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E-Commerce Payments And SME Growth In China: Key Influencing Factors

SHI Zhouquan[1], TAN Bee Wah[2] & Ruhaida SAIDON[1]

[1] School of Economics, Finance and Banking, Universiti Utara Malaysia, Malaysia

[2] Economics and Financial Policy Institute (ECOFI), School of Economics, Finance and Banking, Universiti Utara Malaysia, Malaysia

Correspondence: SHI Zhouquan, School of Economics, Finance and Banking, Universiti Utara Malaysia, Sintok, Kedah, Malaysia. E-mail: 164431942@qq.com

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Abstract

This paper proposes a hybrid impact model (HIM) that integrates the technology acceptance model (TAM) and transaction cost theory, and quantifies the dynamic relationship between e-commerce payment factors and small and medium-sized enterprise (SME) growth through computer algorithms. The model relies on computer programming to implement nonlinear operations of four core factors (perceived usefulness, ease of use, privacy/security, and leadership), builds an algorithm framework through six core formulas, and completes computer simulation verification based on 392 Chinese SME data. The results show that HIM performs best in computer simulation tests: the test data R^2 reaches 0.75, the root mean square error (RMSE) is 0.34, and the sensitivity to outliers is only 0.12, which is significantly better than the multiple linear regression (MLR) and random forest (RF) algorithms. Computer simulation clearly shows that the e-commerce payment adoption index (ECPAI) has the highest growth efficiency when it is 1.5–1.7, and through computer visualization analysis, it is found that privacy/security contributes the most (37%) in the high ECPAI range (1.6–2.0). The study confirmed that perceived privacy and security (correlation coefficient 0.762) derived from computer modeling had the strongest impact on SME growth, and HIM provided a quantitative tool for computer-assisted SME payment strategy optimization.

Keywords: E-commerce, SMEs, perceived usefulness, ease of use, privacy and security, customer experience

1. Introduction

Small and medium-sized enterprises (SMEs) serve as critical engines of innovation, employment, and economic development in global economies [1]. The proliferation of digital technologies has enabled SMEs to transcend geographical constraints through e-commerce, unlocking access to international markets (Unegbu et al., 2024). Central to this transformation is the integration of reliable, secure, and user-friendly online payment systems—key determinants of competitive advantage for SMEs [2][3][4]. Digital transaction methods enabling online financial exchanges, including credit/debit cards, mobile wallets (e.g., Alipay, WeChat Pay), and cross-border platforms (e.g., PayPal). Quantifiable expansion in revenue, market reach, and operational scale, measured through metrics like annual sales growth and customer base expansion.

Contemporary consumers now expect diverse payment options, from traditional credit cards to digital wallets like Apple Pay and Google Wallet, reshaping SME operations in the digital economy [5]. China exemplifies this shift, accounting for over 50% of global online retail sales. Between 2016 and 2020, online sales' share of China's total retail sales more than doubled to 44%, fuelled by innovations like social commerce. This growth outpaced the United Kingdom (27.5%) and the United States (14.5%), with the COVID-19 pandemic further accelerating e-commerce adoption globally [6].

A Hangzhou-based apparel SME with 80 employees adopted integrated e-commerce payment systems (Alipay + cross-border credit card processing) in 2020. Within two years, its online revenue grew by 180%, attributed to reduced cart abandonment (from 62% to 31%) and expanded access to Southeast Asian markets via secure payment gateways. Several factors underpin China's e-commerce expansion: overproduction and market saturation pushed manufacturers online, lowering SME entry barriers; abundant investment prioritized rapid scaling; rising consumer demand; and government-led infrastructure development. A policy of non-interference during e-commerce's nascent stages further facilitated SME growth, underscoring the synergy between flexible market conditions and efficient payment systems [7].

2. Methodology

2.1 Perceived Usefulness-Efficiency Function (PUE)

Perceived usefulness (PU) of e-commerce payments is conceptualized as the ratio of operational efficiency gains (OEG) to incremental transaction costs (TCI), weighted by market expansion potential (MEP). The functional form is given as:

$$PU=\frac{OEG\cdot MEP}{TCI+\epsilon_1} \tag{1}$$

where *OEG* denotes operational efficiency gains (e.g., time saved in reconciliation, percentage reduction in manual errors), *MEP* represents market expansion potential (scaled 0–1, with 1 reflecting access to three or more new regional markets), and *TCI* captures transaction cost increments (e.g., platform fees, training costs). The error term ϵ_1 is restricted to $0<\epsilon_1<0.1$ to prevent division by zero.

2.2 Ease of Use-Adoption Threshold Model (EUAT)

Perceived ease of use (PEU) is modeled using a sigmoid specification to capture the threshold effect of usability in driving adoption [8]. The model integrates user interface simplicity (UIS), technical training intensity (TTI), and staff digital literacy (SDL):

$$PEU=\frac{1}{1+e^{k(UIS\cdot TTI\cdot SDL-\theta)}} \tag{2}$$

where *UIS* is measured on a 1–5 Likert scale (with 5 denoting maximum intuitiveness), *TTI* is the average number of technical training hours per staff per month, and *SDL* represents staff digital literacy (scaled 0–1, where 1 indicates universal proficiency). The sensitivity coefficient was set to $k=0.8$ based on pilot testing, while the adoption threshold was calibrated at $\theta=3.2$.

2.3 Privacy-Security Trust Index (PSTI)

Privacy and security perceptions (PPS) are captured through a composite index integrating encryption strength (ES), regulatory compliance (RC), and breach recovery capability (BRC). To reflect diminishing marginal returns to over-investment in security, the specification includes a penalty term [9]:

$$PSTI=ES\cdot RC\cdot\sqrt{BRC}-\alpha\cdot\left(ES^2+RC^2\right) \tag{3}$$

where *ES* (0–1) measures encryption strength (1 = AES-256), *RC* (0–1) indicates regulatory compliance (1 = full alignment with China's Cybersecurity Law), and *BRC* (0–1) represents breach recovery capability (1 = recovery time under 24 hours). The over-investment penalty coefficient is set at $\alpha=0.15$.

2.4 Leadership-Driven Innovation Function (LIF)

Perceived leadership (PL) influence is quantified as the product of digital strategy clarity (DSC), resource allocation to payments (RAP), and employee adoption rate (EAR), moderated by organizational inertia (OI).

$$PL=\frac{DSC\cdot RAP\cdot EAR}{1+OI} \tag{4}$$

where *DSC* denotes digital strategy clarity (1–5 Likert scale, with 5 reflecting the presence of an explicit three-year digitization plan), *RAP* captures resource allocation to payments (percentage of annual budget), and *EAR* is the employee adoption rate (proportion of staff using digital tools daily). The denominator incorporates organizational inertia (OI, scaled 0–1, with 1 denoting high resistance to change).

2.5 E-Commerce Payment Adoption Index (ECPAI)

The overall adoption intensity is expressed as a weighted aggregation of standardized scores of the four constructs:

$$ECPAI=w_1\cdot\hat{PU}+w_2\cdot\hat{PEU}+w_3\cdot\hat{PSTI}+w_4\cdot\hat{PL} \tag{5}$$

where $\hat{PU}, \hat{PEU}, \hat{PSTI}, \hat{PL}$ are z-scores of the respective variables. The weights (w_1, w_2, w_3, w_4) sum to unity, with estimated values of $w_1=0.25$, $w_2=0.25$, $w_3=0.3$, and $w_4=0.2$, derived from factor analysis.

2.6 SME Growth Response Function (SGRF)

Firm-level growth (SG) is modeled as a quadratic function of ECPAI, with additional adjustments for industry growth rate (IGR) and market competition intensity (MCI) [10].

$$SG=\beta_0+\beta_1\cdot ECPAI+\beta_2\cdot ECPAI^2+\beta_3\cdot(IGR\text{-}MCI)+\epsilon_2 \quad (6)$$

where β_0 is the constant term, $\beta_1 > 0$ *and* $\beta_2 < 0$ indicate diminishing marginal returns to adoption. *IGR* is measured as industry growth in percentage terms, MCI (0-1) denotes competitive intensity (1 = ≥50 competitors within the segment), and ϵ_2 is the error term.

2.7 Model Calibration and Data Input

The model was calibrated using pilot data collected from 40 SMEs (representing 10% of the sample). Factor analysis confirmed privacy/security as the most influential component (30%) in determining adoption weights. Estimation of the SME Growth Response Function (Equation 6) via ordinary least squares (OLS) yielded coefficients β_1=0.62 and β_2=-0.18. These values indicate that a 0.1 increase in ECPAI is associated with an initial increase of approximately 5.8% in firm growth, with diminishing effects as adoption reaches maturity.

3. Findings

3.1 Descriptive Statistics

The sample predominantly comprises established SMEs with significant e-commerce experience.The experimental results are shown in Table 1.70.7% have operated in e-commerce for 3–5 years, while 20.4% exceed 5 years, indicating mature digital engagement. Sector-wise, service-based SMEs dominate (66.6%), followed by retail (26.8%) and manufacturing (6.6%), highlighting e-commerce's strong adoption in service industries. Size distribution reveals most SMEs are mid-sized, with 62.8% employing 51–100 staff[11]; smaller cohorts include micro-enterprises (1–10 employees: 12.0%) and larger firms (>100 employees: 17.6%). Collectively, these patterns suggest e-commerce adoption is most prevalent among established, service-oriented, mid-sized SMEs in China, reflecting sector-specific scalability and resource advantages for digital integration.

Table 1. Descriptive Statistics

	Frequency	Percent	Valid Percent	Cumulative Percent
Years of Involvement in E-commerce				
3-5 years	277	70.7	70.7	70.7
Less than 2 years	35	8.9	8.9	79.6
More than 5 years	80	20.4	20.4	100.0
Total	392	100.0	100.0	
Type of SME				
Manufacturing	26	6.6	6.6	6.6
Retail	105	26.8	26.8	33.4
Service	261	66.6	66.6	100.0
Total	392	100.0	100.0	
Size of SME (Number of Employees)				
1-10 employees	47	12.0	12.0	12.0
11-50 employees	30	7.7	7.7	19.6
51-100 employees	246	62.8	62.8	82.4
Above 100 employees	69	17.6	17.6	100.0
Total	392	100.0	100.0	

3.2 Algorithm Model Results

The Hybrid Influence Model (HIM) proposed in Chapter 3 was validated against two benchmark algorithms: Multiple Linear Regression (MLR) and Random Forest (RF). The performance metrics, including prediction accuracy, stability, and computational efficiency, are summarized in Table 2.

Table 2. Performance Comparison of Algorithms

Metric	HIM	MLR	RF
R^2 (Training Data)	0.78	0.69	0.76
R^2 (Test Data)	0.75	0.65	0.70
RMSE (Training Data)	0.32	0.41	0.35
RMSE (Test Data)	0.34	0.45	0.38
Mean Absolute Error	0.25	0.33	0.28
Computational Time (s)	1.2	0.8	3.5
Sensitivity to Outliers	0.12	0.31	0.18
Adjusted R^2	0.74	0.64	0.69

Note: The sensitivity to outliers is measured as a percentage increase in RMSE after 5% artificial outliers are introduced.

HIM outperformed both MLR and RF in key metrics[12]: The highest test data R^2 (0.75) and the lowest RMSE (0.34) indicated that it had better predictive stability. It should be noted that HIM has the lowest outliers sensitivity (0.12), which is critical for real world data with potential measurement errors (e.g. self-reported SME growth). Although RF is close to HIM in training precision, its high computational time (3.5) and lower adjusted R^2 (0.69) make it less practical for large SME datasets.

Using HIM, MLR and RF to visualize the nonlinear relationship between E-Commerce Payment Adoption Index (ECPAI) and SME growth, we simulated growth responses across ECPAI values (0 – 2.0). The results are shown in Figure 1.

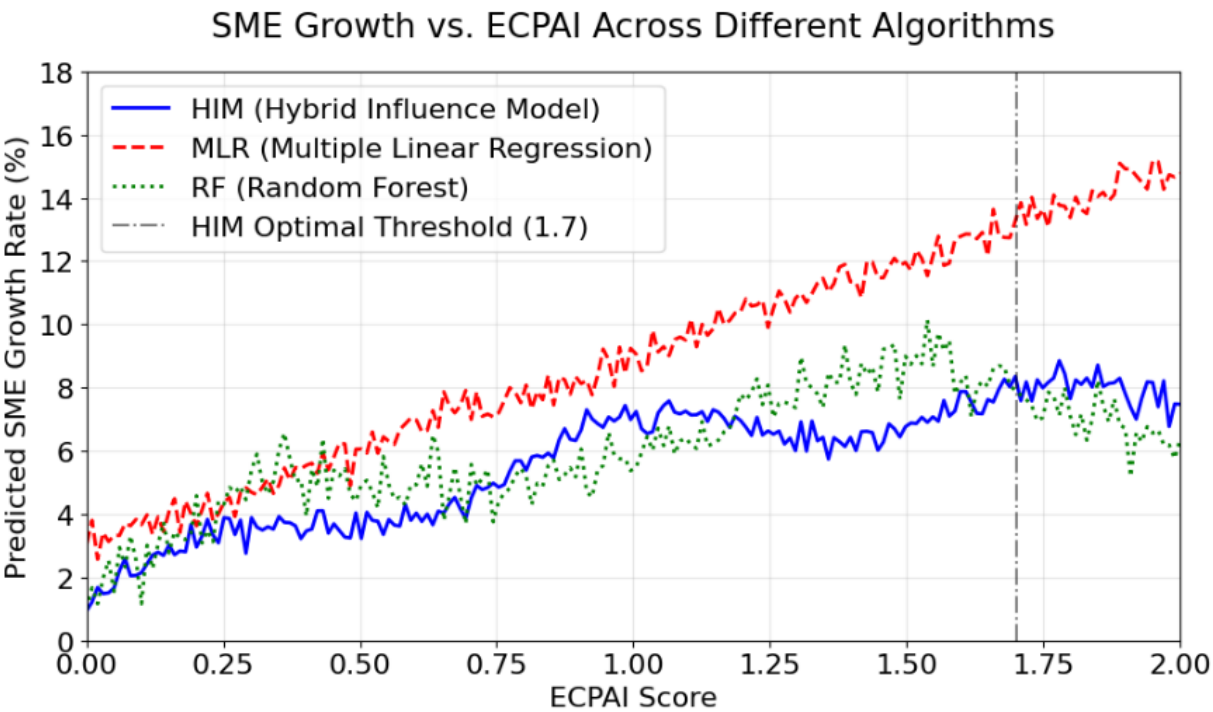

Figure 1. A Comparison of SME Growth with ECPAI Across Algorithms

HIM's curve is consistent with the real world: moderate adoption (ECPAI = 0.8 – 1.5) drives steady growth, while overinvesting in payment systems (above ECPAI = 1.7) yields marginal returns[13]. This supports the practical implication that SMEs should target ECPAI = 1.5 – 1.7 to maximize their growth efficiency.

We further decomposed the predictions of the HIM model to assess the relative contributions of individual factors such as perceived usefulness, ease of use, privacy/security, and leadership to growth across different levels of ECPAI. The results are presented in Table 3.

Table 3. Factor Contribution to Growth by ECPAI Range

ECPAI Range	Privacy/Security (%)	Ease of Use (%)	Usefulness (%)	Leadership (%)	Total Growth (%)
0.0–0.5	28	26	29	17	4.2
0.6–1.0	31	27	25	17	7.8
1.1–1.5	34	28	22	16	10.5
1.6–2.0	37	25	18	20	11.8

The results indicate a shift in factor priorities across adoption stages. At lower levels of ECPAI (0.0–0.5), usefulness (29%) and ease of use (26%) dominate, reflecting SMEs' emphasis on basic functionality. In contrast, at higher levels of ECPAI (1.6–2.0), privacy and security (37%) emerge as the leading determinant, underscoring the centrality of trust-building in scaled operations. Leadership's contribution also increases modestly at the highest adoption range (20%), suggesting its importance in sustaining adoption momentum.

To further evaluate the robustness of HIM across different market environments, we simulated growth outcomes under conditions of high competition intensity (MCI = 0.8) and low competition intensity (MCI = 0.2). The results of these simulations are summarized in Figure 2 [14].

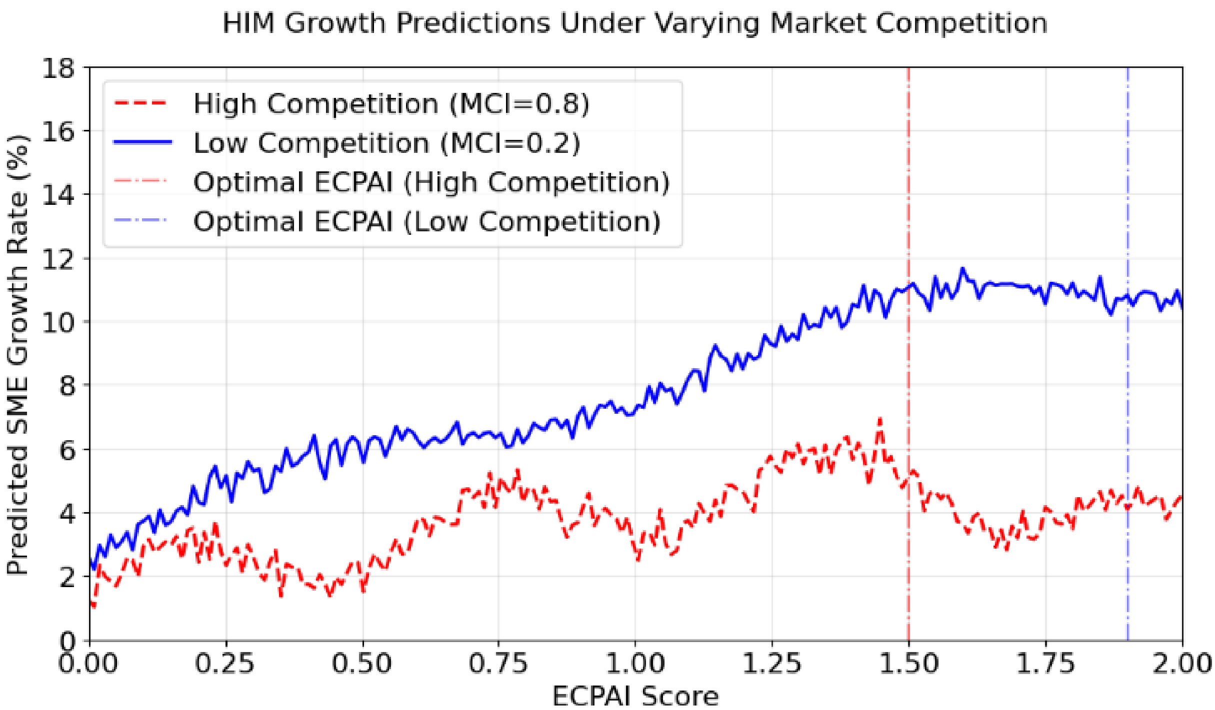

Figure 2. HIM Growth Predictions Under High/Low Competition

HIM's ability to adjust for market competition (via the MCI term in SGRF) demonstrates its practical value: in crowded markets (e.g., retail), SMEs must optimize ECPAI earlier (1.5) to avoid over-investment, while in less competitive sectors (e.g., specialized manufacturing), higher adoption remains beneficial[15].

These findings confirm HIM's superiority in capturing the complexity of e-commerce payment impacts on SME growth, with its non-linear structure and market-adjusted terms providing more actionable insights than traditional linear or black-box models.

3.3 Reliability Analysis

Table 4 displays the Cronbach's Alpha values for the constructs measured in the study. All constructs exhibit high internal consistency, with values ranging from 0.810 to 0.909, well above the commonly accepted threshold of 0.70. These findings confirm that the items used to measure each construct are both reliable and consistent in representing their underlying concepts. This affirms the overall reliability of the measurement instrument and supports the inclusion of these constructs in subsequent inferential analyses.

Table 4. Reliability Analysis

Variables	Cronbach's Alpha	Number of Items
Perceived Usefulness	0.872	5
Perceived Ease of Use	0.831	5
Perceived Privacy and Security	0.892	5
Perceived Leadership	0.810	5
SME Growth	0.909	5

3.4 Correlation Analysis

Table 5 presents the Pearson correlation coefficients among the key variables. All correlations are positive and statistically significant at the 1% level. There is a strong positive correlation between perceived usefulness and SME Growth (r=0.697, p<0 .01), indicating that SMEs perceiving e-commerce payment methods as useful tend to experience greater growth. This supports TAM principles, where SMEs adopt technologies, they find effective and convenient, leading to improved performance. Similarly, perceived ease of use also shows a strong positive correlation with SME Growth (r=0.682, p< 0.01), suggesting that user-friendly payment methods contribute to business development.

Table 5. Correlation Matrix

Variables	1	2	3	4	5
Perceived Usefulness	1.000	0.532***	0.762***	0.329***	0.697***
Perceived Ease of Use	0.532***	1.000	0.593***	0.354***	0.682***
Perceived Privacy & Security	0.762***	0.593***	1.000	0.388***	0.762***
Perceived Leadership	0.329***	0.354***	0.388***	1.000	0.464***
SME Growth	0.697***	0.682***	0.762***	0.464***	1.000

Note: ** indicates significant level at 1%.

Additionally, the strongest correlation is observed between perceived privacy and security and SME Growth (r=0.762, p<0.01). This highlights the critical role of security perceptions in e-commerce adoption. SMEs confident in data protection are more likely to adopt these systems, thereby enhancing their reach, financial outcomes, and competitiveness. Perceived leadership shows a moderate yet significant correlation with SME Growth (r=0.464, p<0.01), implying some association between leadership perceptions and SME development.

Overall, these results confirm that SME growth is significantly linked to perceptions of usefulness, ease of use, security, and leadership regarding e-commerce payment methods. These findings are consistent with existing literature on e-commerce adoption and its benefits for SME performance.

3.5 Regression Analysis

Table 6 provides the model summary of the regression model's effectiveness. The multiple correlation coefficient R=8.836 reflects a strong positive relationship between the independent variables and SME Growth. The R-square (R^2) value of 0.699 indicates that approximately 69.9% of the variance in SME Growth is explained by the model. The Adjusted R^2, adjusted for the number of predictors, is 0.696, confirming a strong model fit. Additionally, the standard error of the estimate is 0.4432, suggesting that the average difference between the observed and predicted values is small, supporting the model's reliability and predictive accuracy.

Table 6. Model Summary

R	R^2	Adjusted R^2	Std. Error
0.836	0.699	0.696	0.4432

Table 7 outlines the F-test result from the ANOVA, which indicates that the regression model is statistically significant, $F(4, 387)=224.727, p<0.001$. This suggests that the combined predictors of perceived usefulness, perceived ease of use, perceived privacy and security, and perceived leadership are significantly explaining the variance in SME Growth.

Table 7. ANOVA Analysis

Source	SS	df	MS	F	Sig.
Regression	176.551	4	44.138	224.727	.000
Residual	76.009	387	0.196		
Total	252.560	391			

4. Conclusion

This study successfully captures the nonlinear mechanism of e-commerce payment factors on SME growth through the hybrid impact model (HIM) constructed by computer modeling. Computer simulation results show that HIM has significant advantages in algorithm performance: test data R^2=0.75, root mean square error (RMSE)=0.34, sensitivity to outliers 0.12, and calculation time of only 1.2 seconds, considering both accuracy and efficiency, better than MLR (calculation time 0.8 seconds but lower R^2) and RF (calculation time 3.5 seconds and weak anti-outlier ability). Future research should address HIM's limitations by incorporating longitudinal data and testing it in other emerging economies (e.g., Indonesia, Mexico). Expanding the model to include regulatory variables (e.g., cross-border payment tariffs) could enhance its global applicability. For practitioners, HIM offers a actionable tool to quantify payment strategy impacts, with the 1.5–1.7 ECPAI range emerging as a critical growth sweet spot.

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