CSCHOLAR Publishing INC

Volume 1 Number 1 2025

Digital-Intelligent Economy and Scientific Management

https://diesm.cscholar.com

Digital-Intelligent Economy and Scientific Management

Volume 1, Issue 1, 2025

Quarterly (Issue No. 1)

Cover Design: ConnectSix Scholar Publishing INC

Publishing Unit: ConnectSix Scholar Publishing INC

Publisher's website: http://www.cscholar.com/

Publisher's address:

6547 N Academy Blvd #2265

Colorado Springs CO 80918

US

Website of the *Digital-Intelligent Economy and Scientific Management*:

https://diesm.cscholar.com/

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https://doi.org/10.71204/k816a227

Unveiling the Inaugural Issue of Digital-Intelligent Economy and Scientific Management

Sokolov B.I. [1], Xuyan Jiang [2, *]

[1] Department of Credit Theory and Financial Management, St. Petersburg State University, St. Petersburg 190000, Russia

[2] Beijing City University, Beijing 100083, China

*** Correspondence:**

Xuyan Jiang

msjiangxy90@163.com

Received: 6 September 2025/ Accepted: 14 September 2025/ Published online: 3 November 2025

Keywords: DIESM; Digital-Intelligence Era; Financial Systems; Scientific Management

With immense pride and a profound sense of mission, we are delighted to present the inaugural issue of Digital-Intelligent Economy and Scientific Management (DIESM). This launch marks not only the birth of a new academic journal, but also an important milestone in advancing the integration of economics and management in the digital-intelligence era.

DIESM is an international academic journal that rigorously adheres to a double-blind peer review process. It is dedicated to exploring how digital and intelligent technologies are reshaping economic systems, financial decision-making, and organizational management. The journal pays particular attention to the integration of cutting-edge technologies such as artificial intelligence, big data, and machine learning with financial systems, corporate governance, organizational practices, and public policy—endeavouring to bridge the gap between theoretical exploration and practical application.

DIESM features a diverse collection of articles, ranging from monetary policy, capital markets, financial risk management, corporate governance, financial accounting and auditing, ESG and sustainable development, data science and intelligent decision-making. Together, these contributions reflect interdisciplinary and cross-sectoral academic perspective. We anticipate that these high-quality research outputs will provide fresh theoretical insights for the academic community, whilst also offering valuable reference for policymakers and corporate practitioners.

At a time when technological innovation and economic transformation are accelerating worldwide, we believe that the exchange of ideas and dissemination of research findings are essential for the advancement of economics and management. DIESM aspires to be a leading international platform where scholars, researchers, policymakers, and practitioners from around

the world come together to examine the opportunities and challenges of the digital-intelligence era.

In today's world where global technology evolves rapidly and economic management models undergo constant innovation, we firmly believe that the exchange of ideas and the dissemination of academic achievements are crucial to the development of the discipline of economics and management. DIESM is dedicated to building a high-level international exchange platform, bringing together scholars, researchers, and practical experts from around the world to jointly explore the opportunities and challenges presented by the digital-Intelligent wave.

We are committed to upholding academic integrity, prioritizing quality, and pursuing excellence at all times. We sincerely welcome scholars worldwide to actively submit their manuscripts, and work with us to advance the theoretical innovation and practical development of the economics and management in the digital-Intelligent era.

Welcome to the Digital-Intelligent Economy and Scientific Management. We hope this inaugural issue inspires your research and practice, and we look forward to your long-term attention and support.

Digital-Intelligent Economy and Scientific Management, 2025, 1(1), 3-38
https://doi.org/10.71204/09rp1x07

The Spillover Effect of Customer Digital Transformation on Enterprise Value Co-creation:Micro Evidence From The Enterprise Efficiency Perspective

Jiao Wang [1, 2, *], Xuan Pei [3], Xingkai Nie [4], Jinxuan He [1]

[1] Shanxi Normal University, Taiyuan 030031, China

[2] Hainan Institute of Digital Innovation, Haikou 570100, China

[3] University of International Business and Economics, Beijing 100029, China

[4] Beijing National Accounting Institute, Beijing 101312, China

*** Correspondence:**

Jiao Wang

1345785269@qq.com

Received: 5 August 2025/ Accepted: 22 September 2025/ Published online: 3 November 2025

Abstract

As the phenomenon of digital spillover at the macro-economic level gains prominence, the impact of digital spillover generated by enterprise digital transformation at the micro-economic level is also amplified. Using the top five customer data sets of Chinese A-share listed enterprises from 2007 to 2021, this research explores the potential for customer digital spillover to foster enterprise value co-creation in supply chain, i.e., whether customer digital transformation can increase enterprise value. The benchmark tests document customer digital spillover is positively associated with enterprise value co-creation in the supply chain, and this finding holds to a battery of robustness tests. Moreover, channel tests from the perspective of enterprise efficiency indicate that customer digital spillover impacts enterprise value co-creation in the supply chain through the improvement of enterprise production efficiency, enterprise innovation efficiency, and enterprise investment efficiency. Finally, the heterogeneity tests reveal that the effect of customer digital spillover on value co-creation among enterprises is more pronounced for enterprises with the wider digital gap, the more trade credit supply, the higher financial constraints and the greater dedicated assets. Overall, this research extends prior literature on the real effects of customer digital transformation and the influencing factors of value co-creation, providing references for exploring the interactive logic among enterprises in the supply chain.

Keywords: Enterprise Value; Digital Transformation; Production Efficiency; Innovation Efficiency; Investment Efficiency; The Supply Chain

1. Introduction

The impact of digital spillover exceeds that of digitalization alone, as evidenced by the joint Oxford Economics and Huawei report "Digital Spillover-measures the True Impact of the Digital Economy", which highlights the need for more research in both academic and practical circles. In actuality, there are several typical instances of publicly traded enterprises like Intel and General Aircraft reconstructing the supply chain business model, strengthening ecological partners' collaboration, and enhancing the industrial chain's operational efficiency. This creates the conditions for the emergence of the value co-creation production mode, driven by the digital revolution and marked by strategic subversion. Accelerating the development of an efficient mechanism for supply chain value creation is a necessary way to drive the industrial chain towards high-end modernization, especially given the prevalence of adverse factors like the impact of trade protectionism and economic downward pressure. Among them, actively exploring the enabling role of enterprise digital transformation is the fundamental driving force to improve the symbiotic development ecology and value upgrading of the supply chain.

Generally speaking, the vertical economic connection between customers and enterprises in the commodity market based on the supply chain not only facilitates the flow of factors and resource flow between upstream and downstream enterprises, but also promotes the formation of an interest correlation mechanism of sharing weal and woe among enterprises. Therefore, as an innovative and natural economic connection, the bridge role of supply chain is believed to be an important and reasonable research situation for the potential economic impact of customers and micro economic channel for the spillover effect, according to Cohen and Frazzini (2008). Given this, using the top five customer data sets of Chinese A-share listed enterprises from 2007 to 2021, this research explores the potential for customer digital spillover to foster enterprise value co-creation in the supply chain, i.e., whether customer digital transformation can increase enterprise value.

This research hypothesizes that customer digital transformation supports enterprises in the supply chain in developing a multi-factor-driven value co-creation system as well as forming a cooperative strategic partnership with complementary benefits and risk sharing (Van and Van, 2011) because of the strong synergy and permeability of digital technology adopted in customer digital transformation (Majchrzak, 2016), which helps enterprises achieve efficiency and kinetic energy conversion (Li and Choi, 2009). Therefore, customer digital transformation improves enterprise value by the circulation and sharing of information resources and the enhancement of cooperation and trust relationship (Marrone et al., 2007; Novikov and Sazonov, 2020), that is, customer digital spillover realizes value co-creation. Next, this research examines at least three potential channels that customer digital transformation can significantly affect enterprise value. Firstly, customer digital transformation drives enterprise production efficiency to improve enterprise value by realizing the professional division of labor among enterprises and improving the input-output ratio of the production means (Li et al., 2021; Reiman et al., 2021). Secondly, customer digital transformation drives enterprise innovation efficiency to improve enterprise value by realizing the joint innovation among enterprises and boosting the independent innovation ability of enterprises (Schneider and Kokshagina, 2021; Li et al., 2023). Thirdly, customer digital

transformation drives enterprise investment efficiency to improve enterprise value by alleviating the synergistic contradiction between supply and demand information and helping enterprises to capture investment opportunities(Taylor and Xiao, 2010; Hofmann, 2017; Eller et al., 2020). Thus, along the supply chain, customer digital spillover resulting from customer digital transformation will foster enterprise value co-creation.Furthermore, considering that the spillover effect of customer digital transformation on enterprise value depends on the strength of the customer digital spillover effect, this research hypothesizes that the positive spillover effect is more prominent when enterprises have a wider digital gap, the more trade credit supply, the higher financial constraints, and the greater dedicated assets because a higher marginal contribution from the digital spillover caused by customer digital transformation to the improvement of enterprise value in the above situations.

The main contributions include the following aspects: Firstly, the literature on the economic consequences of customer digital spillover resulting from digital transformation in the supply chain is particularly enriched. Recent studies have innovatively examined the impact of customer digital transformation on enterprise innovation behavior (Yang et al., 2022) and enterprise digital transformation behavior (Guo et al., 2023), which examined the interactive relationship between digitalization and innovation among enterprises in the supply chain. This research deeply dissects that the spillover of customer digital transformation, a mostly random spontaneous event independent of market mechanisms, affects enterprise value from the micro level, which effectively identifies the external characteristics of digital spillover and enhances all circles' understanding of the supply chain digital spillover.

Secondly, the associated research on the influencing aspects of value co-creation is expanded. Previous research has already been conducted to examine whether or how to accomplish value co-creation between enterprises from the viewpoints of digital ecosystems (Zaki et al., 2017), digital servitization (Sjödin et al., 2021), and digital platforms (Jovanovic et al., 2022). The achievement of value co-creation through digital spillover brought about by customer digital transformation, however, has not been the subject of any literature. Furthermore, in terms of research methodology, the majority of the investigation currently on value co-creation is mostly focused on exploring the development mechanisms of traditional commercial enterprises through theoretical research (Sheth, 2019), model construction (Ranjan and Read, 2016), or case analysis (Matarazzo et al., 2021), lacking a relatively rigorous empirical test involving a sizable sample to mine the influencing factors of value co-creation and empirically examining whether value co-creation is occurring in the digital context (Hamidi and Machold, 2020). As a result, this research employs large sample data to statistically assess the value co-creation impacting elements, providing convincing micro-empirical evidence of value co-creation and serving as a reference for subsequent research on value co-creation.

Thirdly, there is an expansion of the research on the logic of interaction among supply chain enterprises. As of right now, most studies on the interactive logic in the supply chain between enterprises mostly concentrate on figuring out how resource sharing and competitive pressure influence enterprise behavior (Yan et al., 2025; Guo et al., 2023). Nevertheless, this research demonstrates customer digital spillover can bring economic consequences to enterprises by

affecting enterprise efficiency which based on production relationship, innovation relationship and investment relationship of the supply chain, thus providing an more clear understanding of the micro-interaction channels between upstream and downstream enterprises and displaying suggestions for the subsequent interaction between enterprises through empirical evidence based on the idea of an endogenous supply chain.

2. Literature Review

This research is related to two streams of literature. The first stream of literature focusing on the economic consequences of customer digital spillover that has been an initial stream of writing Lately. At present, the majority of the literature examines the reasons for and effects of enterprise digital transformation, that is, how digital transformation affects enterprises to restructure their business models and production processes (Fitzgerald et al., 2014; Vial, 2021). Only a small amount of literature focuses on the spillover effects on related enterprises caused by the large number of data elements created and accumulated by enterprise digital transformation (Xiao, 2020). For example, digital spillover can lead to the improvement of enterprise innovation levels (Yan et al., 2025) and the realization of enterprise digital transformation when enterprises are in a supply chain ecosystem (Guo et al., 2023).However, a review of the existing literature reveals that different expressions, such as the spillover effect of enterprise digital transformation, the contagion effect of enterprise digital transformation, or the industrial linkage effect of enterprise digital transformation, are used by academic circles, and digital spillover is not included as a professional term in academic papers.Therefore, as an important extension of the theme of enterprise digital transformation, the connotation, characteristics and theoretical framework of digital spillover should be clarified.

In this research, digital spillover, known as a digital externality, refers to the potential unconscious benefits and harms that the digital activities of macro- and microeconomic individuals bring to other individuals or the whole society without costing the beneficiaries or the producers. Firstly, digitalization activities are the obvious place to start for digital spillover. Digitalization refers to the process of economic individuals using digital technology to arrange and combine the data of perceptual object existence and object activity encoded as 0 and 1 (Parviainen et al., 2017). This coding process reintegrates existing resources at the organizational level into the basic elements that can be created, stored, and transported: data. Digitalization activities thus become the logical starting point for digital spillovers. Secondly, data is the fundamental component of digital spillover. Data, as a distinctive commodity, has unique traits such as non-competitiveness and incomplete exclusivity (Huang, 2022). The non-competitiveness of data indicates that the use of data by one individual does not affect the use of data by other individuals; that is, data can be duplicated and shared by different individuals at the same time without intangible or value loss(Saarikko et al., 2022). Incomplete exclusivity means that the data cannot be exclusively owned by one individual; that is, it is impossible to completely exclude other individuals from the data consumption process and completely prevent them from enjoying the data's value. Therefore, the nature of some public goods of data makes it easy to spillover the endogenous interaction process of data among individuals in different economies, giving birth to

digital spillover. Thirdly, the essence of digital spillover is the externality of digitalization activities. The externality of digital spillover requires two conditions to be met: digital spillover is independent of the market mechanism, and digital spillover is produced unintentionally and involuntarily and affects the welfare of other individuals or the whole society. Fourth, the basic components of digital spillover include spillover source, spillover host, spillover channel, spillover performance, and spillover factor. The source of digital spillover refers to the economic individual that takes part in digitalization activities; the host of digital spillover refers to the receiver of the digitalization activities of the economic individual; the spillover channel of digital spillover refers to the connection form with network characteristics and permeability, which mainly includes agglomeration, industry, and supply chain; the manifestations of digital spillover include external economies and external diseconomies ; and the factor of digital spillover is the inducing condition of digital spillover, which mainly includes the demonstration and imitation effect, competition effect, connection effect, and human capital flow effect. Fifth, relational deterioration and dynamic spillover are characteristics of digital spillover. Because of relationship deterioration, digital spillover is determined by the degree of correlation and interaction between economic individuals. That is, as the degree of correlation and interaction between economic individuals decreases, so will the radiation range and impact of digital spillover. The dynamic spillover implies that enterprises' characteristics, the amplitude and breadth of the data flow, and the smoothness of the spillover channel all influence digital spillover.

The second stream of literature focuses on the research of value co-creation among enterprises. The existing studies have carried out detailed theoretical discussions on how to achieve value co-creation among enterprises from the perspectives of resource complementary (Agrawal and Rahman, 2015), capability integration (Williams and Aitken, 2011), and value process (Corsaro, 2019), but there is no literature on whether and how to achieve value co-creation of digital spillover caused by digital transformation of customers. The mainstream view is that the essence of value co-creation is to change the positioning of customer value destroyers, let them directly participate in the production process of enterprises as value producers, and help empower enterprises to determine the production through value expression and value transmission, and finally realize the enterprise value creation and realization. Also, research shows that in the era of the digital economy, the evolution of enterprise value creation pathed from separate value creation to common production to create value change. Enterprise value creation logic also realized commodity dominant logic (Normann and Ramirez, 1993), customer dominant logic (Prahalad and Ramaswamy, 2000), and service dominant logic conversion (Vargo and Lusch, 2004). Customer-led logic is mainly based on the dual interaction between customers and enterprises, paying attention to the original value that customers bring to enterprises (Heinonen et al., 2010); service-led logic is mainly based on the multiple relationships of multiple participants creating value and analyzing the improvement effect of multiple participants participating in the enterprise value from the perspective of the network system (Pinho et al., 2014). However, regardless of the perspective or logic, value co-creation focuses on the interaction process between the enterprise and stakeholders (Gronroos and Voima, 2013). In addition, the existing topics of value co-creation mostly focus on using theoretical research, model construction, or case analysis to explore the value co-creation mechanisms of traditional commercial enterprises

(Matarazzo et al., 2021), with a lack of relatively rigorous large sample empirical tests. It is necessary to explore the influencing factors of value co-creation and clarify the relationship between customer digital transformation and value co-creation to lay a solid theoretical foundation for micro-digital spillover to drive the symbiotic development of the supply chain.

3. Research Hypothesis

3.1. The Spillover Effect of Customer Digital Transformation on Enterprise Value

Customer digital transformation supports enterprises in the supply chain in developing a multi-factor-driven value co-creation system as well as forming a cooperative strategic partnership with complementary benefits and risk sharing (Van and Van ,2011). The reason for this is that the integration of digital technology adopted in customer digital transformation has strong synergy and permeability (Majchrzak, 2016), and digital, informational, and innovative elements fundamentally affect an enterprise's production, innovation, investment, and other business processes, which helps enterprises achieve efficiency and kinetic energy conversion (Li and Choi, 2009).

On the one hand, customer digital transformation not only promotes the circulation and sharing of information resources (Cubillas et al., 2024) and changes the pattern and method, saving the traditional marketing human from collecting customer information (Popkova et al., 2022), but also helps enterprises obtain accurate market information (Endres et al., 2024) and analyze and predict customer response to products (Novikov and Sazonov, 2020), improving the effectiveness of marketing. At this time, customer digital transformation improves enterprise value; that is, customer digital spillover realizes value co-creation.

On the other hand, customer digital transformation not only builds a strong trust relationship with customer stakeholders and improves cooperative stability (Marrone et al., 2007), significantly reducing the enterprise transaction costs caused by the uncertainty of the market environment (Vargo and Lusch, 2016), but also provides enterprises with more market opportunities and market channels due to long-term partnerships (Wynstra et al., 2015), boosting enterprises to well integrate production factors (Barrett et al., 2015) and realize scale economies (Hortacsu and Syverson, 2015). At this time, customer digital transformation improves enterprise value; that is, customer digital spillover realizes value co-creation.

In summary, the second hypothesis H1 is proposed:

H1: Customer digital transformation improves enterprise value, that is, customer digital spillover realizes value co-creation.

3.2. The Channels of Customer Digital Transformation Affecting Enterprise Value

This research believes that there are three main channels which based on production relationship, innovation relationship and investment relationship of the supply chain.

The first is the enterprise production efficiency channel based on production relationship of the supply chian. In other words, customer digital transformation improves enterprise value by

driving enterprise production efficiency. On the one hand, customer digital transformation utilizes digital technology to dramatically speed up information dissemination and improve communication efficiency between upstream and downstream enterprises in the supply chain (Setia et al.,2013; Li et al., 2021), which facilitates the development of labour professional division production mode (Howard et al., 2007) by resource integration and connection modularization among enterprises (Xue et al., 2013). Labour professional division gives full play to the comparative advantages of various production factors, promoting the growth of enterprises production efficiency (Bai et al., 1997), which helps enterprises to realize value creation. On the other hand, customer digital transformation promoting supply chain data connectivity is beneficial for enterprises to repair their operation process, modify their production schedule, and optimize production allocation from production control, material scheduling, energy control, and other aspects through dynamic management and intelligent analysis (Zhou et al., 2021). In this situation, enterprises achieve more output with less input of production resources and factors by lowering the production cost, improving production flexibility and increasing production efficiency, which helps enterprises generate more value (Reiman et al., 2021).

The second is the enterprise innovation efficiency channel based on innovation relationship of the supply chian. In other words, customer digital transformation improves enterprise value by driving enterprise innovation efficiency. On the one hand, customer digital transformation has narrowed the distance between enterprises and customers because of the twin and cross-time nature of digitalization (Lanzolla et al., 2021), providing enterprises with a timely understanding of the customers' demand data, usage, opinions, and suggestions (Liu et al., 2023), as well as precisely predicting customers' consumption tendencies (Steiber et al., 2021), which has become an important source for enterprises to carry out targeted independent innovation(Schneider and Kokshagina, 2021). Not only do product development and design boost innovation efficiency, but the enterprise's technological upgrades and improvements also do so (Li et al., 2023). These factors provide a solid basis for the continuous improvement of enterprise value. On the other hand, customer digital transformation fosters networked joint innovation among enterprises by offering a data and knowledge-sharing platform for enterprises to obtain cutting-edge digital technologies (Geng et al., 2025), and expedite the exchange of innovation resources and technical knowledge among enterprises (Condea et al., 2017). Joint innovation strengthens innovation collaboration (Forman and Zeebroeck, 2012) while also bolstering innovation efficiency between enterprises (Abdalla et al., 2021). The efficient yields of enterprise innovation are transformed into economic benefits which boosts enterprise value (Bresciani et al., 2021).

The third is the enterprise investment efficiency channel based on investment relationship of the supply chian. In other words, customer digital transformation improves enterprise value by driving enterprise investment efficiency. On the one hand, customer digital transformation broadens the enterprise information access channels and enhances the enterprise information source, assisting enterprises in promptly obtaining market demand and market trends (Xu et al., 2023), as well as coordinating enterprise investment activities based on customer orders and forecast data (Taylor and Xiao, 2010). As a result, lowering the level of information asymmetry

across enterprises successfully resolves the supply and demand collaboration paradox (Lee et al., 1997; Hofmann, 2017), increasing enterprise investment efficiency. Under this circumstances, the improvement of enterprise investment efficiency contributes to the preservation of a favourable operating environment and increases enterprise value (Raman and Shahrur, 2008). On the other hand, customer digital transformation deepens the breadth and depth of enterprise information (Cachon and Lariviere, 2001), which benefits enterprises in accurately understanding changes in customer operations (Özer et al., 2011), identifying profitable investment opportunities, and projecting future returns on investment (Lee et al., 1997). In this situation, the best investment plan and the right investment choice enhance the enterprise investment decision's quality (Eller et al., 2020), which in turn results in an increase in enterprise value through increased enterprise investment efficiency.

In summary, the second hypothesis H2 is proposed:

H2a: Customer digital transformation improves enterprise value by driving enterprise production efficiency.

H2b: Customer digital transformation improves enterprise value by driving enterprise innovation efficiency.

H2c: Customer digital transformation improves enterprise value by driving enterprise investment efficiency.

3.3. The Heterogeneity of Customer Digital Transformation Affecting Enterprise Value

The spillover effect of customer digital transformation on enterprise value depends on the strength of the customer digital spillover effect. This research considers the difference in benchmark results from four different perspectives of the digital gaps between customers and enterprises: enterprise trade credit supply, enterprise financing constraints, and enterprise dedicated assets.

Firstly, the wider digital gap between customers and enterprises results in a higher marginal contribution from the digital spillover caused by customer digital transformation to the improvement of enterprise value, which means that the spillover effect of customer digital transformation on the enterprise value is more obvious.

Secondly,the more trade credit supply between customers and enterprises results in the closer relationship and the more frequent communication among enterprises,which is a higher marginal contribution from the digital spillover caused by customer digital transformation to the improvement of enterprise value, making the spillover effect of customer digital transformation on the enterprise value is more evident.

Thirdly, the higher financial constraints of enterprises indicate that the difficulty of the enterprise transformation makes enterprises have a stronger willingness to actively capture and employ the resource advantages from the digital spillover caused by customer digital transformation, resulting in a higher marginal contribution from the digital spillover to the improvement of enterprise value. Therefore, the value co-creation effect of customer digital spillover is stronger when enterprise financing constraints are greater.

Fourth, the greater dedicated assets of enterprises represent the deeper binding relationship between enterprises and customers, which results in a higher marginal contribution from the digital spillover caused by customer digital transformation to the improvement of enterprise value, indicating that the impact of customer digital transformation on enterprise value is more prominent.

In summary, the second hypothesis H3 is proposed:

H3a: The effect of Customer digital transformation on enterprise value is more pronounced for enterprises with the wider digital gap.

H3b: The effect of Customer digital transformation on enterprise value is more pronounced for enterprises with the more trade credit supply.

H3c: The effect of Customer digital transformation on enterprise value is more pronounced for enterprises with the higher financial constraints.

H3d: The effect of Customer digital transformation on enterprise value is more pronounced for enterprises with the greater dedicated assets.

Figure 1 shows the research idea diagram for this research. It can be seen that customer digital transformation maybe effect enterprise value because of the improvement of enterprise production efficiency, enterprise innovation efficiency and enterprise investment efficiency.And the above effect may be more pronounced for enterprises with the wider digital gap, the more trade credit supply, the higher financial constraints and the greater dedicated assets.

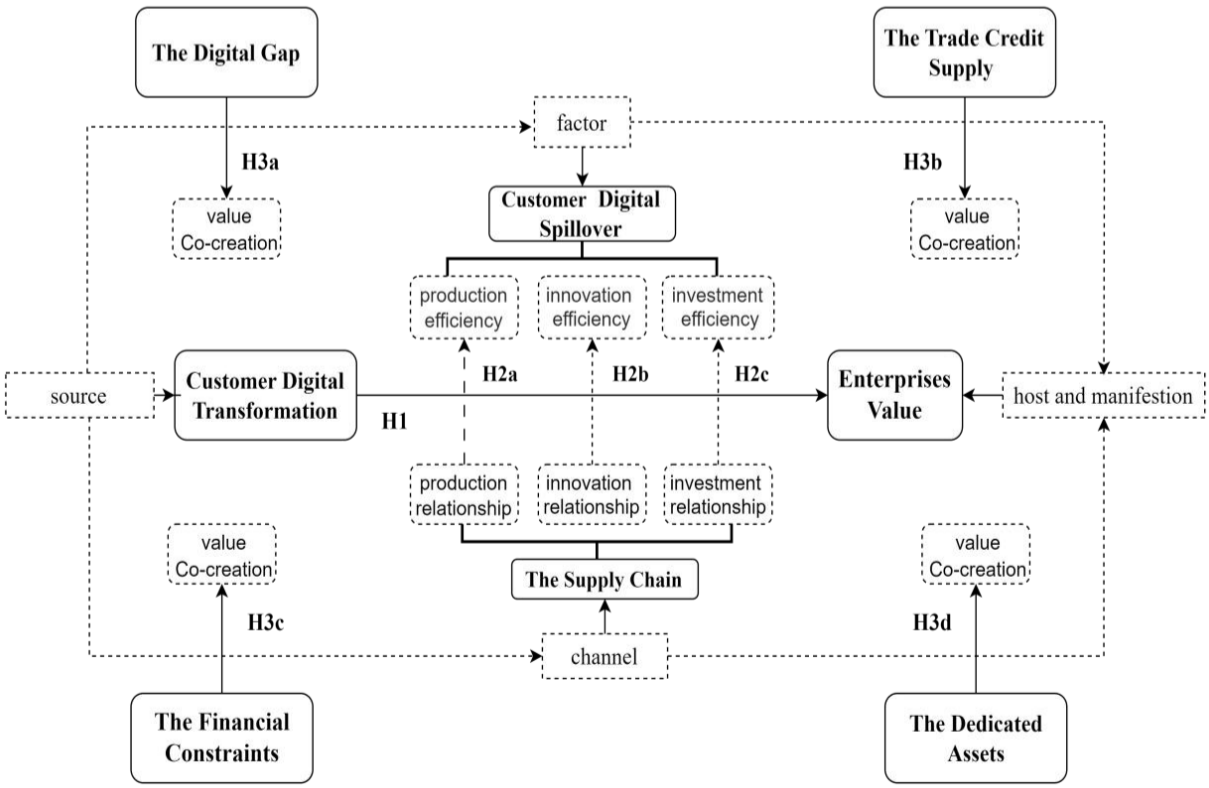

Figure 1. The Research Idea Diagram

4. Research Design

4.1. Sample Selection and Data Sources

In order to match the enterprise-customer-year starting sample, this study employs the top five customer data given with the genuine name in the Chinese A-share listed enterprises' annual reports from 2007 to 2021. The following procedures are used in this research to screen the samples based on the initial enterprise-customer-year samples: First, eliminate sample observations whose customers are not listed enterprises; second, eliminate ST, *ST, and PT sample observations; third, eliminate the financial industry sample observations; fourth, eliminate the sample observation of a single business that discloses the name of the customer but not their precise sales volume; and fifth, eliminate the sample observations that have missing values in the financial data.

In the end, A total of 1,755 enterprise-customer-year matching observations were obtained. There are numerous instances where a particular business (J) matches multiple customers (W, Y, and P) in the same year (2015). At the same time, to eliminate the influence of outliers, this research Winsorize all continuous variables on 1% and 99% quantiles. The fixed effects of industry and year were controlled in the regression model. In fact, using the top five listed customers of listed enterprises to build research samples has the following advantages: First, the interference of some unobstructed factors on research results can be controlled through the pairing relationship between enterprises; Second, the data of the top five listed customers used are more concentrated and consistent in caliber, which is helpful to reduce the problems caused by extreme values.

The data used mainly includes three parts. The first is the data of the digital transformation degree of listed enterprises, which is obtained by text analysis according to existing research practices. The second is the matching data between enterprises and customers and the financial data of listed enterprises,which mainly come from the China Research Data Service Platform Database (CNRDS) and the China Stock Market & Accounting Research Database (CSMAR).

4.2. Variable Definition and Model Setting

This research constructs the following regression model and takes the OLS regression model to test the spillover effect of customer digital transformation on enterprise value:

$$\begin{aligned} TOBIN_{i,t} = {} & \beta_0 + \beta_1 \mathrm{DIG}_{i,t-1} + \beta_2 LEV_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 SOE_{i,t} + \beta_5 \mathrm{LHR}_{i,t} \\ & + \beta_6 DUAL_{i,t} + \beta_7 \mathrm{INDEP}_{i,t} + \beta_8 \mathrm{ROA}_{i,t} + \beta_9 \mathrm{GDP}_{i,t} + \beta_{10} \mathrm{CUS\_VOL}_{i,t-1} \\ & + \beta_{10} \mathrm{CUS\_AGE}_{i,t-1} + \sum YEAR + \sum IND + \delta_{i,t} \end{aligned} \quad (1)$$

Where, the subscript i and t represent the enterprise and the year respectively, and the characteristic variables of the customer all adopt one period lag; Customer digital transformation (DIG) is the core explanatory variable; Enterprise value (TOBIN) is the core explained variable. To eliminate the systematic interference that may be caused by the fixed characteristics of various industries that do not change with time, the fixed effect of industry is controlled .To eliminate the trend of firm value changing over time, this research also controls the year fixed effect.To reduce the interference of unobserved confounders on the identification of causal effect , this research is

based on existing studies (Bai et al., 2005) further added a series of influencing factors related to firm value. The specific variables are defined in Table 1.

Table 1. Main Variable Definitions

Categories	Name	Symbol	Definition
Dependent variable	Enterprise value	TOBIN	(equity market value + debt market value)/ending total assets
Independent variable	Degree of customer digital transformation	DIG	Take logarithm of the frequency of text keywords for enterprise digital transformation by adding 1
Enterprise characteristic variable	Asset liability ratio	LEV	Ratio of total ending liabilities to total ending assets
	Enterprise size	SIZE	Add 1 to total ending assets to take the natural logarithm
	Nature of the Enterprise	SOE	If it is a state-owned enterprise, the value is 1, otherwise it is 0
	The shareholding ratio of the largest shareholder	LHR	The ratio of the number of shares held by the largest shareholder to the number of shares held by the total shareholders
	The combination of two positions	DUAL	The value is 1 if both jobs are in one, otherwise it is 2
	Proportion of independent directors	INDEP	Number of independent directors as a percentage of the total number of directors on the board
	Return on total assets	ROA	Ratio of operating profit to total assets at the end of the period
Customer characteristic variable	Customer age	CUS_AGE	Take the natural logarithm of the listed age of the business by adding 1
	Customer sales revenue volatility	CUS_VOL	Volatility of customer sales revenue weighted by sales share
Macro level variables	Economic growth	GDP	Take the natural logarithm of gross domestic product per capita by adding 1
Fixed effect	Industry	IND	Control the influence of the industry
	Year	YEAR	Control the impact of the year

5. Empirical Tests and Result Analysis

5.1. Descriptive Statistics

Descriptive statistics of the main variables are shown in Table 2. The mean value of enterprise value (TOBIN) is 1.945 and the standard deviation is 1.234, indicating that the enterprise value of different enterprises varies greatly. The mean and standard deviation of enterprise digital transformation (DIG) are 2.561 and 1.074 respectively, and the minimum and maximum values are 0.000 and 5.273 respectively, indicating that the degree of digital transformation of listed enterprises in China is quite different, and there is still much room for improvement in the degree of digital transformation of some enterprises. And the control variables' distribution characteristic is basically similar to that of previous research literatures.

Table 2. Descriptive Statistics

Variable	N	Mean	SD	Min	p25	p50	p75	Max
TOBIN	1755	1.945	1.234	0.856	1.226	1.529	2.154	8.201
DIG	1755	2.561	1.074	0.000	1.792	2.485	3.219	5.273
LEV	1755	0.422	0.214	0.045	0.250	0.418	0.581	0.908
SIZE	1755	21.97	1.282	19.66	20.96	21.77	22.79	25.42
SOE	1755	0.426	0.495	0.000	0.000	0.000	1.000	1.000
LHR	1755	0.369	0.153	0.102	0.245	0.340	0.480	0.760
DUAL	1755	1.782	0.413	1.000	2.000	2.000	2.000	2.000
INDEP	1755	0.365	0.047	0.333	0.333	0.333	0.375	0.556
ROA	1755	0.037	0.064	-0.292	0.013	0.040	0.069	0.193
GDP	1755	10.85	0.521	9.122	10.46	10.87	11.21	12.12
CUS_VOL	1755	1.813	2.435	0.065	0.498	1.019	1.982	14.38
CUS_AGE	1755	2.236	0.782	0.000	1.946	2.485	2.773	3.258

5.2. Customer Digital Spillover and Value Co-creation

The regression results of the spillover effect of customer digital transformation on enterprise value are shown in Table 3. The results show from the perspective of statistical significance, the regression coefficients of customer digital transformation and enterprise value are both significant at the level of 1%, which proves that customer digital transformation has a positive spillover effect on enterprise value.Therefore, the hypothesis H1 is verified.

Table 3. Customer Digital Spillover and Value Co-creation

	(1)	(2)	(3)
	TOBIN	TOBIN	TOBIN
DIG	0.107***	0.099***	0.098***
	(3.07)	(3.19)	(3.13)
LEV		0.853***	0.850***
		(4.63)	(4.62)
SIZE		-0.542***	-0.537***
		(-15.63)	(-15.46)
SOE		0.123**	0.125**
		(1.97)	(2.00)
LHR		-0.707***	-0.710***
		(-3.66)	(-3.69)
DUAL		0.135**	0.133**
		(2.19)	(2.16)
INDEP		1.039*	1.048*
		(1.92)	(1.92)
ROA		1.947***	1.945***
		(2.68)	(2.68)
GDP		-0.024	-0.015
		(-0.40)	(-0.25)
CUS_VOL			0.012
			(1.11)
CUS_AGE			-0.028
			(-0.77)
_cons	1.253***	12.269***	12.122***
	(4.54)	(8.71)	(8.53)
IND	Yes	Yes	Yes
YEAR	Yes	Yes	Yes
N	1755	1755	1755
Adj. R^2	0.213	0.387	0.387

5.3. Robustness Tests

5.3.1. Instrumental Variable Method

The enterprise value will affect the success implementing probability of customer digital transformation. For example, higher enterprise value will send a signal to the asset market of the

strength of upstream companies and stable supply, which will affect the degree of support of market investors for customers to implement digital transformation. When investors' support for customers' implementation of digital transformation is high, it will effectively alleviate the financing constraints faced by customers' implementation of digital transformation, and then affect the digital transformation of customers. Therefore, to overcome the interference of reverse causality, the mean value of customer digital transformation in the same industry in the same year (DIG_IND) and the mean value of customer digital transformation in the same province in the same year (DIG_PROV) are selected as the instrumental variables of customer digital transformation (DIG). The regression results obtained by using the two-stage least square method are shown in Table 4. This result proves that reverse causality does not affect the positive spillover effect of customer digital transformation on firm value.

Table 4. Instrumental Variable Method

	(1)	(2)	(3)	(4)
	STAGE 1	STAGE 2	STAGE 1	STAGE 2
	DIG	TOBIN	DIG	TOBIN
DIG_IND	0.815***		0.817***	
	(23.22)		(23.39)	
DIG_PROV	0.446***		0.449***	
	(10.74)		(10.81)	
DIG		0.301***		0.295***
		(6.32)		(6.28)
LEV	-0.115	0.721***	-0.120	0.723***
	(-1.00)	(3.56)	(-1.04)	(3.60)
SIZE	-0.023	-0.461***	-0.015	-0.470***
	(-1.30)	(-14.23)	(-0.80)	(-14.27)
SOE	-0.023*	0.116*	-0.086*	0.116*
	(1.87)	(1.88)	(1.91)	(1.88)
LHR	-0.071	-0.403**	-0.089	-0.392**
	(-0.56)	(-2.13)	(-0.71)	(-2.11)
DUAL	-0.027	0.242***	-0.028	0.241***
	(-0.58)	(3.50)	(-0.59)	(3.48)
INDEP	0.399	0.328	0.404	0.390
	(1.14)	(0.57)	(1.16)	(0.66)
ROA	-0.332	1.632**	-0.307	1.615**
	(-1.04)	(2.33)	(-0.96)	(2.32)
GDP	-0.055	-0.089	-0.043	-0.102*
	(-1.21)	(-1.58)	(-0.95)	(-1.77)

CUS_VOL			0.022**	-0.019**
			(3.04)	(-1.96)
CUS_AGE			-0.030	0.060
			(-1.20)	(1.57)
_cons	0.419	11.427***	0.419	11.667***
	(0.77)	(13.51)	(0.77)	(13.57)
IND	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes
N	1755	1755	1755	1755
Adj. R^2	0.508	0.195	0.508	0.198
Correlation Test				
Partial R^2	0.439		0.441	
F-value	675.39		680.40	
Exogeneity Test				
Chi2		2.287		2.462
P-value		0.131		0.117

5.3.2. Sample Selection Bias

The interference of sample self-selection bias that Chinese listed enterprises have a voluntary tendency to disclose information to the top five customers, this research adopts the Heckman two-stage model to re-estimate. The regression results again confirmed that the basic results are robust.

Table 5. Regression of Heckman Two-stage Model

	(1)	(2)	(3)
	DIG_H	TOBIN	TOBIN
DIG		0.078**	0.079**
		(2.25)	(2.27)
IMR		-1.363	-1.268
		(-0.77)	(-0.72)
LEV	-1.274**	0.905***	0.898***
	(-2.31)	(3.31)	(3.27)
SIZE	0.137*	-0.565***	-0.568***
	(1.91)	(-13.36)	(-13.42)
SOE	-0.077	0.127**	0.124**
	(-0.38)	(2.00)	(1.97)
LHR	-1.442***	-0.532*	-0.529*
	(-2.65)	(-1.90)	(-1.89)

DUAL	0.092	0.193***	0.195***
	(0.44)	(3.22)	(3.25)
INDEP	4.064	0.847	0.797
	(1.55)	(1.20)	(1.12)
ROA	-2.435	2.309***	2.279***
	(-1.52)	(3.09)	(3.04)
GDP	0.329*	-0.079	-0.083
	(1.81)	(-1.01)	(-1.06)
CUS_VOL			-0.013
			(-1.44)
CUS_AGE			-0.020
			(-0.56)
_cons	-4.632*	14.041***	14.236***
	(-1.80)	(9.46)	(9.59)
IND	Yes	Yes	Yes
YEAR	Yes	Yes	Yes
N	1600	1571	1571
Adj. R^2	0.321	0.419	0.419

5.3.3. Different Customer Transaction Amounts

Because the transaction amounts of the top five customers disclosed by listed companies in China are different, this research constructs DIG_A based on the sales weight calculated by the customer's own sales in the sales of the top five customers, and DIG_B based on the sales weight calculated by the sales weight of the customer's own sales in the total sales of the enterprise to overcome the interference of the transaction amounts weight of different customers.The regression results are shown in Table 6.This result proves that the basic results have not changed substantially.

Table 6. Exclude the Interference of Different Customer Transaction Amounts

	(1)	(2)	(3)	(4)
	TOBIN	TOBIN	TOBIN	TOBIN
DIG_A	0.003***	0.003***		
	(8.07)	(8.17)		
DIG_B			0.113**	0.141**
			(2.13)	(2.42)
LEV	0.788***	0.789***	0.805***	0.811***
	(4.15)	(4.16)	(4.20)	(4.24)

SIZE	-0.554***	-0.558***	-0.537***	-0.541***
	(-15.22)	(-15.26)	(-15.20)	(-15.20)
SOE	0.124**	0.122*	0.114*	0.109*
	(1.96)	(1.94)	(1.83)	(1.76)
LHR	-0.728***	-0.716***	-0.733***	-0.711***
	(-4.02)	(-3.99)	(-4.02)	(-3.95)
DUAL	0.206***	0.207***	0.193***	0.194***
	(3.40)	(3.42)	(3.19)	(3.21)
INDEP	1.241**	1.169**	1.230**	1.113**
	(2.35)	(2.19)	(2.34)	(2.08)
ROA	2.105***	2.090***	2.180***	2.174***
	(3.10)	(3.07)	(3.24)	(3.25)
GDP	-0.033	-0.038	-0.038	-0.051
	(-0.54)	(-0.61)	(-0.62)	(-0.83)
CUS_VOL		-0.010		-0.022**
		(-1.13)		(-2.14)
CUS_AGE		-0.027		-0.035
		(-0.74)		(-0.97)
_cons	13.757***	13.988***	13.417***	13.793***
	(11.11)	(11.21)	(11.02)	(11.25)
IND	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes
N	1752	1752	1752	1752
Adj. R^2	0.414	0.414	0.416	0.417

5.3.4. The Reliability of the Top Five Customer Data

To verify the reliability of top five customer data of sample enterprises , this research takes the top three customers of sample enterprises as sub-samples to re-estimate. The regression results are shown in Table 7. This result verifies the reliability of the data of the top five customers of the sample enterprises and the basic results.

Table 7. The Regression of the Top Three Customer Subsamples

	(1)	(2)	(3)
	TOBIN	TOBIN	TOBIN
DIG	0.102**	0.086**	0.087**
	(2.45)	(2.29)	(2.32)

LEV		0.860***	0.863***
		(3.73)	(3.76)
SIZE		-0.541***	-0.547***
		(-12.25)	(-12.33)
SOE		0.175**	0.173**
		(2.26)	(2.23)
LHR		-0.773***	-0.751***
		(-3.43)	(-3.36)
DUAL		0.292***	0.296***
		(3.89)	(3.92)
INDEP		1.101*	0.958
		(1.79)	(1.52)
ROA		2.978***	2.972***
		(4.17)	(4.16)
GDP		-0.027	-0.036
		(-0.34)	(-0.46)
CUS_VOL			-0.013
			(-1.41)
CUS_AGE			-0.048
			(-0.96)
_cons	2.001***	12.824***	13.253***
	(4.45)	(9.01)	(9.06)
IND	Yes	Yes	Yes
YEAR	Yes	Yes	Yes
N	1013	1013	1013
Adj. R^2	0.258	0.436	0.436

5.3.5.The Sample's Multiple Situations

This research constructs DIG_MEAN and DIG_MEDIAN of top five customers of the same firm in the same year and replaces the explanatory variables in model (1) to re-estimate to overcome the interference of multiple customers of the same firm. The regression results are shown in Table 8. This result proves that the multi-pair situation of the study sample does not affect the basic results.

Table 8. Exclude the Interference of the Sample in the Multi-on-one Case

	(1)	(2)	(3)	(4)	(5)	(6)
	TOBIN	TOBIN	TOBIN	TOBIN	TOBIN	TOBIN
DIG_MEAN	0.111***	0.101***	0.101***			
	(2.82)	(2.83)	(2.81)			
DIG_MEDIAN				0.112***	0.100***	0.100***
				(2.86)	(2.85)	(2.83)
LEV		0.793***	0.795***		0.793***	0.794***
		(4.20)	(4.21)		(4.20)	(4.21)
SIZE		-0.550***	-0.554***		-0.550***	-0.554***
		(-15.19)	(-15.24)		(-15.19)	(-15.24)
SOE		0.115*	0.114*		0.115*	0.114*
		(1.85)	(1.83)		(1.85)	(1.83)
LHR		-0.698***	-0.685***		-0.700***	-0.687***
		(-3.91)	(-3.88)		(-3.92)	(-3.89)
DUAL		0.196***	0.197***		0.195***	0.196***
		(3.24)	(3.26)		(3.22)	(3.25)
INDEP		1.105**	1.038*		1.106**	1.039*
		(2.09)	(1.93)		(2.09)	(1.94)
ROA		2.131***	2.114***		2.117***	2.100***
		(3.15)	(3.13)		(3.13)	(3.11)
GDP		-0.057	-0.062		-0.056	-0.061
		(-0.92)	(-1.01)		(-0.91)	(-1.00)
CUS_VOL			-0.012			-0.012
			(-1.38)			(-1.38)
CUS_AGE			-0.019			-0.020
			(-0.53)			(-0.54)
_cons	2.207***	13.802***	14.041***	2.211***	13.801***	14.040***
	(6.25)	(11.09)	(11.20)	(6.25)	(11.09)	(11.19)
IND	Yes	Yes	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes	Yes	Yes
N	1755	1755	1755	1755	1755	1755
Adj. R^2	0.233	0.417	0.417	0.233	0.418	0.417

5.3.6. The Alternative Explanation

The supply chain digital transformation, mentioned in the Guiding Opinions on Actively Promoting Innovation and Application of Supply Chain issued by The State Council in 2017 May, also improves the adaptability, competitiveness and market value of enterprises by forming a customer-centered supply chain management reform using digital technology.This research uses the sub-sample from 2007 to 2017 to re-estimate to overcome this interference. The regression results are shown in Table 9. This result excludes the alternative explanations of supply chain digital transformation.

Table 9. Excluse Alternative Explanations: Supply Chain Digital Transformation

	(1)	(2)	(3)
	TOBIN	TOBIN	TOBIN
DIG	0.105***	0.097***	0.099***
	(2.68)	(2.82)	(2.85)
LEV		0.797***	0.797***
		(3.83)	(3.83)
SIZE		-0.546***	-0.549***
		(-13.91)	(-14.00)
SOE		0.106	0.104
		(1.58)	(1.55)
LHR		-0.745***	-0.733***
		(-3.90)	(-3.89)
DUAL		0.205***	0.207***
		(3.05)	(3.07)
INDEP		1.052*	1.014*
		(1.84)	(1.75)
ROA		2.277***	2.253***
		(2.87)	(2.83)
GDP		-0.072	-0.077
		(-1.11)	(-1.18)
CUS_VOL			-0.011
			(-1.14)
CUS_AGE			-0.004
			(-0.11)
_cons	1.717***	13.503***	13.669***
	(18.40)	(12.21)	(12.28)
IND	Yes	Yes	Yes
YEAR	Yes	Yes	Yes
N	1407	1407	1407
Adj. R^2	0.244	0.418	0.418

5.3.7. The Placebo Tests

Because some random factors may induce the improvement of enterprise value, this research adopts the randomly generated placebo test using Monte Carlo to simulate repeated regression model (1) for 500 times to support the basic results. The regression results are shown in Figure 2 and Figure 3. The results show the distributions of the obtained coefficients and P-values is near zero and follows normal distribution, which are in line with the expectations of placebo test. Therefore, the reliability of the basic results is confirmed once again.

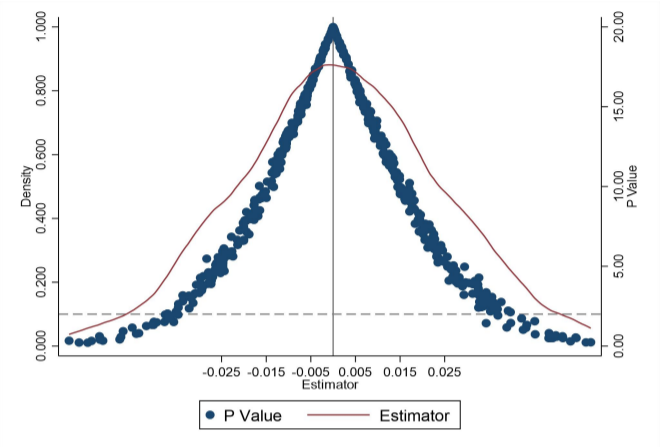

Figure 2. The placebo test of contains only the enterprise characteristics

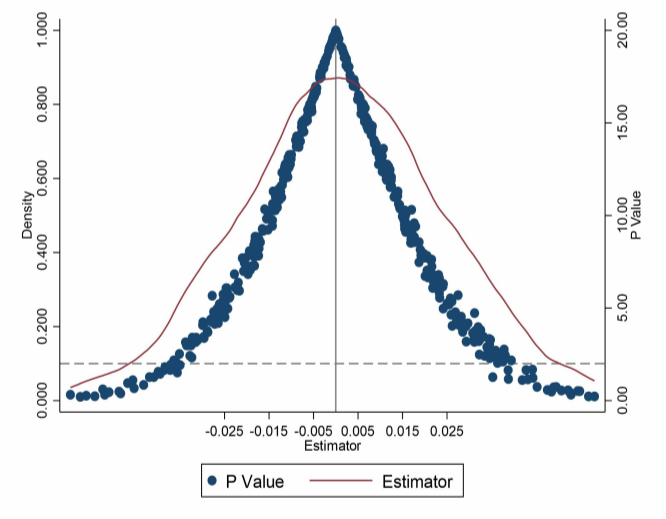

Figure 3. The Placebo Test of contains the enterprise characteristics and customer characteristics

5.3.8. The Potential Factors at the Level of Industries, Cities and Provinces

Some potential factors at the level of enterprises, industries, cities and provinces may interfere with the basic results, this research sets the clustering of industries, cities and provinces.Those results prove the basic results have not changed substantially.

Table 10. Clustering Results

	IND		CITY		PRO	
	(1)	(2)	(3)	(4)	(5)	(6)
	TOBIN	TOBIN	TOBIN	TOBIN	TOBIN	TOBIN
DIG	0.086*	0.087*	0.086**	0.087**	0.086***	0.087***
	(1.86)	(1.86)	(2.41)	(2.41)	(2.85)	(2.89)
LEV	0.792***	0.794***	0.792***	0.794***	0.792***	0.794***
	(3.23)	(3.25)	(2.84)	(2.85)	(3.07)	(3.08)
SIZE	-0.551***	-0.555***	-0.551***	-0.555***	-0.551***	-0.555***
	(-9.91)	(-9.97)	(-10.08)	(-10.09)	(-10.94)	(-11.02)
SOE	0.118	0.116	0.118	0.116	0.118	0.116
	(1.50)	(1.47)	(1.35)	(1.32)	(1.52)	(1.52)
LHR	-0.703***	-0.689**	-0.703***	-0.689***	-0.703***	-0.689**
	(-2.76)	(-2.66)	(-2.94)	(-2.89)	(-2.77)	(-2.70)
DUAL	0.196***	0.198***	0.196**	0.198**	0.196**	0.198**
	(2.92)	(2.95)	(2.31)	(2.32)	(2.61)	(2.62)
INDEP	1.120	1.045	1.120	1.045	1.120	1.045
	(1.50)	(1.42)	(1.39)	(1.30)	(1.31)	(1.22)
ROA	2.128**	2.111**	2.128**	2.111**	2.128**	2.111**
	(2.25)	(2.23)	(2.35)	(2.32)	(2.30)	(2.26)
GDP	-0.049	-0.056	-0.049	-0.056	-0.049	-0.056
	(-0.59)	(-0.70)	(-0.59)	(-0.67)	(-0.71)	(-0.80)
CUS_VOL		-0.012		-0.012		-0.012
		(-1.24)		(-1.33)		(-1.16)
CUS_AGE		-0.024		-0.024		-0.024
		(-0.56)		(-0.55)		(-0.51)
_cons	13.754***	14.017***	13.754***	14.017***	13.754***	14.017***
	(9.43)	(10.07)	(8.47)	(8.63)	(9.48)	(9.60)
IND	Yes	Yes	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes	Yes	Yes
N	1755	1755	1755	1755	1755	1755
Adj. R^2	0.417	0.417	0.417	0.417	0.417	0.417

5.3.9. The High Dimensional Fixed Effect Model

This research uses a high-dimensional fixed effects model to re-estimate to absorb the multi-layered fixed effects of panel linear regression. The regression results are shown in Table 12. Those results prove the basic results are robust.

Table 11. The Regression of High-dimensional Fixed Effect Model

	(1)	(2)	(3)	(4)	(5)	(6)
	TOBIN	TOBIN	TOBIN	TOBIN	TOBIN	TOBIN
DIG	0.074**	0.069**	0.070**	0.068**	0.063**	0.063**
	(2.11)	(2.17)	(2.19)	(2.00)	(2.04)	(2.03)
LEV		0.836***	0.839***		1.007***	1.011***
		(4.37)	(4.40)		(4.91)	(4.94)
SIZE		-0.549***	-0.553***		-0.564***	-0.566***
		(-14.60)	(-14.64)		(-13.14)	(-13.17)
SOE		0.129*	0.126*		0.119	0.114
		(1.85)	(1.81)		(1.34)	(1.27)
LHR		-0.777***	-0.761***		-0.773***	-0.760***
		(-4.15)	(-4.11)		(-3.18)	(-3.13)
DUAL		0.214***	0.216***		0.123	0.122
		(3.38)	(3.42)		(1.62)	(1.62)
INDEP		1.225**	1.169**		0.778	0.730
		(2.13)	(2.02)		(1.14)	(1.05)
ROA		2.170***	2.153***		2.324***	2.303***
		(3.17)	(3.14)		(3.06)	(3.04)
GDP		1.053***	1.020***		1.298***	1.268***
		(2.75)	(2.65)		(3.02)	(2.94)
CUS_VOL			-0.013			-0.005
			(-1.41)			(-0.54)
CUS_AGE			-0.021			-0.024
			(-0.60)			(-0.62)
_cons	1.740***	1.374	1.897	1.751***	-0.668	-0.234
	(20.08)	(0.33)	(0.46)	(20.96)	(-0.14)	(-0.05)
IND	Yes	Yes	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes	Yes	Yes
PRO	Yes	Yes	Yes	No	No	No
CITY	No	No	No	Yes	Yes	Yes
N	1749	1749	1749	1709	1709	1709
Adj. R^2	0.265	0.431	0.430	0.345	0.491	0.491

6. Further Research

6.1. The Channel Tests

6.1.1.The Improvement Enterprise Production Efficiency By Customer Digital Spillover

The enterprise system productivity of enterprise technology upgrading, management mode improvement, product quality improvement, and enterprise structure upgrading is represented by total factor productivity (Van, 2012). Consequently, enterprise total factor productivity, which is calculated by the LP method and the GMM method, serves as a proxy for enterprise production productivity. TFP_LP and TFP_GMM are the positive variable. Table 12 displays the results of the regression. According to the findings, enterprise value and consumer digital transformation have a favorable association since consumer digital spillover improves enterprise production efficiency.

Table 12. The Improvement Enterprise Production Efficiency By Customer Digital Spillover

	(1)	(2)	(3)	(4)
	TFP_LP	TFP_LP	TFP_GMM	TFP_GMM
DIG	0.031**	0.033**	0.043**	0.044**
	(2.23)	(2.34)	(2.48)	(2.53)
LEV	0.898***	0.908***	0.688***	0.694***
	(9.72)	(9.83)	(6.50)	(6.55)
SIZE	0.532***	0.529***	0.164***	0.163***
	(34.55)	(33.93)	(9.19)	(8.95)
SOE	0.057	0.057*	0.047	0.048
	(1.63)	(1.66)	(1.12)	(1.15)
LHR	0.262**	0.257**	0.117	0.112
	(2.55)	(2.51)	(0.93)	(0.89)
DUAL	0.038	0.039	0.014	0.015
	(1.22)	(1.25)	(0.36)	(0.38)
INDEP	0.284	0.323	0.469	0.525
	(0.91)	(1.03)	(1.20)	(1.33)
ROA	2.918***	2.952***	2.692***	2.715***
	(9.40)	(9.46)	(8.06)	(8.10)
GDP	0.201***	0.196***	0.328***	0.327***
	(5.39)	(5.24)	(7.35)	(7.37)
CUS_VOL		-0.005		0.001
		(-1.01)		(0.23)
CUS_AGE		0.043**		0.036
		(2.46)		(1.61)

_cons	-7.601***	-7.553***	-4.669***	-4.737***
	(-16.41)	(-15.96)	(-8.51)	(-8.45)
IND	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes
N	1450	1450	1450	1450
Adj. R^2	0.784	0.785	0.477	0.478

6.1.2. The Improvement Enterprise Innovation Efficiency By Customer Digital Spillover

Enterprise innovation efficiency is served by the proxy variable INN_EFF_1, which is calculated by ln(number of patent applications+1), and the proxy variable INN_EFF_2, which is calculated by (number of authorized patents)*10^7/(current R&D+lagging first phase R&D+lagging second phase R&D). INN_EFF_1 and INN_EFF_2 are the positive variable. Table 13 displays the results of the regression. According to the findings, enterprise value and consumer digital transformation have a favorable association since customer digital spillover improves enterprise innovation efficiency.

Table 13. The Improvement Enterprise Innovation Efficiency By Customer Digital Spillover

	(1)	(2)	(3)	(4)
	INN_EFF_1	INN_EFF_1	INN_EFF_2	INN_EFF_2
DIG	0.086***	0.087***	0.579*	0.556*
	(2.70)	(2.74)	(1.72)	(1.65)
LEV	-0.205	-0.202	1.829	1.923
	(-1.12)	(-1.10)	(0.83)	(0.87)
SIZE	0.708***	0.702***	-0.430	-0.539
	(21.85)	(21.41)	(-1.17)	(-1.46)
SOE	-0.079	-0.082	-0.849	-0.858
	(-1.06)	(-1.09)	(-0.88)	(-0.88)
LHR	0.915***	0.924***	-1.233	-1.150
	(4.18)	(4.23)	(-0.48)	(-0.45)
DUAL	-0.133*	-0.131*	-0.446	-0.403
	(-1.87)	(-1.84)	(-0.49)	(-0.44)
INDEP	0.267	0.200	0.866	-0.234
	(0.42)	(0.31)	(0.13)	(-0.03)
ROA	0.294	0.287	-3.499	-3.604
	(0.58)	(0.56)	(-0.64)	(-0.67)
GDP	0.156**	0.145**	0.189	0.071
	(2.15)	(1.99)	(0.21)	(0.08)

CUS_VOL		-0.016		-0.240***
		(-1.33)		(-2.97)
CUS_AGE		-0.003		-0.450
		(-0.07)		(-0.94)
_cons	-16.041***	-15.759***	7.974	13.061
	(-12.47)	(-12.02)	(0.75)	(1.19)
IND	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes
N	1754	1754	959	959
Adj. R^2	0.500	0.500	0.183	0.186

6.1.3. The Improvement Enterprise Investment Efficiency By Customer Digital Spillover

Enterprise investment efficiency is served by the proxy variable PEE which is calculated by (Total assets-Total current assets)/Total assets and the proxy variable ABS_INV which is calculated by the absolute value of enterprise investment efficiency calculated using the Richardson model (2006). PEE and ABS_INV are the negtive variable. Table 14 displays the results of the regression. According to the findings, enterprise value and consumer digital transformation have a favorable association since customer digital spillover improves enterprise investment efficiency.

Table 14. The Improvement Enterprise Investment Efficiency By Customer Digital Spillover

	(1)	(2)	(3)	(4)
	PPE	PPE	ABS_INV	ABS_INV
DIG	-0.014***	-0.014***	-0.002*	-0.003*
	(-3.23)	(-3.26)	(-1.74)	(-1.85)
LEV	-0.097***	-0.098***	-0.005	-0.006
	(-3.36)	(-3.38)	(-0.58)	(-0.63)
SIZE	0.035***	0.036***	0.000	0.001
	(7.74)	(7.88)	(0.28)	(0.53)
SOE	0.028**	0.028**	-0.016***	-0.016***
	(2.46)	(2.48)	(-4.80)	(-4.83)
LHR	-0.114***	-0.113***	0.019	0.020*
	(-3.20)	(-3.19)	(1.59)	(1.67)
DUAL	0.015	0.015	-0.003	-0.003
	(1.41)	(1.36)	(-0.73)	(-0.79)
INDEP	-0.068	-0.058	-0.045	-0.046
	(-0.77)	(-0.65)	(-1.62)	(-1.64)

ROA	-0.390***	-0.388***	0.008	0.008
	(-5.48)	(-5.42)	(0.37)	(0.38)
GDP	0.009	0.010	0.001	0.002
	(0.78)	(0.90)	(0.36)	(0.55)
CUS_VOL		0.003*		0.001*
		(1.65)		(1.76)
CUS_AGE		0.001		-0.003
		(0.21)		(-1.45)
_cons	-0.169	-0.214	-0.006	-0.020
	(-1.21)	(-1.51)	(-0.14)	(-0.41)
IND	Yes	Yes	Yes	Yes
YEAR	Yes	Yes	Yes	Yes
N	1358	1358	1358	1358
Adj. R^2	0.576	0.576	0.066	0.069

6.2. The Heterogeneity Tests

6.2.1. The Digital Gap

Drawing on the practice of Cho et al.(2023), this research sets the digital gap variable (DG), which is defined as the difference between the degree of customer digital transformation and the degree of enterprise digital transformation. DG is the positive variable. The regression results are shown in Table 15.The results show the effect of customer digital spillover on value co-creation is more significant in the sample of enterprises with wider digital gaps.

Table 15. The Heterogeneity About The Digital Gap

	(1)	(2)
	TOBIN	TOBIN
DIG×DG	0.065***	0.064***
	(4.32)	(4.25)
LEV	0.802***	0.799***
	(4.00)	(4.00)
SIZE	-0.574***	-0.569***
	(-15.85)	(-15.70)
SOE	0.075	0.077
	(1.13)	(1.16)
LHR	-0.505**	-0.507**
	(-2.40)	(-2.42)
DUAL	0.034	0.033

	(0.49)	(0.48)
INDEP	1.212**	1.221**
	(2.10)	(2.11)
ROA	2.307***	2.309***
	(3.09)	(3.09)
GDP	-0.023	-0.013
	(-0.35)	(-0.19)
CUS_VOL		0.014
		(1.16)
CUS_AGE		-0.026
		(-0.66)
_cons	12.000***	11.800***
	(10.52)	(10.27)
IND	Yes	Yes
YEAR	Yes	Yes
N	1583	1583
Adj. R^2	0.426	0.426

6.2.2. The Trade Credit Supply

Drawing on the practice of Lee and Rhee(2011), this research sets the trade credit supply variable (TC), which is defined (accounts receivable +notes receivable -accounts receivable in advance) / total assets. TC is the positive variable.The regression results are shown in Table 16.The results show the effect of customer digital spillover on value co-creation is more significant in the sample of enterprises with more trade credit supply.

Table 16. The Heterogeneity About The Trade Credit Supply

	(1)	(2)
	TOBIN	TOBIN
DIG×TC	0.401***	0.415***
	(3.08)	(3.13)
LEV	0.754***	0.754***
	(3.58)	(3.56)
SIZE	-0.561***	-0.562***
	(-14.41)	(-14.44)
SOE	0.153**	0.152**
	(2.28)	(2.27)
LHR	-0.684***	-0.679***

	(-3.29)	(-3.29)
DUAL	0.134**	0.134**
	(2.01)	(2.02)
INDEP	0.960	0.869
	(1.64)	(1.46)
ROA	2.685***	2.678***
	(3.64)	(3.62)
GDP	-0.007	-0.012
	(-0.11)	(-0.18)
CUS_VOL		-0.007
		(-0.69)
CUS_AGE		-0.043
		(-1.07)
_cons	11.511***	11.709***
	(9.75)	(9.83)
IND	Yes	Yes
YEAR	Yes	Yes
N	1426	1426
Adj. R^2	0.444	0.444

6.2.3. The Financing Constraints

Drawing on the practice of Kaplan and Zingales(1997), this research sets the financing constraints variable (KZ), which is defined as KZ index. KZ is the positive variable.The regression results are shown in Table 17.The results show the effect of customer digital spillover on value co-creation is more significant in the sample of enterprises with higher financial constraints.

Table 17. The Heterogeneity About The Financing Constraints

	(1)	(2)
	TOBIN	TOBIN
DIG×KZ	0.081***	0.081***
	(10.84)	(10.79)
LEV	-0.924***	-0.922***
	(-3.98)	(-3.97)
SIZE	-0.467***	-0.462***
	(-14.71)	(-14.62)
SOE	0.049	0.051

	(0.79)	(0.81)
LHR	-0.280	-0.282
	(-1.38)	(-1.40)
DUAL	-0.050	-0.051
	(-0.75)	(-0.78)
INDEP	0.919*	0.946*
	(1.70)	(1.74)
ROA	4.223***	4.225***
	(6.41)	(6.42)
GDP	-0.056	-0.046
	(-0.90)	(-0.73)
CUS_VOL		0.015
		(1.26)
CUS_AGE		-0.014
		(-0.39)
_cons	9.947***	9.720***
	(11.61)	(11.20)
IND	Yes	Yes
YEAR	Yes	Yes
N	1563	1563
Adj. R^2	0.511	0.510

6.2.4. The Dedicated Assets

Drawing on the practice of Handfield and Bechtel(2002), this research sets the dedicated assets variable (DA), which is defined as DA index. DA is the positive variable.The regression results are shown in Table 18.The results show the effect of customer digital spillover on value co-creation is more significant in the sample of enterprises with greater dedicated assets.

Table 18. The Heterogeneity About The Dedicated Assets

	(1)	(2)
	TOBIN	TOBIN
DIG×DA	0.270***	0.265***
	(3.38)	(3.30)
LEV	0.764***	0.761***
	(4.12)	(4.12)
SIZE	-0.529***	-0.524***
	(-15.38)	(-15.20)

SOE	0.120*	0.122**
	(1.94)	(1.97)
LHR	-0.652***	-0.654***
	(-3.37)	(-3.40)
DUAL	0.104*	0.102*
	(1.70)	(1.67)
INDEP	1.007*	1.010*
	(1.86)	(1.85)
ROA	1.901***	1.895***
	(2.60)	(2.59)
GDP	0.014	0.023
	(0.23)	(0.37)
CUS_VOL		0.012
		(1.18)
CUS_AGE		-0.034
		(-0.93)
_cons	11.820***	11.671***
	(8.51)	(8.32)
IND	Yes	Yes
YEAR	Yes	Yes
N	1750	1750
Adj. R^2	0.386	0.386

7. Research Conclusions and Implications

The real rate of return of the digital economy as a whole includes not only the direct productivity improvement brought by digital investment but also the additional economic benefits generated by the chain reaction of digital investment in the economic field, that is, digital spillover. Digital spillovers are the unintended or involuntary effects that occur independently of market mechanisms and actually affect other individuals or society as a whole. In general, the channels of digital spillover include industry, agglomeration, and the supply chain. As the economic linkage between enterprises formed through the supply chain is particularly common in the commodity market, such economic linkage not only facilitates the flow of factors and resources among the upstream and downstream enterprises but also provides a hidden way for the formation of a shared interest linkage mechanism among enterprises. Therefore, based on the reasonable and important research context provided by the supply chain,matching samples of listed enterprises in China's capital market from 2007 to 2021 and their top five customers, this research examines the customer digital spillover resulting from customer digital transformation on enterprise value.

The benchmark tests document customer digital spillover is positively associated with enterprise value co-creation in the supply chain, and this finding holds to a battery of robustness tests. Moreover, channel tests from the perspective of enterprise efficiency indicate that customer digital spillover impacts enterprise value co-creation in the supply chain through the improvement of enterprise production efficiency, enterprise innovation efficiency, and enterprise investment efficiency. Finally, the heterogeneity tests reveal that the effect of customer digital spillover on value co-creation among enterprises is more pronounced for enterprises with wider digital gaps, more trade credit supply, higher financial constraints and greater dedicated assets. In a word, this research which integrates upstream and downstream enterprises into a single research framework and deeply explores the interaction logic among enterprises, breaks the reality of the previous research on the supply chain spillover effect and value co-creation between enterprises.

This research has far-reaching policy implications. First, both customers and enterprises should not only make full use of resource elements brought by social capital, such as rich knowledge spillover, advanced technology spillover, and more accurate information spillover, but also actively promote digital transformation and take the initiative to carry out innovative research and development activities to build a supply chain community with competitive advantages to realize the value of the co-creation. Second, the government should pay attention to the phenomenon of the spillover effect in the digital transformation of enterprises at the micro level, deepen its understanding that digital spillover is one of the important sources of the core value of the digital economy, and take a series of measures to maximize the economic growth brought by digital spillover.

Author Contributions:

Conceptualization: Jiao Wang; Data curation:Jiao Wang. Formal analysis: Jiao Wang; Funding acquisition: Xingkai Nie; Methodology: Jiao Wang; Resources: Jiao Wang; Software: Jin-xuan He; Supervision: Xuan Pei; Writing -original draft: Jiao Wang; Writing-review & editing: Jiao Wang. All authors have read and agreed to the published version of the manuscript.

Funding:

This research was funded by Shanxi Province Science and Technology Innovation Project of Higher Education Institutions, grant number 2025W018.

Institutional Review Board Statement:

Not applicable.

Data Availability Statement:

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments:

The authors thank the editors and the anonymous reviewers for their efforts to improve the quality of this research.

Conflict of Interest:

The authors declare no conflict of interest.

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Digital-Intelligent Economy and Scientific Management, 2025, 1(1), 39-62
https://doi.org/10.71204/2bzhn793

Digital-Intelligent Barriers to Resource Re-extraction in China's Agrifood Manufacturing

Xia Yang [1, *], Ling Chen [2], Xi Wang [1]

[1] Universiti Malaya, Kuala Lumpur 50603, Malaysia

[2] Beijing City University, Beijing 100083, China

*** Correspondence:**

Xia Yang

22062517@siswa.um.edu.my

Received: 21 August 2025/ Accepted: 14 September 2025/ Published online: 3 November 2025

Abstract

China's agrifood manufacturing sector produces millions of tons of organic and packaging waste annually, creating an urgent need for circular production models. Resource re-extraction (RE), the digital-enabled recovery of nutrients and materials from waste streams, offers a pathway toward sustainable value creation. However, its adoption remains limited despite strong policy incentives. Understanding why this resistance persists is critical for advancing the digital-intelligent circular economy agenda. This study addresses that gap by examining how cognitive barriers shape Resource Re-extraction Resistance (RRER), with a focus on identifying which obstacles carry the most weight in an emerging economy context. Drawing on Innovation Resistance Theory (IRT), we surveyed 256 agrifood manufacturers across multiple Chinese provinces and applied partial least squares structural equation modelling (PLS-SEM) to test the hypothesised barrier – resistance relationships. The model was evaluated using reliability, convergent and discriminant validity, and collinearity diagnostics, ensuring robust measurement quality. Structural analysis revealed that risk barriers exert the strongest influence on RRER, followed by image barriers and usage barriers, while tradition and value barriers had no significant effect. These results imply that resistance is driven more by concerns over operational failure, brand reputation, and process complexity than by cultural attachment or perceived return on investment. In response, we propose targeted digital-intelligent solutions such as AI-driven process simulation to mitigate perceived risks, blockchain-enabled traceability to safeguard brand image, and AR/VR-based training to lower complexity in implementation. By linking barrier diagnosis with technology-enabled management strategies, this research advances theoretical applications of IRT in industrial sustainability and provides actionable guidance for accelerating the circular transition in emerging markets.

Keywords: Resource Re-extraction Resistance; Circular Economy; Digital Barriers; Agrifood Manufacturing; Industry 4.0

1. Introduction

China's agrifood manufacturing sector is a formidable economic engine that also exerts significant environmental pressure. In 2019, food-related production, processing, packaging, and waste disposal collectively accounted for approximately 13.5% of China's total greenhouse gas emissions, reflecting the scale of the industry's environmental impact (Sandalow et al., 2022). Although official national data on waste tonnage is limited, industry reports estimate that hundreds of millions of tonnes of agricultural residues, livestock by-products, and packaging waste are generated each year (China-Italy Chamber of Commerce, 2022). When mismanaged, these waste streams contribute significantly to environmental degradation by releasing greenhouse gases, reducing soil fertility, and accelerating nutrient-driven eutrophication in surface waters (Abate et al., 2024). Nevertheless, research in Zhejiang's Huangyan region highlights the latent resource potential embedded in these waste streams—showing that theoretical recovery of nitrogen and phosphorus from tangerine and water bamboo residues could replace up to 59% of nitrogen and 15% of phosphorus fertilizer inputs, reinforcing resource re-extraction's promise for supply chain resilience and circular economy development (Santolin et al., 2024).

Resource re-extraction (RE) describes the process of retrieving these secondary resources from waste through specialized technological interventions. The integration of digital-intelligent technologies such as IoT-enabled monitoring, AI-driven process optimization, and robotic automation has further expanded the feasibility and efficiency of RE. Beyond improving recovery rates, these technologies generate operational data that support better traceability, predictive maintenance, and real-time quality assurance (Ellen MacArthur Foundation, 2021). Recent advancements in AI and digital twin technologies have further enhanced the capacity of agrifood manufacturers to simulate operational changes, reduce perceived risks, and optimize resource recovery processes (Ali et al., 2025; Meng & Li, 2025; R. Zhang et al., 2025).

In recognition of these opportunities, China has institutionalized RE within its broader circular economy framework through pivotal legislation and planning initiatives. The Circular Economy Promotion Law, enacted in 2009, explicitly mandates the reuse and comprehensive utilization of agricultural and industrial by-products, and includes incentives such as fiscal and technological support for recycling and waste recovery (Ministry of Ecology and Environment of the People's Republic of China [MEE], 2009). More recently, the 14th Five-Year Plan for Circular Economy Development (2021–2025), issued by the National Development and Reform Commission, advances this agenda by emphasizing enhanced recycling of agricultural materials, the construction of rural recycling infrastructure, and the expansion of biomass energy systems, with financial incentives and infrastructure support for agrifood sustainability (China Briefing, 2021).

Despite these favorable policies, adoption of RE practices remains uneven across agrifood manufacturers. Many firms perceive RE systems as financially risky, operationally disruptive, or possibly detrimental to brand image, especially in settings where consumer trust in food safety is paramount. This misalignment between policy intent and ground-level adoption underscores the urgency of examining the cognitive and organizational barriers that obstruct RE uptake.

The majority of existing research on RE adoption originates from developed economies with mature regulatory environments and digital infrastructure (Geissdoerfer et al., 2017; Kirchherr et al., 2018). In the Chinese context, leading studies on RE have typically concentrated on technical performance indicators such as nutrient recovery efficiencies and economic feasibility through cost-benefit analyses while largely overlooking the underlying behavioral and cognitive factors that influence organizational adoption decisions (Li et al., 2021; Xia & Ruan, 2020). Furthermore, while the literature on innovation resistance in manufacturing is well established, few studies have explored how digital-intelligent technologies could strategically target and reduce these barriers in a circular economy setting.

While China has made significant policy commitments to advancing a circular economy, the agrifood manufacturing sector still faces mounting sustainability and security pressures. A strategic 10-year initiative underscores the state's commitment to food resilience, yet rising waste volumes, nearly 27% lost across the supply chain, rivet this urgency (Dong et al., 2024; Reuters, Apr 7 2025) . The agrifood system transformation itself introduces new stressors, such as growing demand for feed and meat, greater reliance on imports, and the balancing act between food production and environmental goals (Zhao et al., 2023) . Compounding these dynamics, agriculture accounts for nearly 19% of China's greenhouse gas emissions, intensifying the challenge of safeguarding food security within climate-targeted transitions (China Daily, Jul 31 2025) . The persistence of adoption resistance amid these pressures not only slows progress toward a digital-intelligent circular economy but directly threatens the long-term sustainability and resilience of China's food systems. Against this backdrop, this study advances both theory and practice in three distinctive ways. Contextually speaking, It applies Innovation Resistance Theory (IRT) (Ram & Sheth, 1989) to an emerging economy agrifood sector, a context characterized by different institutional pressures, cultural norms, and digital maturity levels compared to developed economies. Theoretically speaking, it integrates digital-intelligent solution pathways such as AI-based risk modeling, blockchain-enabled traceability, and augmented reality (AR) operational guidance directly into the conceptualization of barrier mitigation, bridging the gap between resistance theory and Industry 4.0 applications. Empirically speaking, it employs partial least squares structural equation modelling (PLS-SEM) analysis on a cross-regional sample of 256 Chinese agrifood manufacturers, offering a robust empirical basis for ranking the influence of different cognitive barriers on RE adoption resistance. By doing so, the research not only clarifies the hierarchy of barriers in a real-world industrial context but also aligns these insights with digital-intelligent management strategies that can accelerate circular economy transitions.

Overall, this study contributes to digital economy scholarship by showing how cognitive resistance factors interact with digital-intelligent management interventions in shaping technology adoption. It also informs policy design by identifying which barriers require targeted support measures and which are less influential in the current Chinese agrifood manufacturing environment. The study addresses the following research question: What cognitive barriers significantly influence resource re-extraction resistance in China's agrifood manufacturing sector, and what digital-intelligent technologies can be leveraged to mitigate them?

This question serves as the foundation for this study and outlines the following sections. Section 2 discusses the theoretical framework and hypotheses, where we define each barrier, derive our hypotheses, and link them to potential digital-intelligent management solutions. Section 3 describes the methodology used in this study, followed by the results and analysis in Section 4. Section 5 discusses the major findings and answers the research question. Section 5 concludes this study by showing its implications, contributions, limitations, and future research suggestions.

2. Theoretical Framework and Hypotheses

Innovation adoption in industrial contexts rarely depends solely on technical feasibility or policy alignment; rather, it is mediated by a range of organizational, cognitive, and cultural factors that can significantly delay or derail implementation (Menichini et al., 2024; Sharma et al., 2025). For China's agrifood manufacturers, the decision to integrate resource re-extraction (RE) technologies must be evaluated not only in terms of cost-benefit outcomes but also through the lens of perceived risks, operational compatibility, and stakeholder perception. Understanding these resistance drivers is critical because they directly influence the pace and scale of circular economy adoption, regardless of regulatory incentives.

To systematically capture and analyze these drivers, this study employs Innovation Resistance Theory (IRT) as its conceptual foundation. IRT provides a structured way to categorize and measure the distinct psychological and functional barriers that can hinder technology uptake (Kaur et al., 2020). In adapting IRT to the context of digital-intelligent RE, we not only identify the barriers but also consider how emerging Industry 4.0 tools can actively counteract them. The following subsections outline how IRT is applied in this research, define each barrier construct, and develop hypotheses for empirical testing.

2.1. Innovation Resistance Theory in a Digital-Circular Economy Context

Innovation Resistance Theory (IRT), first articulated by Ram and Sheth (1989), posits that adoption of new technologies is not simply a function of perceived benefits but is often hindered by various functional and psychological barriers. These barriers arise when the innovation disrupts existing processes, challenges established norms, or introduces uncertainties that exceed an adopter's tolerance threshold.

In the context of digital-enabled resource re-extraction (RE), IRT offers a valuable analytical lens for understanding why Chinese agrifood manufacturers, despite technical feasibility and policy support, still resist adoption. The decision to adopt RE systems often requires altering established workflows, reconfiguring supply chains, and committing financial resources to unproven technology, all of which can trigger resistance (Aktaş et al., 2021; Zhao et al., 2024a).

This study adapts IRT to the digital-circular economy by integrating Industry 4.0 tools like digital twins, IoT, and blockchain as potential countermeasures to the barriers identified. In this way, it helps to test IRT's explanatory power in a novel agrifood manufacturing setting and

demonstrate how specific technologies can address distinct resistance barriers (Zhao et al., 2024a; Zhao et al., 2024b).

2.2. Conceptualizing Resource Re-extraction Resistance (RRER)

For this study, Resource Re-extraction Resistance (RRER) refers to the degree to which agrifood manufacturers demonstrate reluctance, whether overt or implicit, toward adopting technological solutions for recovering secondary materials from waste streams. RRER encompasses unctional concerns, such as operational fit, cost-effectiveness, and supply chain integration, and psychological factors, including brand image, consumer perception, and cultural preferences (Heidenreich & Kraemer, 2016; Talwar et al., 2021).

In China's agrifood manufacturing sector, these resistance dynamics are shaped by historical risk aversion linked to food safety incidents, the complexity of production processes, and the dominance of low-margin operational models that prioritize short-term cost control over long-term sustainability investments (Bleischwitz et al., 2022; Farooque et al., 2019). Even when RE technologies are technically viable and supported by policy incentives, adoption may be hampered if perceived risks outweigh anticipated returns (Laukkanen, 2016).

2.3. Defining and Linking the Barriers

Having established the conceptual definitions and interrelationships of the five barriers, it is now essential to examine each in greater depth. This allows us to unpack the mechanisms through which they may influence resistance to RE adoption in the agrifood manufacturing context. We begin with the risk barrier, which, given the sector's operational sensitivities and the preliminary results of prior research, is expected to exert a particularly strong influence.

2.3.1. Risk Barrier (RB)

The risk barrier arises from the perception that an innovation could lead to financial losses, operational inefficiencies, or reputational harm (Heidenreich & Kraemer, 2016). In RE, these risks may be heightened by uncertainties surrounding equipment reliability, regulatory compliance, product quality, and market acceptance (Bleischwitz et al., 2022; Farooque et al., 2019). In China's agrifood sector where past food safety incidents have intensified managerial risk aversion (Despoudi et al., 2025; Reitano et al., 2024), perceived vulnerability to operational failure or public backlash can deter adoption. As a potential mitigation strategy, AI-driven digital twins can model RE processes under varying operational scenarios, enabling firms to forecast performance outcomes and identify possible points of failure before physical implementation (Ball & Badakhshan, 2022; Javaid et al., 2023). Hypothesis 1 is proposes as follows.

H1: The risk barrier has a positive and significant effect on RRER.

2.3.2. Image Barrier (IB)

The image barrier reflects the extent to which an innovation is seen as misaligned with a firm's desired brand image or public reputation (Rogers, 2003). For agrifood manufacturers, adopting RE might be misconstrued as an admission of excessive waste generation or potential contamination risks, especially if stakeholders misunderstand the technology's purpose

(Despoudi et al., 2025) . In China's consumer market where brand trust is fragile, these perceptions can significantly shape managerial decisions. Digital solutions such as blockchain-enabled traceability can counteract such concerns by providing verifiable proof of sustainable practices, reframing RE adoption as a brand-enhancing innovation rather than a reputational liability (Saberi et al., 2019). Hypothesis 2 is proposed as below.

H2: The image barrier has a positive and significant effect on RRER.

2.3.3. Usage Barrier (UB)

The usage barrier emerges when a new technology is perceived as complex, requiring significant changes in routines or extensive training (Ram & Sheth, 1989) . For RE, these challenges may involve integration with existing production lines, new waste segregation protocols, and advanced data management systems (Chauhan et al., 2022; Vahdanjoo et al., 2025) . Such perceptions can slow adoption, particularly in small and medium-sized enterprises with limited technical capacity. Immersive training tools such as augmented reality (AR) and virtual reality (VR) can reduce perceived complexity by enabling hands-on simulations that simplify the learning process (Masood & Egger, 2019). Hypothesis 3 is proposed as below.

H3: The usage barrier has a positive and significant effect on RRER.

2.3.4. Tradition Barrier (TB)

The tradition barrier reflects resistance rooted in cultural norms, habitual practices, and organizational inertia (Talwar et al., 2021). In the agrifood industry, some firms may prefer long-standing waste disposal methods even when these are environmentally suboptimal due to perceived reliability and familiarity (Okaibedi Eke et al., 2024). While China's efficiency-driven manufacturing culture may reduce the weight of tradition compared to other contexts, it can still limit openness to process innovations. Digital tools such as gamified training and knowledge-sharing platforms can gradually shift organizational norms, although the effect may be weaker where performance metrics dominate decision-making. Hypothesis 4 is proposed accordingly.

H4: The tradition barrier has a positive and significant effect on RRER.

2.3.5. Value Barrier (VB)

The value barrier arises when the perceived return on investment (ROI) of an innovation is insufficient to justify its adoption (Laukkanen, 2016) . For RE, this could involve doubts about the market value of recovered materials, payback periods, or overall cost savings (Masi et al., 2017) . In China's agrifood sector where profit margins are often thin, such concerns may be particularly influential. Predictive analytics can enhance perceived value by modeling long-term cost savings, identifying secondary revenue streams, and quantifying the strategic benefits of adopting RE technologies (Tseng et al., 2020). Hypothesis 5 is thereby proposed.

H5: The value barrier has a positive and significant effect on RRER.

2.4. Proposed Research Model

Figure 1 depicts the conceptual model tested in this study. Each barrier is hypothesized to positively influence RRER, with the relative strength of these relationships revealing a barrier

hierarchy. By examining these links, the study identifies where digital-intelligent interventions can have the most impact, thereby operationalizing IRT within a digital-circular economy framework.

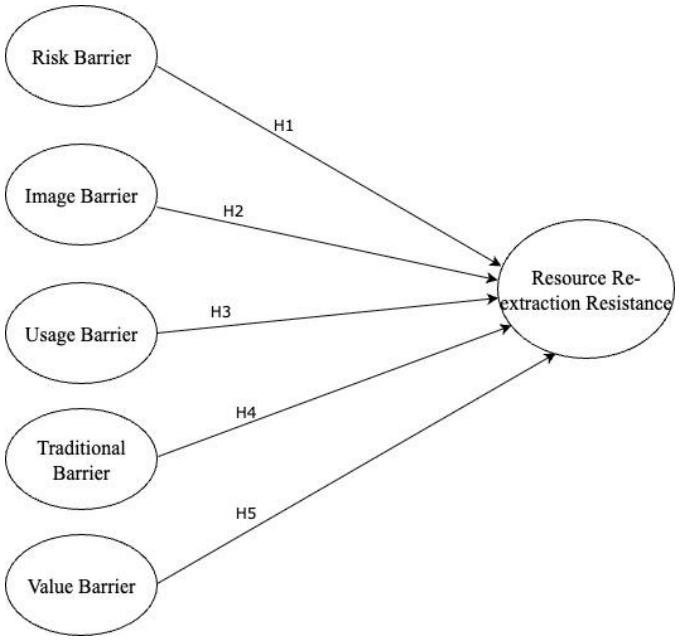

Figure 1. Conceptual Framework

3. Methodology

Having established the theoretical underpinnings and hypotheses in Section 2, the next step is to empirically test the proposed model using reliable contextually relevant data. The methodological design is informed by the dual need to capture nuanced perceptions of cognitive barriers among agrifood manufacturers and apply an analytical approach that can handle the predictive and explanatory aims of the study.

3.1. Research Design

This research adopts a cross-sectional survey design, which is well suited to examining perceptions and attitudes across a broad geographically dispersed sample (Creswell & Creswell, 2018) . While longitudinal designs can track changes over time, a cross-sectional approach provides a robust snapshot of current resistance patterns, particularly valuable in a sector undergoing active policy and technological change.

3.2. Sampling and Data Collection

The study targeted 256 agrifood manufacturing firms across seven major regions in China, selected through stratified random sampling to ensure diversity in sub-sectors and firm sizes. Provinces were chosen to capture regional variations in industrialization levels and policy enforcement intensity. From June to October 2024, data were collected via structured questionnaires distributed both electronically and in person, with follow-up calls to increase response rates. Respondents were typically senior operations managers or sustainability officers, as these roles hold decision-making authority over technology adoption. To minimize social

desirability bias, the survey assured anonymity and emphasized that there were no "right" or "wrong" answers.

3.3. Measurement Development

The constructs were operationalized using 5-point Likert scales (1 = strongly disagree, 5 = strongly agree), adapted from established innovation resistance measures (Heidenreich & Kraemer, 2016; Ram & Sheth, 1989) and tailored to the RE context. Each barrier construct, risk, image, usage, tradition, and value, was measured using four to five items, while RRER was measured using four items assessing reluctance to adopt RE technologies. Pilot test was conducted with 19 industry practitioners and three academic experts in industrial management to refine wording and ensure cultural and sectoral relevance. Minor adjustments were made to clarify technical terms and align with Chinese manufacturing practices.

3.4. Data Analysis Method

Partial Least Squares Structural Equation Modeling (PLS-SEM) was selected for three reasons:

Prediction-oriented focus: The study aims to identify which barriers have the greatest predictive power for RRER (Hair, 2019).

Model complexity: The framework includes multiple latent variables, each with reflective measurement models, requiring an approach that can handle multicollinearity and smaller sample sizes.

Adaptation of theory: As this is among the first applications of IRT in the digital-circular economy context of China's agrifood sector, PLS-SEM's flexibility makes it suitable for theory extension and model refinement.

Analysis was conducted using SmartPLS 4, which offers advanced bootstrapping and predictive relevance testing capabilities.

3.5. Analytical Procedure

The analysis proceeded in three stages. The first stage is for the measurement model assessment through testing for reliability (Cronbach's α, composite reliability), convergent validity (average variance extracted, AVE), and discriminant validity (Fornell–Larcker criterion). The second stage is for the structural model assessment by estimating path coefficients, significance levels (t-values, p-values), and effect sizes (f^2). The third stage is for the predictive relevance testing by using Q^2 statistics from blindfolding procedures to determine the model's predictive validity. The methodological rigor outlined here ensures that the empirical findings are statistically robust and contextually grounded. With the data collection and analytical procedures firmly established, the next section presents the results accordingly.

4. Results

Following the procedures outlined in Section 3, the results are presented in three major parts: (1) demographic and descriptive analyses; (2) measurement model validation, ensuring that the

constructs meet the reliability and validity requirements; and (3) structural model assessment, testing the hypothesized relationships and evaluating the predictive strength of the model.

4.1. Demographic Analysis

The demographic profile of surveyed firms provides further context to the resistance patterns (see Figure 2). The largest proportion of respondents came from fruit and vegetable processing companies (18.8%), followed by jam, jelly, and preserve manufacturers (14.1%) and frozen food manufacturers (13.3%). This distribution reflects the strong representation of firms engaged in the processing and preservation of perishable commodities, a sub-sector where waste generation is a notable challenge due to product shelf-life constraints. In addition, a considerable share of participants were organic and natural food brands (11.7%) and juice and beverage manufacturers (10.9%), both of which operate in high-volume production environments where process innovation could substantially impact waste management and RE adoption.

Category	Sub-Category	Frequency (R = 256)	Percentage (%)
Main Industry	Fruit and Vegetable Processing Companies	48	18.8
	Jam, Jelly, and Preserve Manufacturers	36	14.1
	Frozen Food Manufacturers	34	13.3
	Organic and Natural Food Brands	30	11.7
	Juice and Beverage Manufacturers	28	10.9
	Sauce and Condiment Producers	15	5.9
	Specialty Food Producers	14	5.5
	Culinary and Artisanal Food Producers	12	4.7
	Private Label and Contract Manufacturers	12	4.7
	Distribution and Retailers	12	4.7
	Dried Fruit and Nut Companies	6	2.3
	Others	5	2.0
	Pickling and Fermentation Companies	4	1.6
Years Established	6 – 10 years	113	44.1
	Less than 5 years	107	41.8
	11 – 20 years	28	10.9
	21 – 30 years	6	2.3
	More than 30 years	2	0.8
Total Employee Size	51 - 100 employees	94	36.7
	101 - 500 employees	64	25.0
	Less than 50 employees	58	22.7
	501 - 1000 employees	32	12.5
	More than 1000 employees	8	3.1
Annual Revenue (CNY)	Less than RMB30 million	103	40.2
	RMB30 million – RMB50 million	83	32.4
	RMB50 million – RMB100 million	52	20.3
	More than RMB100 million	18	7.0
Ownership Status	Private	180	70.3
	State-owned	26	10.2
	Shareholding	25	9.8
	Foreign invested	24	9.4
	Others	1	0.3
Firm Location	East China	88	34.4
	South China	46	18.0
	Central China	44	17.2
	North China	36	14.1
	Northeast China	18	7.0
	Southwest China	17	6.6
	Northwest China	7	2.7
Monthly food waste generated	6-10 tons	109	42.6
	Less than 5 tons	80	31.3
	11-20 tons	44	17.2
	21-30 tons	18	7.0
	31-40 tons	5	2.0

Figure 2. Distribution of Firm Profile

In terms of business maturity, nearly half of the firms had been established for 6 to10 years (44.1%), and a further 41.8% had been operating for less than 5 years. Only 10.9% had been in business for 11 to 20 years, and less than 3% had operated for more than two decades. This relatively young age profile suggests that the sample is dominated by firms still in their growth or consolidation phases, where investment priorities may be shaped by rapid market adaptation rather than long-term tradition.

Firm size also varied considerably. The most common category was 51–100 employees (36.7%), followed by 101–500 employees (25.0%) and less than 50 employees (22.7%). Larger firms employing over 500 workers accounted for 15.6% of the sample, indicating a mixture of small-to-medium-sized enterprises (SMEs) and larger industrial players. This diversity is important because firm size often influences the resources available for technological adoption and risk mitigation strategies.

In terms of financial capacity, 40.2% reported annual revenues below RMB 30 million, while 32.4% fell into the RMB 30–50 million range. Approximately one-fifth (20.3%) generated between RMB 50–100 million, and only 7% exceeded RMB 100 million in revenue. The predominance of lower-revenue firms suggests that capital constraints could shape perceptions of financial risk associated with RE investments, particularly in digital-intelligent solutions.

Ownership structures were dominated by private enterprises (70.3%), with smaller proportions of state-owned enterprises (10.2%), shareholding companies (9.8%), and foreign-invested firms (9.4%). The dominance of privately-owned companies may indicate a higher sensitivity to cost-benefit considerations and market image.

Geographically, the majority of firms were located in East China (34.4%), reflecting the region's industrial concentration and export-oriented agrifood processing capacity. Other notable clusters were in South China (18.0%) and Central China (17.2%), while the remaining regions had smaller shares, with Northwest China representing just 2.7% of respondents. This regional distribution highlights that the study's results are most representative of industrially developed areas, though inputs from less developed regions add diversity to the dataset.

Finally, the analysis of monthly food waste generation revealed that most firms produced 6–10 tons per month (42.6%), followed by those generating less than 5 tons (31.3%). A smaller share reported waste levels of 11–20 tons (17.2%) or more than 20 tons (less than 10% combined). This waste volume distribution aligns with the industrial scale of respondents and underscores the sector's potential for resource recovery if technological and cognitive barriers can be addressed.

Taken together, this demographic profile indicates a sample characterized by sectoral diversity, relatively young firms, predominance of SMEs, and a strong private ownership base. These characteristics have direct implications for understanding the cognitive barriers to RE adoption: younger, smaller, and privately-owned firms may exhibit higher sensitivity to risk and operational complexity, whereas larger or more established entities may have greater absorptive capacity for innovative digital-intelligent solutions.

4.2. Descriptive Analysis

Table 1 presents the descriptive statistics for the five barrier constructs. Mean scores indicate moderately high perceptions across all barriers, with usage (M = 3.77) ranked highest, followed by value (M = 3.66), image (M = 3.53), risk (M = 3.48), and tradition (M = 3.41). While these descriptive results highlight which barriers are perceived as most salient, their true influence on RRER requires testing through structural modelling, which is presented in the subsequent sections.

Table 1. Descriptive Analysis of Barrier Constructs

Construct	Mean	SD	Interpretation
Risk Barrier (RB)	3.48	1.101	High perceived uncertainty in financial/operational outcomes
Image Barrier (IB)	3.53	1.023	High concern over brand and market perception
Usage Barrier (UB)	3.77	0.887	Operational complexity and training burden highly significant
Value Barrier (VB)	3.66	0.935	High skepticism on ROI
Tradition Barrier (TB)	3.41	1.08	High attachment to legacy production habits

4.3. Measurement Model Validation

Table 2 reports the reliability and validity statistics for all constructs. Internal consistency was confirmed, with Cronbach's α values exceeding the 0.70 benchmark (Hair et al., 2010; Nunnally & Bernstein, 1995) for all constructs. Composite reliability (CR) scores were also above the 0.70 threshold, indicating that each construct's items consistently reflect their underlying latent variable. Convergent validity was supported, as the Average Variance Extracted (AVE) for all constructs exceeded 0.50 (Fornell & Larcker, 1981), confirming that the majority of variance in the indicators was explained by the respective constructs. Collinearity diagnostics revealed Variance Inflation Factor (VIF) values well below the critical value of 5 (Hair et al., 2019), with the exception of two items in the Usage Barrier construct (UB3 and UB5), which approached cautionary levels (4.237 and 4.136, respectively). Although these values remain within acceptable limits, they suggest a degree of redundancy between items. Retaining them is justified on theoretical grounds to preserve construct validity; however, this issue is acknowledged as a limitation. Future studies may refine these measures, consider formative approaches, or test item reduction strategies to minimize multicollinearity risk while maintaining robust construct representation.

Table 2. Measurement model evaluation

Construct	Items	Loadings	Cronbach's α	CR	AVE	VIF range
RRER	4	0.709–0.799	0.746	0.84	0.567	1.237–1.621
Risk Barrier (RB)	4	0.723–0.779	0.746	0.839	0.566	1.428–1.627
Image Barrier (IB)	5	0.789–0.874	0.897	0.924	0.709	2.059–3.794
Usage Barrier (UB)	4	0.692–0.840	0.794	0.866	0.62	1.413–4.237
Value Barrier (VB)	4	0.775–0.819	0.818	0.878	0.643	1.510–3.643
Tradition Barrier (TB)	4	0.818–0.897	0.865	0.908	0.712	1.745–2.837

The Fornell–Larcker criterion confirmed discriminant validity: the square root of each construct's AVE was greater than its correlations with other constructs. This suggests that the measures are empirically distinct and that multicollinearity is not a critical issue in the model.

4.4. Structural Model Results

Table 3 presents the structural path coefficients, t-values, p-values, effect sizes (f^2), and predictive relevance (Q^2). Hypotheses H1, H2, and H3 were supported, while H4 and H5 were not.

The Risk Barrier (H1) emerged as the strongest predictor of RRER ($\beta = 0.546$, $p < 0.001$), with a large effect size ($f^2 = 0.280$). This finding reflects the central role of operational uncertainty in agrifood manufacturing, a sector characterized by perishable raw materials, thin margins, and tight regulatory oversight. Even small disruptions in processing can lead to significant financial losses, product recalls, or export rejections. RE technologies, while promising, are still perceived as untested at scale, which amplifies managerial caution. This aligns with prior research suggesting that firms in food-related industries are disproportionately risk-averse when innovation introduces potential quality or safety variability (Shakuri & Barzinpour, 2024).

The Image Barrier (H2) also showed a significant positive effect ($\beta = 0.217$, $p = 0.009$), underscoring the reputational sensitivity of agrifood firms. Brand trust in China is fragile due to recurring food safety scandals, and consumers often equate product safety with purity and minimal interference (Tao & Chao, 2024). In this environment, reusing or reprocessing materials can easily be misconstrued as compromising quality. With digital media amplifying reputational risks, firms perceive RE as a potential liability unless supported by strong traceability and certification mechanisms. This helps explain why image considerations, even more than operational cost concerns, act as a major deterrent to adoption.

The Usage Barrier (H3) exerted a smaller but still significant influence ($\beta = 0.140$, $p = 0.027$). While not as dominant as risk or image, this barrier remains relevant due to the inherent complexity of perishable food operations. The review from Osman et al. (2023) of perishable food supply chain challenges illustrates how logistical and process barriers persist in this sector, supporting the significance of perceived usage complexity in RE adoption. It reflects the technical complexity of integrating RE systems into existing production lines, especially for small and medium-sized enterprises (SMEs) that dominate China's agrifood sector. Many SMEs lack advanced digital infrastructure or sufficient skilled labor to manage RE operations, making adoption appear resource-intensive and disruptive. Although digital literacy is increasing, the perceived effort of retraining workers and reconfiguring production processes continues to generate hesitation.

By contrast, the Tradition Barrier (H4) and Value Barrier (H5) did not significantly predict RRER. This divergence from findings in other cultural settings suggests that industrial modernization and strong state-led incentives in China reduce the influence of cultural inertia and short-term ROI skepticism. Firms increasingly prioritize efficiency and regulatory compliance over preserving traditional waste management practices. Moreover, subsidies and circular economy programs already improve the financial attractiveness of RE, diminishing value-related

concerns. This resonates with arguments from institutional theory that coercive pressures from state policy can override traditional practices, while supportive incentives mitigate cost-related hesitation (Castro-Lopez et al., 2023; Juráček et al., 2025).

Table 3. Structural model evaluation

Hypothesis	Path	β (O)	t-value	p-value	f^2	Status
H1	RB → RRER	0.546	6.507	0	0.28	Supported
H2	IB → RRER	0.217	2.632	0.009	0.041	Supported
H3	UB → RRER	0.14	2.215	0.027	0.027	Supported
H4	TB → RRER	-0.069	0.916	0.359	0.004	Rejected
H5	VB → RRER	0.073	1.108	0.268	0.006	Rejected
Model fit	$R^2 = 0.640$	$Q^2 = 0.615$				

The model explains 64.0% of the variance in RRER, indicating substantial predictive power (Chin, 1998). The dominance of the risk barrier reflects firms' concerns over operational stability in perishable food production, where system failures can cause disproportionate losses. Image barriers highlight the sector's reputational sensitivity, particularly in consumer-facing subsectors such as organic, beverage, and specialty foods. Usage barriers, though weaker, remain significant due to the technical integration and training demands of RE adoption, especially for SMEs with limited digital infrastructure. By contrast, tradition and value barriers did not significantly influence resistance, suggesting that regulatory incentives and modernization pressures may already be mitigating cultural inertia and ROI skepticism. The Q^2 value of 0.615 confirms that the model has predictive relevance, indicating that it can forecast resistance patterns beyond the sample data. These findings provide the empirical foundation for the discussion that follows, where digital-intelligent strategies are mapped onto the most pressing barriers.

5. Discussion

This study examined the cognitive barriers influencing RRER in China's agrifood manufacturing sector. While the empirical results in Section 4.4 establish the hierarchy of barriers, this section explicitly links these findings to digital-intelligent solutions, demonstrating how tools such as AI-driven simulations, blockchain-enabled traceability, and AR/VR training can directly address the most influential resistance factors. The hierarchy of barriers reflects the sector's operational realities. Unlike many studies in developed contexts where tradition and value perceptions are prominent drivers of resistance (Ram & Sheth, 1989; Talwar et al., 2021), the Chinese agrifood industry appears to be pragmatically oriented. Here, firms are not bound by

entrenched customs or skeptical about the intrinsic value of innovation; rather, they are constrained by the perceived dangers, reputational vulnerabilities, and practical difficulties of implementing RE technologies.

The findings of this study demonstrate that operational risk, image, and usage barriers significantly contribute to RRER in China's agrifood manufacturing sector, whereas tradition and value barriers do not exert a measurable influence. This ordering contrasts with studies in Western contexts, where tradition and value often feature prominently in explaining resistance to circular innovations (Talwar et al., 2021). The divergence highlights the context-specific nature of innovation resistance theory, underscoring the need to account for industrial priorities, regulatory pressures, and market structures.

The risk barrier demonstrated the strongest influence on RRER, confirming previous research that firms in resource-intensive sectors often perceive technological change as financially hazardous when future payoffs are uncertain (Ram & Sheth, 1989; Talwar et al., 2021). The demographic analysis offers important explanatory insight. More than 85% of participating firms were established within the last decade, and over 62% reported annual revenues below RMB 50 million. Such firms typically have tighter cash flows, less financial buffering capacity, and shorter investment horizons, making them more risk-averse in allocating resources to untested processes like resource re-extraction. The concentration of small and medium-sized enterprises (SMEs) further compounds this effect, as SMEs in China often rely heavily on short-term profitability to maintain competitiveness (An & Zhang, 2021). These operational uncertainties are further magnified in contexts where digital infrastructure adoption is still maturing, as shown by recent findings on the digital–green coupling transition in Chinese agriculture, which highlight persistent gaps in technological integration and risk management (Hu et al., 2025). Thus, the dominance of the risk barrier in our model is not only statistically significant but also logically consistent with the financial and structural realities of the sampled firms.

The image barrier ranked second, aligning with prior studies that highlight reputational concerns as a core impediment to adopting green innovations in consumer-facing industries (Kumar & Nayak, 2022). This finding is reinforced by our demographic data. A large share of respondents operate in sectors such as fruit and vegetable processing, beverage manufacturing, and organic/natural products, where brand identity and consumer trust are critical assets. In such markets, perceived risks of product contamination, inconsistency in quality, or misalignment with brand values can outweigh the potential sustainability gains from RE. Moreover, for firms exporting to global markets, where sustainability narratives are often closely scrutinized, the fear of unintended reputational harm may act as a powerful deterrent to early adoption. Integrating blockchain-enabled traceability (Apeh & Nwulu, 2025) within RE systems has been shown to alleviate such concerns by offering verifiable proof of product integrity, a finding supported by recent reviews on sustainable circular agri-food supply chains (Zhao et al., 2025).

The usage barrier also emerged as a significant, though less dominant, factor. While technological solutions for RE are increasingly available, their integration into existing workflows remains challenging for firms with limited digital infrastructure or operational expertise (Muller et al., 2024; Raj et al., 2020). The demographic results show that over 70% of surveyed firms are

located in East, South, and Central China, regions with stronger industrial infrastructure, but these advantages may be offset by the fact that more than one-third of firms employ fewer than 50 staff, limiting in-house capacity for technological onboarding. Additionally, high reported monthly food waste volumes among many respondents indicate that while potential input material for RE exists, process redesign and workforce training requirements may appear daunting, further reinforcing the perception of complexity.

The non-significant influence of tradition and value barriers offers an intriguing contrast to some innovation adoption studies in other cultural contexts (e.g., Talke & Heidenreich, 2014). This divergence can be interpreted through complementary theoretical lenses. From the perspective of Institutional Theory, firms in China's agrifood sector face strong coercive and mimetic pressures from government regulations and industry benchmarks that prioritize modernization and sustainability (Juráček et al., 2025). Such institutional forces can weaken the relevance of tradition, as firms adapt not primarily out of cultural preference but in response to regulatory compliance and competitive imitation. Similarly, insights from the Resource-Based View (RBV) help explain why value barriers did not significantly influence resistance. Policy instruments such as subsidies, tax incentives, and national standards effectively reduce the financial burden of adoption, allowing firms to perceive RE technologies less as risky investments and more as strategic resources that enhance competitiveness (Awad et al., 2025) . Together, these complementary lenses highlight that institutional and resource configurations in China's agrifood industry mediate the salience of traditional and value-related concerns.

When viewed through the lens of Innovation Resistance Theory, these results extend the understanding of how barrier salience may shift in emerging market contexts. Whereas much of the IRT literature highlights tradition and value barriers as prominent obstacles, our findings suggest that in dynamic, policy-supported sectors like China's agrifood manufacturing, these barriers are overshadowed by risk, image, and usage considerations. This aligns with emerging evidence from sustainability adoption studies in Asia, where operational uncertainty and market perception increasingly determine the pace of technological uptake (Rizos et al., 2016).

By incorporating demographic evidence, this study adds nuance to existing frameworks, showing that barrier intensity is not uniform but shaped by firm age, size, market positioning, and product category. For instance, younger SMEs in consumer-oriented industries are disproportionately sensitive to financial and reputational uncertainties, which explains why technological complexity and brand image concerns remain highly salient even in regions with strong digital infrastructure.

Collectively, these findings suggest that strategies to promote RE adoption in China should not rely solely on financial incentives or appeals to cultural change. Instead, interventions must directly reduce perceived risk, safeguard brand image, and streamline operational integration, priorities that are consistent with the technological potential of Industry 4.0 solutions. However, it is important to recognize that the sample in this study is skewed toward firms in more industrialized regions, particularly East China, which accounted for over one-third of respondents. This regional concentration means that the findings are most representative of areas with advanced infrastructure and stronger policy enforcement, and they may not fully capture the

barriers faced by firms in less developed regions such as Northwest China. Future research should therefore adopt a more balanced regional sampling strategy to improve generalizability and to reveal whether the observed barrier hierarchy is consistent across different institutional and economic settings.

Overall, these findings reaffirm the relevance of the innovation resistance framework while signalling the need for sector-specific recalibration. In China's agrifood manufacturing sector, the weight of operational and reputational considerations surpasses both cultural and short-term economic concerns, providing clear strategic priorities for policymakers, technology providers, and industry leaders seeking to advance the circular economy agenda.

6. Implications

The findings of this study carry several actionable implications for theory, practice, and policy.

6.1. Theoretical Implications

By extending Innovation Resistance Theory to the context of digital-enabled circular food systems, this study highlights the context-dependent salience of barriers, showing that operational risk, image, and usage outweigh tradition and value in China's agrifood sector. Future research should further integrate complementary theories such as Institutional Theory and the Resource-Based View.

6.2. Managerial Implications

For agrifood manufacturing managers, these findings signal the need to prioritize risk mitigation over tradition-challenging initiatives. Operational risk emerged as the strongest deterrent, suggesting that investments in predictive digital tools such as AI-powered process simulations should precede large-scale RE rollout. By providing empirical evidence of system reliability under various scenarios, these tools can address managers' loss-aversion tendencies and operational hesitations (Vecchio et al., 2021).

Second, the prominence of image concerns calls for proactive brand management strategies. Blockchain-enabled traceability platforms can provide transparent proof of quality and safety, ensuring that sustainability claims are credible and verifiable. This transparency is particularly crucial for export-oriented firms that face stricter international scrutiny on food safety standards (FAO, 2021).

Third, the complexity barrier underscores the necessity of human capital development alongside technological adoption. AR/VR-based training programs can accelerate skill acquisition while minimizing production disruptions. By embedding these training tools into daily workflows, firms can reduce the perceived operational burden of RE adoption.

6.3. Policy Implications

From a policy perspective, these results suggest that generic sustainability subsidies may not be sufficient to overcome the most influential barriers. Instead, targeted policy instruments that build on China's existing frameworks are needed. For instance, government-backed

demonstration projects using AI-driven simulations, such as the MARA-sponsored "Fuxi Farms" under the 2024–2028 Smart Agriculture Action Plan (Ministry of Agriculture and Rural Affairs of the People's Republic of China, 2024) could be aligned with the *Digital China* initiative. These farms exemplify how AI-enabled "digital brain" systems, sensor networks, and real-time data platforms foster transparency and operational confidence (People's Daily Online, 2025) , supporting the broader digital and circular transition. Similarly, a national digital traceability standard for reextracted resources could be developed under the *"Zero-Waste City"* pilot programs (Chai et al., 2025) , ensuring consistent quality assurance and transparency across regions while aligning with China's export competitiveness goals (OECD, 2023) . Moreover, skills development policies could be explicitly tied to the *"Double Carbon"* objectives by supporting digital upskilling programs for agrifood workers (Zhang et al., 2023) , co-funded through public–private partnerships. Linking these targeted measures with existing national strategies ensures coherence, accelerates implementation, and embeds RE adoption within China's broader sustainability agenda (Ghisellini et al., 2016).

6.4. Research Limitations and Future Research Suggestions

While this study makes both theoretical and practical contributions, several limitations warrant consideration. First, the empirical analysis relies on cross-sectional survey data, which captures perceptions and behaviours at a single point in time. This limits our ability to observe how resistance to RRER evolves as firms gain more exposure to digital-intelligent solutions or as regulatory environments shift. Future research should adopt longitudinal designs to track barrier dynamics over time, enabling more robust causal inferences.

Second, the sample is geographically confined to Chinese agrifood manufacturers, a sector characterised by distinct operational, cultural, and regulatory contexts. While this focus enhances internal validity, it constrains the generalisability of findings to other industries or economies. Comparative studies across emerging and developed markets, particularly in the ASEAN and EU contexts, could reveal whether the barrier hierarchy observed here is universal or context-specific.

Third, the study's operationalisation of barriers follows IRT constructs adapted from prior literature. Although these constructs demonstrated strong measurement validity, they may not fully capture sector-specific nuances such as supply chain traceability requirements or the perishability of input materials. Incorporating qualitative approaches such as in-depth interviews or ethnographic fieldwork could enrich our understanding of the micro-level mechanisms underlying resistance.

Finally, the digital-intelligent solutions proposed in this study remain conceptual. While grounded in technological feasibility and aligned with Industry 4.0 developments, their effectiveness in practice has not yet been empirically tested. Future studies should examine the scalability of integrated AI–digital twin frameworks, as they have shown promising results in improving both operational efficiency and environmental outcomes in China's agrifood manufacturing (Ali et al., 2025; Andika et al., 2025; Hu et al., 2025; Meng & Li, 2025; R. Zhang et al., 2025).

By addressing these limitations, future scholarship can build a more comprehensive, context-sensitive, and empirically validated framework for overcoming resistance in circular economy transitions.

6.5. Conclusion

This study set out to investigate the cognitive barriers that significantly influence RRER in China's agrifood manufacturing sector and to propose digital-intelligent strategies capable of overcoming these barriers. Drawing on IRT and employing PLS-SEM, we provided empirical evidence that risk, image, and usage barriers are the primary determinants of RRER, whereas tradition and value barriers have little to no significant impact in this context. The dominance of risk concerns underscores the sector's sensitivity to operational uncertainty, while the significance of image and usage barriers reflects the reputational and procedural challenges manufacturers perceive in adopting RE practices.

By integrating these findings with the technological capabilities of Industry 4.0, we have outlined targeted solutions, AI-driven risk simulations, blockchain-enabled traceability, and AR/VR-based training, that directly address the most influential barriers. This linkage between barrier diagnosis and tailored technological intervention advances the application of IRT in the digital-circular economy domain, offering a model that is both theoretically grounded and practically actionable.

The implications extend beyond the Chinese context, suggesting that in other emerging economies, effective RE adoption strategies should prioritise the mitigation of uncertainty and complexity rather than solely focusing on altering cultural traditions or demonstrating economic returns. Policymakers, industry leaders, and researchers can draw from this framework to design integrated management strategies that align digital transformation with circular economy objectives.

In closing, the study not only answers its initial research question but also contributes to a broader understanding of how cognitive barriers interact with technological enablers in shaping industrial sustainability transitions. By doing so, it lays a foundation for academic inquiry and policy innovation aimed at accelerating the adoption of resource re-extraction in global manufacturing systems.

Author Contributions:

Conceptualization, X.Y. and L.C.; methodology, X.Y.; software, X.Y.; validation, X.Y., L.C. and X.W.; formal analysis, X.Y.; investigation, X.Y.; resources, X.Y.; data curation, X.Y.; writing—original draft preparation, X.Y.; writing—review and editing, X.Y., L.C. and X.W.; visualization, X.Y.; supervision, X.Y.; project administration, X.Y., L.C. and X.W. All authors have read and agreed to the published version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Research Ethics Committee of Universiti Malaya (protocol code UM.TNC2/UMREC_3241 on March 5th, 2024).

Informed Consent Statement:

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement:

The raw data supporting the conclusions of this article will be made available by the authors on request.

Acknowledgments:

The authors gratefully acknowledge the guidance and constructive feedback provided by mentors at Universiti Malaya. Special thanks are extended to Professor Suhaiza Zailani at the Ungku Aziz Centre, Department of Decision Science, Faculty of Business and Economics, Universiti Malaya, who provided valuable methodological advice during the survey design and data analysis phases. Appreciation is also extended to the participating agrifood manufacturers in China for their valuable time and insights during the survey process. Finally, the encouragement and thoughtful suggestions from fellow doctoral colleagues and research peers helped to refine the theoretical framing and strengthen the empirical contributions of this study.

Conflict of Interest:

The authors declare no conflict of interest.

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Digital-Intelligent Economy and Scientific Management, 2025, 1(1), 63-97
https://doi.org/10.71204/xtcwnd69

Information Visualization analysis of the Hot Research Topics and the Research Fronts of Corporate Competitive Advantage

Yuan Zheng [1, *], Ling Chen [1, 2]

[1] Universiti Malaya, Kuala Lumpur 50603, Malaysia

[2] Beijing City University, Beijing 100083, China

*** Correspondence:**

Ling Chen

chenling1111@gmail.com

Received: 25 August 2025/ Accepted: 18 September 2025/ Published online: 3 November 2025

Abstract

The study is intended to explore the motivating forces and the dynamics behind the development of competitive advantage in markets characterized by rapid change focusing on the aspects of innovation, organizational reputation, and supply chain resilience. Utilizing bibliometric analysis of 1,944 papers from 1993 to 2023, it identifies trends, popular research areas, and future directions in emerging markets. Key findings highlight green innovation as a prominent topic and summarize eight determinants of competitive advantage. The research also suggests independent innovation capacity and green subsidizing as critical areas for further exploration. Overall, the study provides meaningful contributions for academics, decision-makers, and practitioners by shedding light on the present dynamics of competitive advantage and outlining avenues for future research.

Keywords: Competitive Advantage; Corporate; Literature Review; Bibliometric Analysis

1. Introduction

The COVID-19 crisis, alongside anti-globalization forces and economic separation, has reshaped the dynamics of contemporary business environments. This dynamic environment prompts investors to prioritize qualitative indicators, such as regulatory compliance and innovation, over traditional quantitative metrics like revenue and profit. As a result, pursuing corporate competitive advantage has become a key objective for organizations. This concept reflects a company's ability to adapt and learn while sustaining superior performance, offering greater relevance and depth than mere financial indicators for investors and policymakers.

Although research on competitive advantage has expanded in recent years, an integrated overview of the field remains limited. To date, there is no systematic review that provides a detailed visualization and multi-perspective analysis of corporate competitive advantage. This

study addresses that gap by delivering a comprehensive examination of the theoretical foundations, strategic approaches, and key determinants that shape an organization's capacity to attain and sustain a competitive position. Through synthesizing prior studies, the review contributes to a deeper understanding of the dynamic nature of competitive advantage and highlights its significance in modern business strategy.

In this study, a scientometric approach was applied to address the following research questions (RQs):

Q1: What current trends are there in the literature on competitive advantage?

Q2: Who are the most well-known experts and contributors on this topic?

Q3: What key topics does competitive advantage cover?

Q4: What elements have the greatest impact on competitive advantage?

Q5: What is the intellectual structure of current research?

Q6: What areas require special attention to gain a competitive advantage?

The structure of this review is organized as follows: Section 1 introduces the study; Section 2 describes the methodology, detailing data sources, collection procedures, search strings, software settings, and analytical techniques. Section 3 presents the findings, arranged by themes such as author, journal, and document citations, as well as keyword and reference clustering. Section 4 examines different dimensions of corporate competitive advantage, including its conceptual basis, critical determinants, and the role of independent innovation. Section 5 highlights the key findings and research limitations, while Section 6 outlines directions for future studies.

Ultimately, this review offers readers an in-depth perspective on corporate competitive advantage, the strategies for attaining it, and its wider relevance in an increasingly dynamic marketplace. It contributes to the academic community by serving as a useful reference for scholars and researchers in business and management, while also delivering practical guidance for corporate leaders seeking to address contemporary challenges and achieve long-term success.

2. Methodology

This study utilized the Web of Science (WoS) Core Collection as the main database, drawing specifically from the Science Citation Index Expanded (SCI-EXPANDED) and the Social Science Citation Index (SSCI) to obtain relevant records. The search was restricted to publications addressing the topics of "competitive advantage" and "corporate." Given our objective to comprehend the entire trend from the 1970s, the timespan was not delimited. Document types were confined to articles and review articles only, while the language was restricted to English. Lastly, the research areas were confined to Business Economics and Social Science Other Topics. Finally, up to date on October 19^{th,} 2023, the search yielded 1,966 papers (See Figure 1). We chose Citespace (version 6.2.R3 64-bit) to conduct the bibliometric analysis. Since the longest time span of Citespace is only 30 years. The 1,965 data extracted from WoS were shrunk to 1944. Time slicing was set as 1 year per slice from January 1993 to December 2023.

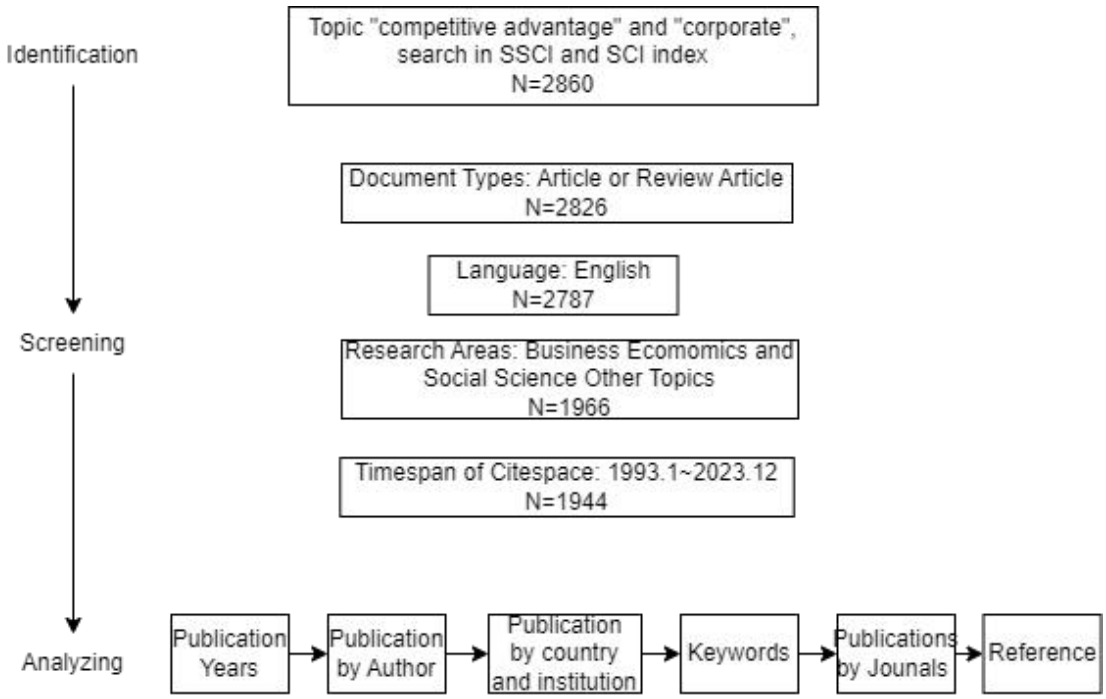

Figure 1. Process of Data Sourcing and Analyzing

3. Findings

3.1. Trend Analysis

To address RQ1, Figure 2 illustrates the timeline of publications on corporate competitive advantage, divided into three periods: 1985-2005, 2005-2015, and 2015-present. The first paper appeared in 1987, with a gradual increase in publications over the next two decades. However, post-2005 saw a significant rise, with 86% of the 1,965 articles published after that year. The average number of papers increased from 18 per year before 2005 to 89 thereafter, likely reflecting growing awareness of corporate sustainability and social responsibility following the 2007 financial crisis. Notably, after the Paris Agreement in 2015, over a third (34.5%) of articles were published between 2019 and 2023, emphasizing environmental considerations in assessing competitive advantage**.**

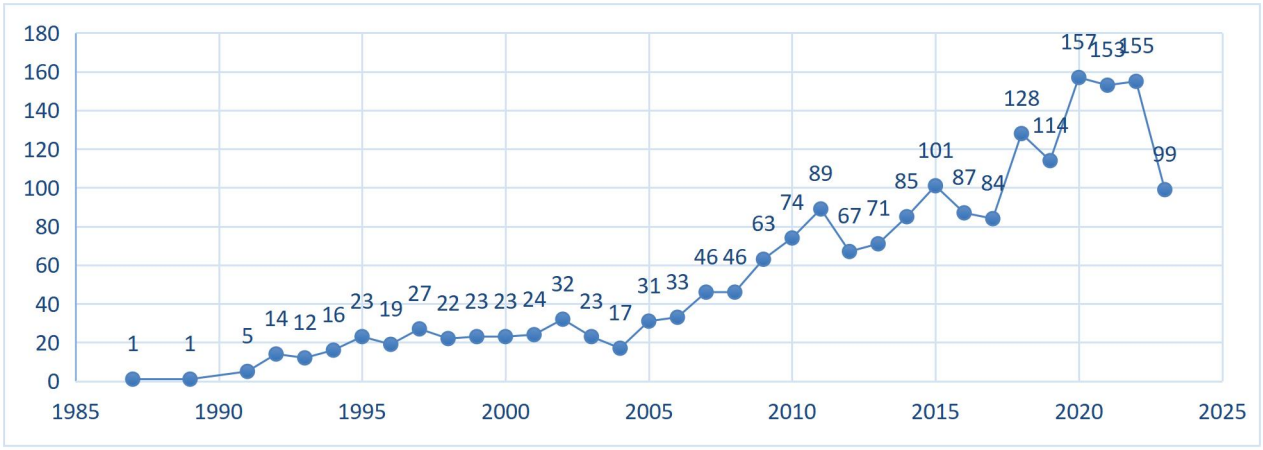

Figure 2. Number of Publications Per Year

3.2. Network of Author and Co-authorship

Answering RQ2, we analyzed publications by authors and analysis of the authorship network.

Figure 3 presents the top 25 authors ranked according to their number of publications in the WoS database. Among them, Chen YS. worked on green innovation in Taiwan(Chen, 2008; Chen et al., 2006). Molina-Azorin Jose F. and Lopez-gamero MD. collaborated on the environment management and competitive advantage of the hotel industry in Spain(Molina-Azorín et al., 2015). Leonidou LC. specialized on environmental marketing strategy of hotel and export industries(Leonidou et al., 2013, 2015). Hitt MA studied corporate political strategy(Hillman & Hitt, 1999).

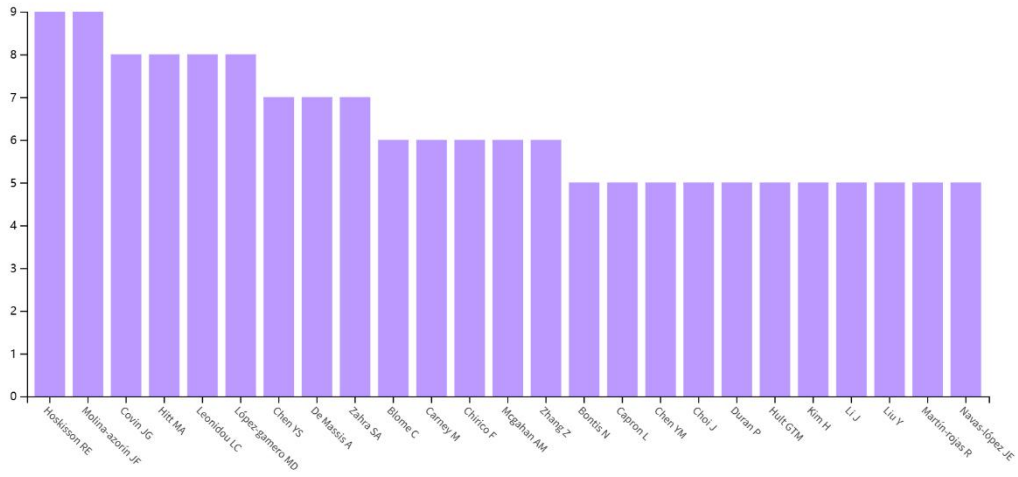

Figure 3. Publications by Authors (Source: Web of Science)

The Citespace visualization shows a collaboration network among 427 authors with 138 links, indicating that 138 authors have collaborated. Font size reflects publication frequency, with larger names for more frequent authors. Thicker lines between nodes denote stronger collaboration, while link color indicates publication age—red for recent and light grey for older works. The low network density of 0.0015 suggests a loose structure, where most authors work individually, with only a small group of three to five collaborating.

There were two recent collaborations (indicated with red links) highlighted in Figure 4. In their joint work, Agyabeng-Mensah Yaw, Afum Ebenezer, and Baah Charles investigated how corporate environmental ethics and green creativity serve as antecedents of green competitive advantage (Baah et al., 2023).

Alam Mohammad Nurul, Hossain Kamal, and Azizan Noor Azlinna studied entrepreneurial orientation and export performance(Hossain et al., 2023).

Knemeyer A Michael, Amos Clinton, and Brockhaus Sebastian worked in collaboration in 2019 to evaluate how service perceptions influence customer views of the authenticity of corporate sustainability claims(Amos et al., 2019).

De Massis Alfredo, Kotlar Josip, and Memili Esra proposed in 2018 that willingness, ability, and resource availability influence the internationalization of family firms(Fang et al., 2018).

Figure 4. Network of Authors and Co-authorship

3.3. Country and Institution Analysis

This analysis tries to depict a map of countries and institutions working globally on the topic of competitive advantage.

The country network (See Figure 5) comprises 84 nodes and 357 links, with a density of 0.1024, indicating a concentrated and closely connected structure. The top ten countries in this field are the USA (618 publications, Centrality = 0.53), China (255, 0.12), England (229, 0.26), Spain (175, 0.20), Canada (128, 0.24), Italy (100, 0.05), Taiwan (99, 0.01), Australia (98, 0.14), Germany (95, 0.03), and France (80, 0.09). Notably, China is the only developing country among the top ten.

The top five countries with high centrality are the USA(Centrality=0.53), England (0.26), Canada (0.24), Spain (0.20), and Australia (0.14). They act as joining nodes in the network.

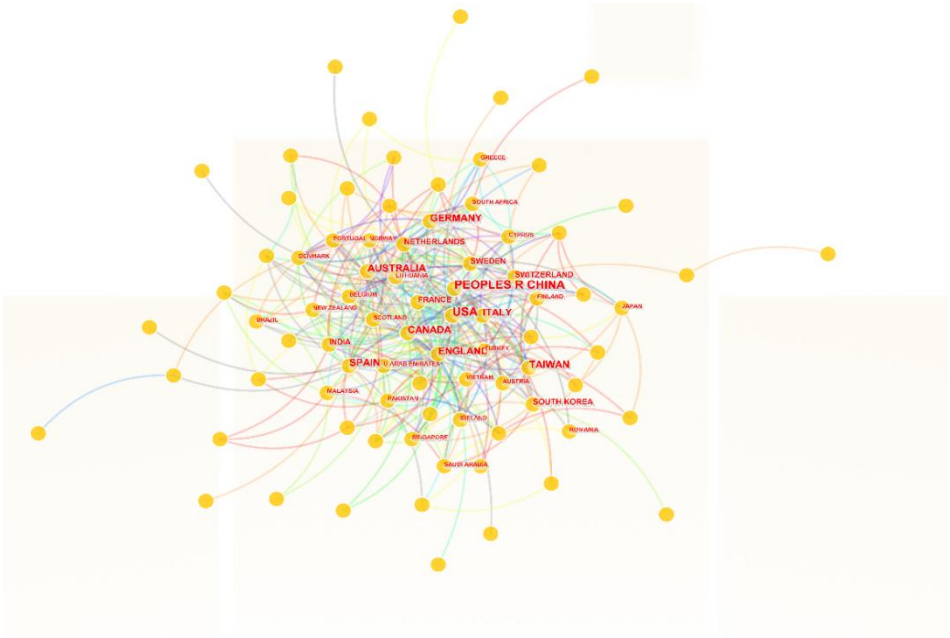

Figure 5. Country Network Analysis

The institution network (See Figure 6) consists of 479 nodes and 520 links, with a low density of 0.0045, indicating weak cooperation among institutions. The top five contributors are the State University System of Florida (32 publications, Centrality = 0.13), University System of Ohio (30, 0.08), Texas A&M University System (22, 0.04), Harvard University (20, 0.01), and California State University System (19, 0.16). The nodes are shown in the tree ring history. Different colors represent different periods. The grey color in the middle represents the oldest while the red color at the edge represents the latest.

Nodes with thicker red edges represent institutions that have more articles published recently. Among them, Indiana Institute of Management (Frequency=14), Xi'an Jiaotong University (13), Auburn University (8), Auburn University System (7), Northwestern Polytechnical University (9), and Egyptian Knowledge Bank (4) are more active.

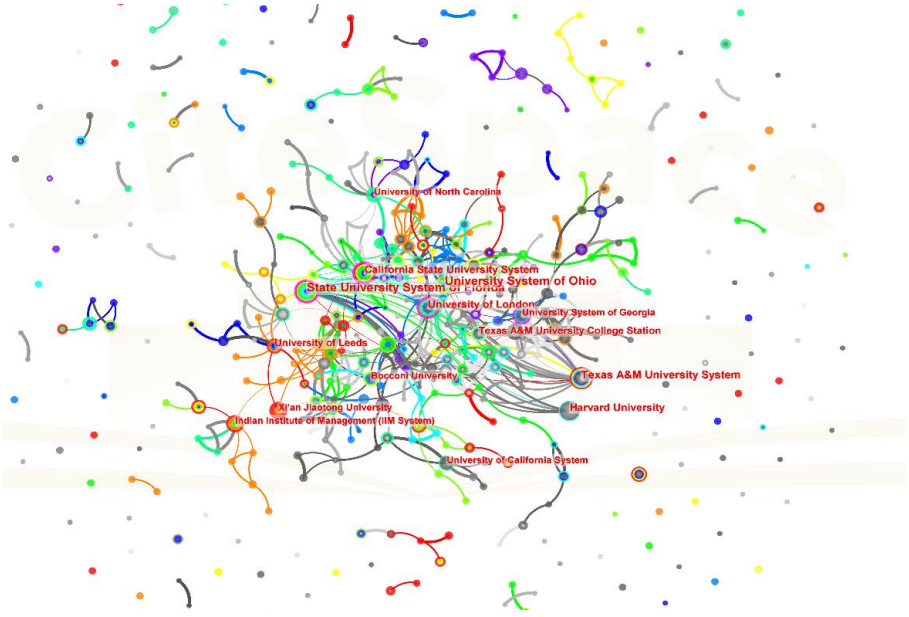

Figure 6. Institution Network Analysis

3.4. Keyword Network Analysis

This section is to identify the most popular themes among the scholars working on competitive advantage and to answer RQ3 (Which key themes involve competitive advantage?). Keywords can reflect the development direction and hot themes in a certain field.

The keyword network (See Figure 7) consists of 459 nodes and 2422 links (Density=0.023). The top 15 keywords are competitive advantage (Frequency=953), performance (473), corporate social responsibility (357), management (324), firm performance (303), impact (264), financial performance (263), resource-based view (259), strategy (253), firm (221), innovation (210), corporate governance (166), capacity (145), dynamic capacity (121), and model (117).

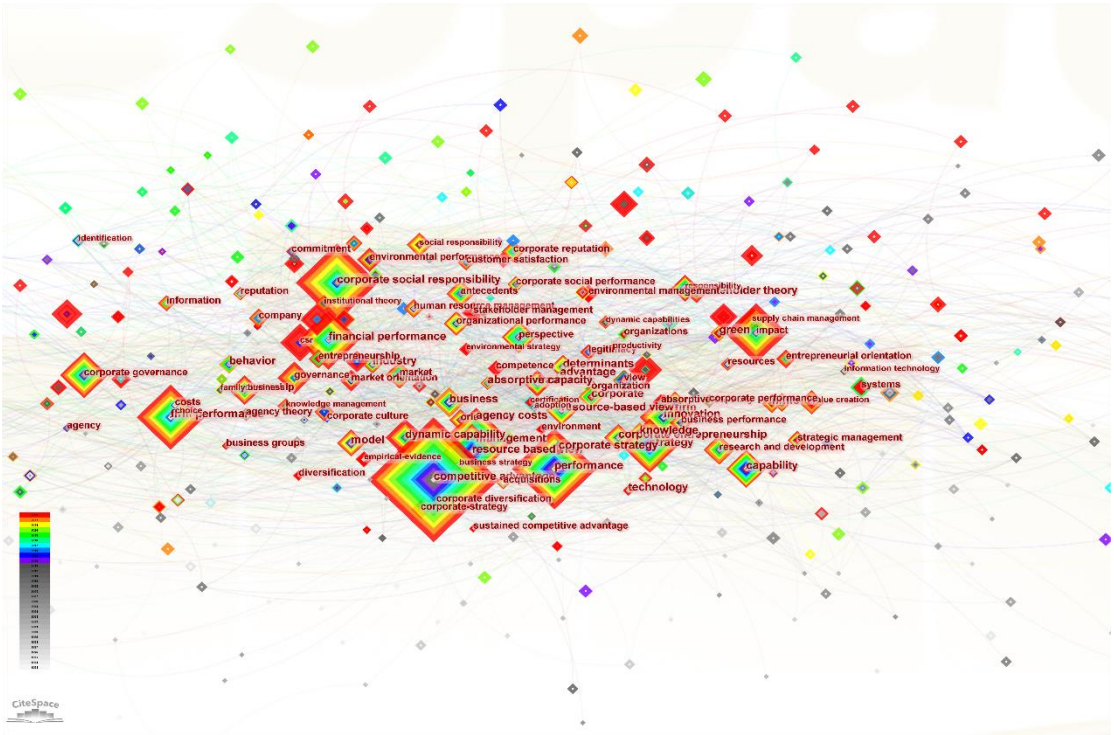

Figure 7. Network of Keywords

Table 1 shows the sudden increases in keyword citations and the length they last. We can see that “csr”, “green innovation”, “sustainability”, and “socioemotional wealth” are keywords that are very popular now.

Table 1. Keywords Citation Burst

Keywords	Year	Strength	Begin	End	1993 - 2023
firm	1993	21.25	1993	2010	
corporate strategy	1993	17.53	1993	2013	

corporate-strategy	1993	7.72	1993	2007	
sustained competitive advantage	1995	10.34	1995	2010	
strategic management	1995	10.11	1995	2009	
systems	1995	9.65	1995	2012	
competence	1995	5.39	1995	2014	
diversification	1997	5.79	1997	2011	
environment	1998	6.43	1998	2012	
strategy	1994	7.1	2000	2005	
technology	1995	6.08	2001	2012	
capability	1995	7.47	2002	2010	
view	1995	7.8	2005	2011	
productivity	2005	5.57	2005	2012	
knowledge	2000	5.78	2006	2009	
corporate	2004	6.22	2007	2012	
stakeholder management	2003	6.35	2008	2017	
green	2003	6.4	2015	2017	

socioemotional wealth	2017	9.21	2017	2023	
mediating role	2015	13.8	2019	2023	
sustainability	2016	7.85	2019	2023	
supply chain management	2009	5.41	2019	2021	
csr	2014	9.03	2020	2023	
moderating role	2012	7.99	2020	2023	
green innovation	2021	9.08	2021	2023	

To identify the specific research areas that most scholars working on, we clustered the keywords by log-likelihood ratio (LLR) and labeled them with titles, keywords, and abstracts (KTA). Then we got 8 clusters, namely corporate reputation (Cluster#0), asset divestiture (Cluster#1), family firm (Cluster#2), entrepreneurial orientation (Cluster#3), capital structure (Cluster#4), sustainable supply chain initiative (Cluster#5), corporate network (Cluster#6), and own brand (Cluster#7).

We visualized the clusters in a timeline view (See Figure 8), where keywords are located in the year it appeared first time. The size of the square represents the frequency of the keyword. The red square represents the keywords' burstiness.

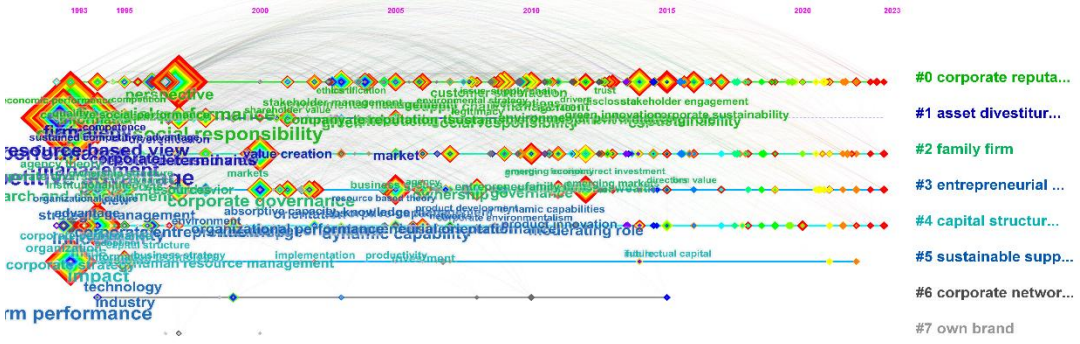

Figure 8. Clusters of Keywords-timeline View

3.5. Journals

The leading ten journals, as illustrated in Figure 9, include the Strategic Management Journal (105), Journal of Business Ethics (96), Journal of Business Research (78), Corporate Social Responsibility and Environmental Management (65), Business Strategy and the Environment (57), Management Decision (47), Journal of Management (29), Technological Forecasting and Social Change (28), Industrial Marketing Management (25), and Harvard Business Review (24).

Based on the JCR journal map (2011), we built a dual overlay map to show the connections between citing journals (the left side of the map) and cited journals (the right side of the map). As Figure 10 indicates, journals like “Psychology, Education, Social”, “Economics, Economic, Political”, and “Environmental, Toxicology, and Nutrition” are highly cited by “Economics, Economic, Political” headed journals.

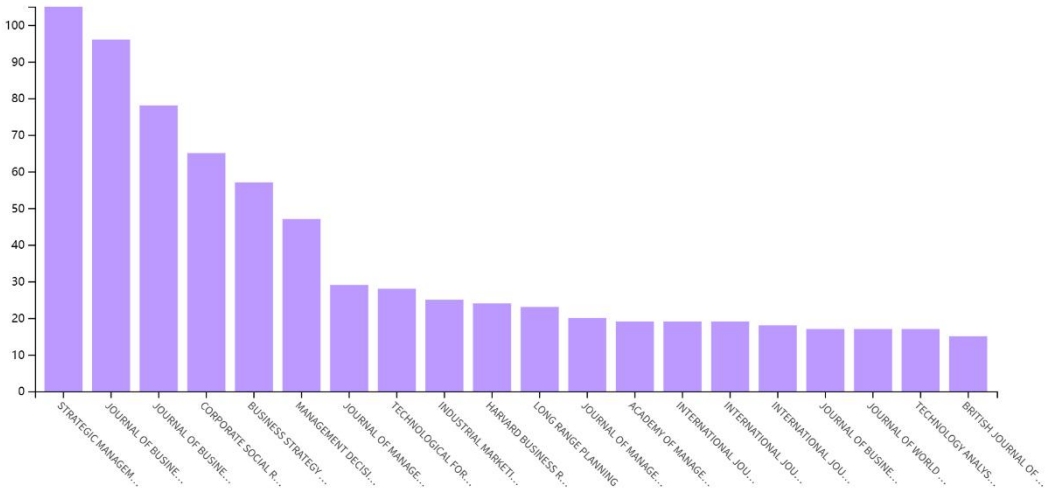

Figure 9. Publications by journals (Source: Web of Science)

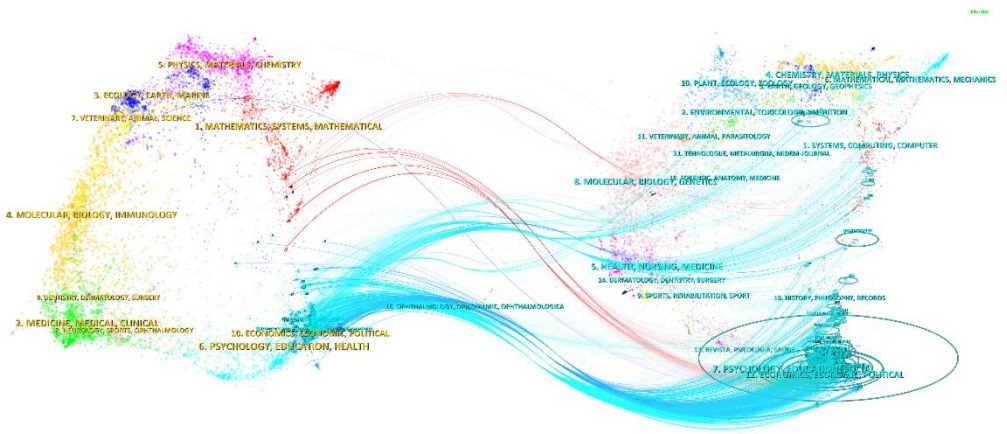

Figure 10. Dual Overlay Map of Citing and Cited Journals

3.6. Document Co-Citation Network

The author co-citation network is used to determine the relationships between different authors who have published and had work cited in a particular field of study. To respond to RQ4 (The most influential articles in the ESG and sustainability disclosures), the node type is chosen to be a reference.

The co-citation network, presented in Figure 11 and Figure 12, consists of 1,462 nodes and 5,014 links (Density = 0.0047, Modularity Q = 0.8493, Silhouette S = 0.9404), which means it is a highly organized and homogenous cluster network. Keywords were used in identifying the clusters and labeled using the log -likelihood ratio (LLR). Generally, Q=0.3 and S=0.7 are the appropriate thresholds that indicate a strong cluster structure and homogeneity of a clustering solution, respectively.

Table 2 shows the top 20 papers with the highest citations. The first with the highest citation (Frequency=138) is an overview of techniques in multivariate data analysis, not related to competitive advantage. Table 3 lists the citation bursts of references. We examined those articles in the sequence of clusters.

Table 2. List of Top 20 Papers with the Highest Citations

Rank	Frequency	Year	Cited References
1	138	2019	Hair J. F., 2019, MULTIVARIATE DATA AN, V8th, P0, DOI 10.1016/J.IJPHARM.2011.02.019
2	26	2015	Saeidi SP, 2015, J BUS RES, V68, P341, DOI 10.1016/j.jbusres.2014.06.024
3	25	2019	Hair JF, 2019, EUR BUS REV, V31, P2, DOI 10.1108/EBR-11-2018-0203
4	23	1991	BARNEY J, 1991, J MANAGE, V17, P99, DOI 10.1177/014920639101700108
5	20	2006	Porter ME, 2006, HARVARD BUS REV, V84, P78
6	19	2018	Kim KH, 2018, J MANAGE, V44, P1097, DOI 10.1177/0149206315602530
7	18	2017	Thompson J. D., 2017, ORG ACTION SOCIAL SC, V0, P0
8	16	2018	Barney JB, 2018, STRATEGIC MANAGE J, V39, P3305, DOI 10.1002/smj.2949
9	15	1993	PETERAF MA, 1993, STRATEGIC MANAGE J, V14, P179, DOI 10.1002/smj.4250140303
10	15	2011	Porter M. E., 2011, COMPETITIVE ADVANTAGE, V0, P0

11	15	1993	AMIT R, 1993, STRATEGIC MANAGE J, V14, P33, DOI 10.1002/smj.4250140105
12	15	2012	Aguinis H, 2012, J MANAGE, V38, P932, DOI 10.1177/0149206311436079
13	14	2020	Kraus S, 2020, TECHNOL FORECAST SOC, V160, P0, DOI 10.1016/j.techfore.2020.120262
14	13	2012	Campbell BA, 2012, ACAD MANAGE REV, V37, P376, DOI 10.5465/amr.2010.0276
15	13	1992	MAHONEY JT, 1992, STRATEGIC MANAGE J, V13, P363, DOI 10.1002/smj.4250130505
16	13	2017	Martinez-Conesa I, 2017, J CLEAN PROD, V142, P2374, DOI 10.1016/j.jclepro.2016.11.038
17	12	2017	Lins KV, 2017, J FINANC, V72, P1785, DOI 10.1111/jofi.12505
18	12	1997	Teece DJ, 1997, STRATEGIC MANAGE J, V18, P509, DOI 10.1002/(SICI)1097-0266(199708)18:73.0.CO;2-Z
19	12	2016	Duran P, 2016, ACAD MANAGE J, V59, P1224, DOI 10.5465/amj.2014.0424
20	11	2019	Xie XM, 2019, J BUS RES, V101, P697, DOI 10.1016/j.jbusres.2019.01.010

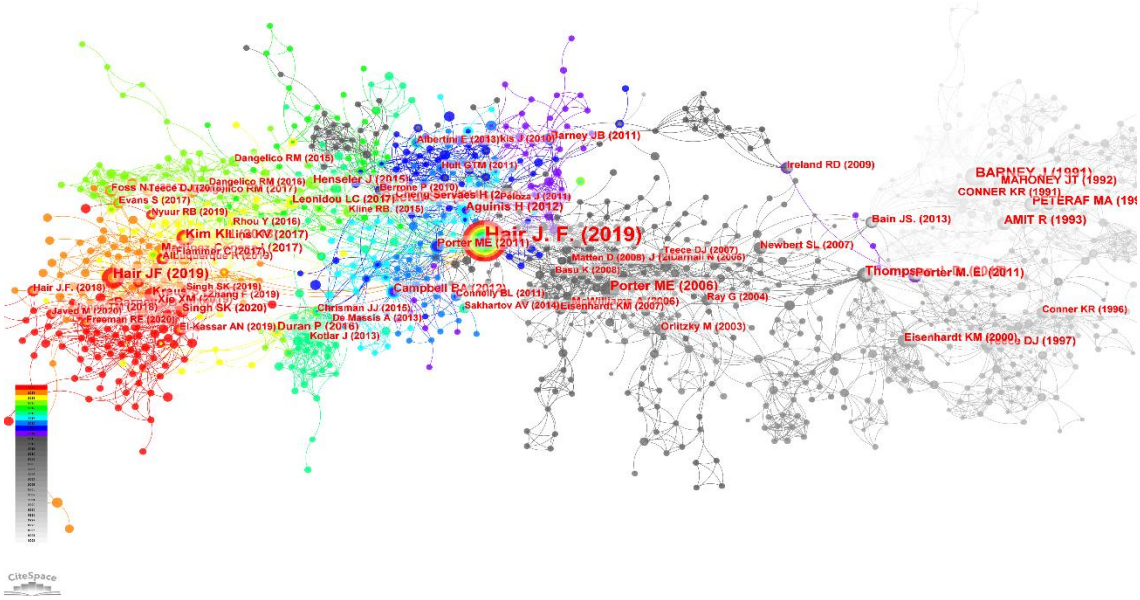

Figure 11. Reference Co-Citation Network

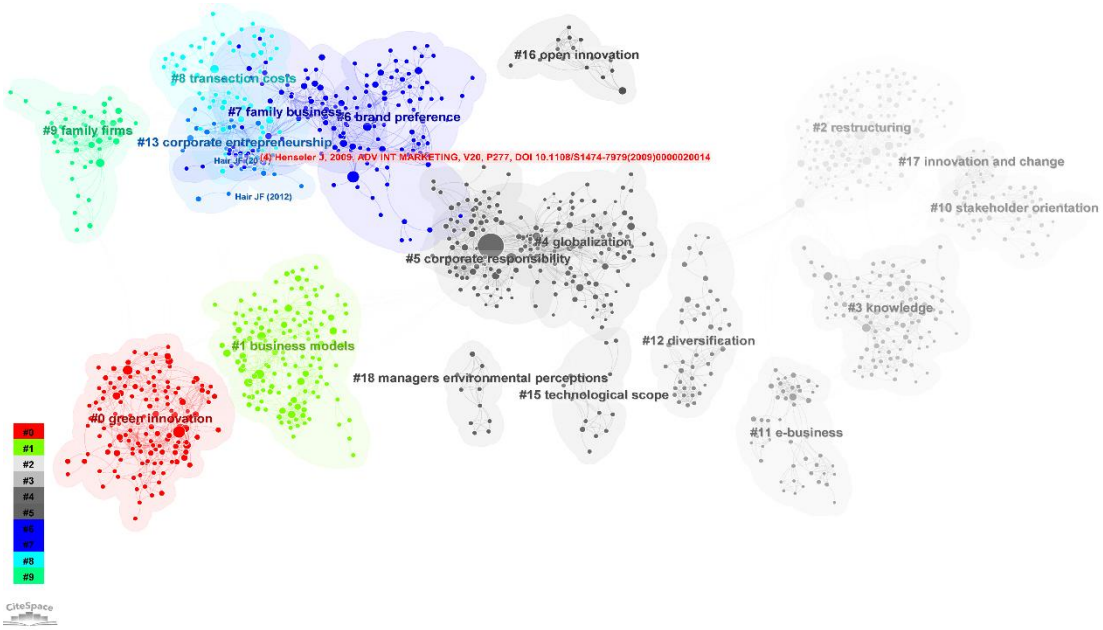

Figure 12. Clusters of Co-Citation Network

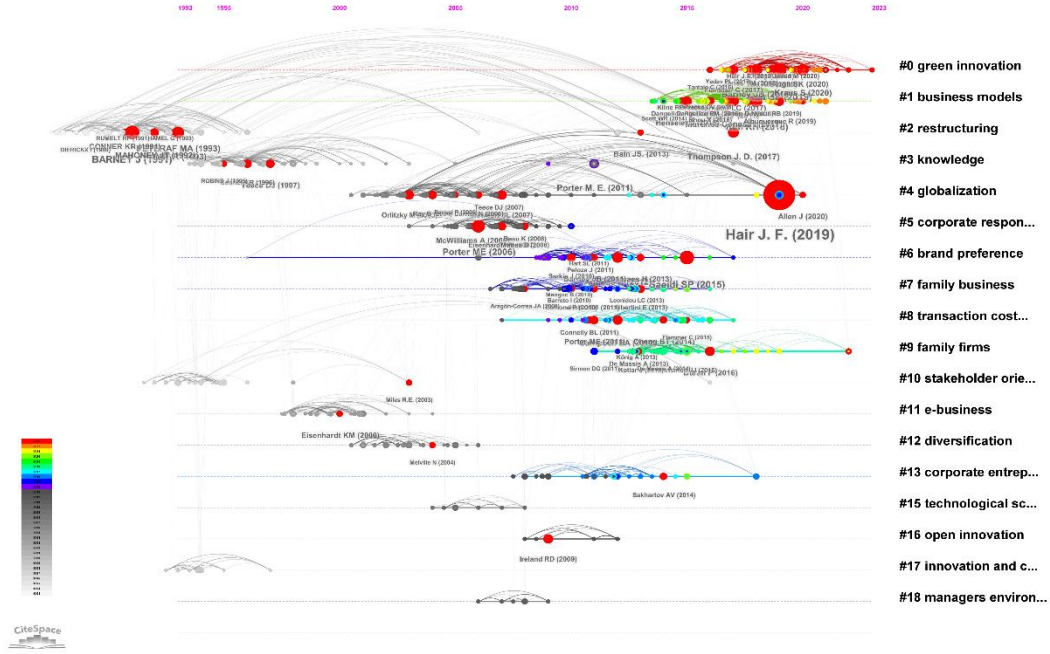

Figure 13. Cluster of Co-citations-timeline View

Cluster #0, titled “Green Innovation” (Size =142, Silhouette=0.948, Mean Yea =2019), represents the most recent research focus attracting significant global scholarly attention. Within this cluster, Jay B. Barney (Frequency =16) emphasized that the resource-based theory model should integrate stakeholder perspectives in order to secure and sustain diverse types of resources (J. B. Barney, 2018). Sacha Kraus et al. (Frequenc =14) empirically proved that CSR is positively correlated to environmental strategy and green innovation, which in turn improves the corporate environmental performance (Kraus et al., 2020). Xie XM et al. (Frequency=11) found that both green process innovation and green product innovation can improve corporate financial performance. Green product innovation mediates the relationship between green process

innovation and financial performance. A firm's green image can moderate the relationship between green product innovation and financial performance (Xie et al., 2019). Sanjay Kumar Singh et al. (Frequency=10) suggested that green transformational leadership significantly influences human resource management practices and that in turn mediates the influence of green transformational leadership on green innovation (S. K. Singh et al., 2020).

Cluster #1, labeled "Business Model" (Size = 142, Silhouette = 0.889, Mean Year = 2017), focuses on innovations in business models. Within this cluster, Kim K. H. et al. (Frequency = 19) highlighted that competitive actions act as a crucial contingency influencing how corporate social responsibility (CSR) initiatives affect a firm's financial performance (Kim et al., 2018). Isabel M. C. et al. (Frequency =13) suggested that small and medium-sized enterprises (SMEs) can enhance their innovation capabilities through CSR initiatives, thereby strengthening their competitive advantage (Martinez-Conesa et al., 2017). Karl V. Lins et al. (Frequency =12) suggested investing in social capital, which is measured by CSR intensity, to resist the risks during the financial crisis (Lins et al., 2017). Leonidas C. Leonidou et al. (Frequency =10) shed light on how internal company factors help to formulate a green business strategy among small manufacturing firms, and how this, in turn, influences their competitive advantage and performance(Leonidou et al., 2017).

Cluster#2 restructuring (Size=133, Silhouette=0.944, Mean year=1992) is the oldest topic. J. Barney (Frequency =23) analyzed the potential of four firm resources, rareness, imitability, and sustainability- for generating sustained competitive advantage (J. Barney, 1991). This paper is widely regarded as the first formalization of the then-fragmented resource-based literature into a comprehensive (and thus empirically testable) theoretical framework(Newbert, 2007). Margaret A. Peteraf (Frequency =15) discussed four conditions that underlie sustained competitive advantage, namely superior resources (heterogeneity within an industry), ex-post limits to competition, imperfect resource mobility, and ex-ante limits to competition (Peteraf, 1993). Both asset divestiture and resource redeployment can contribute to acquisition performance(Capron, 1999). Asset divestiture is a logical consequence of the process of reconfiguration of resources within firms (Capron et al., 2001). Property, plant, and equipment (PPE) volatility and intangible asset volatility can complement R&D volatility in improving a firm's performance(Patel et al., 2018).

Cluster #3, labeled "Knowledge" (Size = 106, Silhouette = 0.963, Mean Year = 1997), highlights the link between competitive advantage and rapid innovation. Within this cluster, D. J. Teece et al. introduced the dynamic capabilities framework, arguing that wealth creation in fast-changing technological environments largely depends on the firm's ability to develop and refine its internal technological, organizational, and managerial processes (Teece et al., 1997).

Cluster#4 globalization (Size=105, Silhouette=0.906, Mean year=2005) is related to how to establish competence for multinational companies. SL. Newbert (Frequency =10) assessed the RBV's support in the empirical literature (Newbert, 2007). Knight and Cavusgil investigated born-global firms and highlighted the critical role of innovative culture, knowledge, and capacities (Knight & Cavusgil, 2004). Rugman and Verbeke developed a framework to assess patterns of competence building in MNEs (Rugman & Verbeke, 2001).

Cluster #5, titled "Corporate Responsibility" (Size = 83, Silhouette = 0.897, Mean Year = 2007), addresses research on the relationship between corporate social responsibility (CSR) and firm performance. In his seminal work, M. E. Porter (Frequency = 20) proposed the "Strategy and Society" framework, which includes an inside-out perspective outlining the activities companies can pursue in their business operations and an outside-in perspective showing how social initiatives influence competitiveness ("Strategy and Society," 2007). Similarly, Marc Orlitzky et al. (Frequency = 9) conducted a meta-analytic review to clarify the link between corporate social performance (CSP) and corporate financial performance (CFP) (Orlitzky et al., 2003). A. McWilliams et al. (Frequency = 10) examined a wide range of CSR studies and proposed a research agenda highlighting unresolved theoretical and empirical issues, such as defining CSR, understanding institutional variations across countries, identifying CSR motivations, modeling CSR effects on firms and stakeholders, and evaluating the role of leadership and culture (McWilliams et al., 2006).Additionally, Herman Aguinis and Ante Glavas (Frequency = 15) offered a comprehensive review of CSR literature across institutional, organizational, and individual levels, pinpointing research gaps and suggesting directions for future investigation (Aguinis & Glavas, 2012).

Cluster #6 (Size = 79, Silhouette = 0.913, Mean Year = 2011) focuses on brand preference. Within this cluster, Saeidi S. P. et al. (Frequency = 26) demonstrated that corporate reputation and competitive advantage act as mediators in the relationship between CSR and firm performance (Saeidi et al., 2015). Henri Servaes and Ane Tamayo (Frequency = 10) argued that firms can create value through CSR initiatives only when these activities are consistent with and reinforce the company's reputation (Servaes & Tamayo, 2013).

The other clusters are either too small or too old to facilitate thematic analysis.

Table 3. List of References with Strongest Citation Burst

No.	References	Year	Strength	Begin	End	1993 - 2023
1	BARNEY J, 1991, J MANAGE, V17, P99, DOI 10.1177/014920639101700108, DOI	1991	14.11	1993	1996	
2	AMIT R, 1993, STRATEGIC MANAGE J, V14, P33, DOI 10.1002/smj.4250140105, DOI	1993	8.46	1993	1998	
3	MAHONEY JT, 1992, STRATEGIC MANAGE J, V13, P363, DOI 10.1002/smj.4250130505, DOI	1992	7.64	1993	1997	
4	CONNER KR, 1991, J MANAGE, V17, P121, DOI 10.1177/014920639101700109, DOI	1991	6.32	1993	1995	
5	PETERAF MA, 1993, STRATEGIC MANAGE J, V14, P179, DOI 10.1002/smj.4250140303, DOI	1993	8.73	1994	1998	
6	Thompson J. D., 2017, ORG ACTION SOCIAL SC, V0, P0	2017	7.63	2017	2009	

7	Teece DJ, 1997, STRATEGIC MANAGE J, V18, P509, DOI 10.1002/(SICI)1097-0266(199708)18:7509::AID-SMJ882>3.0.CO;2-Z, DOI	1997	7.53	1999	2002	
8	Eisenhardt KM, 2000, STRATEGIC MANAGE J, V21, P1105, DOI 10.1002/1097-0266(200010/11)21:10/111105::AID-SMJ133>3.0.CO;2-E, DOI	2000	6.47	2002	2005	
9	Orlitzky M, 2003, ORGAN STUD, V24, P403, DOI 10.1177/0170840603024003910, DOI	2003	5.7	2006	2008	
10	Porter ME, 2006, HARVARD BUS REV, V84, P78	2006	11.54	2008	2011	
11	McWilliams A, 2006, J MANAGE STUD, V43, P1, DOI 10.1111/j.1467-6486.2006.00580.x, DOI	2006	5.75	2008	2011	
12	Newbert SL, 2007, STRATEGIC MANAGE J, V28, P121, DOI 10.1002/smj.573, DOI	2007	5.68	2009	2010	
13	Barney JB, 2011, J MANAGE, V37, P1299, DOI 10.1177/0149206310391805, DOI	2011	5.73	2013	2015	
14	Aguinis H, 2012, J MANAGE, V38, P932, DOI 10.1177/0149206311436079, DOI	2012	8.01	2014	2017	
15	Campbell BA, 2012, ACAD MANAGE REV, V37, P376, DOI 10.5465/amr.2010.0276, DOI	2012	6.94	2014	2017	
16	Saeidi SP, 2015, J BUS RES, V68, P341, DOI 10.1016/j.jbusres.2014.06.024, DOI	2015	12.39	2016	2020	
17	Servaes H, 2013, MANAGE SCI, V59, P1045, DOI 10.1287/mnsc.1120.1630, DOI	2013	5.68	2016	2018	
18	Hair J. F., 2019, MULTIVARIATE DATA AN, V8th, P0, DOI 10.1016/J.IJPHARM.2011.02.019, DOI	2019	8.12	2019	2023	
19	Duran P, 2016, ACAD MANAGE J, V59, P1224, DOI 10.5465/amj.2014.0424, DOI	2016	5.94	2018	2021	
20	Henseler J, 2015, J ACAD MARKET SCI, V43, P115, DOI 10.1007/s11747-014-0403-8, DOI	2015	6.62	2019	2020	
21	Lins KV, 2017, J FINANC,	2017	5.61	2019	2023	

	V72, P1785, DOI 10.1111/jofi.12505, DOI					
22	Kim KH, 2018, J MANAGE, V44, P1097, DOI 10.1177/0149206315602530, DOI	2018	7.78	2020	2023	
23	Hair JF, 2019, EUR BUS REV, V31, P2, DOI 10.1108/EBR-11-2018-0203, DOI	2019	11.75	2021	2023	
24	Barney JB, 2018, STRATEGIC MANAGE J, V39, P3305, DOI 10.1002/smj.2949, DOI	2018	7.5	2021	2023	
25	Martinez-Conesa I, 2017, J CLEAN PROD, V142, P2374, DOI 10.1016/j.jclepro.2016.11.038, DOI	2017	7.3	2021	2023	

4. Discussion

4.1. The Key Determinants

Corporate competitive advantage is the holy grail of business strategy, and its achievement and sustainability depend on a multitude of determinants. In this discussion, we will explore and analyze the key determinants of corporate competitive advantage, shedding light on how they shape an organization's ability to gain and maintain a competitive edge.

4.1.1. Corporate Social Responsibility (CSR)

In today's era of increased environmental and social awareness, companies that prioritize sustainability and corporate responsibility can gain a competitive advantage. International cultural diversification is positively linked to the social performance of multinational enterprises viewed as socially responsible (Aguilera-Caracuel et al., 2015). CSR can promote firm performance indirectly through enhancing reputation and competitive advantage(Saeidi et al., 2015). A green corporate image can mediate the relationship between environmental management system (EMS) and firm performance (Martín-de Castro et al., 2016). Green practices and social initiatives can resonate with consumers and attract ethically-minded investors. Empirical research shows that firms with strategic CSR achieve growth through both their product and their process innovations (Bocquet et al., 2017). Corporate reputation moderates the positive relationship between CSR and organizational performance (K. Singh & Misra, 2021). Also, it is important for corporates to effectively publicize their CSR activities (Rhou et al., 2016).

4.1.2. Entrepreneurial Orientation

Lumpkin and Dess (1996) defined entrepreneurial orientation (EO) as the decision-making styles and processes guiding a firm's entrepreneurial activities, also characterizing it as a form of strategic orientation (Wiklund & Shepherd, 2003, 2005). They identified five dimensions of EO: risk-taking, innovativeness, proactiveness, competitive aggressiveness, and autonomy. Research shows that EO positively impacts business performance, especially through proactiveness and

innovativeness, while risk-taking has negative effects. Competitive aggressiveness and autonomy appear to hold no business performance value at an embryonic stage of firm growth (Hughes & Morgan, 2007). Johan Wiklund et al. developed an integrated model of small business growth that includes entrepreneurial orientation, environmental characteristics, firm resources, and managers' attitudes (Wiklund et al., 2009).

4.1.3. Green Innovation and Technology

Green innovation, which integrates product and process innovations, aims to reduce energy use, minimize pollution, recycle waste, and promote sustainable resource use. This enhances environmental performance and competitive advantage. Likewise, green process innovation improves both environmental and organizational performance, further boosting competitive advantage (El-Kassar & Singh, 2019). In addition, firms with greater intellectual capital tend to attract more investors' attention and have greater market value (Nimtrakoon, 2015).

4.1.4. Human Capital

A skilled and motivated workforce can be a significant determinant of competitive advantage. Human capital, including the knowledge, skills, and creativity of employees, can be a source of innovation and differentiation. Firm-specific human capital- knowledge and skills embodied in individuals that cannot be easily applied in other firms- is assumed to support sustained competitive advantage (Campbell et al., 2012). The ability to attract and retain top talent is crucial.

4.1.5. Supply Chain Management

Efficient supply chain management, streamlined operations, and effective cost control can lead to cost advantages that drive competitive positioning. Firms that implement sustainable supply chain initiatives can realize positive reverse logistics outcomes (Hsu et al., 2016). Retailers must revise their supply chain structures, strategies, and management practices to adapt to the recent global sourcing, multichannel, and relation-based innovation (Ganesan et al., 2009). Companies must ensure their international suppliers comply with their corporate codes of conduct to meet the challenge of satisfying stakeholders' alternating sustainability expectations across their global supply base (Reuter et al., 2010). Three global trends- sourcing practices, multichannel routes to market, and relationship-based innovation- are enhancing retailers' competitive advantage with regard to brand image, reputation, sales and profits, innovation, and relationship (Ganesan et al., 2009). Profound Sustainable global supplier management (SGSM) capacities were a source of competitive advantage in the chemical industry (Reuter et al., 2010). Sustainable supply chain initiative can realize positive reverse logistics outcomes (Hsu et al., 2016).

To maintain the competitive advantage under the extreme conditions like sanctions or a scenario of economic decoupling and de-risking, companies must adopt several key strategies. Firstly, diversification is essential (Lin et al., 2020). This involves diversifying products, services, markets, and supply chains. Companies should seek new markets, reduce reliance on sanctioned regions, and explore alternative suppliers. Additionally, stringent compliance and risk management are essential to align with international regulations and navigate the evolving sanctions landscape, avoiding legal and reputational risks. Collaborative strategies, such as

forming partnerships with needed institutions or being part of a cluster (Porter, 2000), can also provide a competitive edge.

4.1.6. Brand and Reputation

Building a strong brand and a positive reputation can create a significant competitive advantage. Consumers are often willing to pay a premium for products or services associated with trusted and recognized brands. Corporate reputation can moderate the relationship between CSR and organization performance (K. Singh & Misra, 2021). Reputation is one of the consequences of high customer satisfaction over the long term. Customer satisfaction mediates the relationship between CSR and financial performance (Saeidi et al., 2015). The special characteristics of family firms, such as the owning family's involvement and control or its strong identification with the business, make creating and preserving a good reputation desirable. Good reputation has positive financial and non-financial effects on family firms and helps create competitive advantages (Sageder et al., 2018).

4.1.7. Scale and Network

For some industries, economies of scale and network effects can be critical determinants of competitive advantage. As a company grows and gains more customers, it can achieve cost efficiencies and create a more valuable product or service due to network effects. Cheng BT. et al. (Frequency=10) found that firms with better CSR performance face significantly lower capital constraints (Cheng et al., 2014). However, highly specific and opaque resources limit the borrowing capacity of the firm (Vicente-Lorente, 2001).

ME. Porter mentioned that a cluster, which is a geographically group of companies and institutions in a particular field, can affect competitive advantage by increasing the current (static) productivity of constituent firms or industries, increasing the capacity of cluster participants for innovation and productivity growth, and stimulating new business formation that supports innovation and expands the cluster (Porter, 2000).

4.1.8. Regulatory Environment

Government regulations, policies, and compliance can significantly impact a company's competitive advantage. Firms that can navigate regulatory challenges effectively and stay ahead of industry-specific regulations gain a strategic edge. For example, many countries have government-funded ISO 14001 support program, which play an important and positive role in assisting firms to gain a competitive advantage (Delmas, 2001). Other measures include public procurement and the creation of partnerships that engage different stakeholders (Doran & Ryan, 2016).

The role of public policy is crucial in incentivizing firms to engage in innovation through the use of subsidies or by imposing penalties for non-engagement (Doran & Ryan, 2016). Firms frequently engage in eco-innovation in anticipation of stringent environmental regulations, as this strategy enables them to proactively reduce future compliance costs while simultaneously gaining a competitive edge over their industry counterparts (Doran & Ryan, 2016). Advocating for a

pragmatic, progressive policy enables firms to shape future policies around their existing environmental strengths and systematically embracing advancing regulation enables firms to satisfy activists who would place pressure on policy makers to force firms to conform to higher environmental standards (Marcus et al., 2011).

In conclusion, the determinants of corporate competitive advantage are multifaceted and interrelated, evolving over time. Adaptability and strategic agility are essential in today's dynamic business landscape. Achieving and sustaining competitive advantage requires a holistic approach that strategically combines these determinants to fit an organization's specific context and goals.

4.2. The Measurement of Competitive Advantage

One challenge in studying competitiveness is the lack of comprehensive and accurate measurement. Researchers face difficulties in assessing competitive advantage through objective or subjective measures, with no standardized approach currently available. Previous studies have used widely accepted scales ranging from 6 to 16 items (summarized in Appendix 1), covering qualitative dimensions like corporate image, product quality, R&D investment, management ability, profitability, and product differentiation. Alternatively, some researchers opt for quantitative metrics like ROA or sales growth rate to assess corporate efficiency (Lin et al., 2020).

Another challenge lies in the fact that many researchers employ alternative concepts, such as firm performance, financial performance, organizational performance, and company value, to substitute the concept of corporate competitive advantage when conducting quantitative research.

For financial performance, return on asset (ROA) is widely used as a proxy (Lin et al., 2020; Nimtrakoon, 2015). ROA is more stable than sales growth or return on sales in measuring financial performance because of both the managerial effect of short-term activities and uncertainty about the external environment in emerging markets (Xie et al., 2019).

For firm performance, Tobin's Q is widely used to measure firm performance incorporating current operations, potential growth opportunities, and future operating performance (Memili et al., 2015; Rhou et al., 2016). The advantage of using Tobin's q over profitability is that profitability is a short-term measure, whereas Tobin's q is a long-term measure because it is based on the market value of the firm (Servaes & Tamayo, 2013). This measure takes into account the present value of future expected cash flows discounted at the required rate of return, thereby inherently adjusting for risk.

Compared to accounting-based measures, stock market-based measures of performance are less subjective to different accounting procedures and managerial manipulation.

Numerous measurement methods can result in inconsistencies in experimental outcomes and a lack of comparability, potentially leading to confusion regarding enterprise competitiveness for management perception. Considering the complexity of competitive advantage, the measurement of enterprise competitiveness is better conducted using a combination of both subjective and objective indicators, as well as short-term and long-term indicators.

5. Conclusions

This study utilized Citespace for a bibliometric analysis of corporate competitive advantage. For RQ1, the trend analysis revealed a significant increase in published papers from 2019 to 2023. RQ2 mapping highlighted key experts and collaborations in the field. In addressing RQ4, we identified research that gained substantial attention over time, marked by bursts of activity in previously overlooked areas. For RQ3 and RQ5, we clustered references by keywords and created a research timeline. RQ6 pointed to government intervention and independent innovation capacity as critical areas for further exploration in emerging markets.

Despite its advantages, the bibliometric method has limitations. It relies on the researcher's theoretical knowledge and should complement comprehensive literature reviews rather than replace them. Long publication times, self-citations, and atypical citations can distort co-citation analysis. Additionally, focusing solely on the Web of Science database and SSCI/SCI-indexed papers may overlook key contributions due to limited coverage.

6. Future Avenues

Customer and regulatory pressures influence enterprise decision-makers to address environmental challenges. A green entrepreneurial orientation has been shown to foster innovation (Jiang et al., 2018), while a strong green brand image can translate into green competitive advantage (Zameer et al., 2020). Moreover, green product innovation positively impacts dynamic capabilities and competitive advantage in the manufacturing sector (Qiu et al., 2020; M. Wang et al., 2021). However, empirical evidence is lacking on the moderating role of green subsidies in the relationship between green product innovation and financial performance (Xie et al., 2019). This nonsignificant effect may result from the relatively slow pace of green innovation (Xie et al., 2019) and the high uncertainty of environmental policies (Xie et al., 2019). Future research could further explore the moderating influence of governmental interventions or green subsidies on the link between green innovation and competitive advantage.

Author Contributions:

Conceptualization, Yuan Zheng and Ling Chen .; methodology, Yuan Zheng; writing—original draft preparation, Yuan Zheng.; writing—review and editing, Ling Chen; visualization,Yuan Zheng.; supervision, Ling Chen. All authors have read and agreed to the published version of the manuscript.

Funding:

This research was supported by the Beijing Education Science "14th Five-Year Plan" Project [Grant Number: CDGB25543]. The funder had no role in study design, data collection, analysis, interpretation, manuscript preparation, or the decision to publish.

Institutional Review Board Statement:

Not applicable.

Informed Consent Statement:

Not applicable.

Data Availability Statement:

Not applicable.

Acknowledgments:

The authors would like to express their sincere gratitude to the funding agency for its financial support, to all colleagues and partner institutions for their valuable guidance and assistance throughout this study, and to the editors for their thoughtful comments and professional handling of the manuscript.

Conflict of Interest:

The authors declare no conflict of interest.

Appendix A

Variable	Measurement	Items	Reference
Competitive advantage	The measurement of corporate competitive advantage contained eight items:	(1) the company has the competitive advantage of low cost compared to other competitors; (2) the quality of the products or services that the company offers is better than that of the competitor's products or services; (3) the company is more capable of R&D and innovation than the competitors; (4) the company has better managerial capability than the competitors; (5) the company's profitability is better; (6) the growth of the company exceeds that of the competitors; (7) the company is the first mover in some important fields and occupies the important position; (8) the corporate image of the company is better than that of the competitors.	(Chen et al., 2006)
Competitive advantage	CA was measured by using 16 items from Zhang (2001) and Bratic (2011). The 16-item scale was organized into five dimensions: price/cost, 2. quality, 3. delivery dependability, 4. product innovation and 5. time to	1. Price/Cost: an organization is capable of competing against major competitors based on low price We offer competitive prices We are able to offer prices as low or lower than our competitors 2. Quality: an organization is capable of offering product quality and performance that creates higher value for	(Bratić, 2011; Nyuur et al., 2019)

	market.	customers We are able to compete based on quality We offer products that are highly reliable We offer products that are very durable We offer high quality products to our customer 3. Deliver Dependability: an organization is capable of providing on time the type and volume of products required by customers We deliver the kind of products needed We deliver customer order in time We provide dependable delivery 4. Time to Market: an organization is capable of introducing new products faster than major competitors We deliver product to market quickly We are first in the market in introducing new products We have time-to-market lower than industry average We have fast product development 5. Product Innovation: an organization is capable of introducing new products and features in the market place We provide customized products We alter our products offerings to meet client needs We respond well to customer demand for new features	
Competitive advantage	The competitive advantage (CA) was measured using items that focused on investment in research and development, cost savings, and growth opportunities in new markets.	1.Being environmentally conscious can lead to substantial cost advantages for our firm. 2.Our firm has realized significant cost savings by experimenting with ways to improve the environmental quality of our products and processes. 3.By regularly investing in research and development on cleaner products and	(Banerjee et al., 2003; Leonidou et al., 2013, 2017)

		processes, our firm can be a leader in the market. 4.Our firm can enter lucrative new markets by adopting environmental strategies. 5.Our firm can increase market share by making our current products more environmentally friendly. 6.Reducing the environmental impact of our firm's activities will lead to a quality improvement in our products and processes.	
Competitive advantage	The sustainability of competitive advantage refers to the persistence of a firm's superior performance, which is measured by the percentage of superior performance in any prior period.		(Villalonga, 2004; Yadav et al., 2017)
Competitive advantage	The CA was measured using differentiation (4 items) and cost (3 items) scales. These items were obtained from the works by Miller (1988), Govindarajan (1988), Lee and Miller (1996) and Beal (2000).	Differentiation competitive advantage (reflective) 1. Creation of a brand image identifying the firm 2. The quality of the service offered is better than that offered by competitors 3. A great number of supplementary services is offered, adding value for customers 4. Important innovations are made in the service Costs competitive advantage (reflective) 1. General costs are minimized 2. An attempt is made to improve productivity 3. Efforts are made to reach economies of scale,	(Khan et al., 2019; Molina-Azorín et al., 2015)
Competitive advantage	CA was assessed by two dimensions – effectiveness and efficiency.	Firm effectiveness as the sales growth rate and firm efficiency as profitability in return on assets (ROA).	(Lin et al., 2020)
Competitive advantage	The research adopted six items from Barney (1991),	1. Products/services are better than its competitors;	(S. K. Singh et al., 2019)

	and Porter and van der Linde (1995) to measure firm competitive advantage.	2. R&D capabilities are better than its competitors; 3. Managerial capabilities are better than its competitors; 4. Profitability is better than its competitors; 5. Image is better than its competitors; 6. Competitive advantage is better than its competitors.	
Competitive advantage	Competitive Advantage (CA) was measured with seven items. The items sought to determine innovative skills, product quality, customer satisfaction, and production costs. Reductions in wastes and emissions, and consumption of fewer resources along with compliance to regulations were also measured.	1. Reduction of hazardous waste, emissions, etc. 2. Consume less resources, such as energy, water, electricity, gas and petrol, etc. 3. Compliance to environmental regulations 4. Customer satisfaction in relation to product design and development 5. Product design and innovation skill 6. Quality of product and service 7. Production cost	(El-Kassar & Singh, 2019)
Firm performance	To measure firm performance, this research used a variable focused on competitive performance, similar to that adopted by Marín et al. (2012) or Gallardo-Vazquez and S anchez-Hern andez (2013).	Firm Perf. 1 In the last 3 years, our company has improved regarding ... FP1 Profits FP2 Return on assets Firm Perf. 2 In the last 3 years, our company has introduced improvements relative to .... FP3 Customer service FP4 Relations with customers FP5 Customer loyalty Firm Perf. 3 In the last 3 years, our company has improved with regard to ... FP6 Staff absenteeism FP7 The working environment FP8 Employees' loyalty and morale	(Martinez-Conesa et al., 2017)
Firm performance	The main dependent variable is firm growth, our proxy for firms' economic performance (Orlitzky et al. 2003; Roberts 1992; RussoandFouts1997). We measured growth in turnover between 2007 and 2009 in two ways.	First, we computed growth for the overall time period using the variation of firm turnover in real price (DVCA79). Second, we calculated an average growth rate, to account for likely evolution during the overall time period. This variable is simply the arithmetic mean of the two-period growth rate (MOYDVCA79)	(Bocquet et al., 2017)

Firm performance	Firm performance as the sole dependent variable in this study will be measured through seven items which are related to financial performance in Balanced Scorecard (BSC) methodology. Developed by Robert Kaplan and David Norton in 1992 the Investment Balanced Scorecard methodology is a comprehensive approach that analyzes an organization's overall performance in four ways.	Market share growth and growth in sales as the growth determinant, and Return on Equity (ROE), Return on Sales (ROS) Return on Assets (ROA), Return on (ROI), and net profit margin of the firm as monetary accounting performance constructs	(Saeidi et al., 2015)
Firm performance	The research used two measures for performance: one that was objective (accounting-based) and one which was subjective (perceptual-based).	Objective performance: return on assets (ROA); Subjective performance: 4-items measurement scale ITEM Related to your business' largest competitor: 1. The profits obtained by your firm are 2. The size of your firm is 3. The market share of your firm is 4. The rate of growth that your firm has is	(Guerrero-Villegas et al., 2018, 2018)
Firm financial performance	The research focused on economic results (ROA growth, ROE growth and ROCE growth) relative to competitors, following the same line as other scholars within the environmental field (Hart and Ahuja, 1996; Russo and Fouts, 1997; Wagner et al., 2002; González-Benito and González-Benito, 2005; Aragón-Correa and Rubio-López, 2007).		(Martín-de Castro et al., 2016)
Firm performance	Firm performance is measured via Tobin's Q	((common shares outstanding × calendar year closing price) + (current liabilities-	(Memili et al., 2015)

	(Chung and Pruitt, 1994) with accounting data provided by Thomson Reuters. The use of this firm performance measurement in this study followed Anderson and Reeb (2004), Villalonga and Amit (2006a, b, 2009), and Miller et al. (2007).	current assets) + (long-term debt) + (liquidating value of preferred stock)/total assets).	
Firm performance	Prior studies have recommended selfreported measures for FP in cases involving SMEs (Shirokova, Bogatyreva, Beliaeva, & Puffer, 2016). We thus relied on self-reported measurements used by (Stam & Elfring, 2008; see Appendix A for details).	Our firm performs well relative to our key competitors in Sales growth Employment growth Market share Gross Profit Net Profit Margin Innovation in products Speed in developing new products Quality of products Cost control Customer satisfaction	(Khan et al., 2019)
Financial performance	The research used ROA to measure the financial performance of the firms.		(Xie et al., 2019)
Financial performance	Tobin's Q, ratio of the market value of a firm to the replacement cost of its assets, is used as dependent variable following past studies testing the impact of strategic choices (e.g., CSR) on firm value both in the mainstream and hospitality-finance literature.	The market's evaluation of a firm's future profitability is calculated as {(TA − EQ − TXDB) + (Shares outstanding × Price)}/TA, where TA is total assets, EQ is the book value of company equity, TXDB is deferred taxes, Shares outstanding is total number of shares outstanding, and Price is stock price at fiscal year-end.	(Rhou et al., 2016)
Financial performance	Source: Alayo n et al. (2017), Jabbour et al. (2020), Baah et al. (2021b, c)	1. Our business has a large market share 2. Our firm accrues high returns on investment 3. Our company has high growth of market share 4. Our business has high profit margin on sales 5. Our firm has high returns on equity	(Baah et al., 2023)
Financial	Two traditional	Margin ratio = net profit/total net sales	(Nimtrakoo

performance	performance measures are used in the study, including margin ratio and ROA. Margin ratio, a measure of profitability from sales, demonstrates the ability of firms to generate net profit from total sales.	ROA =operating income/average total assets.	n, 2015)
Firm performance	To measure performance, the research employed Tobin's q, which is the market value of the firm, divided by the replacement value of its assets.	Tobin's q = (book value of assets − book value of equity−deferred taxes+ market value of equity)/book value of assets.	(Servaes & Tamayo, 2013)
Organization performance	Organizational performance (OP) was measured by four items drawn from a previous study (Lin et al., 2013). These items measured the improvement in market position, sales volume, profit rate, and reputation.	Market position improvement Enhancing sale volume Enhancing the profit rate Enhancing the reputation	(El-Kassar & Singh, 2019)
Organization performance	Four items developed by Deshpandé, Farley, and Webster (1993); Jaworski and Kohli (1993); Samiee and Roth (1992) were used to measure organizational performance.		(K. Singh & Misra, 2021)
Business performance	Two dimensions: customer performance and product performance. A firm's customer performance is usually characterized by customer acquisition and customer retention (e.g., Hansotia, 2004; Jayachandran, Sharma, Kaufman, & Raman, 2005; Reinartz, Thomas, & Kumar, 2005; Thomas, 2001). Product performance measures were	Product performance Relative to competing products, those of our business have been more successful in terms of sales Relative to competing products, those of our business have been more successful in terms of achieving and establishing market share Customer performance We have been able to attract totally new customers this year We have been able to expand our existing	(Hughes & Morgan, 2007)

	based on the relative success of the firm's products in terms of sales and at achieving market share. Support for these measures is drawn from the new product performance research of Atuahene-Gima and Li (2004), Song and Xie (2000),andWei and Morgan (2004).	customer base this year We have succeeded in sustaining our customer base and achieving repeat orders	

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Digital-Intelligent Economy and Scientific Management, 2025, 1(1), 98-113
https://doi.org/10.71204/kvdqqw36

Research on the Fintech Ecosystem of BOC Financial

Yimiao Zhang [1,*], Jiayue Lang [1], Ziqi Gao [1], Chuheng Lei [1]

[1] Faculty of Economics and Management, Beijing City University, Beijing 100083, China

*** Correspondence:**

Yimiao Zhang

17207131913@163.com

Received: 31 August 2025/ Accepted: 6 October 2025/ Published online: 3 November 2025

Abstract

With the rapid development of financial technology, BOC Financial Technology Company has promoted the digital transformation of financial services by building an ecosystem covering multiple fields. This report analyzes its operating model, product services, and profit methods, and explores the challenges and opportunities it faces. Research shows that BOC Financial Technology Company, relying on technological innovation and data advantages, holds an industry-leading position in areas such as intelligent risk control and biometric identification. In the future, it needs to strengthen technological investment and cross-border cooperation to consolidate market competitiveness. The report also provides suggestions based on personal skill enhancement, offering reference for financial technology practitioners.

Keywords: Fintech; Ecosystem; BOC Financial Technology; Digital Transformation; Artificial Intelligence

1. Introduction

The wave of economic globalization and the fintech revolution has swept across the globe, profoundly impacting the traditional financial industry. As a leader in China's fintech sector, BOC Financial Technology Company has taken a pioneering role in this wave of change, constructing a fintech ecosystem covering multiple fields. Exploring the company's development history, operating model, product services, and profit methods is crucial for gaining insights into fintech development trends and business value.

In fact, fintech has already permeated all aspects of financial services, becoming a key driver for improving efficiency, reducing costs, and optimizing user experience. Based on emerging technologies such as cloud computing, big data, and artificial intelligence, fintech companies are reshaping the rules of the financial industry. Against this backdrop, BOC Financial Technology Company, relying on advanced technological capabilities, innovation capacity, and data advantages, has become a significant participant and leader in the fintech ecosystem.

Therefore, this report will comprehensively analyze the fintech ecosystem of BOC Financial Technology Company, dissecting its unique role in promoting financial inclusion and enhancing user experience. By presenting the company's development history, operating model, and other aspects from multiple angles, it will help better grasp the development trajectory of fintech and identify future opportunities and challenges. Simultaneously, the analysis and suggestions on personal skills will be beneficial for improving professional competence and preparing adequately for future career development.

This report comprehensively elaborates on the construction process, current operating status, and development prospects of BOC Financial Technology Company's fintech ecosystem. The article first introduces the company's development history, tracing its journey from its establishment to becoming a leading domestic fintech enterprise, reviewing its history of continuous innovation and growth.

Next, the report details the company's current operating model, including key aspects such as business scope, profit model, and core competitiveness. It is worth mentioning that BOC Financial Technology Company adheres to the concept of openness and win-win cooperation, establishing close alliances with numerous partners to form a fintech ecosystem covering multiple fields. The report will focus on the composition, operating mechanism, and product services of this ecosystem.

Finally, the article will prospectively look at the company's development prospects. The fintech wave is still rising. How will BOC Financial Technology Company ride this wave and seize development opportunities? What challenges and tests does it face? The report will provide professional analysis and suggestions, pointing the way for the company's future. Additionally, this article will also discuss how to enhance relevant skills in the context of personal career development, preparing to better utilize talents in the fintech industry in the future.

2. Overview of the Fintech Industry

2.1. Global Fintech Development Status

In recent years, the vigorous development of fintech is reshaping traditional financial business models. This wave of reform has swept the globe, with countries increasing investment in fintech to seize this cutting-edge trend. As an emerging industry, fintech is still in a relatively early stage of development but has already demonstrated enormous potential and broad application prospects.

The core of fintech is to improve financial service efficiency and optimize user experience through innovative technological means. In this process, emerging technologies such as artificial intelligence, big data, cloud computing, and blockchain play key roles. They empower financial institutions to achieve intelligent risk control, precise marketing, process optimization, etc., significantly reducing operating costs; simultaneously, they bring users more convenient and customized financial products and services.

Globally, fintech development shows a diversified trend. Technology companies represented by Silicon Valley in the US are continuously penetrating and reshaping the financial sector with

their advanced technological advantages; China, led by internet giants, is promoting the deep integration of fintech with the traditional financial industry. Furthermore, places like Singapore and the UK have also become important hubs for fintech development. The differentiated development paths of different countries and regions are collectively enriching the fintech ecosystem landscape.

Table 1. Global Major Fintech Development Trends

Country/Region	Fintech Development Characteristics
USA	Tech company dominance, technology innovation driven
China	Internet giants lead, penetrating traditional finance
Singapore	Strong government support, creating a favorable environment
UK	Significant fintech cluster effect

Overall, fintech is becoming a significant force driving global financial innovation. It not only promises to improve the accessibility and convenience of financial services but will also profoundly affect the structure of the entire financial ecosystem. Therefore, understanding and grasping the general trend of fintech development will be a long-term strategic task for stakeholders such as governments, financial institutions, and technology companies.

2.2. Overview of China's Fintech Market

Over the past decade, China's fintech market has experienced rapid development. As the world's second-largest economy, China's innovation and application in the fintech field have attracted global attention. The vigorous rise of fintech companies has changed the landscape of China's traditional financial industry and also promoted the transformation of financial services towards inclusiveness, digitization, and intelligence.

China's fintech market exhibits unique characteristics. Emerging fields such as third-party payment, internet finance, and big data risk control have taken initial shape, and the overall market size continues to expand. At the same time, cooperation between fintech and traditional financial institutions is becoming increasingly close. Banks, securities, and insurance institutions are actively deploying fintech, seeking transformation and upgrading. Additionally, government departments attach great importance to fintech development, empowering the industry through relevant policies and creating a favorable environment for financial technology innovation.

Notably, Chinese fintech companies are in a leading position in emerging technology fields such as artificial intelligence, big data, and cloud computing, possessing numerous innovative application cases. However, the fintech market also faces some challenges. For example, industry regulation needs improvement, data security and privacy protection issues need urgent resolution, and there remains a significant talent gap in fintech. Nevertheless, with the continuous improvement of relevant systems, China's fintech market will maintain strong vitality and usher in a new round of development opportunities.

2.3. Composition and Role of the Fintech Ecosystem

The fintech ecosystem consists of multiple links and participants interacting and developing synergistically. At its core is the cooperation between technology companies and financial institutions, using advanced technologies to empower traditional financial services. The periphery includes multiple forces such as regulatory agencies, investors, and users, jointly promoting the virtuous cycle of the ecosystem (Zeng & Li, 2021).

The establishment of this ecosystem has effectively promoted the innovative development of financial services. On the one hand, technology companies inject innovation momentum into financial institutions, helping to create more intelligent and online financial products and service models, enhancing user experience. On the other hand, financial institutions provide technology companies with professional knowledge, a vast user base, and compliance operation support, facilitating the implementation of fintech innovations. The two sides complement each other's advantages, forming a synergistic effect.

Other participants in the ecosystem also play important roles. Regulatory authorities issue relevant policies and regulations, creating a favorable environment for ecosystem development. Investors inject capital into innovation, promoting the continuous growth of fintech companies. User feedback guides the optimization and iteration of fintech products. Various forces converge to jointly shape the healthy development pattern of the fintech ecosystem.

It can be said that the fintech ecosystem is an important carrier for advancing financial innovation and popularizing financial services. Technology empowerment makes financial services more efficient and inclusive, thereby benefiting the masses. At the same time, traditional financial institutions also gain new development opportunities through innovation, and the industry is moving towards a more inclusive, intelligent, and sustainable direction. The fintech ecosystem will undoubtedly inject lasting momentum into the sustainable development of the economy and society.

3. Analysis of BOC Financial Technology Company's Development Prospects

3.1. Technology and Data

The future development of fintech is inseparable from the continuous infusion of technological power. Since its establishment, BOC Financial Technology Company has regarded technological innovation as the fundamental driving force for development and continuously increased investment in emerging technology fields. The company has become a leading domestic enterprise in the application of technologies such as artificial intelligence, big data, and cloud computing, mastering a large number of cutting-edge technologies. At the same time, the company's data advantages are becoming increasingly prominent. Relying on massive financial data assets accumulated over the years, the company can mine insights and drive business innovation.

BOC Financial Technology Company uses big data and artificial intelligence as core technologies to promote the precision and intelligence of financial services. For example, its

intelligent marketing platform uses machine learning to analyze customer data, enabling full customer lifecycle management and improving conversion efficiency. Meanwhile, the development of environmental climate assessment models reflects the application of data technology in green finance, supporting corporate ESG management by quantifying environmental risks, aligning with the "Environmental Risk Management Theory" in fintech. Technological strength and data advantages are becoming the core competitiveness of BOC Financial Technology Company in the fintech market. The company uses technologies such as AI and big data to build an intelligent financial service system for retail, corporate, and government sectors, forming multiple leading products and services including intelligent investment advisory, intelligent risk control, and intelligent marketing. Taking intelligent risk control as an example, the company has built scoring models and anti-fraud models based on massive data, greatly improving credit approval efficiency and risk control capabilities. Notably, BOC Financial Technology Company has made breakthroughs in privacy computing technology, achieving "usable but invisible" data through federated learning technology, completing cross-institution data modeling while ensuring user privacy. This technology has been applied in the anti-fraud field, increasing recognition accuracy to over 95%.

Table 2. Performance of BOC Financial Technology's Intelligent Risk Control Models

Risk Control Model	Accuracy	Efficiency Improvement
Scoring Model	92.6%	50%
Anti-fraud Model	96.8%	70%

Data Source: BOC Financial Technology Company 2022 Annual Report

The above table shows that the company's intelligent risk control models are highly accurate, with the scoring model achieving 92.6% accuracy and the anti-fraud model reaching 96.8%, while approval efficiency is significantly improved. It can be foreseen that with the continuous iteration of technologies such as artificial intelligence and big data, the company's technological advantages will continue to strengthen, injecting momentum for subsequent business development.

In the digital finance field, BOC Financial Technology Company actively explores the combination of new technologies such as the metaverse and financial services, for example, extending service reach through virtual scenarios, aligning with the theory of user experience optimization in the "Technology Acceptance Model" (TAM). Furthermore, its "BOC Smart Park Service Platform" integrates IoT and financial data, promoting the digital transformation of industrial parks, reflecting ecological synergy under the concept of "Open Banking."

3.2. Innovation and Transformation

Firstly, BOC Financial Technology Company has made breakthroughs in strategic layout and model, positioning "Technology Finance, Green Finance, Inclusive Finance, Pension Finance, Digital Finance" as its core strategic directions, covering multiple dimensions of financial innovation:

Technology Finance: Supporting technology innovation enterprises through a virtuous cycle system of "Technology - Industry - Finance." For example, the BOC Smart Park Service Platform provides precise financing matching for technology parks in the Yangtze River Delta region. By 2024, it facilitated financing for technology innovation enterprises exceeding RMB 20 billion, increasing the technology commercialization rate by 20%. This model aligns with the "Diffusion of Innovations Theory," meaning technology empowerment requires ecological synergy to achieve large-scale application. The company developed intelligent risk control models, including scoring models (92.6% accuracy) and anti-fraud models (96.8% accuracy), improving credit approval efficiency by 50%-70%. These models integrate over 40 types of data sources such as PBOC credit reporting and tax data, intercepting an average of 230,000 suspicious transactions daily.

Green Finance: Establishing carbon accounting models and green credit systems to help enterprises achieve dual carbon goals. For example, a steel enterprise obtained a green loan through BOC Financial Technology Company's environmental risk assessment model, achieving an annual emission reduction of 100,000 tons of CO2 while reducing financing costs by 1.5 percentage points. BOC Financial Technology Company's innovation in the green finance field is not limited to product design but also includes the underlying technical architecture. Its developed carbon account system can track corporate carbon emission data in real-time and interface with the central bank's green finance standards, providing comprehensive services such as carbon quota trading and green bond issuance for enterprises. This system was included in the national green finance pilot project, receiving policy subsidies exceeding RMB 50 million.

Inclusive Finance: Launching products such as "Credit Easy Loan" and "UnionPay Data Merchant E-Loan," combining government data with bank risk control models to provide unsecured loans for small and micro customers. By the end of 2024, inclusive finance business covered 30 provinces nationwide, with a non-performing loan ratio controlled below 1.2%, reflecting the coverage of the "Financial Inclusion Theory" for the long-tail market.

Pension Finance: BOC Financial Technology Company launched a smart pension online platform, integrating medical, insurance, and community service resources to provide one-stop services. For example, the platform provides real-time health risk warnings through AI health monitoring functions and cooperates with insurance companies to launch customized pension insurance products. Furthermore, the platform connects to 6,300 community service centers nationwide, accumulating 230,000 health risk warnings. Catering to the needs of the elderly, BOC Financial Technology Company launched the "Age-friendly Smart Screen," supporting voice interaction, anti-glare eye protection technology, and built-in health monitoring and entertainment resources. This product set up experience zones in over 100 stores in Shenzhen, helping the elderly bridge the digital divide. Simultaneously, Bank of China Chongqing Branch launched a mobile banking section for the elderly through age-friendly modifications, featuring large fonts and voice assistants to improve operational convenience for elderly users. BOC Financial Technology Company developed a fund supervision platform for pension institutions to monitor fund flows in real-time and prevent misappropriation risks. The platform has covered over 170 pension institutions in Chongqing and interconnects data with civil affairs departments to ensure

fund safety. In the personal pension field, BOC Fund launched several pension target fund products to meet different risk preferences. By 2024, cumulative accounts opened exceeded 180,000.

Digital Finance: Developing a "Digital RMB+" ecosystem platform supporting programmable payments with smart contracts. In the Guangzhou digital RMB pilot, 12 innovative scenarios were realized, including precise government subsidy distribution and smart wage distribution for migrant workers. Established a Digital RMB Scenario Construction Center to promote innovative applications such as dual offline payments and smart park payments. Developed an environmental climate assessment model to quantify corporate environmental risks, supporting carbon peak and neutrality goals (Zhao, 2018). For example, providing scientific basis for green finance through an ESG evaluation system, promoting green credit and sustainable development.

Fintech is driving profound changes in the financial industry, and BOC Financial Technology Company has keenly grasped this trend. The company adheres to a customer-centric approach, continuously innovating products and service models to provide users with a more intelligent and personalized experience. Its core advantage lies in accumulating extensive practical scenarios, enabling continuous optimization and innovation based on real user needs.

For example, the company launched an AI-based intelligent investment advisory system, replacing traditional financial advisors with algorithmic models to provide users with precise investment portfolio allocation suggestions. The system not only considers the customer's risk preference but also incorporates factors such as macroeconomics and industry cycles into the analysis, making investment decisions more scientific and reasonable. According to calculations, the intelligent investment advisory system's annualized return rate is 3.8 percentage points higher than similar products managed by humans.

Another innovative highlight is the company's self-developed biometric technology, which enables multi-dimensional identity authentication such as palm prints, irises, and faces, significantly improving the security of financial services. This technology has been implemented in online and offline channels of multiple banks, effectively preventing fraud risks and enhancing customer experience. At the same time, the company has also extended biometric technology to scenarios such as anti-money laundering and credit reporting, safeguarding the compliance operations of financial institutions.

It is evident that BOC Financial Technology Company continues to increase R&D investment, adheres to independent innovation, and has secured a place in the fintech arena. With leading technological strength and innovative vitality, the company is bound to play an important role in building a new open, intelligent, and inclusive financial ecosystem (Song, 2025).

3.3. Capital Market Recognition

Recently, BOC Financial Technology Company's stock price has risen significantly after being favored in multiple institutional reports, reflecting the market's optimistic expectations for the company's long-term development potential. At the same time, as a wholly-owned subsidiary of Bank of China, BOC Financial Technology Company has inherent advantages in policy response (e.g., the central bank's fintech development plan) and resource acquisition. Its strategic

positioning is highly synergistic with the parent bank's goal of "technology empowerment," enhancing capital market confidence in its long-term value (Wang, 2025). The continuous addition of new institutional investors to BOC Financial Technology Company's shareholder base also reflects the capital market's good confidence in the company. Several well-known domestic and foreign fund companies and banks have established significant shareholding positions, hoping to benefit from the company's future growth. Notably, institutional rating reports have consistently rated BOC Financial Technology Company as a "Buy" in the industry for many years, fully demonstrating the capital market's positive outlook on the company's prospects.

Table 3. Comparison of Key Indicators Among Bank-affiliated Fintech Companies (2024)

Indicator	BOC Financial Technology	Financial OneConnect	Industrial Digital Finance
Revenue Growth	1.38%	-5.2%	-3.8%
Net Profit Margin	37.6%	-18.4%	-12.1%
Customer Stickiness	83%	67%	71%
Scenario Coverage	210	158	132

Currently, bank-affiliated technology subsidiaries generally face profitability challenges. Taking Industrial Digital Finance and Financial OneConnect as examples, in 2024, their net losses reached RMB 380 million and RMB 520 million respectively. However, BOC Financial Technology Company by serving parent bank customers and focusing on core scenarios (such as smart parks and inclusive finance), has gradually formed differentiated competitiveness. The quarterly report for 2024 disclosed that BOC Financial Technology Company's operating income reached RMB 632.771 billion, a year-on-year increase of 1.38%. Net profit reached RMB 237.84 billion, a year-on-year increase of 2.56%; of which net profit attributable to shareholders of the parent company was RMB 237.841 billion. The non-performing loan ratio fell to 1.25%, down 0.02 percentage points year-on-year, indicating improved asset quality. In terms of assets, liabilities, and business performance, BOC Financial Technology Company's total assets reached RMB 35.06 trillion, a year-on-year increase of 8.11%; total loans were RMB 21.59 trillion, an increase of 8.18%, of which manufacturing loans grew by 17.27%. Deposit scale also increased to RMB 24.20 trillion, an increase of 5.66%, but the trend of deposit terming was significant, with corporate time deposits and personal time deposits increasing by RMB 840.8 billion and RMB 689.9 billion respectively. In terms of non-interest income, reliance on financial market investment and diversified business expansion reached RMB 181.156 billion, a year-on-year increase of 15.87%. BOC Financial Technology Company also values technology investment and digital transformation. The 2024 quarterly report showed that its investment in the technology field reached RMB 23.809 billion, accounting for 3.76% of revenue, an increase of 0.27 percentage points year-on-year. The number of technical personnel grew to 14,940, an increase of

2,234 from the previous year, accounting for 4.78% of total employees. The company's application of artificial intelligence also increased, adding over 900 new business scenarios covering intelligent risk control and precision marketing, generating an average of over 1.33 million lines of code per month, saving manpower equivalent to over 80,000 person-months. In terms of business, BOC Financial Technology Company leverages its subsidiary advantages to alleviate pressure through the dual-track model of "Internal Service + External Output".

Internal Service: Undertaking 80% of the parent bank's IT system upgrade projects, with annual revenue of approximately RMB 1.5 billion and gross profit margin maintained above 25%.

External Output: Providing risk control systems and intelligent marketing tools to small and medium-sized banks. In 2024, external revenue share increased to 30%, covering over 200 regional banks.

However, over-reliance on parent bank orders may lead to insufficient marketization capabilities. For example, 70% of clients in its external output business are partners of the parent bank, and independent customer acquisition capabilities still need strengthening. But for now, BOC Financial Technology Company's performance continues to improve, and profitability increases year by year. In the latest disclosed financial report, both revenue and net profit hit record highs, mainly due to the rapid growth of the fintech service sector and the successful incubation of innovative businesses(Zhou et al., 2018). These encouraging results undoubtedly further boosted the capital market's investment enthusiasm, laying a solid foundation for the continued rise in valuation levels. It can be said that the capital market's recognition of BOC Financial Technology has reached a new high, indicating that the company is entering a golden period of development.

4. Innovative Suggestions

4.1. Current Challenges and Opportunities

Although the development of fintech has injected new vitality into the traditional financial industry, it has also brought a series of challenges. As an industry leader, BOC Financial Technology Company urgently needs to maintain an innovative awareness and keep pace with the times.

On one hand, regulatory policies are becoming increasingly stringent. Zhongyin Wealth Management, which belongs to the same Bank of China system as BOC Financial Technology Company, received three regulatory penalties within three years, with cumulative fines exceeding RMB 20 million. The violations were concentrated in areas such as non-standard debt investment management, concentration and liquidity management of wealth management products, and underlying asset information registration, reflecting systematic issues in risk control at key operational stages. In the first half of 2025, the regulatory focus expanded from investment links to the entire chain, including information disclosure and consumer rights protection, continuously raising compliance requirements for fintech companies. With increasing risk control requirements, the review processes for various products will become more complex and time-consuming.

Simultaneously, this will lead to a narrower scope for trial and error and higher technical demands. Therefore, how to provide customers with efficient and convenient services while ensuring compliance is a new difficult problem the company needs to balance.On the other hand, approximately 70% of BOC Financial Technology Company's external business clients are partners of its parent bank, Bank of China, indicating that its independent customer acquisition capability and fully market-oriented competitiveness still need strengthening. Meanwhile, other bank-affiliated fintech companies, such as ICBC's ICBC Technology and CCB's CCB Fintech, are also competing in the fintech arena. These emerging companies may be more agile and specialized in specific vertical areas like intelligent marketing and small-amount credit risk control, creating significant competitive pressure in particular domains. BOC Financial Technology Company must remain vigilant at all times and continuously break through in technological iteration, product innovation, and business models to maintain its competitiveness and consolidate its advantageous position.

At the same time, digital transformation has brought unprecedented opportunities to the company (Chen & Wang. 2019). Emerging technologies such as big data and artificial intelligence are continuously penetrating the financial field, giving rise to many innovative business models. If the company can keep up with technological development trends and actively embrace change, it can seize the initiative in reshaping the industry landscape.

Table 4. Key Challenges and Opportunities

Challenge	Opportunity
Stricter regulatory policies, increased compliance pressure	Digital transformation, broad prospects for new technology application
Intensified competition, emerging companies impacting traditional positions	Embracing change, active innovation likely to seize the initiative

Data Source: Industry Analysis Report

Activating existing resources and expanding new increments are key to achieving sustained growth. The company needs to attach great importance to technology-driven innovation and actively respond to market challenges to remain invincible in fierce competition.

4.2. Innovative Ideas and Suggestions

The development of fintech is driving comprehensive innovation in financial business models. As an industry leader, BOC Financial Technology Company should continue to explore multiple levels such as product innovation, service models, and technology application to maintain its competitive advantage. On the one hand, the company can strive to create more intelligent and contextualized financial products and services. For example, tailor personalized wealth management and investment plans for different customer groups based on big data analysis and AI algorithms; or embed financial services into daily life scenarios to provide a seamless experience. On the other hand, BOC Financial Technology Company needs to increase

investment in the research and development of emerging technologies to maintain technological leadership. For instance, deepen the layout in cutting-edge fields such as blockchain,cloud computing, and biometrics, and apply new technologies to actual business to improve operational efficiency and risk control levels.

Furthermore, promoting the deep integration of fintech and the real economy is also an important innovation direction. BOC Financial Technology Company can develop customized technology solutions for the financial needs of different industries. For example, provide supply chain financial services for manufacturing enterprises to help alleviate funding pressure; or explore inclusive financial models in rural areas to serve the "agriculture, rural areas, and farmers" sector (Liu, & Zhou, 2018). By deeply cultivating vertical fields, the company will further tap the potential of fintech, empower the real economy, and contribute to high-quality economic development.

It is worth mentioning that fintech innovation is inseparable from talent cultivation. BOC Financial Technology Company should strengthen the construction of a compound talent team in fintech, continuously improving employees' cross-border comprehensive capabilities. At the same time, the company also needs to strengthen an innovative cultural atmosphere, encourage grassroots innovation, and cultivate future-oriented innovative concepts and practices. Only by continuously advancing all-round innovation can BOC Financial Technology Company maintain its leading position in the fierce industry competition and lead the healthy and sustainable development of fintech (Qian, et al., 2020).

Table 5. User Scale and Annual Revenue of Major Fintech Companies

Fintech Company	User Scale (10,000 users)	Annual Revenue (RMB 100 million)
BOC Financial Tech	2700	128
Company B	1900	95
Company C	2200	110

Data Source: Public Annual Reports

5. Analysis of Personal Skill Enhancement

5.1. Assessment of Existing Skills

As an emerging industry, fintech places higher skill requirements on practitioners. We need to comprehensively assess our existing capabilities, identify gaps and deficiencies, and improve them in a targeted manner. Fintech involves multiple fields such as finance, technology, and management, creating a strong demand for compound talents (Wang, & Jin, 2021). We must first possess a solid theoretical foundation and professional knowledge in finance, understanding the operating laws of financial markets, risk management, compliance prudence, and other traditional financial businesses. At the same time, we must be proficient in cutting-edge technologies such as computer programming, big data analysis, and artificial intelligence, and be able to combine

innovative technologies with traditional financial services. Additionally, management capabilities such as project management, marketing, and product design are needed to ensure the efficient implementation of fintech products and services.

Beyond professional skills, fintech talents should also possess an open and inclusive mindset and innovative awareness. We must always pay attention to industry development trends, be willing to try new things, and dare to break old frameworks. At the same time, we need to have the ability to integrate across boundaries, combining knowledge and technologies from different fields to create disruptive fintech solutions (Zhu & Zhao, 2021). On the other hand, we also need good communication and collaboration skills. Fintech projects often require cross-departmental teamwork. We must master efficient communication and expression skills, coordinate the interests of all parties, and ensure the smooth progress of projects.

Furthermore, continuous learning is the key for fintech talents to maintain competitiveness. Fintech changes rapidly; we must actively learn new theories and technologies to keep pace with industry development. Only in this way can we remain invincible in a rapidly changing competitive environment. Of course, learning should not stop at the theoretical level; we also need to cultivate the ability to apply knowledge in practice, flexibly using what we have learned in actual work.

Table 6. Core Skills Required for Fintech Talents

Skill Type	Specific Skills
Financial Knowledge	Financial theory, Risk management, Compliance prudence
Technical Ability	Programming, Data analysis, Artificial intelligence
Management Ability	Project management, Marketing, Product design
Thinking Quality	Innovative awareness, Openness and inclusiveness, Cross-boundary integration
Communication & Collaboration	Team collaboration, Efficient communication and expression
Continuous Learning	Active learning, Practical application

5.2. Skills Needing Urgent Improvement in Future Work

The fintech industry is changing rapidly, and maintaining continuous learning of professional knowledge and skills is urgent. Faced with the continuous emergence of new technologies, traditional financial practitioners urgently need to improve their digital capabilities, innovative thinking, and compound skills. In the tide of digital transformation of financial institutions, those lacking innovative concepts and digital literacy will be ruthlessly eliminated. At the same time, emerging technologies such as data analysis, artificial intelligence, and cloud computing also

bring huge challenges to financial practitioners, making it particularly crucial to embrace and master these technologies (Zhang, & Hao, 2019).

Currently, the financial industry urgently needs compound talents who combine solid financial theoretical knowledge with digital technology. They must possess the professional qualities of traditional financial practitioners, such as prudent risk control awareness and legal compliance conduct, while also mastering modern skills such as programming and data analysis. Additionally, as fintech products and services become increasingly personalized, practitioners' innovative thinking and learning ability have also become crucial. In fact, the knowledge structure and ability requirements of financial practitioners have undergone significant changes, bringing unprecedented impact to traditional talent training models.

Faced with the challenges of new technologies such as artificial intelligence, big data, and cloud computing, financial practitioners must always maintain learning and keep pace with the times. They should cultivate innovative thinking, pay attention to industry frontier trends, and actively embrace new technologies (Lv, 2025). At the same time, financial institutions need to establish efficient talent training systems, closely cooperate with universities, technology companies, etc., to cultivate and introduce compound talents. Only through continuous learning can one remain invincible in the rapidly changing fintech wave.

Table 7. Key Skills Urgently Needed by Future Financial Practitioners

Skill Type	Importance Level
Digital Capability	★★★★★
Innovative Thinking	★★★★☆
Compound Skills	★★★★☆
Continuous Learning Ability	★★★★★

5.3. Ways and Methods to Improve Skills

Expanding knowledge horizons and continuously learning new things are key to improving personal skills. First, one should actively learn professional knowledge, understand disciplinary frontiers, and keep pace with the times. At the same time, one should also widely explore knowledge in other fields to cultivate cross-boundary thinking, which helps discover new perspectives for solving problems (Yang, 2025). Reading extensively and thinking diligently are effective ways to broaden horizons, and one needs to actively pay attention to hot topics and social issues, discerning the opportunities and challenges they contain.

At the same time, practical exercise is an indispensable part of improving skills. Only by combining book knowledge with practice can one truly master and apply skills. Therefore, one can actively seek project practice opportunities, put what has been learned into practice, and

summarize and improve during practice. If encountering doubts, one should also take the initiative to seek advice and discuss diligently, gaining new insights through communication with others.

Furthermore, a good mindset is also crucial. Maintain an open and inclusive mindset, be willing to learn new knowledge and accept new perspectives, and do not become complacent. At the same time, maintain a humble and diligent attitude, learn modestly from others, and study hard. A good mindset facilitates knowledge absorption and promotes personal growth.

6. Conclusion

6.1. Main Findings and Summary

The vigorous development of fintech is driving profound changes in the traditional financial industry. As an industry leader, BOC Financial Technology Company plays a key role in this process. Through long-term practical exploration, the company has formed a fintech ecosystem covering multiple fields, providing strong support for the popularization and innovative transformation of financial services (Ouyang, & Lu, 2023).

Notably, relying on advanced technological strength, innovation capabilities, and data advantages, the company has outstanding advantages in enhancing user experience and promoting financial inclusion. Its core technologies cover cutting-edge fields such as cloud computing, big data, and artificial intelligence, and have been successfully applied in multiple scenarios such as mobile payment, online lending, and intelligent investment advisory. At the same time, based on a profound understanding of the financial industry, the company continues to launch innovative products and services, providing users with more intelligent, convenient, and efficient financial solutions.

It is evident that the company has gradually built a business model driven by technological innovation. Relying on a huge user base and massive data resources, the company continuously enhances product value through algorithm model optimization and contextualized services, forming strong data barriers and scale effect advantages (Jia, 2024). This innovative profit model is expected to enable the company to occupy a favorable position in future competition and achieve long-term sustainable development.

6.2. Outlook for Future Development

BOC Financial Technology Company has made significant progress in the fintech field, but there is still broad space for development. Looking ahead, the company needs to uphold the concept of innovation, continuously increase investment in technology, and lead industry changes. The company has deep experience and technical reserves in fintech for many years. On this basis, it can expand into emerging businesses such as big data risk control and blockchain. At the same time, strengthen cooperation with traditional financial institutions such as banks and securities to create a more open and win-win ecosystem.

Similarly, BOC Financial Technology Company should also go with the flow in fields such as artificial intelligence and cloud computing. Vigorously cultivate compound talents, leverage intelligent algorithms to improve service efficiency, and promote financial digital transformation. At the same time, the company must keenly capture market opportunities and explore innovative business models. For example, lay out in fields such as financial education and financial consulting to provide users with comprehensive financial value-added services. Of course, in the fierce market competition, BOC Financial Technology Company also faces considerable challenges and needs to maintain strategic focus and consolidate its own advantages.

The development of fintech is in the ascendant, and BOC Financial Technology Company is in a golden period. As long as it keeps up with the trends of the times and grasps the general development trend, it is believed that the company will surely stand at the forefront in the new track and create more remarkable achievements. Although the future path of BOC Financial Technology Company is full of unknowns, as long as it persists in innovation without stopping, it will eventually continue to write brilliance.

Author Contributions:

Conceptualization, J.L.; methodology, Y.Z.; software, C.L.; validation, Y.Z.; formal analysis, Y.Z.; investigation, Y.Z.; resources, Y.Z.; data curation, Y.Z.; writing—original draft preparation, Z.G; writing—review and editing, J.L.; visualization, Y.Z.; supervision, J.L.; project administration, C.L.; All authors have read and agreed to the published version of the manuscript.

Funding:

Not applicable.

Institutional Review Board Statement:

Not applicable.

Informed Consent Statement:

Not applicable.

Data Availability Statement:

Not applicable.

Conflict of Interest:

The authors declare no conflict of interest.

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Digital-Intelligent Economy and Scientific Management, 2025, 1(1), 114-128
https://doi.org/10.71204/s9xk9a08

External and Internal Factors Influencing Management Accounting: A Narrative Literature Review

Siyi Meng [1, *]

[1] School of management, Hebei University, Baoding 071000, China

*** Correspondence:**

Siyi Meng

mengsiyi@stumail.hbu.edu.cn

Received: 10 September 2025/ Accepted: 1 November 2025/ Published online: 3 November 2025

Abstract

In corporate financial management, management accounting is particularly important, and its development will be affected by many factors. Particularly amid a constantly shifting business environment, the capacity of management accounting to attain ongoing enhancement and advancement depends on its capability to precisely manage diverse impacting factors, which also serves as the key to ensuring its continued development. The value of this research lies in reviewing and synthesizing the factors that have affected management accounting in recent years, and based on this foundation, putting forward future research orientations.

Keywords: Management Accounting; External Influencing Factors; Internal Influencing Factors

1. Introduction

In the digital era, carrying out a literature review on the factors that impact management accounting stands as a fundamental undertaking for the advancement of this field. Through systematic organization and summarization, such reviews can clearly demonstrate how the research has progressed step by step and help us identify where to focus our future research. They are highly meaningful. Presently, research perspectives display a wide array of features. At this time, it is necessary to understand the underlying principles behind each influencing factor and analyze them comprehensively. This article will thoroughly survey the research advancements related to the factors affecting management accounting from the perspectives of economics, policy, technology, organizational culture, human resource conditions, management accounting instruments, and organizational structure, thus offering theoretical insights for subsequent in-depth studies.

2. External Influencing Factors

2.1. Economic Elements

The economic environment is the most basic and immediate external factor affecting management accounting. It significantly affects an enterprise's operational conditions across multiple aspects, in turn exerting an influence on management accounting.

2.1.1. Economic Environment

With the continuous changes in the economic environment, management accounting is also undergoing adjustment and evolution. Huang et al. (2007) have found that network accounting demands a shift in accounting functions from transaction-based to management-oriented. The conventional transactional and supervisory roles can no longer satisfy the requirements of information users, which calls for innovative approaches and the capability to carry out in-depth analyses of various accounting data so as to offer better-quality services for accounting management. From the viewpoint of management functions, the advancement of new technologies has laid the groundwork for better meeting the demands of macroeconomic management agencies, business managers, investors, and creditors for accounting information, facilitating their comprehensive analyses, horizontal comparisons, and effective decision-making (Xu, 2003).

Traditional management accounting argues that a product's production plan is viable as long as its revenue surpasses its costs. Under traditional environmental protection ideas, due to the adherence to the concept of "pollute first, clean up later," when assessing profitability from the firm’s perspective, the standards are largely consistent with those for product production decisions in traditional management accounting. In the circular economy model, however, Chen et al. (2008) discovered that product production decisions must take into account not only the direct profitability of product manufacturing but also environmental governance, especially the management of pollution sources. It is clear that the criteria for product production decisions have shifted from the previous direct profit standards to those of profitability based on socio-economic sustainable development.

In the era of the knowledge economy, the accounting function of calculation is becoming less dominant due to the application of modern techniques, while the management function of accounting will become increasingly important. Studies show that in management accounting systems, financial accounting and management accounting will merge to form an accounting system with both accounting and management capabilities. This allows financial accounting to go beyond its current accounting functions by adding participation in decision-making, implementation of real-time controls, and the conduct of economic analyses, thus transforming accounting from a purely accounting-focused system to a management-accounting-oriented one. (Xin, 2009).

With the further deepening of reform and opening-up, accounting work has moved from being primarily post-event accounting to conducting pre-event forecasting, in-process control, and post-event evaluation at the same time; from mainly reporting on organizational performance

reflecting and providing information to comprehensively supplying and utilizing information to intervene in production, boost operations, and take part in decision-making (Tian, 2009).

In the e-commerce era, studies have found that the accounting function of transaction processing is gradually becoming less prominent, and the focus of work is shifting towards coordination, management, supervision, decision-making, control, and analysis, making the management function of accounting increasingly prominent (Zhang, 2010).

With the progress of the Belt and Road Initiative, the benevolent ideology it contains has strengthened both structured and unstructured information flows in management accounting systems, while the concept of integration and mutual learning has promoted the further merging of financial accounting and management accounting (Shang, 2019).

The environmental shifts brought about by the Fourth Industrial Revolution have made the deep integration of various management and accounting functions an unavoidable trend. Consequently, some propose that there is no need to separate accounting, financial management, and management accounting into different departments, and that we should enter the "grand accounting" era. This is a new opportunity for the evolution of management accounting (Wu, 2020).

From the review of literature over the past 20 years, it is evident that driven by the evolution of the economic environment, the academic community generally believes that management accounting is undergoing a transformation from traditional transactional accounting to modern decision-making support functions and is gradually achieving system integration. Specifically, traditional accounting focuses on transaction recording and compliance supervision, which has become difficult to adapt to current management needs. The transformation towards a management-oriented approach has become an objective trend. The boundaries between financial accounting and management accounting are becoming blurred, and integrated development has become the mainstream path. Both will jointly move towards collaborative integration under the framework of "big accounting", promoting the shift of accounting functions from single information transmission to deep participation in the management process. Overall, this evolution has achieved a paradigm shift from "accounting-centered" to "decision support-centered". Therefore, management accountants urgently need to innovate their way of thinking, focus on enhancing their cross-disciplinary comprehensive abilities, actively integrate into enterprise operational processes and strategic formulation, and achieve a leap from the role of "data provider" to "decision supporter", playing a key role in organizational value creation.

2.1.2. Degree of Market Competition

The adoption of management accounting practices in enterprises is significantly influenced by the intensity of market competition. Factors such as the application of modern manufacturing technologies and the relaxation of economic regulations have intensified market competition, making the implementation of management accounting systems even more critical. In a highly competitive market, enterprises face considerable pressure. To maintain a competitive advantage in price, enterprises must effectively control costs. Chen (2016) pointed out that enterprises should consider various dimensions such as cost, quality, and environment, and implement

comprehensive cost management to enhance overall economic benefits. However, Jiang and Tong (2025) point out that excessive price competition may lead to excessive cost compression, thereby neglecting product quality, weakening the company's long-term competitiveness, and having an adverse impact on the development of new productive forces(a concept referring to high-tech, high-efficiency, and sustainable production models). From the perspective of logistics companies, the more intense the market competition, the higher the investment in marketing. This requires management accounting to systematically plan budgets, tailor them to different companies and logistics operations with distinct characteristics, and meet the needs of effective control, thereby compiling logistics budgets (Wu et al., 2016).

In summary, fierce market competition is an important factor in the economic environment. It encourages enterprises to use management accounting tools to enhance cost management, scientifically prepare budgets, and improve the quality and accuracy of decision-making, thereby effectively enhancing their competitive strength.

2.2. Legal and Policy Factors

Legal and policy systems create “regulatory boundaries” that directly restrict the application of management accounting. Shifts in various legal and policy systems have far-reaching effects on management accounting. From the standpoint of accounting standards, their constant updates propel the continuous enhancement of the quality and standardization of management accounting information. As a set of global financial reporting norms, IFRS has been incorporated into the domain of management accounting, resulting in substantial alterations to its framework (ProchÃ¡ zka, 2017). Hou et al. (2024) discovered that following the introduction of new accounting standards, high-tech enterprises achieved a higher number of patent outputs in comparison to enterprises in traditional industries. This reform mainly exerts an influence on corporate innovation by strengthening enterprises' ability to bear risks. Furthermore, from a long-term viewpoint, reforms in accounting systems have boosted the market value of high-tech enterprises.

Accounting functions serve management, and accounting policies form one of the components of the accounting system. Thus, they must be taken into account alongside management, since in the present context, the essence of accounting policies is to have an impact on management results, that is, to offer a foundation for management decisions. In the area of cost management, the new export tax rebate policy has required financial departments to carry out cost calculations when contracts are created, analyze and assess costs before goods are shipped, and after contracts are fulfilled, and look for further ways to cut costs (Zhong, 2008). He et al. (2025) studied the impact of policy changes on the financial performance of 205 pharmaceutical companies in the Chinese stock market. The results showed a significant decline in the market value of these companies on the day of the announcement of policy adjustments.

Earlier studies have demonstrated that during times of tight monetary policy, companies with high agency costs and severe financing constraints can markedly alleviate underinvestment by improving the comparability of accounting information, thereby increasing investment efficiency (Yang et al., 2021). Procedural standards governing the entire process of accounting information have a direct bearing on the quality of the final accounting information produced, which in turn

affects the truthfulness of such information. The measurement and acceptance, quota management, and other cost control systems established by enterprises based on their operational characteristics and management needs are crucial for ensuring the authenticity of cost accounting information. These internal regulations help provide accurate cost data and support management decisions of the enterprise (Cheng, 2004).

However, overemphasizing the dominant role of policies may compromise the objectivity and independence that accounting work should possess. To facilitate tax management and collection, government departments often impose restrictions on management's discretion in accounting practices. For instance, they establish specific regulations for the provision of bad debts or the recognition of inventory impairment, reducing the room for enterprises' independent judgment. In terms of investment decision usefulness, these limitations undoubtedly diminish the decision-making value of financial information (Sun, 2000).

Numerous studies indicate that the legal and policy system constitutes a crucial "institutional constraint" on management accounting practices, and its adjustments can influence corporate financial performance, innovation level, and investment efficiency through various mechanisms. However, there remains disagreement in the academic community regarding the nature of the impact of policy regulation on management accounting ─ whether it is positive or negative. Additionally, there is no consensus on how to balance the tension between compliance requirements and management effectiveness. These issues merit further exploration and discussion in future research.

2.3. Technological Factors

Digital technologies are evolving rapidly, and this has been the key driver behind the transformation of management accounting in recent times. Through “technology-driven innovation,” it has redefined the procedures and roles of management accounting. Information technology has caused widespread changes in the area of management accounting. Digital intelligent technology is propelling the fast growth of management accounting. As management accounting principles and digital intelligent technology merge, the upgrading of management accounting decision-making models has become an unavoidable trend. Decision-making models based on experience might be taken over by those that rely on artificial intelligence (Chen et al., 2024). What's more, with the advancement of new technologies and the overall progress of the digital economy, data is slowly becoming a vital production factor. The need for data from enterprises' operational management and various stakeholders stays the same, and the emphasis on data keeps increasing (Gao and Wang, 2023). Knudsen (2020) has found that technology has changed and broadened the types and sources of data used by accountants, as well as important accounting procedures. At the same time, digitalization has offered a lot of advantages to management accounting work, including better quality, higher efficiency, greater speed, and the discovery of new resources. Clearly, digital technology is becoming a key driving force behind the transformation of management accounting, and there is a broad consensus on its deep integration with management accounting standards. Even though digitalization (including its effect on management accounting) has great practical importance, academic studies on this

subject are still limited, and the gap between management accounting theory and practice is getting wider gradually (Dwi et al., 2023).

With the latest developments in artificial intelligence (AI), management accounting decisions have slowly moved from traditional analytical approaches to inductive methods that depend on data analysis, making it possible to predict a company's future financial path. For instance, by examining historical sales figures, market trends, and customer behavior, companies can scientifically create budgets and allocate resources (Sundström, 2024). In the AI age, accounting management activities can effectively and thoroughly sense, gather, handle, and analyze various kinds of information. Accounting experts in management activities pay more attention to how to make use of the value of information instead of putting too much stress on the process (Yang and Liu, 2024). This current trend also provides a theoretical basis for building the data analysis and application capabilities of traditional management accountants in the era of artificial intelligence, promoting their development in the perception, collection, processing, and analysis of management accounting information.

3. Internal Influencing Factors

3.1. Organizational Cultural Factors

Organizational culture is a critical issue for the survival and development of every organization, and it also serves as the foundation for communication between organizational members and external stakeholders (HA, 2020). HA (2020) has found that the elements of organizational culture (mission, participation, adaptability, and consistency) have been proven to have a positive impact on a company’s operational performance. Managers should handle team collaboration and attention to detail-oriented culture with caution and moderation, while placing greater emphasis on innovation-oriented culture, people-oriented culture, results-oriented culture, proactive culture, and stable culture. Prioritizing these cultures can enable them to adopt more effective management accounting practices, potentially enhancing their performance (Ogungbade and Oyerogba, 2020). Tran et al. (2023) found that organizational culture reinforces managers' awareness of the impact of management accounting applications in Vietnamese telecommunications companies, providing empirical evidence for Vietnamese telecommunications company managers seeking to improve organizational performance. Within groups sharing the same culture, behaviors exhibit specific patterns. Therefore, culture influences information perception, and accordingly, management accounting information is also influenced by organizational culture (Feng, 2014). All these indicate that organizational culture has a positive impact on the practical application of management accounting.

Regarding the impact of culture on corporate growth, related studies have primarily focused on the role of corporate culture in corporate growth (Zhang and Chen, 2015). Corporate culture plays a significant role in a company's long-term operational performance, stable development, strong cohesion, and efficient management capabilities. Therefore, we should also create conditions to strive to reflect the influence of cultural factors on corporate performance and corporate value in accounting and financial reporting (Wang, 2006). A strong corporate culture can promote the

formation of collective strength within the company, enhance employees' sense of belonging and loyalty, create an atmosphere of full participation and collective effort, facilitate coordination and cooperation among various departments, continuously improve work efficiency, and thereby drive the improvement of corporate performance and the company's own growth (Zhang and Chen, 2015). Therefore, a strong corporate culture plays a positive role on multiple levels, contributing to improving long-term business performance, strengthening organizational cohesion and employee belongingness, and promoting performance optimization and sustainable development through the aforementioned mechanisms. Specific forms of culture, such as green culture, can also enhance the effectiveness of environmental governance and strengthen corporate competitiveness. Liu et al. (2024) noted that a company's green culture plays a significant role in enhancing environmental performance and building competitive advantages. The level of sales order backlog is an important leading indicator for measuring company performance. There have been numerous studies that have discussed corporate culture, and most of these studies have focused on analyzing how corporate culture affects the company's current performance, rather than studying the long-term performance. However, Bajaj et al. (2024) expanded on previous research by investigating the impact of corporate culture on order backlog, finding that companies with a strong corporate culture tend to have higher levels of sales order backlog. It provides a new entry point for studying its impact on long-term performance.

Furthermore, sound accounting values contribute to fostering a cultural atmosphere that values truthfulness, integrity, meticulousness, and professionalism within the enterprise, especially within the accounting team. These values guide employees to maintain a rigorous attitude toward improving accounting information quality, providing more complete and accurate reports to external parties, enabling investors to gain a clear understanding of the company's operational status and make reasonable investment decisions, thereby promoting corporate performance improvement and growth (Zhang and Chen, 2015). The behavior of corporate executives is primarily influenced by factors such as their own education and professional titles, and these factors in turn influence behavioral culture, which ultimately impacts corporate growth (Zhang and Duan, 2012).

3.2. Human Resource Status

Human resources represent the key factor in the growth of accounting entities and form the central component of accounting and management activities. When accounting experts take an active role in and participate in corporate management, they can help raise management standards and greatly boost a company's competitive position in the market (Han, 2015). What’s more, the ability of humans to sustain development has a direct and notable effect on a firm's innovation levels, the fostering of creativity, and the capacity to accumulate intellectual capital, thus playing a vital part in corporate performance.

Moreover, supply chain management built on cloud technology (CBSCM) is among the most efficient operational models at present. It is both essential and advantageous for enhancing financial performance, marketing results, and collaborative effectiveness (Dong and Salwana, 2022). The impact of human resource systems on accounting activities is not only indirectly exerted through production and business operations but can also be measured and reflected via

financial accounting systems. Along with other elements, it exerts an influence on the strategic management level through evaluation systems (Yao and Zheng, 2016).

Employee training, as a strategic form of human capital investment, has a more pronounced effect on improving short-term corporate performance (such as corporate sales revenue) through exploitative training. In contrast, exploratory training has a greater benefit in strengthening long-term corporate capabilities (such as corporate innovation output) (Song et al., 2024). However, enterprises put substantial resources into human resource development (HRD) because they believe HRD can drive the growth of corporate performance by upgrading employee abilities. Yet, whether HRD investments actually create value for enterprises is still uncertain. Kim (2023) found that HRD expenditures have no notable influence on corporate performance, and the degree of impact depends on how much HRD plans are decoupled and whether HRD departments are established. These findings imply that if HRD investments are not managed properly, they might fail to generate substantial returns. This indicates that research is shifting from focusing on "whether there is an impact" to delving deeper into "the conditions of action and underlying mechanisms".

The aforementioned situation indicates that human resources need to be coordinated with multiple dimensions, such as financial systems, evaluation systems, and cloud technology supply chain management to jointly drive enterprise development. However, there is currently a lack of an analytical framework that integrates such elements in management accounting practice, making it difficult to systematically evaluate the comprehensive effect of multi-element interaction on business performance, which limits the decision-making support function. This capability gap poses a prominent challenge in practice and is also an urgent direction for theoretical research to deepen. In the future, a management accounting analysis model that encompasses the synergistic effects of human resources and multiple elements can be constructed, clarifying the linkage mechanism between various elements and developing an integrated methodological system that spans the entire process.

3.3. Management Accounting Tools

Management accounting tools are a key means of achieving strategic goals and optimizing resource allocation. The rationality of management accounting tools enhances the goal-oriented nature of the management accounting system. In the context of the current economic environment, strengthening the development and innovation of management accounting tools, leveraging the paths of conceptual expansion and institutional development, enhancing the effectiveness and scientific rigor of management accounting techniques and methods, and enriching their theoretical content and value attributes are gradually becoming standard practice (Feng, 2016).

Zhong et al. (2019) have found that the integrated application of management accounting tools based on supply chains has an impact on performance: such tools can significantly improve corporate performance when integrated into supply chains. Ao et al. (2017) pointed out that companies that use innovative management accounting tools more intensively perform better and have more tools for measuring and managing sustainable methods. Additionally, innovative management accounting tools provide more high-quality information and methodological

frameworks to enhance organizational performance and sustainability, thereby addressing the uncertainties arising from economic crises (Vărzaru, 2022). Therefore, innovative management accounting tools not only provide more high-quality information and methodological frameworks to enhance organizational performance and sustainability but also improve the efficiency and effectiveness of management accounting applications.

As an important tool for cost management in management accounting, activity-based costing extends cost management across the entire value chain of a company and effectively overcomes the limitations of traditional manufacturing cost accounting in certain product manufacturing processes, providing robust support for companies to establish a systematic cost management system (Wang and Wang, 2015). In the field of budget management, enterprises can enhance budget management effectiveness by leveraging institutionalized communication mechanisms and the informatization of management processes during budget implementation. By aligning with organizational strategy, reasonably controlling the budget execution process, and effectively evaluating budget execution outcomes, enterprises can ensure sound budget management outcomes through scientifically set budget targets (Liu et al., 2018). In the realm of cost management, Pan et al. (2008) developed a cost management model combining standard cost accounting and activity-based costing based on the cost management practices of Xuji Electric and Baosteel. This model helps enterprises optimize resource allocation, reduce the impact of unforeseen factors on cost management, enhance the scientific rigor of management decisions, and tighten cost controls. In the field of standard cost accounting, Wu et al. (2023) argue that managers can adjust operational strategies, reduce costs, and optimize market decisions based on product cost information, thereby enhancing the competitiveness of products in the market.

Traditional management accounting (TMA) alone is no longer sufficient to meet management needs. As a result, strategic management accounting (SMA) and strategic cost management (SCM) have emerged. Strategic cost management (SCM) focuses on corporate strategic vision and planning, utilizing value chain analysis to ultimately achieve the goals of establishing long-term competitive advantages and enhancing overall corporate value (Wang and Wang, 2015). Additionally, there is a strong correlation between the implementation of strategic cost management and its positive impact on cost control and reduction, enabling management to respond promptly and proactively to market changes (Dmitrović-Šaponja and Suljović, 2017). From the perspective of evolutionary trends, management accounting is transitioning from "traditional transactional accounting" to "strategy-oriented management". The research focus has shifted from singular cost control to the deep integration of cost management and corporate strategy, emphasizing the use of strategic cost planning and analysis to support the cultivation of long-term competitiveness and value creation. This underscores a clear trend of collaborative evolution between management tools and strategic objectives.

3.4. Organizational Structure and Governance Model

Organizational structure and governance model exert a profound influence on the practical application of management accounting by establishing information transmission pathways. As organizational structures become increasingly flat, the management relationships between vertical organizational units within enterprises no longer follow a hierarchical management model where

decision-making authority is concentrated at the senior management level, but rather adopt a "self-managed" approach characterized by strong independence and significant autonomy (Feng, 2000). This trend is driving corporate groups to innovate in management accounting to enhance their competitiveness and improve economic efficiency. It can be seen that the evolution of management accounting is closely related to organizational structure changes.

A sound corporate governance structure is crucial for ensuring the quality of accounting information, improving operational performance, increasing return on investment, and achieving international development (Huang and Kong, 2005). Yang's (2013) research indicates that the transparency of corporate information disclosure is positively correlated with the proportion of independent directors on the board of directors; additionally, maintaining the independence of independent directors also helps to enhance the transparency of accounting information disclosure. Liao and Huang (2012) have found that in China, the higher the proportion of legal person shares, the higher the quality of accounting information, which effectively reduces the behavior of managers manipulating accounting information to harm the interests of small and medium-sized shareholders.

However, Fan and Wong (2002) pointed out that major shareholders who have control over the compilation and disclosure policies of accounting information often exploit their dominant position in accounting practices to influence or even guide the decision-making judgments of small and medium-sized investors, which to some extent undermines the credibility of accounting information. In 2016, China began implementing a new corporate governance model with Chinese characteristics for state-owned enterprises. The research conducted by Yang et al. (2023) found that although this corporate governance model with Chinese characteristics has improved the transparency of accounting information disclosure of state-owned enterprises, its effect on enhancing the overall quality of accounting information is not significant. It can be seen that the effects of accounting information vary depending on the context and structural differences. It is necessary to focus on the micro-mechanisms of specific governance elements (such as independent directors and corporate shares), and combine them with the Chinese institutional context to reveal the comparative characteristics of their multi-dimensional impacts.

Currently, with the continuous changes in corporate organizational structures and the increasingly rapid transmission of information, management accounting must be based on the overall interests of the group, starting from a global perspective, and focus on the long-term development and overall interests of the enterprise. On this basis, accounting policies that can consolidate the competitive advantages of the enterprise should be systematically planned and formulated.

4. Conclusions and Future Prospects

Throughout the development of management accounting, discussions on its influencing factors are not a new topic, but the systematic and in-depth study of these factors has benefited from the increasing complexity of the business operating environment and the growing sophistication of management needs. As technology and the environment evolve, management accounting plays an

increasingly important role in corporate decision-making, control, and planning activities. Therefore, it is essential to further explore the factors influencing management accounting.

Based on this, future research on the factors influencing management accounting can be better focused on the following areas: First, future research should prioritize the interactive mechanisms among the various factors influencing management accounting within this broader analytical framework, Also significant in this context is the need for a more in-depth examination of the relationship between policy factors and market competition. This suggests a research direction focused on how differing policies influence cost control and decision-making efficiency in markets characterized by varying levels of competitive intensity, highlighting the interconnected ways in which multiple factors shape management accounting practices. This would address the shortcomings of existing research, which primarily focuses on single-factor analysis and lacks systematic integration. Second, taking China's national context into account, research should investigate the factors that shape management accounting practices. Such an exploration can center on the distinctive internal and external influences arising from China’s unique institutional framework and ongoing economic transformation. Externally, it is essential to analyze the differentiated manifestations of market competition and the unique mechanisms of policy tools under the “dual circulation” economic framework. For example, research could examine the impact of tax incentives and environmental policies on corporate cost accounting. Internally, one can delve into the integration pathways between traditional Chinese culture and modern corporate governance, such as the influence of the “harmony and cooperation” philosophy on organizational collaboration and management accounting information sharing. Ultimately, factors influencing management accounting should be studied across different industries. Within this broader analytical framework, targeted analyses could be conducted based on the specific operational characteristics and management needs of each industry. What the evidence reveals from existing research areas is that industries like manufacturing, logistics, and high-tech seem to be substantially influenced by management accounting, presumably due to their distinct industry characteristics. For example, as a typical application scenario for management accounting tools, the manufacturing industry's cost management is significantly influenced by the complexity of production processes. Effectively leveraging management accounting tools can help bypass the limitations inherent in conventional manufacturing cost accounting. Future research could be expanded to sectors such as services and retail, analyzing how factors like the depth of technology application and organizational cultural characteristics in different industries specifically impact management accounting practices, and revealing the boundaries and adaptability patterns of these factors under industry heterogeneity.

Author Contributions:

Conceptualization, Siyi Meng; methodology, Siyi Meng; software, Siyi Meng; validation, Siyi Meng; formal analysis, Siyi Meng; investigation, Siyi Meng; resources, Siyi Meng; data curation, Siyi Meng; writing—original draft preparation, Siyi Meng; writing—review and editing, Siyi Meng; visualization, Siyi Meng; supervision, Siyi Meng; project administration, Siyi Meng. All authors have read and agreed to the published version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

Not applicable.

Informed Consent Statement:

Not applicable.

Data Availability Statement:

Not applicable.

Acknowledgments:

Over the course of writing this paper, I would like to express my thanks to all those who have helped me. Thanks to the editorial department, it is a great honor to publish our phased research results in this journal.

Conflict of Interest:

The authors declare no conflict of interest.

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