, 2017). The role of rhythm management has been confirmed. Based on the existing literature on the definition of the term “rhythm,” this article defines innovation rhythm as the degree of change in the occurrence of innovation investment behavior over time, reflecting the regularity of the occurrence of innovation investment behavior over time. For two different innovation rhythms, even if the final investment level of enterprises is roughly the same, there are significant differences in the accumulation process of their innovation investment level, which can be divided into unstable innovation rhythm and stable innovation rhythm.

B. Innovation Rhythm and Enterprise Value

The Resource Based View (RBV) theory points out that the internal resources and capabilities of a company are the key to its competitive advantage. A stable rhythm of innovation means that enterprises have formed a continuous accumulation of capabilities in research and development, market acquisition, and technology transfer. Enterprises can continuously optimize their core competitiveness, maintain technological leadership through continuous innovation, and thus obtain higher profit performance and brand value in the market (Zahra, 1996), ultimately enhancing the overall value of the enterprise. Furthermore, from the perspective of investment return, a stable rhythm of innovation means that companies can more effectively plan and manage their R&D investments, and achieve better investment returns through continuous investment and stable promotion of innovative projects. Stable innovation reduces project uncertainty (O'Connor and Rice, 2013), enhances investor and partner confidence, and may attract more external funding, further enhancing the market value of the enterprise. In summary, this article proposes hypothesis 1.

H₁: A stable rhythm of innovation will enhance the value of the enterprise.

C. The Moderation Effect of Supply Chain Coordination

The Synergy Theory emphasizes that when various parts within or outside an organization can effectively collaborate and optimize resource utilization, overall performance will exceed the sum of the individual effects of each part. Therefore, enterprises that are good at integrating resources from upstream and downstream of the supply chain ensure smooth flow of information, capital, and logistics, and can achieve more efficient cooperation. High supply chain coordination makes the production behavior of enterprises more market-oriented and timely (Min, Mentzer and Ladd,

2007), thereby enhancing the promotion effect of stable innovation rhythm on enterprise value. Overall, the text proposes hypothesis 2.

H₂: Supply chain coordination has a moderation effect between innovation rhythm and enterprise value.

D. The Threshold Effect of Innovation Rhythm

When the stability of a company’s innovation rhythm is below a certain threshold, although the rhythm tends to stabilize, the increase in company value may not be significant. Although the rhythm of innovation tends to stabilize, if resource allocation does not reach its optimal level (Jensen, 2002), enterprises still find it difficult to achieve value enhancement; Furthermore, the innovation rhythm of enterprises that have not reached the stability threshold may not have timely integrated market feedback into innovation practices, resulting in a disconnect between innovation activities and market demand, thereby limiting the growth of enterprise value (Esper, Ellinger, Stank, Flint and Moon, 2010). However, when the stability of the innovation rhythm exceeds a certain critical threshold, the enterprise may significantly increase its value. At this time, enterprises can better adapt to market changes, effectively integrate various resources, form a joint force, and quickly adjust strategies to respond to customer needs, enhance customer satisfaction and loyalty, thereby improving enterprise value.

In summary, this article proposes hypothesis 3.

H₃: There is a threshold effect between innovation rhythm and enterprise value.

III. RESEARCH DESIGN

A. Sample Selection and Data Sources

The research sample of this article is Chinese A-share listed companies from 2019 to 2022. The following screening methods were applied to the sample: (1) excluding observation samples with severe missing key data, as the severe missing key data cannot be empirically tested and analyzed. (2) Excluding observation samples with abnormal trading states, as abnormal trading states do not meet the general principles of sample selection and have a significant uncontrollable impact on empirical results. The research data comes from CSMAR.

B. Variable Measurement

- Dependent variable

The dependent variable of this article is enterprise value (TobinQ), and TobinQ value is chosen as the proxy variable for enterprise value. The four different measurement methods for enterprise value variables in this article (TobinQ/TobinQ2/TobinQ3/TobinQ4) are shown in Table 1.

Table 1. Variables table

Variable type	Variable	Variable Symbol	Variable Declaration
Dependent variable	Enterprise value	TobinQ	market value A / (total assets-net value of intangible assets - net value of goodwill)
		TobinQ2	market value A / total assets
		TobinQ3	market value B / total assets
		TobinQ4	market value B / (total assets - net value of intangible assets - net value of goodwill)
Control variables	Enterprise size	Size	Logarithmic treatment of total assets of the enterprise
	Enterprise age	Age	Add 1 to the difference between the observation year and the establishment year of the enterprise and logarithmize it
	Cash holding level of enterprise	Cash	Logarithmic processing of enterprise monetary funds
	Fixed assets of enterprise	Fa	Logarithmic treatment of the total value of fixed assets in enterprises
	Intangible assets of enterprises	Ia	Logarithmic treatment of the total value of intangible assets of enterprises

- Independent variable and threshold variable

The independent variable and threshold variable of this article is the innovation rhythm (Rhythm). According to Vermeulen and Barkema’s (2002) research, the innovation rhythm of enterprises is measured by the fluctuation of the ratio of R&D expenses to operating income over time. The calculation formula is as follows. Calculate the negative value of the kurtosis coefficient of the ratio of R&D expenses to operating revenue within the quarterly window period [t, t+4]. The calculation method is shown in Eq. (a). The higher the value, the stronger the stability of the innovation rhythm of the enterprise from quarter t to t+4. The calculation results retain data based on the annual statistical caliber, which represents the innovation rhythm of the enterprise in that year.

$$Rhythm_{it} = -\frac{n(n+1)}{(n-1)(n-2)(n-3)} \sum_{i=1}^n \left(\frac{x_i - \bar{x}}{s} \right)^4 - \frac{3(n-1)^2}{(n-2)(n-3)} \quad (a)$$

In addition, for the robustness of the conclusion, this article draws on the research of Zhang, Lu and Zhang (2021) and uses the change in the ratio of R&D expenses to operating

income of enterprises over a certain period of time as a proxy variable for innovation rhythm (Rhythm2). This article establishes a linear regression model for the relationship between the time variable (t) and the natural logarithm of the ratio of R&D expenses to operating revenue during the quarterly window period [t-4, t]. The calculation method is shown in Eq. (b) below. The negative value of the inverse natural logarithm of the standard deviation of the regression coefficient is used to measure the rhythm of enterprise innovation. The larger the value, the more stable the rhythm of enterprise innovation. The calculation results retain data based on the annual statistical caliber, which represents the innovation rhythm of the enterprise in that year.

$$Ln(R\&D_t) = a_1 + a_2t + \delta \quad (b)$$

- Moderator

The moderator in this article is supply chain coordination (ART), which is measured by the accounts receivable turnover rate of the enterprise.

- Control variables

The control variables for this article are enterprise size (Size), enterprise age (Age), enterprise cash level (Cash), total fixed assets of the enterprise (Fa), and total intangible assets of the enterprise (Ia). The specific measurement method is shown in Table 1. The measurement methods for market value A and market value B are consistent with those in CSMAR. In order to eliminate the influence of extreme values on the regression results, this study conducted a 1% truncation process on all continuous variables.

C. Model Settings

$$TobinQ_{it} = \alpha_0 + \alpha_1 Rhythm_{it} + \alpha_2 Control_{it} + \delta_t + \mu_m + \varepsilon_{it} \quad (1)$$

$$TobinQ_{it} = \theta_0 + \theta_1 Rhythm_{it} + \theta_2 ART_{it} + \theta_3 Control_{it} + \delta_t + \mu_m + \varepsilon_{it} \quad (2)$$

$$TobinQ_{it} = \varphi_0 + \varphi_1 Rhythm_{it} + \varphi_2 ART_{it} + \varphi_3 Rhythm_ART_{it} + \varphi_4 Control_{it} + \delta_t + \mu_m + \varepsilon_{it} \quad (3)$$

$$TobinQ_{it} = \lambda_0 + \lambda_1 Rhythm_{it} \times IF(Rhythm_{it} \leq \vartheta) + \lambda_2 Rhythm_{it} \times IF(Rhythm_{it} > \vartheta) + \lambda_3 Control_{it} + \delta_t + \mu_m + \varepsilon_{it} \quad (4)$$

This article constructs model (1) to test the causal relationship between innovation rhythm (Rhythm) and firm value (TobinQ). If the coefficient α_1 is significantly positive, it indicates that the stability of innovation rhythm can significantly increase firm value. Among them, $Control_{it}$ represent all the control variables, δ_t is the time fixed effect, μ_m is the industry fixed effect, and ε_{it} is the random error term.

For causal inference of moderation effects, construct models (2) and (3) for causal testing. Among them, ART_{it} is the moderator, $Rhythm_ART_{it}$ is the interaction term between the independent variable and the moderator, and should focus on the direction and significance of the coefficients φ_3 . Model (3) assumes that the coefficient φ_1 is positive. If the coefficient φ_3 is significantly positive, there is a significant positive moderation effect. The larger the moderator, the greater the positive causal relationship between the independent variable and the dependent variable; If the coefficient φ_3 is significantly negative, there is a significant negative moderation effect, and the larger the moderator, the weaker the positive causal relationship between the independent variable and the dependent variable.

In terms of causal inference of threshold effects, model (4) is constructed for testing. λ_1 and λ_2 respectively represent the coefficients of the impact of innovation rhythm on enterprise value in different stability intervals of innovation rhythm, $IF(\cdot)$ represent the indicative function, and ϑ represent the threshold value to be estimated.

IV. EMPIRICAL ANALYSIS

A. Descriptive Statistics

Table 3. Correlation Analysis

	TobinQ	Rhythm	ART	Size	Age	Cash	Fa	Ia
TobinQ	1.000							
Rhythm	0.022**	1.000						
ART	0.034***	0.005	1.000					
Size	-0.277***	-0.011	0.177***	1.000				
Age	-0.150***	-0.013	0.111***	0.450***	1.000			
Cash	-0.195***	-0.001	0.172***	0.481***	0.381***	1.000		
Fa	-0.286***	0.004	0.197***	0.411***	0.388***	0.451***	1.000	
Ia	-0.217***	-0.015	0.153***	0.408***	0.379***	0.472***	0.465***	1.000

Note: p -value < 0.01, marked as ***; p -value < 0.05, mark **; p -value < 0.1, mark *.

Table 2 presents the descriptive statistical results. The mean and median of the dependent variable TobinQ are 2.248 and 1.797, respectively. If the mean is greater than the median, it indicates that the overall distribution of TobinQ is skewed to the right; And its minimum value is 0.851, maximum value is 9.431, and standard deviation is 1.459. Further analysis shows that there is a significant difference in the enterprise value of the sample companies. Similarly, by comparing the mean and median of the independent variable Rhythm and the moderator ART, it can be concluded that the overall distribution of innovation rhythm and supply chain coordination in the sample companies is skewed to the right, with standard deviations of 0.025 and 0.521, respectively. This indicates that there is a significant difference in innovation rhythm and supply chain coordination among the sample companies.

Table 2. Descriptive statistics

Variable	Obs.	Mean	Std.	Min	Median	Max
TobinQ	11056	2.248	1.459	0.851	1.797	9.431
Rhythm	11056	-0.006	0.025	-0.040	-0.012	0.057
ART	11019	0.168	0.521	0.009	0.046	4.173
Size	11056	22.447	1.299	20.181	22.248	26.497
Age	11056	2.318	0.682	0.693	2.398	3.401
Cash	11056	20.493	1.399	17.569	20.363	24.642
Fa	11056	20.493	1.644	16.139	20.389	25.096
Ia	11056	18.966	1.642	14.614	18.876	23.547

B. Correlation Analysis

Table 3 shows the results of the correlation analysis. The correlation coefficient between Rhythm and TobinQ is 0.022, which is significant at the 5% statistical level, indicating a significant positive correlation between Rhythm and TobinQ. This preliminarily proves the correctness of hypothesis 1, and the causal relationship test will be analyzed in the following text. Most of the correlation coefficients in the correlation analysis table are significant at the 1% statistical level, indicating good correlation between variables. Furthermore, all correlation coefficients are less than 0.5, indicating that there is no multicollinearity among the explanatory variables; For the sake of robustness, this article conducted a Variance Inflation Factor test (VIF) on all explanatory variables, and the results showed that the VIF values of all explanatory variables were less than 10, indicating that there was no multicollinearity among them. This conclusion is robust and lays the foundation for the validity and consistency of the regression analysis in the following text.

C. Main Path Analysis

Table 4 presents the results of the main path analysis. The results showed that, with the addition of control variables, the regression coefficients of the dependent variable enterprise value (TobinQ/TobinQ2/TobinQ3/TobinQ4/) to the independent variable innovation rhythm (Rhythm/Rhythm2)

in the following 8 models were all positive, and each regression coefficient was significant at least 10% of the statistical level, indicating a significant positive causal relationship between the stability of innovation rhythm and the size of enterprise value. This further proves the correctness and robustness of hypothesis 1, that is, a stable innovation rhythm will increase enterprise value.

Table 4. Main path inspection

	TobinQ	TobinQ2	TobinQ3	TobinQ4	TobinQ	TobinQ2	TobinQ3	TobinQ4
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rhythm	0.991** (0.493)	0.843* (0.448)	1.031* (0.534)	1.179** (0.582)				
Rhythm2					0.433** (0.202)	0.335* (0.184)	0.416* (0.219)	0.535** (0.239)
Size	-0.290*** (0.033)	-0.281*** (0.030)	-0.293*** (0.036)	-0.303*** (0.039)	-0.291*** (0.033)	-0.282*** (0.030)	-0.294*** (0.036)	-0.304*** (0.039)
Age	-0.112*** (0.021)	-0.116*** (0.019)	-0.452*** (0.023)	-0.467*** (0.025)	-0.108*** (0.021)	-0.113*** (0.020)	-0.448*** (0.023)	-0.462*** (0.025)
Cash	0.120*** (0.020)	0.164*** (0.018)	0.237*** (0.022)	0.190*** (0.024)	0.119*** (0.020)	0.164*** (0.018)	0.236*** (0.022)	0.189*** (0.024)
Fa	-0.162*** (0.017)	-0.075*** (0.016)	-0.136*** (0.019)	-0.235*** (0.020)	-0.162*** (0.017)	-0.075*** (0.016)	-0.136*** (0.019)	-0.235*** (0.020)
Ia	0.098*** (0.015)	-0.025* (0.014)	-0.020 (0.016)	0.119*** (0.018)	0.098*** (0.015)	-0.025* (0.014)	-0.020 (0.016)	0.119*** (0.018)
Constant term	8.021*** (0.262)	7.291*** (0.238)	8.253*** (0.283)	9.088*** (0.309)	8.493*** (0.344)	7.656*** (0.313)	8.707*** (0.373)	9.671*** (0.406)
Industry Fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11056	11056	11056	11056	11056	11056	11056	11056
Adj.R ²	0.212	0.209	0.247	0.249	0.212	0.209	0.247	0.249

Note: Standard error reported in parentheses. p -value < 0.01, mark ***; p -value < 0.05, mark **; p -value < 0.1, mark *.

D. Moderation Effect Analysis

Table 5 shows the results of the moderation effect analysis. For the moderation effect, if the regression coefficients of the independent variable and the moderator are both positive and significant after introducing the moderator and the interaction term between the moderator and the independent variable in the model, it indicates that when the moderator is at a high level, it will enhance the positive causal relationship between the independent variable and the dependent variable. The results show that in the model (1), the regression coefficient of the moderator supply chain coordination (ART) is significantly positive, which initially proves the correctness of hypothesis 2. On the basis of model (1), an interaction term (Rhythm-ART) is introduced into model (2), and the regression coefficient of the interaction term is 0.608, which is significant at the 1% statistical level. This indicates that supply chain coordination has a significant positive moderation effect between innovation rhythm and enterprise value, confirming the correctness of hypothesis 2. Therefore, when supply chain coordination is high, the stability of innovation rhythm will more significantly promote the enhancement of its enterprise value.

Table 5. Moderation effect test

	TobinQ	TobinQ
	(1)	(2)
Rhythm	0.954** (0.434)	0.792** (0.344)
ART	0.026*** (0.003)	0.024*** (0.003)
Rhythm_ART		0.608*** (0.065)
Size	-0.306*** (0.033)	-0.309*** (0.033)
Age	-0.102*** (0.021)	-0.100*** (0.021)
Cash	0.125*** (0.020)	0.120*** (0.020)
Fa	-0.160*** (0.017)	-0.157*** (0.017)
Ia	0.099*** (0.015)	0.099*** (0.015)
Constant term	8.200*** (0.262)	8.299*** (0.261)
Industry Fixed	Yes	Yes
Year Fixed	Yes	Yes
Observations	11019	11019
Adj.R ²	0.213	0.219

Note: Standard error reported in parentheses. p -value < 0.01, mark ***; p -value < 0.05, mark **; p -value < 0.1, mark *.

E. Threshold Effect Analysis

Table 6 shows the results of threshold effect analysis. In the single threshold effect, the F-statistic of the threshold effect model is 7.53, with a *p*-value of 0.077. If it is less than 0.1, it indicates the existence of a single threshold effect, with a threshold of -0.022. Furthermore, in the double threshold effect, the F-statistic of the model is 7.03, and its *P*-value is 0.240. If it is greater than 0.1, it indicates that the double threshold effect does not exist. Therefore, this article will analyze the nonlinear relationship between innovation rhythm and enterprise value from the perspective of single threshold effect, and also prove the correctness of hypothesis 3. The results showed that before the value of innovation

rhythm exceeded the threshold, the regression coefficient of enterprise value (TobinQ) to innovation rhythm (Rhythm) was -0.817, indicating that on the left side of the threshold, an increase in the stability of innovation rhythm would reduce enterprise value. However, the *p*-value of the coefficient was 0.165, indicating that the negative impact of innovation rhythm stability on enterprise value was not significant without crossing the threshold. On the contrary, when the value of innovation rhythm exceeds the threshold, the regression coefficient of innovation rhythm is 1.345 and significant at the 1% statistical level, indicating that the stability of innovation rhythm increases significantly and positively affects enterprise value when crossing the threshold.

Table 6. Threshold effect test

Threshold Model	Threshold	RSS	MSE	F- statistic	p-value	Crit10	Crit5	Crit1
Single	-0.022	4828.7240	0.5823	7.53	0.077	6.939	7.927	11.903
Double	-0.029	4824.6313	0.5818	7.03	0.240	8.780	10.746	14.407

TobinQ	Coefficient	Std.	t-value	p-value	95% Confidence interval	
Rhythm						
0	-0.817	0.589	-1.390	0.165	-1.972	0.337
1	1.345	0.456	2.950	0.003	0.450	2.240
Size	-0.707	0.057	-12.390	0.000	-0.819	-0.595
Age	0.771	0.055	13.910	0.000	0.663	0.880
Cash	-0.024	0.023	-1.020	0.310	-0.069	0.022
Fa	0.000	0.032	0.010	0.995	-0.063	0.063
Ia	0.096	0.023	4.110	0.000	0.050	0.142
Constant term	14.969	0.852	17.560	0.000	13.298	16.640
sigma_u				1.355		
sigma_e				0.763		
rho				0.759		
Observations				11056		

V. CONCLUSION AND IMPLICATIONS

The conclusion of this article is as follows: (1) A stable rhythm of innovation will enhance the value of enterprises. Prove the robustness of this conclusion through a series of variable transformation measures. (2) Supply chain coordination significantly moderates the positive relationship between innovation rhythm and enterprise value. When supply chain coordination is at a high level, the stability of innovation rhythm will enhance its promoting effect on enterprise value. (3) There is a threshold effect between innovation rhythm and enterprise value. Before the threshold, the stability of innovation rhythm will reduce the value of the enterprise, but its negative impact is not significant; After the threshold, the positive impact of innovation rhythm on enterprise value is significant, and the stability of innovation rhythm will significantly promote the growth of enterprise value.

Based on the above conclusion, the following enterprise management insights are proposed: (1) Enterprises should focus on maintaining a stable rhythm of innovation to enhance overall value. It is recommended to regularly monitor and evaluate the progress of innovation activities to ensure sustained innovation output and enterprise value enhancement. (2) Strengthen collaboration and communication with various links in the supply chain,

enhance the overall coordination of the supply chain through information sharing and process optimization, and thereby amplify the positive impact on the connection between innovation rhythm and enterprise value. (3) Enterprises should carefully analyze their own innovation rhythm and market environment, identify threshold values, and formulate appropriate innovation strategies. Before the threshold, it is even more important to carefully manage innovation risks and avoid a decrease in value due to innovation investment activities; After the threshold value, it is necessary to increase the management of the stability of innovation rhythm to achieve a significant increase in value. (4) Establish an effective feedback mechanism, adjust innovation strategies in a timely manner, dynamically optimize innovation rhythm based on market changes and corporate performance, and ensure that innovation activities are always aligned with corporate goals.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Sun Zheng was mainly responsible for selecting the main direction of the paper and the entire empirical analysis module; Xie Wenyu proofread the data and was mainly

responsible for organizing literature and theories; Finally, Sun Zheng wrote the entire paper; both authors have approved the final version.

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