PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of **World Economy**

Volume 4, Number 4 **August 2025**

CONTENTS

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of **World Economy**

Volume 4, Number 4 **August 2025**

CONTENTS

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

Level of Self-Assessed Entrepreneurial Competence of Students from Accountancy, Business and Management Programs

Mark Kevin Astrero[1] & Joyce Irene R. Velasco[1]

[1] Faculty, Northeastern College, Santiago City, Philippines
Correspondence: Mark Kevin Astrero, Faculty, Northeastern College, Santiago City, Philippines.

doi:10.56397/JWE.2025.08.01

Abstract

Entrepreneurial competence in students is vital today, and especially for students taking Accountancy, Business, and Management (ABM) programs. This study evaluated the level of Personal Entrepreneurial Competencies (PECs) of ABM students in Santiago City, Philippines, an opening in the empirical literature for situationally embedded competency assessment in the Philippine educational landscape. Utilizing a quantitative-descriptive approach, the researchers surveyed 300 ABM students from Northeastern College, using validated tools for self-assessing and for learning competencies. It is noteworthy that 81.34% of the respondents exhibited at most satisfactory entrepreneurial skill, of which 34.67% exhibited outstanding skill. Higher proficiency levels were observed for the categories of Risk Taking (68.66%) Demand for Quality and Efficiency (68%), and Goal Setting (70.34%); highest proficiency levels allied well with the student's inclination to engage in entrepreneurial opportunities; meanwhile, a significant portion of students had only sufficiently moderate levels of competencies embraced in Opportunity Seeking (79.33%) and Persistence (74%); suggesting it may be prudent to introduce further contextual or experiential applications of the pedagogy. This study demonstrates the need for participatory, innovative education programs like mentoring, experiential learning, and redesigning the curriculum dedicated to taking the students from moderate to high entrepreneurial ability. In the Philippines' socio-economic context, the study emphasizes the importance of starting and growing new businesses as a route to self-employment and for sustainability.

Keywords: ABM, entrepreneurial competence, college students, business education, entrepreneurial mindset

1. Introduction

Recently, the topic of Personal Entrepreneurial Competencies (PECs) has been at the forefront of education, particularly in their relationship to Accountancy, Business and Management courses, and more generally, entrepreneurship education. PECs are an essential component in the students' preparation for entrepreneurship and the success of business. These are defined as the personal traits, knowledge, abilities, and skills that an entrepreneur draws upon to develop, create, and manage business activities

and face challenges and opportunities in an entrepreneurial ecosystem. PECs cover a wide range of characteristics, like opportunity recognition, abiding by risks, innovation, and leadership skills, all of which play a key role in starting and running a successful entrepreneurial venture (Ahmad et al., 2010; Mitchelmore & Rowley, 2010) so understanding on the concept of personal entrepreneurial competencies with students will better improve those students' entrepreneurial skills and competence.

The role of Personal Entrepreneurial Competencies (PECs) in Accountancy, Business, and Management programs is clearly essential because of the relationship between PECs and entrepreneurial performance and business outcomes. Existing evidence demonstrates that entrepreneurs who possess adequate competencies are more able to accept the ambiguities of business environments, which allows them to have increased levels of success, survival rates, and sustainability in their business operations (Ahmad et al., 2010; Barazandeh et al., 2015; Mitchelmore & Rowley, 2010). In today's environment, where entrepreneurship is the key to stimulating future economic growth and employment, it is the responsibility of educational institutions to incorporate PECs into their programs for not only preparing students to be employed but also preparing them to create employment opportunities for others by creating entrepreneurial ventures (Mitchelmore & Rowley, 2013). Hence, it is timely to intentionally and systematically incorporate the development of personal entrepreneurial competencies into the wider business education paradigm.

On an international scale, the study of Personal Entrepreneurial Competencies indicates a rising recognition of the importance of entrepreneurial skills in everyone's educational achievement across economies. Evidence shows that entrepreneurial competencies enhance entrepreneurial intention and business preparedness in students, ultimately impacting national economic performance (Bagheri & Abbariki, 2016; "Evaluating Entrepreneurial Skills Needed by Business Education Students for Self-employment in Colleges of Education, Kano State", 2023). For example, research in educational systems in numerous different countries found that experiential learning practices improve students' entrepreneurial competencies (Kyguolienė & Švipas, 2019). Both developed and developing countries share the sentiment that an overall education in the critical entrepreneurial competencies will bridge the gap between theory and practice in establishing businesses (Bonesso et al., 2018).

Studying the Personal Entrepreneurial Competencies in the context of the Philippines lends itself to research because the country is attempting to modify education to entrepreneurship education modalities progressively. According to Mendoza (2023), students in the Philippines' Accountancy, Business, and Management fields display personal entrepreneurial competencies at all levels of the spectrum, needing intervention. Moreover, given that small businesses and entrepreneurship are increasingly seen as viable pathways the economic self-sufficiency and sustainability in the country, it is critical to understand the PECs of students enrolled in these programs to help reflect better educational practices in line with the national development goals of entrepreneurship and to stimulate students in all these disciplines to create an entrepreneurial culture (Moraes et al., 2018).

Although Personal Entrepreneurial Competencies are acknowledged, gaps exist in research regarding the contextually relevant PECs that are relevant for students in the educational context of the Philippines. There have been some studies identifying a wide range of general entrepreneurial capabilities, it is evident that further inquiry needs to be conducted to specifically identify the PEC's that pertain to local business environments, local culture, and social and economic issues regarding the local area of the Philippines (Hiền et al., 2019). Additionally, while the available empirical evidence does relate to varying ways that PECs have been associated with actual entrepreneurial behavior within specific areas of the Philippine context, the need for an identified cohesive body of contextualized research with associated rigor begins to expand existing literature (Mitchelmore & Rowley, 2010).

Possible action to address these gaps in knowledge might occur through developing context-specific educational programs to create individual Personal Entrepreneurial Competencies of the population of students studying Accountancy, Business, and Management. Potential interventions include experiential learning that provides opportunities

for internships, mentorship, and learning skills workshops anchored within the context of local businesses. For instance, creativity, spotting opportunity and risk in the educational context, is essential as it introduces students to educational content related to the local market needs, enabling them to utilize their entrepreneurial potential (Ahmad et al., 2010; Mendoza, 2023). In this sense, educational contexts can support emerging skills and/or embed skills with suitable practices within priority knowledge and experience. Educational contexts can help develop future entrepreneurs who could show practical outcomes in an increasingly competitive space.

In summary, it is vital to understand Personal Entrepreneurial Competencies when offering Accountancy, Business, and Management programs for the benefit of not only the students' personal development and career prospects but also for wider economic development. By filling existing research gaps and developing a more holistic education approach targeting PECs, higher education institutions can produce the next generation of entrepreneurs capable of dealing with complex issues in a growing business world, ultimately benefiting local and national economies.

1.1 Statement of the Problem

With the body of literature presented, this research aims to identify the level of personal entrepreneurial competencies of the Accountancy, Business, and Management students in Santiago City, Philippines. Thus, this study sought to answer the following research questions:

1) What is the entrepreneurial self-assessment score of the students in accountancy, business, and management programs?
2) What is the level of personal entrepreneurial competence of the students in accountancy, business, and management programs?

2. Review of Related Studies

The importance of personal entrepreneurial competencies (PECs) in Accountancy, Business, and Management (ABM) programs can significantly impact the curriculum and learning outcomes for future entrepreneurs. This review compiles a collection of articles on a variety of entrepreneurial competencies, including Opportunity Seeking, Persistence, Commitment to Work Contract, Demand for Quality and Efficiency, Risk Taking, Goal Setting, Information Seeking, Systematic Planning and Monitoring, Persuasion and Networking, Self-confidence, and Correction Factor. Each section summarizes the definition of the competency that researchers have identified, as well as the research findings and recommendations based on the studies reviewed.

2.1 Personal Entrepreneurial Competencies

Opportunity seeking is defined as the capacity to recognize viable business opportunities in the marketplace. Lv et al. (2021) found that entrepreneurial education significantly increased students' willingness to seek opportunities and that learning entrepreneurial competencies and behaviors facilitated the adoption of a proactive parasitism that characterizes successful entrepreneurs. Similarly, Kusumawijaya & Astuti (2021) also noted that opportunity-seeking capability is connected to a person's characteristics, and suggested that opportunity-seeking competencies should be infused into the ABM curriculum to prepare students for future contexts.

Persistence is the capacity to continue despite setbacks and obstacles, which is important as an entrepreneur. Gunartin et al. (2023) emergently proved that persistence is a vital characteristic of successful SMEs, which provides another rationale for including persistence capacity training within ABM programming. Furthermore, Rico et al. (2020) provided evidence that educational frameworks that emphasize persistence developed greater resilience amongst business students, which indicates that education should intentionally promote persistence through experiential education and application.

Commitment to Work Contract encapsulates the commitment to carrying out the contractual obligation with regard to the commitment to work. According to Hutasuhut et al. (2024), commitment to work contracts is necessary to maintain the trust of stakeholders and to form a strong business relationship. It is indicated through their findings that engaging ethical considerations and commitment principles in the ABM education supports the development of graduates who are best prepared to fulfil obligations to committed work in

self-employment and entrepreneurial endeavors.

The demand for quality reflects the importance of having high standards for organizational outputs. According to Hasbiah (2023), increased emphasis on quality by micro-business owners will also lead to enhanced performance. The authors recommend that the ABM curriculum include quality management concepts to provide aspiring business leaders with a quality mindset.

Risk-taking and the willingness to participate in uncertain activities are often defined as risk-taking abilities, a core component of entrepreneurship. Development of risk tolerance will promote student entrepreneurial intentions and behavior (Kanaan-Jebna et al., 2022). Therefore, to address the risk-taking element of entrepreneurship, the ABM programs should introduce a risk management strategy and offer an entrepreneurial finance course to equip ABM students with the skills to address uncertainty in business equally.

Goal setting is the act of formulating goals and clarifying the action steps needed to accomplish those goals. In their study of the personal entrepreneurial competencies of business students, Istiqomah et al. (2022) found a significant association between good goal-setting practices and entrepreneurship success. They concluded that the educational models developed and implemented supported goal-setting practices for students and intended to provide students with a clearly defined vision and action plans towards their future entrepreneurship experiences.

Information seeking relates to the ability to access information relevant to one's decision-making. Sergeeva et al. (2021) found that searching for practical information enhances entrepreneurs' capacity to show innovation and improve problem-solving capacity. Therefore, ABM programs should consider incorporating information literacy and research methods, enabling students to gain knowledge.

Systematic planning encompasses orderly procedures to devise business intentions. Grewe and Brahm (2020) noted that systematic planning would facilitate students' entrepreneurial thinking. They expressed their support for ABM programs to include project-based learning opportunities in which the systematic planning and monitoring processes would be integrated into those activities. Some form of education in this area would allow students to anticipate plans of action and to measure progress towards their goals related to a business.

Along with networking, persuasion is important in developing valuable business relationships. Mendoza et al. (2023) note that networking opportunities and persuasive ability are essential components of students' entrepreneurial capacities. To support this, ABM programs should develop networking opportunities/events and also provide workshops that focus on negotiation and communication skills relevant to entrepreneurship.

Self-confidence is one's belief in his/her ability to carry out a business idea successfully. Research demonstrates that self-confidence is a predictor of entrepreneurial success and is often a necessary means to address challenges, as stated by Hutasuhut et al. (2024). Based on this understanding, it would be necessary to build self-efficacy through mentorship programs, project-based learning, and positive reinforcement in ABM education to enhance students' self-confidence in their entrepreneurial pursuits.

A broad effort to foster personal entrepreneurial competencies, as a part of ABM programs, is essential in developing the entrepreneurs of the future. ABM students must perform competencies that include, but are not limited to: opportunity seeking; persistence; commitment; demand for quality; willingness to take risks; goal setting; information seeking; systematic planning; persuasiveness; self-confidence; and correction. This review suggests that they must embed these competencies in formal curriculum development and teach them as competencies so students can practice, build upon, learn, and use them as they move along their entrepreneurial journey.

2.2 PECs in Context

The increasing studies researching personal entrepreneurial competencies (PEC) in Accountancy, Business and Management (ABM) courses is noticeable within the research area of entrepreneurship education. Many studies are focused on trying to understand students' self-reflection of PECs, which expands the area of literature as they focus on understanding

ways educational practice fosters the development of mindsets and competencies in student entrepreneurialism.

Hoang et al. (2020) researched the positive relationship between entrepreneurship education and entrepreneurial intentions in Vietnam, noting the indirect mediation of the self-efficacy and learning orientation factor. The study indicated that students participating in structured entrepreneurship education could develop a positive attitude regarding entrepreneurship by demonstrating improved competencies. Interestingly, this aligns with the data indicating students showed higher levels of self-evaluative reflection, indicating structured, entrepreneurship-focused education can foster the development of competencies, and the education can use existing forms of reflection with more structure.

Yi and Duval-Couetil (2021) researched the influence of references to entrepreneurship education on students' self-efficacy and proactiveness. They recommended that there be standards regarding the evaluation of entrepreneurship education. They noted that increased self-efficacy is fundamental to building entrepreneurial intentions. The results of their study highlight that students' self-assessments relating to their competencies are relative to students' educational experiences in entrepreneurship (Yi & Duval-Couetil, 2021). This evidence affirms that reflective assessments can be a meaningful proxy of students' confidence and self-efficacy in an entrepreneurial context.

Firmansyah et al. (2020) evaluated an entrepreneurship education program that included non-classroom experiences and reported significant improvements in students' entrepreneurial self-efficacy (Firmansyah et al., 2020). The researchers defined a relationship between students' competency appraisals and the program under investigation. To conclude, the study augmented the evidence supporting that entrepreneurship education programs that would provide students opportunities for practical application in an educational context can develop students' entrepreneurial skills and self-evaluative standards.

Research by Aulia & Badawi (2023) backed up these results. They revealed that self-efficacy moderated the link between entrepreneurship education and students' interest in entrepreneurship. It was suggested that students with high self-efficacy showed interest in entrepreneurship after education, thereby validating the self-reflection role in developing entrepreneurial intent (Aulia & Badawi, 2023). This suggests a need for an appropriate educational context that allows for self-reflection.

Fröhlich and Welpe (2024) took a different approach and examined self-selection dynamics in entrepreneurship education. They noted that false self-assessments could impact educational programs' (perceived) impact. They examined the role of strong evaluation frameworks to help understand self-selection biases, as self-selection could allow for a better understanding of self-evaluated know-how (Fröhlich & Welpe, 2024). This study explored the necessity of applying appropriate frameworks to evaluate personal competencies correctly.

Boldureanu et al. (2020) engaged in a different discussion by examining how genuine entrepreneurial models in higher education serve effective entrepreneurial education. They proposed that exposure to genuine examples of entrepreneurial practices enhances the students' self-evaluated entrepreneurial competencies. The qualitative assessment of their research findings showed students frequently reflected on experiential learning examples to evaluate their competence, and they confirmed the existence of a link connecting experiential learning and self-evaluation responses (Boldureanu et al., 2020). This would be a clear shift in education systems, incorporating success stories as a necessary part of the curriculum.

Setiawan et al. (2023) considered how entrepreneurship education helps improve students' entrepreneurial self-efficacy, focusing on the cognitive development processes involved in developing entrepreneurial self-efficacy. Their conclusions implied that the cognitive incentive of positively guided self-evaluation could help students be better prepared to face real-time entrepreneurial challenges and increase their perceived capabilities (Setiawan et al, 2023). This further supports the argument for embedding reflective practices in educational paradigms.

Briegas et al. (2021) examined the satisfaction of teachers and students, based on their entrepreneurial programs. They measured the relationship between satisfaction as a teacher, in

terms of students' learning about their entrepreneurial competencies. Briegas et al. (2021) found that effective teaching can positively influence a better level of self-evaluation from students and also impact their confidence and engagement with entrepreneurship. Briegas et al. (2021) suggest that educators play an important role in shaping how students view their competencies and career intentions.

Ping & Yee (2024) developed an assessment model on college students' competencies in innovation and entrepreneurship. Their study highlighted that students benefit from a consistent approach to assessment, whereby assessment feeds into students' self-understanding and self-evaluation of being 'entrepreneurial'. Based on their findings, Ping and Yee (2024) made a case for individualized education plans for students, enabling them to build a more holistic self-evaluation of competencies.

From these studies, we see an emerging theme that asserts that students' ability to self-assess through entrepreneurship education has practical implications for students' entrepreneurial intentions and entrepreneurial competencies. The studies called for educators and educational institutions to provide students with experiential learning opportunities, eliminate self-selection bias, and build learning experiences and learning environments that better support students' self-evaluation activities as accountancy, business, and management students.

3. Methodology

This chapter describes the research design, research instrument, population, data collection, and data analysis in order to achieve the research objectives. The study's main goal was to determine the degree of personal entrepreneurial abilities among accounting, business, and management students.

3.1 Research Design

The quantitative-descriptive method was the research design used in this study. The quantitative method focused on obtaining quantifiable data about the ABM Students' entrepreneurial self-assessed scores and personal entrepreneurial competencies. It contained particular themes, such as students' personal entrepreneurial competencies and entrepreneurial self-assessment scores. The ability to accurately and objectively measure variables makes a complete, detailed study that indicates or shows trends and patterns. In this method, the researcher has established the respondents' personal entrepreneurial competency level. On the contrary, descriptive research is a basic form of research that identifies specific characteristics of a phenomenon. The method is the best for establishing how capable students are in the business, management, and accounting disciplines concerning entrepreneurial capabilities. A questionnaire was used as the primary tool for data collection.

3.2 Locale of the Study

This study was conducted in Santiago City, Philippines, with students majoring in accounting, business, and management at Northeastern College. Northeastern College is located in Villasis, Santiago City, Philippines. It has been shaped under the guidance of Dr. Tomas C. Bautista. The school has a leading standard of being nurturing and competitive. NC offers many graduate and undergraduate programs in accounting, business, and management, including a BS in hospitality management, a BS in business administration, a BS in accountancy, and a BS in management accounting. The location was chosen because the requirements of the study were satisfied, and the purpose of the research study is to focus on the students' entrepreneurial capabilities.

3.3 Respondents of the Study

This research project intends for the student participants to be enrolled in business, management, and accounting degrees. The respondents in the study have been identified according to several criteria to ensure that the study is accurate and relevant. The student participant must be enrolled in any ABM program during the first semester of 2025. These criteria were adequate to achieve the study objectives and provide part of the selection process.

Stratified random sampling with a random selection of participants within each stratum was utilized to produce inclusivity and ensure the collection of relevant, quality data within context. Participants were randomly selected from across all sub-groups to represent the stratifications and minimize sampling error. This process has increased the accuracy and reliability of the study. In the participant

recruitment process, the researcher took an absolute approach to maximize quality and capture efficient data to collect the needed data, improving the inclusivity of all ABM sub-strata. As a result, the sample population criteria in the table below provide the population sample based on these criteria:

Table 1. Sample Size

Accountancy, Business and Management Programs	**Population**	**Sample**
BS Hospitality Management	731	182
BS Accountancy	97	24
BS Business Administration	378	94
Total	**1206**	**300**

A systematic method was followed to determine the total number of survey subjects for this study. The researcher first obtained information regarding Northeastern College's ABM program participants so that the numbers used were relevant to this population. The project identified the overall population for the research group by calculating the total number of all ABM students from each selected program.

The researcher then used the Raosoft sample size calculator to establish the sample size for the study. This software used vital factors, including total population, margin of error, confidence level, and response distribution to derive a final sample that would be statistically valid and reliable.

The researcher calculated a weighted average for each program by taking the size of the population to ensure that the sample represented the distribution of ABM students at Northeastern College. The weighted average for each program was then multiplied by the total sample size calculated by Raosoft to assign it appropriately. This method gave an accurate and representative sample because the number of responders for each program would have a ratio of the overall population. This rigorous method gave an honest result because the researcher intended to have a foundational understanding of the students in the selected programs.

3.4 Research Instrument

The researcher used research tools acquired from Liberal (2017) and Vican and Viletic (2013). The researcher has organized this tool into three sections. The first section has the profile of the respondents, including the program they are affiliated with. The Entrepreneurial Self-Assessment Survey, developed by Vican and Viletic (2013), with 20 items, was used to identify entrepreneurial traits. The second section utilized the Entrepreneurial Self-assessment Survey to identify the entrepreneurial potential of the respondents. The last section presented the entrepreneurial potential of the respondents. The questionnaire was developed by Liberal (2017) and consisted of 55 questions focusing on an entrepreneur's different competencies. This tool has targeted students enrolled in the business, management, and accounting programs during the first semester of 2025.

Furthermore, 25 respondents met the required parameters who participated in a pilot test that the researcher developed. The pilot stage evaluated the appropriateness of the phrasing and intelligibility of the survey's content for the intended audience; this method examined the instrument's feasibility, relevancy, and intelligibility. The pilot test participants were not included in the final sample to avoid possible bias while maintaining the authenticity and integrity of the data collection process. The pilot test participants aided the researcher in correcting misunderstandings or compromises in the survey before proceeding with the full data collection.

3.5 Data Gathering Procedure

The purpose of the data collection process for this study was to collect solid and trustworthy data from the students studying management, business, and accounting. Participants were able to answer to the survey at any time and from any location using the devices of their choice because it was mainly administered online, utilizing a digital tool. Eliminating time and place restrictions improves accessibility and promotes involvement. English was the language of the accessible online survey. This guarantees that respondents, irrespective of their preferred language, may interact with the survey comfortably.

Following survey closure, the collected data were imported into statistical analysis tools from the survey instrument. This involves checking

for mistakes and incorrect input, such as hurried or repetitive responses. This step was followed by the data analysis. The data was analyzed using descriptive statistics to display the demographic information and general replies of the survey respondents.

When the research was concluded, a final report containing a summary of all findings will be submitted. This study findings also includes the data interpretation and statistical analysis. The results that stood out most in terms of participants' entrepreneurial capabilities were primarily discussed in the conclusions presented. The final report findings may be disseminated to stakeholders and participants. If warranted, the conclusions may be disseminated via papers, journals, and conferences.

Therefore, as a result of following the extensive data collection process, the study ensured the information collected was valid, relevant, and sufficient to identify ABM students' entrepreneurial competencies.

3.6 Data Analysis

The collected data was treated by the researcher using various statistical methods.

1) In this study, categorical data were presented using the frequency distribution approach, which indicated the frequency of each response. The data in parts 1, 2, and 3 of the questionnaire were arranged using this tool.

2) *Sum Score:* This statistical method, which adds the scores for each statement, was utilized in the second and third section of the questionnaire. The following table was used to interpret the overall score:

Table 2. Entrepreneurial Self-assessment Survey

Entrepreneurial Self-assessment Survey	
Scores	**Interpretation**
80-100	Outstanding ability to be an entrepreneur.
60-79	Satisfactory ability to be an entrepreneur.
40-59	Self-employment may not be an appropriate career.
0-39	Probably avoid entrepreneurship

3) *PEC Scoring Sheet*: The researchers also used the Personal Entrepreneurial Competence by Liberal (2017). The computation to determine the respondents' competence in various characteristics is described below:

Rating of Statements						Score	PECs
____ (1)	+ ____ (12)	+ ____ (23)	- ____ (34)	+ ____ (45)	+ 6	= ____	Opportunity Seeking
____ (2)	+ ____ (13)	+ ____ (24)	- ____ (35)	+ ____ (46)	+ 6	= ____	Persistence
____ (3)	+ ____ (14)	+ ____ (25)	+ ____ (36)	- ____ (47)	+ 6	= ____	Commitment to work contract
____ (4)	+ ____ (15)	+ ____ (26)	+ ____ (37)	- ____ (48)	+ 6	= ____	Demand for Efficiency & Quality
____ (5)	- ____ (16)	+ ____ (27)	+ ____ (38)	+ ____ (49)	+ 6	= ____	Risk taking
____ (6)	- ____ (17)	+ ____ (28)	+ ____ (39)	+ ____ (50)	+ 6	= ____	Goal setting
____ (7)	+ ____ (18)	- ____ (29)	+ ____ (40)	+ ____ (51)	+ 6	= ____	Information seeking
____ (8)	+ ____ (19)	+ ____ (30)	- ____ (41)	+ ____ (52)	+ 6	= ____	Systematic planning & monitoring
____ (9)	- ____ (20)	+ ____ (31)	+ ____ (42)	+ ____ (53)	+ 6	= ____	Persuasion & Networking
____ (10)	- ____ (21)	+ ____ (32)	+ ____ (43)	+ ____ (54)	+ 6	= ____	Self-confidence
____ (11)	- ____ (22)	- ____ (33)	- ____ (44)	+ ____ (55)	+ 18	= ____	Correction Factor

Figure 1. PEC Computation

After identifying the PEC scores, the researcher then interprets the respondents' level of competence using the table below:

Table 3. Personal Entrepreneurial Competencies Interpretation

Personal Entrepreneurial Competencies Interpretation	
Scores	**Interpretation**
21-25	Very High Level of Competence
16-20	High Level of Competence
11-15	Moderate Level of Competence
6-10	Low Level of Competence
0-5	Very Low Level of Competence

4. Results and Discussion

This section presents the results of the data analysis, and the corresponding discussion based on the findings derived from the data gathered.

4.1 RQ1: Entrepreneurial Self-Assessment Score of the Students in Accountancy, Business, and Management Programs

Table 4. Level of Entrepreneurial Ability

Level of Entrepreneurial Ability	**Frequency**	**Percentage**
Outstanding Ability to be an Entrepreneur.	104	34.67
Satisfactory Ability to be an Entrepreneur.	140	46.67
Self-employment may not be an appropriate career for you.	44	14.67
You should probably avoid	12	4.00
Total	**300**	**100.00**

Table 4 shows a large number of students in Accountancy, Business, and Management (ABM) programs are exhibiting satisfactory entrepreneurial ability, as 81.34% (F=244) of students demonstrate at least a satisfactory capacity for entrepreneurship. This indicates a strong foundational connectivity to the ABM curriculum and principles related to the teaching of entrepreneurship, reiterating that sustainability principles can facilitate business savvy in students. The results correspond with literature that claims entrepreneurship education promotes an environment conducive to developing entrepreneurial skills (Lie et al., 2022; Towers et al., 2020; Mohamad, 2023). More specifically, enhancing student engagement in business programs can significantly enhance the developing of entrepreneurial competencies by using creative learning activities for students (Pathan et al., 2023; Kristiawan et al., 2021).

Notably, the report shows that 34.67% (F=104) of students are classified as having exceptional potential, while 46.67% (F=140) have satisfactory entrepreneurial intention. Furthermore, this information is corroborated by the literature, which highlights that substantial exposure to training and education on entrepreneurship will build strong entrepreneurial mindsets (Bueno et al., 2023; BANATE et al., 2024). Studies show that students who undertake comprehensive entrepreneurship courses will have higher entrepreneurial self-efficacy, which is important in navigating the entrepreneurial space (Lie et al., 2022; Mohamad, 2023). In the Philippines, for example, organizations such as Cavite State University have already introduced entrepreneurship into their course delivery, which could be helpful in preparing students for self-employment and to contribute to their local economies (Banate et al., 2024).

Nonetheless, the data indicates that 14.67% (F=44) of students are operating in an environment where entrepreneurship may not be a good fit, and an additional 4% (F=12) advise students against entrepreneurial avenues. This group outlines the need for interventions of support aimed at enabling alternative career pathways. As research supports, groups aimed at career planning and facilitated skill development can be very valuable for students found to be hesitant or unprepared to engage in entrepreneurial opportunities ("Evaluating Entrepreneurial Skills Needed by Business Education Students for Self-employment in Colleges of Education, Kano State", 2023; Gheorghiță et al., 2022). There is considerable momentum in developing employability skills for students within the Philippine context, which are very much embedded in entrepreneurial education, capable of enhancing

students for alternative career trajectories (Khan et al., 2020).

Furthermore, despite most projects having a firm promise, the findings highlighted a need for a change in teaching practices in order to overall, but especially for students with low entrepreneurial intentions, provide the needed skills for the ever-fluctuating global economy. Educational programming should include experiential learning opportunities for all learners in entrepreneurship, as well as further mentorship opportunities, to allow for all students to either flourish in entrepreneurship or gain stable employment in the corporate sector (Steira et al., 2024).

In conclusion, while the data paints a very optimistic outlook regarding the entrepreneurial skillsets of ABM students, it also highlights an essential need to strengthen supports around more vulnerable populations of students struggling with these skills. Recommendations call for structural supports that not only foster entrepreneurial potential among the vast majority of students but also provide a way for those who may struggle with entrepreneurship to redirect their efforts into more appropriate areas that allow for a full-spectrum student development approach unique in the Philippine context.

4.2 Level of Personal Entrepreneurial Competence of the Students in Accountancy, Business, and Management Programs

Table 5. Level of Personal Entrepreneurial Competence: Opportunity Seeking Frequency Percentage

Level of Personal Entrepreneurial Competence: **Opportunity Seeking**	**Frequency**	**Percentage**
Very High Competence	0	0.00
High Competence	32	10.67
Moderate Competence	238	79.33
Low Competence	30	10.00
Very Low Competence	0	0.00
Total	300	100.00

Table 5 shows that most of the students who enrolled in Accountancy, Business, and Management (ABM) programs have a moderate level of personal entrepreneurial competence in opportunity seeking which is meaningful in understanding the current entrepreneurial status of the Philippine setting. 79.33% (F=238) classified as having a moderate level of competence indicates the students have the necessary basic ability to recognize and act upon business opportunities that are relevant based on the changing nature of the current economy (Agustina et al., 2021; Saadat et al., 2021). The moderate competence provides a solid proposition for providing the students with more advanced entrepreneurial skills through tailored educational interventions.

In addition to this, having 10.67 % only (F=32), demonstrating high competency, is a possible avenue for improvement by the educational programs. Prior research indicates that entrepreneurship education can boost students' competencies, changing them from moderate to high competencies (Saadat et al, 2021; Magasi, 2022). In the Philippines, entrepreneurship education is meaningful, as suggested through studies indicating that it is a necessary contributor to developing entrepreneurial intentions in students (Agustina et al., 2021; Khairuddin et al., 2023). Current education systems can improve by engaging through methodologies such as experiential learning and mentoring programs that are effective in promoting entrepreneurship (Riyanti & Dewi, 2024; Oskoei, 2021).

Regarding the 10% (F=30) demonstrating low competence, this result shows a critical deficiency in the supportive frameworks and education provided to students. The literature shows that academic exposure to entrepreneurship, students may only be adequately exposed to entrepreneurship through academic, and not practically, means is insufficient (Kusumawati et al., 2023). So, it is recommended that institutions develop all-encompassing entrepreneurship curricula that incorporate practice-based insights and resources that would aid entrepreneurship practices (Cui et al., 2021; Kusmintarti et al., 2020).

The absence of learners in the very high or very low competence categories also signifies that skills remain embedded in a normalized environment, which encapsulates challenge and opportunity. It urges institutions to rethink how they deliver learning focused on a deeper breadth of competence, especially methods

which can be tailored to develop entrepreneurial capability (Geng et al., 2021; Looi & Maritz, 2021). Initiatives can include offerings such as business incubators and working with industry partners, which will advance practical experience and help the relevancy of students ascend to increased levels of competence (Mohamad & Hussain, 2021; Lutfiani et al., 2020).

To conclude, the analysis of the data shows the strengths and weaknesses in the entrepreneurial competencies of ABM students in the Philippines. It indicates a timely exigency for curricular improvements and the development of teaching strategies to aid students in advancing from moderate competencies to higher capacities. The transition is essential to strengthening the entrepreneurial ecosystem that supports addressing local and global economic conditions.

Table 6. Level of Personal Entrepreneurial Competence: Persistence

Level of Personal Entrepreneurial Competence: **Persistence**	**Frequency**	**Percentage**
Very High Competence	0	0.00
High Competence	51	17.00
Moderate Competence	222	74.00
Low Competence	27	9.00
Very Low Competence	0	0.00
Total	300	100.00

By interpreting the data in Table 6 pertaining to the persistence level among ABM (Accountancy, Business and Management) students' entrepreneurial competence, the most prominent finding is the 74% (F=222) of students who indicated moderate persistence. This general average resilience toward entrepreneurial challenges suggests there is a shared attribute of persistence among students. The findings are consistent with growing conversations in the literature about educating students in entrepreneurial competence through intentional education models emphasizing different competencies such as persistence, risk taking, and flexibility (Martínez & Ventura, 2020; Mendoza, 2023).

In the case of the Philippines and similar studies, academic institutions must ensure they implement, integrate, and improve entrepreneurial education in order to improve these competencies. For example, a study that included BSBA (Bachelor of Science in Business Administration) students from Lucena indicated that a formal process for education around competencies specific to entrepreneurship was determined necessary, affirming that a moderate number of students possessing persistence would likely provide a mechanism to develop further in entrepreneurial activities (Mendoza, 2023). If students find themselves in an environment ranging from competitive, uncertain, and challenging economic problems, and learning enables them to develop a strong entrepreneurial disposition, then if and when they experience similar environments, they have increased resilience and adaptability to move forward (Christina & Widjojo, 2023; Lie et al., 2022).

Additionally, only 17% (F=51) of the students were classified as high competent, indicating that while there are students who sustain a high level of persistence, they are in the minority. This finding is corroborated in the broader literature, where, although some students may have high entrepreneurial competencies, the majority should typically be expected to have moderate levels of competencies or the wish to perform at moderate levels (Iqbal et al., 2022). It is therefore important for education institutions to identify these students so that they can provide extra support/resources to accompany students with high persistence onto higher levels of entrepreneurial competencies through mentorships and experiential opportunities (Dangana et al., 2023; Rocha et al., 2023).

The lack of students in the very high and very low competency groups supports the idea of an overall positive environment that is not necessarily limiting or overly supportive of students in their entrepreneurial activities. This finding indicates a balanced educational ecosystem, wherein students are developing moderate competencies in relation to entrepreneurship. However, it suggests it is also necessary to begin interventions that can elevate students beyond the threshold to change the balance (Valencia-Arías et al., 2021; Chang et al., 2022). For example, educational strategies based on the social cognitive theory are helpful because they suggest that environments with

much entrepreneurial activity can have meaning effects on students' development of entrepreneurial competencies (Christina & Widjojo, 2023).

By synthesizing these findings, it is evident that despite the fact that most students show moderate persistence, developing entrepreneurial education paradigms for the Philippines and similar contexts can produce better levels of entrepreneurial competencies. Using holistic educational frameworks can equip students for the challenges of entrepreneurship and give them confidence and resilience to deal with potential setbacks (Martínez & Ventura, 2020; Rocha et al., 2023).

Table 7. Level of Personal Entrepreneurial Competence: Commitment to Work Contract

Level of Personal Entrepreneurial Competence: **Commitment to Work Contract**	**Frequency**	**Percentage**
Very High Competence	0	0.00
High Competence	52	17.33
Moderate Competence	225	75.00
Low Competence	23	7.67
Very Low Competence	0	0.00
Total	300	100.00

The data on the entrepreneurial competence of Accountancy, Business, and Management (ABM) students suggest a moderate level of commitment to work contracts, with 75% (F=225) of the cohort having moderate competence. This indicates growing awareness amongst students about upholding professional commitments. However, it also highlights a significant need for improvement, especially in fostering a strong work ethic and reliability and accountability of that work ethic. The only 17.33% (F=52) of students demonstrating high competence, coupled with no students showing very high competence, suggests a clear gap in their preparation for entrepreneurial activities, or for career readiness. Finally, the 7.67% (F=23) of students who displayed low competence would likely have challenges with participating effectively in a business environment (Bolzani & Luppi, 2020; Ratković et al., 2022).

In the Philippine context, the role of entrepreneurship education and experience is essential in developing entrepreneurial competencies of students (Osei et al., 2022; Lim, 2021). Research indicates that participation in entrepreneurship education leads to an increase in students' entrepreneurial skills and intentions (Gunartin et al., 2023), especially with the increased emphasis on entrepreneurship as a vehicle for economic growth in the Philippines, and a noted lack of high and very high competency levels among ABM students. However, partnerships that engage students through entrepreneurship education studies have limited direct experiential student-led initiatives that expose students to actual entrepreneurial experiences, which could affect the students' high/very high competency level. Prior research identified many of the benefits of having students engaged in entrepreneurial projects, including higher levels of motivation and higher levels of intentionality around entrepreneurship (Velasco, 2021).

Additionally, entrepreneurial competencies are not limited to an academic background; entrepreneurial competencies involve critical abilities, including interpersonal skills, analytical skills, and flexibility, which are valuable in the world of today (Šimović, 2020; Destiana et al., 2023). In terms of entrepreneurial learning, beneficial learning would involve an educational approach that includes not only the theoretical side of entrepreneurial competencies, but also giving students various practical and experiential opportunities to set challenges to apply their knowledge, thus giving them a greater commitment to work contracts, and their overall preparation for entrepreneurial activities (Christina & Widjojo, 2023; Mohamad, 2023). Continuously addressing the competency issues identified in the data depends on systematic curriculum improvements and delivered staff training that will promote the development of valued competencies and skills.

Overall, the findings bring out several meaningful understandings of the ABM students' entrepreneurial competencies, highlighting the need for educational reform that allows for a more professional approach to the compulsory aspects of entrepreneurial responsibility. The moderate commitment level pertaining to work contracts points to a basic sense of understanding. However, it again shows the need for structured support systems

to develop a more conclusive work ethic. This is in tune with an educational model that is becoming popular around the world in facilitating and developing detailed entrepreneurial skills that will develop the economy through entrepreneurship, especially within contexts such as the Philippines, where entrepreneurship underpins job growth and creativity and innovation activities ("Level of Entrepreneurship Competence and Readiness Among Medical Students in A Private University in Shah Alam, Malaysia", 2020).

Table 8. Level of Personal Entrepreneurial Competence: Demand for Quality and Efficiency

Level of Personal Entrepreneurial Competence: **Demand for Quality and Efficiency**	**Frequency**	**Percentage**
Very High Competence	18	6.00
High Competence	186	62.00
Moderate Competence	92	30.67
Low Competence	4	1.33
Very Low Competence	0	0.00
Total	300	100.00

Information recently obtained from a study of Accountancy, Business, and Management (ABM) students indicates a high level of entrepreneurial competence in ABM students, particularly with regard to demand for quality and efficiency. The report stated that a strong 62% (F=186) of the students demonstrated a high level of competence, plus another 6% were very high competence. The trend is indicative of a positive attitude towards working at a high standard and with productivity, which is commensurate with findings from current literature about the entrepreneurial mindset.

The high entrepreneurial orientation of ABM students corresponds with the affirmation evident in research conducted within the Philippine context that educational systems are increasingly doing more to encourage entrepreneurial skills and competencies. Juwairia et al. (2024), for example, highlight that entrepreneurial education creates a positive impact on students' entrepreneurial intentions and that curriculum-based interventions can increase students' traits and skills, leading to greater involvement in entrepreneurial opportunities. Furthermore, both Juwairia et al. (2024) and Manafe et al. (2023) show how entrepreneurial education in an academic subject improves students' self-efficacy regarding entrepreneurial intentions.

The data also show that 30.67% (F=92) of students are classified as showing moderate competence and intermediate recognition of the value of quality and efficiency, taking into account opportunities for additional development. According to the literature, this cohort would require increased engagement and support to both their competencies more consistently. Chang et al. (2022) note that academic institutions should allow students to grow in their excitement about the quality and productivity of various businesses by developing an entrepreneurial mindset, using new instructional approaches or methods.

Furthermore, only 1.33% (F=4) of ABM students are categorized as low competence, and there are none in the very low competence category. This is a good sign of positive awareness and application of concepts essential to entrepreneurship. However, this should be viewed in parallel with a statement by Juwairia et al. Juwairia et al. (2024), that after businesses have grown, students require continual nurturing of competencies to prepare them for the increasing challenges facing to entrepreneurial landscape.

To summarize, while the data indicates a hopeful prospect of the competency levels of ABM students in the quality and efficiency perspective, it also indicates the need to keep working to develop these skills. Ongoing commitment to the entrepreneurial education and innovative practice is essential to helping more students transition into higher competency percentages, enabling their entrepreneurial capability.

Table 9. Level of Personal Entrepreneurial Competence: Risk Taking

Level of Personal Entrepreneurial Competence: **Risk Taking**	**Frequency**	**Percentage**
Very High Competence	22	7.33
High Competence	184	61.33

Moderate Competence	93	31.00
Low Competence	1	0.33
Very Low Competence	0	0.00
Total	300	100.00

The data pertaining to the entrepreneurial propensity of Accountancy, Business, and Management (ABM) students illustrates a predominance of high competence in risk-taking behaviors, with 61.33% (F=184) rated as having high competence and 7.33% (F=22) rated as very high. This suggests the students possess an entrepreneurial mindset based on their capacity to take calculated risks, a key characteristic of an entrepreneur. Research shows this mindset is instrumental in developing entrepreneurial intention and activity (Vargas-Martinez et al., 2023; Ahmed et al., 2020).

In addition, the 31% (F=93) of students classified as moderate competence indicates a cohort that takes a more careful entrepreneurial stance. While this could indicate this group makes better decisions, it also represents a potential area for development, including confidence and decision-making development. Research indicates entrepreneurship education may have a significant influence on students' attitudes and competencies, possibly motivating students away from moderate competence and toward higher competence levels through an educational intervention (Aslam, 2022; Ahmed et al., 2020). The faculty member's description of the students with respect to the low competency groups is also noteworthy, as the very low and low competency groups were quite negligible; 0.33% (F=1) is low competence; none in the very low when compared to the findings of students in other geographical contexts where a risk-averse disposition is remains a barrier toward entrepreneurial activities (Lakmal & Fernando, 2023). This is particularly the case for the Philippines, where there is increasing recognition of the role of entrepreneurial education to effectively promote positive risk-taking and practical innovative thinking among youth (Belmonte et al., 2022; Paudel & Ranabhat, 2024).

The results also align with wider evidence that individual attitudes and perceived behavioral controls shape entrepreneurial intentions. The Philippine situation has an important emphasis on embedding entrepreneurial principles within academic curricula, attracting students to a culture of entrepreneurship. The integration of academic entrepreneurship principles would not only enhance students' skills, but it also aligns with the government's intentions to develop entrepreneurship as a conduit for economic growth and resilience (Belmonte et al, 2022; Ndofirepi, 2020). The emphasis on entrepreneurial intentions demonstrates a growing acceptance of risk appetite amongst students, shaped by the role of the curriculum and the educational context in developing innovative thinking and risk-taking behaviors and attitudes (Vargas-Martínez et al, 2023; Borges et al, 2021).

There is a good opportunity to optimize ABM student entrepreneurial readiness by developing strong mentoring programs to support those only moderately competent. Mentorship, along with concrete entrepreneurial experiences, has the potential to increase their belief in their ability to take risks and make decisions that entrepreneurs must make (Aslam, 2022; Ahmed et. al, 2020).

Table 10. Level of Personal Entrepreneurial Competence: Goal Setting

Level of Personal Entrepreneurial Competence: **Goal Setting**	**Frequency**	**Percentage**
Very High Competence	44	14.67
High Competence	167	55.67
Moderate Competence	87	29.00
Low Competence	2	0.67
Very Low Competence	0	0.00
Total	300	100.00

The finding that a sizeable portion of Accountancy, Business, and Management (ABM) students are proficient at goal setting is important evidence for understanding how prepared ABM students will be for entrepreneurship. The finding that 55.67% (F=167) of students had high competence and 14.67% (F=44) had very high competence in goal setting indicated their ability to set specific and realistic goals, and this distinguishes their holistic success in entrepreneurship. This corroborates research that highlights the

importance of goal-setting for entrepreneurs, providing they have the means to make plans, if necessary, and monitor and orchestrate their thoughts, ideas, and actions (Tatpuje et al., 2021; Boldureanu et al., 2020).

In the Philippines, these competencies indicate the outcome of localized entrepreneurship education interventions that are aimed at bolstering students' preparedness to engage with business challenges. Research has shown that entrepreneurial education is a valuable contribution to students' intentions of becoming entrepreneurs (Osei et al., 2022; Campos, 2022). Entrepreneurial education is able to sharpen students' goal-setting abilities and help them develop more of an entrepreneurial mindset. Of concern is the fact that 29% of students with moderate competency in goal-setting means that we need to frame educational interventions better to support this skill development. This means that many of the students are working well in developing entrepreneurial skills, but some additional training and mentoring may help enhance their skills (Noor & Malek, 2021; Ahmed et al., 2020).

Interestingly, only a small proportion of other students (F=2, P=0.67%) were considered low in competence, and none were identified as having very low competence in goal setting. This indicates that generally, ABM students have a sound background, with studies suggesting that engaging in quality entrepreneurship education significantly increases student confidence in an entrepreneurial career (A.M. & Allen, 2022; Colombelli et al., 2022). Additionally, the role of entrepreneurship education, through real-life experiences due to entrepreneurship, has been noted to improve student entrepreneurial skills and intentions (Ahmed et al., 2020; Colombelli et al., 2022). This is an interesting situational significance with regard to the Philippine educational environment as polyester entrepreneurial initiatives are being contextualized into educational curricula to combat unemployment and promote economic development (Igwe et al., 2021; Belmonte et al., 2022).

In addition, the elevated levels of competence in goal setting may be impacted by individual factors such as family background and social capital, especially with Filipino students, where these aspects are critical in developing entrepreneurial intentions (Osei et al., 2022). This underscores how social networks and educational opportunities are linked, which highlights the need to bridge the gap between community support and entrepreneurship education, providing students with educational, emotional, and practical support to help them succeed and flourish (Ahmed et al., 2020; Campos, 2022).

To summarize, the results regarding the entrepreneurial competencies of ABM students in goal setting show that there is a favorable trajectory in terms of preparing to take entrepreneurially orientated action, yet there is still a substantial need for flexibility and structured support systems to develop them further, particularly for moderately competent participants. A collaborative response from educators, policymakers, and other stakeholders would be to develop aligned and effective entrepreneurship education that not just teaches the essential skills but also develops an entrepreneurial mindset, which will enable students to develop their business aspirations further.

Table 11. Level of Personal Entrepreneurial Competence: Information Seeking

Level of Personal Entrepreneurial Competence: **Information Seeking**	**Frequency**	**Percentage**
Very High Competence	41	13.67
High Competence	176	58.67
Moderate Competence	79	26.33
Low Competence	4	1.33
Very Low Competence	0	0.00
Total	300	100.00

Considering the data indicating that Accountancy, Business, and Management (ABM) students have various entrepreneurial competencies, especially in relation to information seeking, is important. The data used revealed that 58.67% of students showed high competence, and 13.67% (F=41) indicated they displayed very high competence. A majority of these students are actively gathering information necessary to make informed entrepreneurial decisions, which is a fundamental skill used in the business context. Martínez and Ventura attributed the presence of

significant entrepreneurial competencies to good educational practice and their specific intention to help develop those competencies in their students, so they assisted their capacity for enterprise (Martínez & Ventura, 2020).

In addition, if there is a 26.33% (F=79) proportion of students scoring moderate competence, there is a gap that, through targeted interventions, could be closed. Previous research by Ojo and Okwilagwe noted that entrepreneurship education plays an essential role in increasing student knowledge and skills with respect to entrepreneurship and may support students with moderate competencies to take their research and entrepreneurial activities to the next level (Ojo & Okwilagwe, 2024). Moreover, while only 1.33% (F=4) of students report low competence (and zero in the very low category), this is consistent with Promma et al. (2023), who found that a favorable learning environment can foster the development of entrepreneurial skills (Promma et al., 2023).

Many empirical findings in various educational contexts can also substantiate the strong entrepreneurial capabilities of ABM students in the Philippine context. For example, according to Iqbal et al., the supportive campus learning environment is a mediator of entrepreneurial competencies, claiming students flourish in an environment that supports proactive learning and critical learning engagement (Iqbal et al., 2022). This framework supports the belief that the educational environment is an essential factor influencing student outcomes in entrepreneurship.

Furthermore, a wider consideration of the value of entrepreneurial education is illustrated by the effectiveness of various teaching methods. Research into different teaching methods, such as experiential learning and project-based learning (citing Khaerunnisa et al), shows a strong correlation between experiential and project-based learning pedagogies with student problem-solving and research abilities (Khaerunnisa et al., 2024). This might suggest experimenting with new teaching strategies to engage the remaining 26.33% (F=79) of the students who demonstrate moderate competence.

In conclusion, the information-seeking competency information gathered from the performance of ABM students is encouraging. It highlights the effectiveness of current strategies for information literacy education. It does, however, also point to areas where education intervention may gain further competencies, and supports a holistic approach to entrepreneurship education that involves diverse pedagogical approaches in a supportive learning environment.

Table 12. Level of Personal Entrepreneurial Competence: Systematic Planning and Monitoring

Level of Personal Entrepreneurial Competence: **Systematic Planning and Monitoring**	**Frequency**	**Percentage**
Very High Competence	28	9.33
High Competence	180	60.00
Moderate Competence	85	28.33
Low Competence	7	2.33
Very Low Competence	0	0.00
Total	300	100.00

The information presented shows that a substantial number of Accountancy, Business, and Management (ABM) students have high entrepreneurial competence in systematic planning and monitoring (F=180, P=60.00%, high competence). This is consistent with an increasing number of studies on components of entrepreneurial competencies, or competence (for example, accounting), for higher levels of overall entrepreneurial success; specifically, studies on students from various higher education institutions indicated the success of entrepreneurship education for student competencies reinforced the correlation between systematic planning and monitoring with an increase in entrepreneurial success (Lv et al., 2021).

As it pertains to the Philippines, the excellent performance of ABM students in systematic planning can reflect how local universities are adopting increasingly relevant and practical frameworks of entrepreneurial education. The literature has emphasized the importance of aligned curricula and innovative and engaging pedagogical practices that allow for real-world applications to better gauge understanding of

required entrepreneurial skills. For example, applying entrepreneurship education has been effective with Filipino students who have had the opportunity to obtain critical skills even when they do not take formal business courses (Iwu et al., 2021).

Moderate competence among 28.33% (F=85) of the students suggests at least a basic understanding of these skills. It acknowledges that while they understand them, these students will need to develop their total competency further. This is supported by several studies indicating the need for a sharply contextualized, ongoing process and content with entrepreneurial education to take the students' skills to a higher level (Edralin & Pastrana, 2023). Thus, educators in the Philippines must offer more structured and comprehensive programs that fill in the gaps of planning and monitoring skills for their students so that they would not be limited in their future careers as "entrepreneurs" (Edralin & Pastrana, 2023).

Notably, only 2.33% (F=7) of students categorized as having low competence highlights the efficacy of current educational efforts in the region. This is part of an overall trend among institutions that further acknowledge the importance of fostering entrepreneurial competencies as an essential component of career preparedness. The nascent positive developments in the Philippines' educational landscape, where such a system is evolving to be more experiential and geared towards entrepreneurial education, echoes what has been found internationally: having strong support systems and a rich and diverse curricular is vital for developing entrepreneurial competencies in students (Christina & Widjojo, 2023; Huang et al., 2021).

In conclusion, the results regarding ABM students' strengths in systematic planning and monitoring reflect an important trend within Philippine higher education in entrepreneurship provision. The results suggest that educational institutions should not only capitalise on students' strengths, but should also acknowledge the need for students with moderate and low competencies to be adequately supported and developed, so that the future workforce is thoroughly prepared.

Table 13. Level of Personal Entrepreneurial Competence: Persuasion and Networking

Level of Personal Entrepreneurial Competence: **Persuasion and Networking**	**Frequency**	**Percentage**
Very High Competence	37	12.33
High Competence	175	58.33
Moderate Competence	82	27.33
Low Competence	6	2.00
Very Low Competence	0	0.00
Total	300	100.00

The data discussed indicates the entrepreneurial competencies of Accountancy, Business, and Management (ABM) students, primarily highlighting their perceived strengths in networking and persuasion. While 58.33% (F=175) of students are perceived to be highly competent in these areas, these results represent an important emerging confidence that is part of a greater shift that will assist with achieving success in business in contemporary contexts (Cano et al., 2022). In fact, the ability to network and persuade is emerging as a key entrepreneurial skill, and especially in the case of the Philippines' apprehension of social capital and family networks, the findings of this research suggest students are gaining more confidence in their own network and persuasion competencies (Osei et al., 2022).

The 27.33% (F=82) of student responses in moderate/competence indicates that students generally have foundational skills that could be developed further in entrepreneurial education. Comprehensive entrepreneurship education could increase their skills based on several aspects of entrepreneurship education (Lie et al., 2022; Iqbal et al., 2022). The low percentage of students with low competence (F=6, P=2%) indicates that there is an environment to develop these entrepreneurial skills, perhaps influenced by educational opportunities and socio-economic contexts that encourage entrepreneurship (Castro et al., 2023; Wibowo et al., 2023).

Additionally, the absence of students in the very low competence category suggests that ABM students are overall competent in understanding and developing entrepreneurial relationships, which is a key aspect of the Philippine business landscape where the success of businesses

operates primarily on personal connections and community ties (Osei et al., 2022; Cano et al., 2022). Programs aimed at building the competencies that could be developed by applying the existing competencies and cultivating a more robust entrepreneurial mindset could enhance these strengths even further. Educators are the conduits of the competencies, and their impact cannot be underestimated. The link between effective pedagogy and positive intentions to become an entrepreneur has been borne out in the literature (Bueno et al., 2023).

In summary, the results highlight the need for ongoing development of entrepreneurship education to foster the capabilities of ABM (accountancy, business and management) students both in learning and in practice — as students engage with networked and persuasive skills relevant to entrepreneurship; this will further strengthen the ABM students' skillsets as they become engaged in professional roles and to contribute to the Philippine economy (Castro et al., 2023; Osei et al., 2022; Cano et al., 2022).

Table 14. Level of Personal Entrepreneurial Competence: Self-confidence

Level of Personal Entrepreneurial Competence: **Self-confidence**	**Frequency**	**Percentage**
Very High Competence	28	9.33
High Competence	173	57.67
Moderate Competence	92	30.67
Low Competence	7	2.33
Very Low Competence	0	0.00
Total	300	100.00

The information on the entrepreneurial self-confidence of Accountancy, Business, and Management students presents a bright view of Filipino youth engagement in entrepreneurship. Some reported 57.67% (F=173) of students showing high competence in entrepreneurial self-confidence and 9.33% (F=28) demonstrating very high competence. This would suggest that students have positive self-beliefs about their ability to take on the risks of entrepreneurship, which has positive relationships with entrepreneurial intentions and outcomes (Krishnawati et al., 2023; Juwairia et al., 2024).

The finding that 30.67% (F=92) of students exhibit moderate competence implies a level for further development. The role of higher education institutions in developing an entrepreneurial mindset that supports risk-taking, innovation, and the intention of business start-ups cannot be overstated. The existence of entrepreneurship education is linked to increased students' self-efficacy and preparedness, enhancing their entrepreneurial attitudes (Wardana et al., 2020; Cahyani et al., 2022). This is very pertinent in the Philippines, where the Department of Education has progressively integrated entrepreneurship into curricula, with the goal of making students more aware and other education stakeholders develop new economic functions in the future (Belmonte & Lira, 2023).

Surprisingly, only 2.33% (F=7) of students reported inadequate competence as a statement of their entrepreneurial self-confidence. This is in accordance with previous research, which shows that entrepreneurship education has a significant effect on self-efficacy and entrepreneurial alertness, and will increase engagement in entrepreneurial activities (Miço & Cungu, 2023; Saadat et al., 2021).

In a worldwide situation, there is a construct of the relationship between emotional intelligence, an entrepreneurial mindset, and educational outcomes. Positive emotional competencies can lead to enhanced entrepreneurial intentions by students. Studies have shown that targeted entrepreneurial education enhances these competencies so students can make better decisions when faced with business decisions (Krishnawati et al., 2023; Manafe et al., 2023). Therefore, creating an entrepreneurial climate within colleges, particularly in courses that ABM students utilize, may result in increased entrepreneurial interests and actions that can facilitate economic growth (Wesarat et al., 2022).

Finally, the research provides evidence of an affirmative stance on entrepreneurial self-confidence for ABM students. This growth may also be supported through the existing framework and pedagogical approaches. Ongoing focus on developing entrepreneurial education geared toward developing entrepreneurial skills as well as an entrepreneurial mindset is needed to maximize Filipino Youth as prospective entrepreneurial

global players to support economic development aspirations.

5. Conclusions

Based on the study, 81.34% of ABM students demonstrated satisfactory or excellent entrepreneurial capability. This shows a strong potential and foundational readiness for students to pursue entrepreneurial careers, which safeguards the importance and relevance of entrepreneurship education for ABM students.

In terms of a variety of entrepreneurial attributes, including opportunity seeking, persistence, commitment to work contract, quality and efficiency, risk-taking, goal setting, information seeking, planning and monitoring, persuasion and networking, and self-confidence, the majority of students demonstrated moderate to high competence. This indicates potential, but there is considerable room for growth and development, specifically by moving students with moderate competency levels to high.

The distribution of PECs data provided by the respondents suggests that most of the students are competent at either the moderate or high levels. In contrast, very few students are skilled at either the very high or very low ends of the scale. This indicates that most of these students are still developing their entrepreneurial competencies and will benefit from more experiential and practical learning, even though there is no critical gap.

On the whole, students had lower competencies in risk-taking, demand for quality and efficiency, and goal-setting traits. The fact that students had better scores on these traits is encouraging, as they are crucial for engaging in entrepreneurial action, following through with strategies, and sustaining businesses in the long run.

Students had moderate levels of competencies, developed opportunity-seeking and persistence traits. The fact that these traits were not as highly developed by students suggests that attention is needed to support proactive business exploratory behaviors and long-term sustainability skill development.

It must be noted that the majority of students demonstrated a high level of self-confidence when responding to the self-confidence, as self-efficacy is a mindset that is important for initiating and sustaining a business. However, with approximately 33% being self-confidence is only to a moderate level, some form of supplementary connection to successful mentorship and exposure may also be helpful when adopting a self-efficacy lens.

Results support the developing recognition for the positive contribution of entrepreneurship education to students' developing competence within ABM programs. A valuable point of interest was that, students need to continue to improve learning opportunities to develop high-level entrepreneurial competencies through supporting entrepreneurship curriculum design and delivery with more engaging experiential learning, real-world business experiences, incubator, and networking experiences, will not only develop robust entrepreneurial capacities for student learning but also have a positive impact on their environment to develop new sustainable business growth prospects.

6. Recommendations

Based on the findings of this study, a number of recommendations are presented to develop the personal entrepreneurial competencies (PEC) of students in Accountancy, Business and Management (ABM) programs.

First, it is highly recommended that educational institutions increase the opportunities for experiential learning, such as student–run enterprises, business incubator participation, and participation in startup simulation projects. These activities will provide students with meaningful engagement in actual business scenarios that will help them develop their skills in opportunity seeking, persistence, and risk-taking.

Second, the ABM curriculum may be enhanced with competency-based learning modules to address other areas, as illustrated by the students who ranked moderate competencies in opportunity recognition and commitment to work demands.

Third, instructional strategies could be expanded to include more case study analysis, project-based learning activities, and simulation activities so that students can better transform knowledge into practice.

In addressing the needs of students who exhibit moderate to low levels of competence, there needs to be access to systematic mentoring and coaching experiences. This can include pairing

students with an entrepreneur or someone successful in industry as a mentor, who can serve as a role model and provide support, or providing regular mentoring opportunities to support competency development. Regular coaching sessions and exercises that facilitate student reflection can enhance self-awareness and learning of entrepreneurial competence.

Additionally, there will need to be provision of support for the 19% of students who indicated low entrepreneurial potential. These students may benefit from career counseling services that allow them to consider alternative career options that are aligned with their areas of strength, including those areas that they may not have previously considered as career options. The development of bridging programs that develop an entrepreneurial background in students will also be necessary for these students. In particular, students need to be coached to develop fundamental skills such as goal setting, managing risk, and mastering the risk-taking process.

Faculty training must also be prioritized in the face of varying degrees of competency in the PEC domains. Professional development training on entrepreneurship education should be delivered to provide teachers with appropriate research-driven strategies for teaching students' entrepreneurial skills. Valuable collaboration among faculty of other disciplines can develop a close-knit community of practices to build upon and share efforts for developing PEC.

To assist in creating a "brewing entrepreneurial mindset," it would also be beneficial to build a culture of entrepreneurship on campus, emphasizing entrepreneurship-related events and community projects. The opportunities for students to participate in pitch competitions, entrepreneurship fairs, and expos will motivate them to exercise, articulate, and develop competency in novel ways. Events can also legitimatize and celebrate students acting entrepreneurially, building on growth mindset principles and encouraging others to take similar action in the future.

Lastly, it would be advantageous for future research to look at longitudinal studies to examine the development of PEC over time. Suppose students continue to practice their PEC after college. Follow-up studies to understand facets of entrepreneurship education's long-term impact thoroughly will also inform the development of entrepreneurship education curriculum and policy in the Philippines and potentially elsewhere.

References

A.M., A. & Allen, M. (2022). Instructional approaches, entrepreneurial competencies development, and business education students' intention to be self-employed after graduating from degree-awarding institutions in Rivers State. *International Journal of Entrepreneurship and Business Innovation, 5*(2), 42–59. https://doi.org/10.52589/ijebi-avlpnxbo

Agustina, T., Fitdiarini, N., & Heru, A. (2021). Entrepreneurial intentions of accounting and management students. *Berdikari Jurnal Inovasi Dan Penerapan Ipteks, 9*(1), 1-13. https://doi.org/10.18196/berdikari.v9i1.10646

Ahmad, N., Ramayah, T., Wilson, C., & Kummerow, L. (2010). Is the relationship between entrepreneurial competency and business success contingent upon the business environment?. *International Journal of Entrepreneurial Behaviour & Research, 16*(3), 182-203. https://doi.org/10.1108/13552551011042780

Ahmed, T., Chandran, V., Klobas, J., Liñán, F., & Kokkalis, P. (2020). Entrepreneurship education programmes: how learning, inspiration and resources affect intentions for new venture creation in a developing economy. *The International Journal of Management Education, 18*(1), 100327. https://doi.org/10.1016/j.ijme.2019.100327

Ali Iliyasu, & Daramola, R. (2023). Evaluating entrepreneurial skills needed by business education students for self-employment in colleges of education, Kano State. *Futurity Education*, 111-121. https://doi.org/10.57125/fed.2023.06.25.07

Aslam, S. (2022). Impact of entrepreneurship education on students' entrepreneurial inclination: a case of public sector universities. *Pakistan Journal of Educational Research, 5*(1). https://doi.org/10.52337/pjer.v5i1.432

Aulia, M. & Badawi, A. (2023). The influence of entrepreneurship education, use of social media, and availability of information against entrepreneurial interests of female

students with self-efficacy as a moderating variable. *International Journal of Economics and Management, 1*(01), 7–18. https://doi.org/10.54209/iem.v1i01.2

Bagheri, A. & Abbariki, M. (2016). Competencies of disabled entrepreneurs in Iran: implications for learning and development. *Disability & Society, 32*(1), 69–92. https://doi.org/10.1080/09687599.2016.1268524

BANATE, R., ADRALES, S., BACLI, S., CANCEL, R., GUARIN, M., & SAGAL, H. (2024). Entrepreneurial development activities and business skills enhancement of business administration students of Cavite State University- Tanza Campus. *International Journal of Research in Education, Humanities and Commerce, 05*(01), 120-135. https://doi.org/10.37602/ijrehc.2024.5110

Barazandeh, M., Parvizian, K., Mehdi, A., & Khosravi, S. (2015). Investigating the effect of entrepreneurial competencies on business performance among early-stage entrepreneurs, Global Entrepreneurship Monitor (GEM 2010 survey data). *Journal of Global Entrepreneurship Research, 5*(1). https://doi.org/10.1186/s40497-015-0037-4

Belmonte, Z. & Lira, P. (2023). Factors influencing engineering students to choose techno-entrepreneurship as a career: An implication for better learning. *International Journal of Evaluation and Research in Education (Ijere), 12*(1), 268. https://doi.org/10.11591/ijere.v12i1.22925

Belmonte, Z., Cruz, C., Castro, P., Estoesta, L., Mitra, E., & Lira, P. (2022). Factors influencing technopreneurial intention among undergraduate engineering students in the Philippines. *Journal of Engineering Education Transformations, 36*(1), 148-157. https://doi.org/10.16920/jeet/2022/v36i1/22146

Boldureanu, G., Ionescu, A., Bercu, A., Bedrule-Grigoruță, M., & Boldureanu, D. (2020). Entrepreneurship education through successful entrepreneurial models in higher education institutions. *Sustainability, 12*(3), 1267. https://doi.org/10.3390/su12031267

Bolzani, D. and Luppi, E. (2020). Assessing entrepreneurial competences: insights from a business model challenge. *Education + Training, 63*(2), 214-238. https://doi.org/10.1108/et-04-2020-0072

Bonesso, S., Gerli, F., Pizzi, C., & Cortellazzo, L. (2018). Students' entrepreneurial intentions: the role of prior learning experiences and emotional, social, and cognitive competencies. *Journal of Small Business Management, 56*, 215-242. https://doi.org/10.1111/jsbm.12399

Borges, A., Lopes, J., Carvalho, C., Vieira, B., & Lopes, J. (2021). Education is a key to the growth of entrepreneurial intentions. *Education + Training, 63*(6), 809-832. https://doi.org/10.1108/et-03-2020-0052

Briegas, J., Citarella, A., Iglesias, A., Ballester, S., Marínez, A., & Castro, F. (2021). Exploring teachers' satisfaction and students' entrepreneurial competencies in four entrepreneurial programs carried out in Extremadura (Spain) schools. *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.484103

Bueno, R., Guzman, B., Aquino, J., Chico, S., Zilva, D., & Gaddi, Z. (2023). Assessment on the entrepreneurial intentions of grade 12 students in San Felipe Neri catholic school. *Cognizance Journal of Multidisciplinary Studies, 3*(7), 268-278. https://doi.org/10.47760/cognizance.2023.v03i07.019

Cahyani, U., Hanafi, S., & Masruri, S. (2022). The nexus between university support and entrepreneurial mindset: does entrepreneurship education matter?. *Indonesian Journal of Business and Entrepreneurship*. https://doi.org/10.17358/ijbe.8.3.351

Campos, K. (2022). Fostering entrepreneurial education and unravelling the conundrum of entrepreneurial intention: a conceptual and empirical insight. *Ijebd (International Journal of Entrepreneurship and Business Development), 5*(4), 735–738. https://doi.org/10.29138/ijebd.v5i4.1903

Cano, J., Kie, H., Chioco, A., Fusingan, R., Matulac, K., Sabio, Z., … & Pat-i, R. (2022). Entrepreneurial attitude and intention of ABM senior high school learners. *International Journal of Multidisciplinary Applied Business and Education Research, 3*(5), 817-827. https://doi.org/10.11594/ijmaber.03.05.10

Castro, D., Daing, C., & Ramos, R. (2023).

Academic performance and attitude towards entrepreneurship education among grade twelve students. *American Journal of Social Development and Entrepreneurship, 1*(1), 28–39. https://doi.org/10.54536/ajsde.v1i1.1103

Chang, A., Chang, D., & Chen, T. (2022). Detecting female students transforming entrepreneurial competency, mindset, and intention into sustainable entrepreneurship. *Sustainability, 14*(20), 12970. https://doi.org/10.3390/su142012970

Christina & Widjojo, H. (2023). A comprehensive entrepreneurship education model based on social cognitive theory. *Jurnal Manajemen Teori Dan Terapan | Journal of Theory and Applied Management, 16*(2), 339-355. https://doi.org/10.20473/jmtt.v16i2.44034

Colombelli, A., Panelli, A., & Serraino, F. (2022). A learning-by-doing approach to entrepreneurship education: evidence from a short intensive online international program. *Administrative Sciences, 12*(1), 16. https://doi.org/10.3390/admsci12010016

Cui, J., Sun, J., & Bell, R. (2021). The impact of entrepreneurship education on the entrepreneurial mindset of college students in China: the mediating role of inspiration and the role of educational attributes. *The International Journal of Management Education, 19*(1), 100296. https://doi.org/10.1016/j.ijme.2019.04.001

Dangana, J., Nafiu, A., & Isienyi, R. (2023). Evaluating entrepreneurship education for the acquisition of entrepreneurial competencies among tertiary institution students in Kogi State, Nigeria. *Asian Journal of Economics, Business and Accounting, 23*(14), 105-115. https://doi.org/10.9734/ajeba/2023/v23i141009

Destiana, D., Yandes, J., Santosa, A., & Fadillah, S. (2023). The effect of entrepreneurial competence on business success through entrepreneurial motivation as an intervening variable. *Jurnal Manajemen, 14*(1), 99. https://doi.org/10.32832/jm-uika.v14i1.9786

Devi, Ashveni & Ghazi, Hasanain & Ariffin, Indang Ariati & Shukri, Mohd. (2020). Level of entrepreneurship competence and readiness among medical students in a private university in Shah Alam, Malaysia. *Journal of Entrepreneurship and Business, 8*(1). https://doi.org/10.17687/jeb.0801.07

Edralin, D. & Pastrana, R. (2023). Technical and vocational education and training in the Philippines: in retrospect and its future directions. *Bedan Research Journal, 8*(1), 138–172. https://doi.org/10.58870/berj.v8i1.50

Entrepreneurship test. (n.d.). Psychology Today. https://www.psychologytoday.com/us/tests/career/entrepreneurship-test

Firmansyah, F., Rahayu, W., & Nurjannah, N. (2020). Evaluation of the entrepreneurship education program through the extracurricular activities of the student company. *Jurnal Penelitian Dan Evaluasi Pendidikan, 24*(1). https://doi.org/10.21831/pep.v24i1.19783

Fröhlich, M. and Welpe, I. (2024). Self-selection into entrepreneurship education and implications for evaluation. *Entrepreneurship Education and Pedagogy, 8*(2), 294-328. https://doi.org/10.1177/25151274241247834

Geng, B., Huang, T., Jiang, X., Lin, N., Gao, G., & Fan, L. (2021). The analysis of the innovation consciousness of college student entrepreneurs under the teaching concept of Chinese excellent traditional culture. *Frontiers in Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.717336

Gheorghiță, M., Ghelbet, A., Bulgaru, V., & Scripcenco, A. (2022). The importance and necessity of entrepreneurial education for students within the textile and polygraphy faculty: research study. *Journal of Social Sciences, V*(1), 13-24. https://doi.org/10.52326/jss.utm.2022.5(1).02

Grewe, U. & Brahm, T. (2020). Development of entrepreneurial competences in mini-companies at schools. *Education + training, 62*(7/8), 917–931. https://doi.org/10.1108/et-08-2019-0186

Hasbiah, S. (2023). The influence of entrepreneurial competence and personal independence on business success in micro businesses in the Tamalate sub-district, Makassar City. *Indonesian J. of. Bus. and. entrepreneurship res., 1*(2), 107-112. https://doi.org/10.62794/ijober.v1i2.145

Hiền, H., Quân, T., & Hảo, D. (2019). Influence of entrepreneurial competencies of women

entrepreneurs on the performance of small and medium enterprises in Thua Thien Hue province. *Hue University Journal of Science, Economics and Development, 128*(5B). https://doi.org/10.26459/hueuni-jed.v128i5b.5010

Hoang, G., Le, T., Tran, A., & Du, T. (2020). Entrepreneurship education and entrepreneurial intentions of university students in Vietnam: the mediating roles of self-efficacy and learning orientation. *Education + Training, 63*(1), 115–133. https://doi.org/10.1108/et-05-2020-0142

Huang, Y., An, L., Wang, J., Chen, Y., Wang, S., & Wang, P. (2021). The role of entrepreneurship policy in college students' entrepreneurial intention: the intermediary role of entrepreneurial practice and entrepreneurial spirit. *Frontiers in Psychology*, 12. https://doi.org/10.3389/fpsyg.2021.585698

Hutasuhut, S., Aditia, R., Thamrin, T., & Syamsuyurnita, S. (2024). Enhancing small industrial enterprise performance: the influence of entrepreneurial competence, education, and self-efficacy. *Al-Ishlah Jurnal Pendidikan, 16*(1), 43-53. https://doi.org/10.35445/alishlah.v16i1.4190

Igwe, P., Okolie, U., & Nwokoro, C. (2021). Towards a responsible entrepreneurship education and the future of the workforce. *The International Journal of Management Education, 19*(1), 100300. https://doi.org/10.1016/j.ijme.2019.05.001

Iqbal, J., Asghar, M., Asghar, A., & Waqar, Y. (2022). Impact of entrepreneurial curriculum on entrepreneurial competencies among students: the mediating role of the campus learning environment in higher education. *Frontiers in Psychology*, 13. https://doi.org/10.3389/fpsyg.2022.950440

Istiqomah, I., SUPARJI, S., & Marniati, M. (2022). The important role of entrepreneurship readiness in education. *Studies in Philosophy of Science and Education, 3*(2), 70-81. https://doi.org/10.46627/sipose.v3i2.314

Iwu, C., Opute, A., Nchu, R., Eresia-Eke, C., Tengeh, R., Jaiyeoba, O., … & Aliyu, O. (2021). Entrepreneurship education, curriculum, and lecturer competency as antecedents of student entrepreneurial intention. *The International Journal of Management Education, 19*(1), 100295. https://doi.org/10.1016/j.ijme.2019.03.007

Juwairia, J., Wardana, L., & Maharani, S. (2024). Determinants of entrepreneurial education on entrepreneurial intention with entrepreneurial mindset as a moderating variable on vocational students. *Journal of Applied Business Taxation and Economics Research, 3*(4), 343–353. https://doi.org/10.54408/jabter.v3i4.274

Kanaan-Jebna, A., Alabdullah, T., Ahmed, E., & Ayyasamy, R. (2022). Firm performance and the impact of entrepreneurial education and entrepreneurial competencies. *Business Ethics and Leadership, 6*(2), 68–77. https://doi.org/10.21272/bel.6(2).68-77.2022

Khaerunnisa, S., Fauziyah, A., & Nurfitriya, M. (2024). The effect of the project-based learning method on creative problem-solving in students of the entrepreneurship study program, Indonesian University of Education. *Jurnal Indonesia Sosial Teknologi, 5*(4), 1464-1475. https://doi.org/10.59141/jist.v5i4.1034

Khairuddin, Z., Sauh, S., & Asmaai, M. (2023). Entrepreneurship education at higher learning institutions (HLI): policy mismatch and recommendations. *Malaysian Journal of Business Economics and Management*, 27-33. https://doi.org/10.56532/mjbem.v2i1.8

Khan, R., Mubaraz, S., Luomakoski, J., & Heikkilä, J. (2020). Students' perception of business idea generation: a case of entrepreneurial hackathon. *14th International Technology, Education and Development Conference.* https://doi.org/10.21125/inted.2020.0563

Krishnawati, N., Nurihsan, J., Budimansyah, D., & Nurdin, E. (2023). The role of entrepreneurship education in shaping students' emotional and cognitive competencies for entrepreneurship. *International Journal of Learning Teaching and Educational Research, 22*(2), 262-280. https://doi.org/10.26803/ijlter.22.2.15

Kusmintarti, A., Ismanu, S., Riwajanti, N., & Anshori, M. (2020). Design of an entrepreneurship learning model with a practice approach to build students' entrepreneurship values. *Advances in Economics, Business and Management*

Research. https://doi.org/10.2991/aebmr.k.200415.022

Kusumawati, F., Santosa, C., & Hasibuan, H. (2023). The perception of non-economics and business major students towards the compulsory entrepreneurship course: Have the learning outcomes of the course been achieved?. *Gema Wiralodra, 14*(3), 1541-1547. https://doi.org/10.31943/gw.v14i3.547

Kyguolienė, A. and Švipas, L. (2019). Personal entrepreneurial competencies of participants in experiential entrepreneurship education. *Management of Organisations Systematic Research, 82*(1), 37-51. https://doi.org/10.1515/mosr-2019-0012

Lakmal, W. & Fernando, H. (2023). Evaluation of entrepreneurial intentions of the Sri Lankan youth generation with special reference to the Kurunegala district. *Sri Lankan Journal of Banking and Finance, 6*(2), 103-123. https://doi.org/10.4038/sljbf.v6i2.50

Li, P. (2024). Entrepreneurial education, entrepreneurial ability, and entrepreneurial intention of college students: basis for entrepreneurial competency framework. *International Journal of Research Studies in Education, 13*(3). https://doi.org/10.5861/ijrse.2024.24612

Liberal, AE.E. (2007). Appraising and developing yourself for an entrepreneurial career. (Eds.) Maghiran, T., Librando, P., Esguerra, D., & Recio, D. In Introduction to Entrepreneurship. Quezon City: Small Enterprises Research and Development Foundations, Inc. In cooperation with UP-ISSI. pp: 43-44.

Lie, L., Guo, M., Huang, J., & Yang, J. (2022). Research on the effect of an entrepreneurial environment on college students' entrepreneurial self-efficacy: the mediating effect of entrepreneurial competence and the moderating effect of entrepreneurial education. *Sustainability, 14*(11), 6744. https://doi.org/10.3390/su14116744

Lim, C. (2021). The effect of the quality of entrepreneurship education and students' participation on entrepreneurial competence and entrepreneurial intention. *Asia-Pacific Journal of Convergent Research Interchange, 7*(7), 37–49. https://doi.org/10.47116/apjcri.2021.07.04

Looi, K. & Maritz, A. (2021). Government institutions, entrepreneurship education, and entrepreneurship education programmes in Malaysia. *Education + Training, 63*(2), 271–291. https://doi.org/10.1108/et-07-2020-0217

Lutfiani, N., Rahardja, U., & Manik, I. (2020). Peran inkubator bisnis dalam membangun startup pada perguruan tinggi. *Jurnal Penelitan Ekonomi Dan Bisnis, 5*(1), 77-89. https://doi.org/10.33633/jpeb.v5i1.2727

Lv, Y., Chen, Y., Sha, Y., Wang, J., An, L., Chen, T., … & Huang, L. (2021). How entrepreneurship education at universities influences entrepreneurial intention: mediating effect based on entrepreneurial competence. *Frontiers in Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.655868

Magasi, C. (2022). The influence of entrepreneurship education on entrepreneurial intentions. *International Journal of Research in Business and Social Science (2147-4478), 11*(2), 371-380. https://doi.org/10.20525/ijrbs.v11i2.1701

Manafe, M., Ohara, M., Gadzali, S., Harahap, M., & Ausat, A. (2023). Exploring the relationship between entrepreneurial mindsets and business success: implications for entrepreneurship education. *Journal on Education, 5*(4), 12540–12547. https://doi.org/10.31004/joe.v5i4.2238

Martínez, S. and Ventura, R. (2020). Entrepreneurial profiles at the university: a competence approach. *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.612796

Mendoza, E. (2023). Examining the entrepreneurial competence of BSBA students across various business schools in Lucena in the 2021-2022 academic year. *Edu. Lrng. Dvp. Ntn, 1*(1), 26-37. https://doi.org/10.26480/eldn.01.2023.26.37

Miço, H. & Cungu, J. (2023). Entrepreneurship education, a challenging learning process towards entrepreneurial competence in education. *Administrative Sciences, 13*(1), 22. https://doi.org/10.3390/admsci13010022

Mitchelmore, S. & Rowley, J. (2010). Entrepreneurial competencies: a literature review and development agenda. *International Journal of Entrepreneurial Behaviour & Research, 16*(2), 92–111.

https://doi.org/10.1108/13552551011026995

Mitchelmore, S. & Rowley, J. (2013). Entrepreneurial competencies of women entrepreneurs pursuing business growth. *Journal of Small Business and Enterprise Development, 20*(1), 125–142. https://doi.org/10.1108/14626001311298448

Mohamad, A. (2023). Developing entrepreneurial skills among university students: a case of student entrepreneurial attachment project. *International Journal of Professional Business Review, 8*(1), e01088. https://doi.org/10.26668/businessreview/2023.v8i1.1088

Mohamad, N. & Hussain, N. (2021). Entrepreneurial readiness among female students: Does the effectiveness of time management matter in attempting businesses?. *International Journal of Academic Research in Business and Social Sciences, 11*(12). https://doi.org/10.6007/ijarbss/v11-i12/11821

Moraes, G., Iizuka, E., & Pedro, M. (2018). Effects of entrepreneurial characteristics and university environment on entrepreneurial intention. *Revista De Administração Contemporânea, 22*(2), 226-248. https://doi.org/10.1590/1982-7849rac2018170133

Ndofirepi, T. (2020). Relationship between entrepreneurship education and entrepreneurial goal intentions: psychological traits as mediators. *Journal of Innovation and Entrepreneurship, 9*(1). https://doi.org/10.1186/s13731-020-0115-x

Noor, N. & Malek, E. (2021). An application of the theory of planned behavior in determining student entrepreneurship intention. *Jurnal Intelek, 16*(1), 207-214. https://doi.org/10.24191/ji.v16i1.382

Ojo, M. and Okwilagwe, E. (2024). Assessment of entrepreneurship education knowledge acquisition, change of attitude to entrepreneurship, and skills acquisition in entrepreneurship among university undergraduates in south-western Nigeria. *European Journal of Theoretical and Applied Sciences, 2*(1), 713-723. https://doi.org/10.59324/ejtas.2024.2(1).64

Osei, C., Nti, N., & Garcia-Castro, M. (2022). The influence of family business and social capital on entrepreneurial intentions among female university students in the Philippines. *Ijebd (International Journal of Entrepreneurship and Business Development), 5*(3), 465-475. https://doi.org/10.29138/ijebd.v5i3.1827

Oskoei, M. (2021). The effect of entrepreneurship education on the ability to recognize entrepreneurial opportunities (case study: technical and vocational training centres in Sari City). *International Journal of Social Science and Human Research, 04*(05). https://doi.org/10.47191/ijsshr/v4-i5-07

Pathan, P., Ishak, N., Nisar, N., & Pathan, S. (2023). What matters in enhancing entrepreneurial skills in science: an exploratory study of science teachers' understanding and teaching practices of entrepreneurial skills?. *Psychology in the Schools, 61*(2), 618–630. https://doi.org/10.1002/pits.23072

Paudel, B. & Ranabhat, D. (2024). Entrepreneurial intention of management students in Pokhara university. *Nepalese Journal of Insurance and Social Security, 6*(1), 28–36. https://doi.org/10.58665/njiss.37

Ping, Y. & Yee, C. (2024). Design of college students' innovation and entrepreneurship education quality evaluation model based on grey relational degree algorithm. *Proc. SPIE 13213, International Conference on Image Processing and Artificial Intelligence*, 1321338. https://doi.org/10.1117/12.3035512

Pratikto, H., Winarno, A., & Restuningdiah, N. (2023). The role of entrepreneurial competencies: successful key SMEs, a literature review. *International Journal of Professional Business Review, 8*(7), e01955. https://doi.org/10.26668/businessreview/2023.v8i7.1955

Promma, W., Salamad, M., Aujirapongpan, S., Imjai, N., Suwannual, P., & Taojoo, T. (2023). Influential factors on entrepreneurial competencies in Thai community development program students: a study in higher education institutions. *Tem Journal*, 2188-2196. https://doi.org/10.18421/tem124-29

Ratković, T., Šlogar, H., & Šokčević, S. (2022). Entrepreneurial competencies of university students. *Economics & Sociology, 15*(4), 129-145. https://doi.org/10.14254/2071-789x.2022/15-4

/6

Rico, M., Llamazares, M., Cruz, T., Jiménez, A., Herrero, Á., Cámara, C., … & Eguizábal, J. (2020). Entrepreneurial interest and entrepreneurial competence among Spanish youth: an analysis with artificial neural networks. *Sustainability 12*, 1351.https://doi.org/10.20944/preprints202001.0263.v1

Riyanti, Y. and Dewi, R. (2024). The influence of entrepreneurship education, entrepreneurial motivation, and income expectations on entrepreneurial interest. *JMET, 2*(2), 276-283. https://doi.org/10.61277/jmet.v2i2.144

Rocha, A., Moraes, G., Vodă, A., & Quadros, R. (2023). Comparative analysis of entrepreneurial intention models: self-efficacy versus entrepreneurial characteristics. *Ram Revista De Administração Mackenzie, 24*(4). https://doi.org/10.1590/1678-6971/eramg230209.en

Saadat, S., Aliakbari, A., Majd, A., & Bell, R. (2021). The effect of entrepreneurship education on graduate students' entrepreneurial alertness and the mediating role of entrepreneurial mindset. *Education + Training, 64*(7), 892-909. https://doi.org/10.1108/et-06-2021-0231

Sergeeva, T., Подболотова, М., Natyrova, E., Аверьянова, С., & Lobanov, I. (2021). Development of student entrepreneurial competence using the resources of social partnership. *SHS Web of Conferences, 98*, 02005. https://doi.org/10.1051/shsconf/20219802005

Setiawan, M., Suwono, H., Nur, H., & Sulisetijono, S. (2023). Reflections on the success of biology entrepreneurship: a case study of developing student entrepreneurial self-efficacy. *Bio Web of Conferences, 79*, 13003. https://doi.org/10.1051/bioconf/20237913003

Šimović, V. (2020). The factors affecting the level of digital entrepreneurial competences of university students. *Economic Analysis, 53*(2), 145-155. https://doi.org/10.28934/ea.20.53.2.pp145-155

Šlogar, H., Stanić, N. I Jerin, K. (2021). SELF-ASSESSMENT OF ENTREPRENEURIAL COMPETENCIES OF STUDENTS OF HIGHER EDUCATION. *Zbornik Veleučilišta u Rijeci, 9*(1), 79-95. https://doi.org/10.31784/zvr.9.1.5

Steira, I., Wigger, K., & Rasmussen, E. (2024). A variety of entrepreneurial skills are measured in the entrepreneurship education literature. *Education + Training, 66*(7), 755–776. https://doi.org/10.1108/et-09-2023-0374

Tatpuje, D., Jadhav, V., & Ganbote, A. (2021). Comparative study on selected models of entrepreneurship education. *Sedme (Small Enterprises Development Management & Extension Journal) a Worldwide Window on Msme Studies, 48*(3), 272–284. https://doi.org/10.1177/09708464211073486

Towers, N., Santoso, A., Sulkowski, N., & Jameson, J. (2020). Entrepreneurial capacity-building in HEIs for embedding entrepreneurship and enterprise creation – a tripartite approach. *International Journal of Retail & Distribution Management, 48*(8), 881–899. https://doi.org/10.1108/ijrdm-06-2019-0185

Valencia-Arías, A., Arango-Botero, D., & Sánchez-Torres, J. (2021). Promoting entrepreneurship based on university students' perceptions of entrepreneurial attitude, university environment, entrepreneurial culture, and entrepreneurial training. *Higher Education Skills and Work-Based Learning, 12*(2), 328-345. https://doi.org/10.1108/heswbl-07-2020-0169

Vargas-Martínez, M., Henríquez, J., Colón-Flores, N., & Domínguez-Valerio, C. (2023). Business environment, attitudes, and entrepreneurial intentions as antecedents of entrepreneurial inclination among university students. *Sustainability, 15*(16), 12280. https://doi.org/10.3390/su151612280

Velasco, R. (2021). Final year project as impetus to entrepreneurial intention: a cross-cultural analysis. *The Research Probe, 1*(1), 55–78. https://doi.org/10.53378/346502

Vican, D., & Vuletić, D. (2013). Self-assessment of Croatian elementary school pupils on the entrepreneurial initiative. *Management: journal of contemporary management issues, 18*(2), 57–79.

Wardana, L., Narmaditya, B., Wibowo, A., Mahendra, A., Wibowo, N., Harwida, G., …

& Rohman, A. (2020). The impact of entrepreneurship education and students' entrepreneurial mindset: the mediating role of attitude and self-efficacy. *Heliyon, 6*(9), e04922. https://doi.org/10.1016/j.heliyon.2020.e04922

Wesarat, P., Benrit, P., Panrod, W., Tongsamsi, K., Useng, N., Kaewsaeng-on, R., … & Tansui, D. (2022). Identifying students' entrepreneurial mindset for the Bachelor of Business Administration program, Faculty of Humanities and Social Sciences, Prince of Songkla University. *Kne Social Sciences*. https://doi.org/10.18502/kss.v7i14.11946

Wibowo, H., Bagis, F., & Kusuma, F. (2023). Comparative analysis of the student entrepreneurial interest inventory test. *Journal of Economics, Finance and Management Studies, 06*(07). https://doi.org/10.47191/jefms/v6-i7-07

Yi, S. & Duval-Couetil, N. (2021). Standards for evaluating impact in entrepreneurship education research: using a descriptive validity framework to enhance methodological rigour and transparency. *Entrepreneurship Theory and Practice, 46*(6), 1685-1716. https://doi.org/10.1177/10422587211018184

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

"From Embroidery to Empowerment": Exploring Barriers to Shui Women's Economic Mobility

Yichen Sun[1]

[1] Fairmont Preparatory Academy, CA 92801, US
Correspondence: Yichen Sun, Fairmont Preparatory Academy, CA 92801, US.

doi:10.56397/JWE.2025.08.02

Abstract

This study explores the socio-economic challenges faced by Shui women, mainly residing in Guizhou Province, China. Despite their rich cultural heritage and traditional skills, Shui women still encounter systemic obstacles in education, employment, and legal rights. Based on thematic analysis of field interviews, policy documents, and academic literature, this study reveals how cultural expectations, insufficient institutional support, and discriminatory labor practices work together to hinder the career development of Shui women. The findings highlight the need for intersectional feminist approaches in rural development policies, and they recommend targeted educational and legal reforms to enhance the empowerment of ethnic minority women. This study enriches the literature on gender and ethnic inequality in China, providing new theoretical insights and practical suggestions for promoting inclusive socio-economic development.

Keywords: exploring barriers to Shui Women's economic mobility

1. Introduction

1.1 Background

The Shui ethnic group in China is a minority with a long history spanning millennia. Their unique language, writing system, and cultural traditions constitute a precious intangible cultural heritage (Ding, 2005a; Zhou & Wei, 2021). Members of this ethnic group are mainly found in Guizhou Province in southern China, especially concentrated in Sandu Shui Autonomous County. The female members of the group are renowned for their exquisite embroidery skills, professional expertise in rice farming, and continuous inheritance of the Shui script and traditional festivals such as the "Duanjie" (Xie, 2021). Although Shui women have rich cultural capital, they face multiple structural predicaments in the real–world society. Traditional gender norms and cultural expectations generally emphasize domestic roles, thereby systematically limiting their access to education and career development (Li et al., 2018). Furthermore, as ethnic minority groups, they also face institutional marginalization, such as insufficient legal protection and uneven access to public resources (Guizhou Provincial Women's Federation, 2019).

The inequality of educational resources is an important obstacle to the development of Shui women. Due to factors such as poverty and parental conservatism, many girls are forced to drop out of school prematurely, thus missing the key path to gaining social capital and economic

independence (Ding, 2005b; Zhao, 2019). They also face discrimination in employment and career choices. They are mainly concentrated in low-income industries such as agriculture and domestic services, making it difficult to achieve upward mobility (Li et al., 2018; Song, 2016). These problems not only reflect gender inequality but also reveal the vulnerable position of ethnic minorities in rural areas within the social structure.

Based on this, this paper aims to (1) systematically examine the key structural barriers to the career advancement and income growth of Shui women and (2) explore potential strategies, particularly institutional and societal interventions, that may promote their financial stability and socio-economic empowerment.

2. Justification

Shui women face unique cultural and economic obstacles in their career development. In addition to experiencing a demographic decline, they have historically had a low social status, with limited educational access and restricted avenues for economic advancement. Despite playing a crucial role in preserving and transmitting traditional culture, their contributions are often undervalued.

In Shui society, women have historically been vital participants in economic activities, particularly domestic labor and crafts like horsetail embroidery. Nevertheless, deeply ingrained patriarchal norms frequently lead to undervalue their contributions. Research by Li et al. (2018) on gendered labor roles in Chinese ethnic minority communities indicates that over 70% of Shui women are engaged in agricultural labor, yet their work receives minimal recognition in economic assessments. Furthermore, the *Guizhou Ethnic Economy Report* (2021) reveals that while female artisans contribute significantly to the local economy, their income is, on average, 35% lower than that of male artisans.

An investigation of the economic status of Shui women not only illuminates the difficulties faced by this specific group but it also sheds light on similar issues confronting marginalized women globally. Many women, including Adivasi women in India, Indigenous women in Australia, and indigenous women in Canada and the United States, navigate economic and social constraints shaped by traditional gender roles, limited educational opportunities, and inadequate access to resources. By examining the situation of Shui women, we gain valuable insights into global inequalities and the systemic barriers that perpetuate gender-based economic disadvantage. This study emphasizes the necessity of policies and interventions that promote women's economic independence while respecting cultural identity and advocating for the economic autonomy of women from diverse backgrounds worldwide.

2.1 A Unique Moment

In today's rapidly digitalized world, Shui women stand at the crossroads of tradition and innovation. For Shui women who have long relied on cultural customs such as embroidery and agriculture for a living, this is not a simple transition. They lack adequate education, digital literacy, and institutional support. Many Shui women still run the risk of being left behind by rapid technological and socioeconomic change. As e-commerce, digital platforms, and cultural tourism reshape the global economy, the value of intangible cultural heritage is being rediscovered. Therefore, by integrating the power of technology and youth entrepreneurship, as well as government policy reforms, this unique moment can become a turning point, empowering Shui women and enabling them to regain economic initiative while retaining their cultural identities.

2.2 A Unique Voice

The unique insights I contribute to this research stem from both personal experience and a broader socio-cultural perspective. Growing up in a patriarchal family environment gave me a deep understanding of the gender-based challenges women encounter in society. This personal history has shaped my awareness of systemic gender inequality and heightened my understanding of the struggles faced by Shui women. In addition to my personal background, my identity as a Han researcher offers an additional dimension. As a member of China's ethnic majority, I am cognizant of the various inequalities that ethnic minorities, including the Shui, face in society. This awareness allows me to critically examine how gender and ethnic identity intersect to influence women's economic opportunities and social roles. My research is motivated not only by a personal resonance with gender inequality but also by a deep understanding of how historical, cultural, and institutional factors collectively shape the lives

of women in marginalized communities. These multifaceted perspectives have fueled my interest in gender equality, particularly in social settings where traditional norms continue to restrict women's autonomy and economic independence.

As a high school student, I offer a fresh perspective on the dynamics of digital globalization and the evolution of emerging economic trends. With support by a team of high school students with diverse specializations, I analyzed the impact of contemporary short video platforms and the internet celebrity economy on the promotion of horsetail embroidery, proposing marketing strategies adapted to the modern digital environment. Based on their skills, some of the team members focused on data collection and field interviews, others on brand image design, and still others on website creation and maintenance and this ultimately yielded a very effective collaboration. Some members concentrated on analyzing digital platform trends, while others focused on creating visual content and online platforms that authentically represent Shui culture. Each member participated equally, and through open discussion, critical thinking, and practical fieldwork, we ensured that our research outcomes were both robust and innovative. This combination of traditional fieldwork with a youth-driven, twenty-first-century perspective has enabled me to provide a unique and forward-looking viewpoint on the changing career trajectories of minority women.

3. Theory

3.1 Intersectionality, Minority Studies, and Women's Education

Fraser's (1997) theory of redistribution and recognition critiques the systemic undervaluation of women's labor in capitalist and patriarchal societies. It highlights a "double injustice" where women earn less and lack social recognition. This aligns with the reality of Shui women, whose labor in agriculture, handicrafts (e.g., horsetail embroidery), and domestic work remains economically invisible. Her later work (2009) on participatory equality argues that economic dependence restricts women's autonomy and full societal participation, a concept relevant in Shui communities where women's decision-making power is often subordinate to male relatives.

Bell hooks (1984) introduces cross-feminism, highlighting the interlocking nature of patriarchy, capitalism, and racism. For Shui women, this framework is critical as they face dual marginalization due to both gender and ethnic identity. Their economic exclusion cannot be understood without considering how cultural and state policies compound their subordination. Crenshaw's (1989) intersectionality theory further demonstrates how overlapping identities (gender, ethnicity, class) create compounded barriers. Shui women's geographic remoteness, minority status, and patriarchal traditions intersect to restrict their access to education, healthcare, and formal employment, reinforcing cyclical poverty.

Craft's (2006) gender education access theory posits that structural underinvestment in women's education perpetuates economic dependence. Historically, Shui women had limited access to education, with formal education typically prioritized for boys. According to the *Education Statistics of Ethnic Minorities in Guizhou* (2020), the literacy rate of Shui women is 62%, significantly lower than the 85% of Shui men. Furthermore, Zhao's (2019) study found that only 18% of Shui women completed secondary education, compared to 42% of men, reflecting the long-term effects of historical gender bias.

Shui families traditionally emphasize women's roles as caregivers and cultural bearers; however, this role often limits women's personal autonomy. A survey by the Guizhou Provincial Women's Federation (2019) found that 84% of Shui families still adhere to a patriarchal structure where men are the primary family decision-makers while women are responsible for housework and child-rearing.

3.2 Focus on Culture and Challenges for Shui Men

Focusing on the culture of ethnic minorities like the Shui is essential today to preserve cultural diversity, given their unique traditions and historical backgrounds. Furthermore, considering the socioeconomic development gap between minority regions and others, a focus on culture can promote national identity and create economic opportunities for local women through traditional skills such as horsetail embroidery, thereby fostering social equity and sustainable development. However, the Shui, like many other ethnic minorities, have faced numerous challenges in recent years. While the

gender division of labor in Shui society primarily limits the social mobility of women, Shui men also encounter obstacles due to the marginalization of their culture and the difficulties within their communities' economic structure.

Shui men have also experienced setbacks in recent decades. As economic development has concentrated in urban centers, many Shui men have migrated to cities for low-paying, labor-intensive jobs, often facing discrimination and limited upward mobility. This migration has led to a loss of connection with their native culture and community, further intensifying the challenges faced by the ethnic group as a whole. The erosion of traditional livelihoods and the lack of inclusive policies have hindered both Shui men and women in distinct yet interconnected ways.

3.3 Literature Review

Existing studies on the economic status of Shui women address the intersection of gender, ethnicity, and rural marginalization. Although relatively limited in number, studies published between 2004 and 2023, mainly in Chinese ethnological, cultural, and regional journals, highlight the impact of gender roles, property inheritance norms, and limited educational and employment access on Shui women's economic autonomy. These works, employing both qualitative and quantitative methods, reveal that despite women's central role in traditional practices such as horsetail embroidery, they often lack decision-making power and access to broader markets. However, few studies explore the potential of cultural heritage as a tool for women's empowerment in the digital economy, revealing a gap that this research aims to address.

3.4 Themes in the Literature

Existing literature consistently demonstrates that Shui women face significant economic marginalization stemming from a combination of cultural norms, gender roles, and structural inequalities. Research indicates that traditional expectations restrict their participation in formal employment, entrepreneurship, and financial decision-making, reinforcing dependence on male family members (Liu et al., 2023). These constraints are further exacerbated by inheritance customs, educational disparities, and weak enforcement of gender equality policies, perpetuating cycles of economic instability (Zhou & Wei, 2021; Pan, 2012; Ding, 2005).

3.5 Cultural and Gender Norms Limiting Economic Participation

Liu et al. (2023) found that Shui women are predominantly engaged in subsistence agriculture and domestic labor, with limited access to formal employment or business opportunities. This economic marginalization is reinforced by deeply ingrained gender roles that prioritize male financial authority. Similarly, Xie (2021) observed that despite modernization, Shui women remain confined to traditional duties, restricting their ability to pursue higher-paying jobs or leadership positions. These cultural expectations discourage financial independence, as women's economic contributions are often undervalued (Kawulich, 2005).

3.6 Structural Barriers: Inheritance, Education, and Legal Enforcement

Zhou and Wei (2021) examined property inheritance practices in Shui communities, revealing a strong male preference that systematically disadvantages women. Without secure land or asset ownership, Shui women lack financial stability and remain economically vulnerable. Additionally, Ding (2005) highlighted how traditional gender roles devalue female education, leading to lower literacy rates and fewer employment opportunities. This educational disparity limits upward mobility, trapping women in low-income roles.

Although legal frameworks exist to promote gender equality, Pan (2012) found weak policy enforcement, allowing discrimination in wages, land rights, and career advancement to persist.

Ding Yueya (2005) further emphasized that Shui women experience dual marginalization—both as an ethnic minority and as women—facing compounded barriers in education, employment, and social mobility.

3.7 Potential Pathways for Economic Empowerment

Some studies suggest that digital platforms and new technologies could offer alternative income opportunities, but rural Shui women often lack access to these resources (International Conference on Education, Management, and Computing Technology 2014). Historical analyses, such as those by the Hubei Institute for Nationalities (2004), indicate that despite gradual modernization, patriarchal traditions

continue to hinder women's economic agency. The limitations acknowledged in the existing literature primarily focus on three areas. First, limited access to digital technology—including poor internet infrastructure, lack of digital literacy, and unaffordable devices—remains a significant issue. While digital platforms offer potential for empowering Shui women, limited technological access in rural areas restricts their economic opportunities and ability to fully utilize these tools for financial independence. Second, weak law enforcement is frequently cited. Despite the existence of policies promoting gender equality in some regions, an inadequate implementation leads to persistent discrimination against women in land ownership, wages, and career advancement, hindering their access to economic opportunities. Finally, deep-seated cultural and institutional barriers persist. While modernization has created some opportunities, entrenched gender norms and patriarchal systems continue to constrain women's economic independence and reinforce their subordination within society.

4. Methodology

4.1 Data Collection

To gain a deeper, firsthand understanding of the Shui women's daily lives and economic roles, I employed participant observation as one of the core ethnographic methods. This immersive approach allowed me to engage directly with the community and witness the realities often hidden behind statistics or secondhand accounts.

4.2 Data Analysis

To analyze the data, I employed thematic analysis to identify recurring patterns and key themes in the interviews. Interview responses were categorized according to major topics such as economic roles, employment challenges, and generational perceptions of gender expectations. Thematic analysis allowed me to examine the frequency and significance of certain topics emerging from the interviews. Additionally, I cross-referenced the interview data with my participant observations to ensure consistency and to deepen the interpretation of the findings. This approach not only enhanced the validity of the results, but it also deepened understanding of the cultural and structural factors influencing the economic independence of Shui women. By analyzing these diverse data sources, I gained a comprehensive understanding of how traditional gender roles and modern influences intertwine to shape the economic status of Shui women.

Thematic analysis is a qualitative research method used to identify, analyze, and report on patterns within datasets. In this study, the six-step thematic analysis proposed by Braun and Clarke (2006) was utilized to systematically classify the experiences of Shui women in the domains of economy, education, and family. These six steps include familiarizing oneself with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. This method facilitates the systematic revelation of the gender inequality faced by Shui women in the context of modernization.

5. Participant Observation

Participant observation is a valuable research method for understanding the nuanced culture of the Shui women. It enables researchers to directly observe the actors in their daily environment and interactions, thereby providing rich descriptions of participants' behaviors, intentions, situations, and events, and offering an opportunity to observe and engage in unscheduled occurrences (Kawulich, 2005). A key advantage of this approach is its ability to capture the subtle dynamics of everyday life, providing researchers with a deeper understanding of the social and cultural context. By directly participating in daily activities with participants, researchers can observe behaviors, interactions, and mannerisms that may not be articulated in direct interviews or surveys. This method can also facilitate a more authentic and nuanced interpretation of participants' perspectives.

5.1 Observation: Community Life and Economic Roles of Shui Women

For this research on the Shui women, I conducted participant observation in Sandu Shui Autonomous County, Guizhou Province, where I resided with a local Shui family for a day. The household comprised a grandmother and two sisters; other family members were absent. I fully immersed myself in their daily activities, beginning in the morning by assisting them in harvesting corn in the fields. At noon, I participated in cooking and preparing meals at home, gaining firsthand experience of their traditional lifestyle and the gendered division of

labor. In addition to my host family, I observed interactions among neighbors who visited throughout the day. Some gathered to converse, highlighting the importance of community relations in Shui society. Children also played on the hill, illustrating how daily life in this rural setting is deeply intertwined with nature and informal social gatherings.

During this field visit, our team conducted a structured analysis of the local horsetail embroidery industry, evaluating the strengths and weaknesses of different business categories. We observed that Shui women of varying ages fulfill distinct roles within their families and the embroidery trade. Older women often serve as custodians of embroidery techniques, while younger women are more receptive to innovation and marketing strategies, viewing embroidery not merely as a tradition but also as a means of financial independence.

We also visited local businesses, such as the Fengzhu horsetail embroidery company. While the company shows potential, we identified clear challenges, most notably a lack of a defined brand identity. Even the embroiderers were unable to articulate the brand story. To address this, our team proposed shaping the brand around the theme of "collective female identity," drawing from the tradition of embroidery being passed down from mother to daughter. The objective is to highlight women's empowerment and bridge tradition with modern consumer expectations.

Further analysis revealed deeper systemic issues within the embroidery business: high labor costs, overhead expenses like rent and utilities, limited marketing channels, and traditional designs lacking modern appeal. In response, we proposed detailed strategies: target audience research to clarify buyer preferences, product development including modern cultural and creative goods, and marketing strategies combining online methods (social media positioning, influencer collaborations) with offline initiatives (interactive experience stores, brand events).

This immersive observation provided me with a clearer understanding of the economic and domestic roles of Shui women and underscored the broader cultural and structural constraints they navigate. By actively participating in their routines and engaging with local artisans and business leaders, I gained a comprehensive, lived perspective of the tensions and possibilities surrounding gender, tradition, and development in Shui communities.

I also immersed myself in the community, engaging directly with local artisans and business leaders. My research specifically focused on horsetail embroidery, a traditional craft unique to Shui women. I interviewed the head of an embroidery company and non-genetic heirs, compiling firsthand accounts that offer an insider perspective often absent in existing literature.

5.2 Key Informant Interview

Key informant interviews represent another method employed in this research, facilitating the direct collection of detailed and rich data. This approach allowed me to establish trust with the interviewees. For my interviews with the Shui women, I interviewed local elders, female community leaders, and educators in Sandu Shui Autonomous County, Guizhou Province. These interviews were conducted in community centers, respondents' homes, and informal settings, fostering a more comfortable and open environment for discussion. The flexibility of interviews permits both structured questioning and open dialogue, enabling respondents to share personal stories, experiences, and perspectives beyond the confines of pre-set questions.

The interviews focused on the historical and cultural factors that have shaped the economic status of Shui women, the challenges they face in employment and education, and the impact of modernization on traditional gender roles. Through these interviews, I gathered diverse perspectives revealing deep-seated cultural norms and societal expectations that continue to limit the economic independence of Shui women. Each interview lasted between 30 and 60 minutes, yielding a wealth of data for in-depth analysis of the structural and cultural barriers confronting Shui women.

The interviews also revealed generational shifts in attitudes toward gender roles, with younger women expressing a desire for greater economic autonomy while still influenced by traditional expectations. The interviews centered on several key themes: historical and cultural influences on the economic roles of Shui women, barriers to employment and education, and the effects of modernization on traditional gender expectations. A recurring insight from the

interviews was the generational shift in attitudes toward gender roles. Younger Shui women articulated a growing desire for economic independence, hope to gain more opportunities for self-control through education and work yet many felt constrained by traditional expectations regarding family and household duties. It is particularly worth mentioning that a relatively open and trusting relationship has been established between me and the shui people interviewed. Perhaps it's because I'm an outsider and also a woman that they seem particularly candid and sincere when they talking about their personal dreams. Some people even say that this is the first time they have truly thought about themselves, such as "working in the city", "earning money to support themselves" or "postponing marriage". For them, such conversations are not only a form of sharing but also a psychological release. In the process of being listened to and understood, they also gained a certain temporary freedom. This generational tension highlights the ongoing challenges Shui women face as they navigate their cultural heritage and evolving societal expectations.

5.3 Thematic Analysis

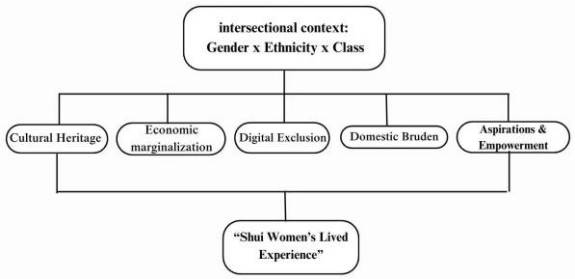

Figure 1.

6. Key Findings

6.1 Ethnic Minority and Cultural Heritage Challenges

The research confirms that that Shui women occupy a vulnerable position in Chinese society, because of gender, ethnic, and economic marginalization. Although they play a vital role in preserving traditional culture, particularly through horsetail embroidery, their contributions are often undervalued and overlooked. Most Shui women are constrained by traditional gender roles and limited educational opportunities, which consequently restrict their access to stable employment and legal protection. Through field interviews and direct conversations with female embroidery artisans, I discovered that while many possess exceptional craftsmanship, they face significant challenges in monetizing their work. The lack of digital literacy, marketing knowledge, and access to broader sales networks prevents them from participating effectively in the digital economy.

Furthermore, the research highlights a significant gap in cultural inheritance between generations. Influenced by modernization and opportunities for work outside the community, the younger generation of Shui women rarely learn horsetail embroidery, posing a threat to the future of this intangible cultural heritage. The decline of intergenerational knowledge transfer not only endangers the continuation of horsetail embroidery but also weakens the cultural identity and cohesion of the Shui ethnic community. Another important finding is that for Shui women, embroidery is not merely a means of livelihood or a traditional skill but also a form of emotional expression and self-expression, symbolizing their resilience and pride in the face of marginalization. This underscores the necessity of integrating cultural understanding and respect into any economic or policy initiatives designed to support them.

Further investigations reveal that many Shui women bear heavy responsibilities in child-rearing, elder care, and household chores, significantly reducing their time and capacity for self-development, training, or business activities. Moreover, due to language barriers and limited access to policy information, they often fail to fully access government subsidies or women's support programs. This information barrier further exacerbates their unequal position in the distribution of social resources. Through on-site interviews and direct communication with female embroidery artisans, I found that many women possess outstanding manual skills but face numerous difficulties in commercializing their work. For instance, an embroiderer in her fifties mentioned learning horsetail embroidery from her mother since childhood and accumulating over thirty years of experience. Currently, while caring for her children at home, she continues to embroider in her spare time. She has no other sources of income, and the family's livelihood primarily depends on her husband's casual labor. She stated, "All the capable young people in the village have gone out to work. Those of us

who stayed behind can only make ends meet by embroidering some things." However, her life was challenging; her husband often subjected her to domestic abuse, causing her significant mental and financial distress. She admitted that although she desired to improve her embroidery skills, these difficulties limited her opportunities for development and creativity.

Another woman attempted to promote her work on WeChat Moments to attract buyers but discontinued her efforts due to a lack of response. She confessed, "I don't know how to write those attractive titles, nor can I take good-looking photos like young people." She added that there are not many young people in the village who know how to take photos or do marketing, but the artisans desperately need such assistance. She also expressed that despite her passion for embroidery; she felt uncertain about the future given market competition and the absence of necessary technical support. She sighed, "If these handicrafts we make could be seen by more people, perhaps they could bring in more income. Unfortunately, we have no platform and no marketing skills." She believes that while demand for traditional handicrafts exists in modern society, the lack of effective promotion and connection methods marginalizes artisans like her in a highly competitive market.

These conversations highlight their deficiencies in digital skills and market awareness and underscore the significant gap between them and the modern digital economy. Despite possessing profound manual skills, they struggle to overcome their predicament through traditional means. Therefore, providing digital skills training and marketing support is particularly urgent to help them establish a foothold in the new economic environment.

Despite these challenges, many expressed enthusiasm about using online platforms to promote and sell their embroidery, demonstrating both their entrepreneurial spirit and the untapped economic potential of Shui women. These findings suggest a pressing need for structural support and targeted initiatives to empower these women and sustain their cultural heritage.

Further observations also indicate that while striving to promote cultural inheritance, Shui women face challenges posed by modernization. With societal changes and shifts in the labor market, many younger women choose to seek employment outside their communities, resulting in a disruption of the intergenerational transfer of knowledge and skills related to traditional handicrafts. Furthermore, the disconnect between the supply of handicrafts and modern market demand makes it difficult for the labor of these women to receive appropriate value recognition and compensation. Consequently, finding effective ways to promote the traditional cultural works of Shui women to a broader market through modern channels and platforms has become a critical issue for research to address.

6.2 Women's Socioeconomic Conditions and Challenges

The research indicates that Shui women occupy a vulnerable position at the intersection of gender, ethnicity, and economic marginalization. Although they play a vital role in preserving traditional culture, particularly through horsetail embroidery, their contributions are often undervalued and overlooked. Most Shui women are constrained by traditional gender roles and limited educational opportunities, which consequently restrict their access to stable employment and legal protection.

Through field interviews and direct conversations with female embroidery artisans, I discovered that while many possess exceptional craftsmanship, they face significant challenges in monetizing their work. The lack of digital literacy, marketing knowledge, and access to broader sales networks prevents them from participating effectively in the digital economy.

Further investigations reveal that many Shui women bear heavy responsibilities in child-rearing, elder care, and household chores, significantly reducing their time and capacity for self-development, training, or business activities. Moreover, due to language barriers and limited access to policy information, they often fail to fully access government subsidies or women's support programs. This information barrier further exacerbates their unequal position in the distribution of social resources.

Through on-site interviews and direct communication with female embroidery artisans, I found that many women possess outstanding manual skills but face numerous difficulties in commercializing their work. For instance, an embroiderer in her fifties mentioned learning horsetail embroidery from her mother

since childhood and accumulating over thirty years of experience. Currently, while caring for her children at home, she continues to embroider in her spare time. She has no other sources of income, and the family's livelihood primarily depends on her husband's casual labor. She stated, "All the capable young people in the village have gone out to work. Those of us who stayed behind can only make ends meet by embroidering some things." However, her life was challenging; her husband often subjected her to domestic abuse, causing her significant mental and financial distress. She admitted that although she desired to improve her embroidery skills, these difficulties limited her opportunities for development and creativity.

Another woman attempted to promote her work on WeChat Moments to attract buyers but discontinued her efforts due to a lack of response. She confessed, "I don't know how to write those attractive titles, nor can I take good-looking photos like young people." She added that there are not many young people in the village who know how to take photos or do marketing, but the artisans desperately need such assistance. She also expressed that despite her passion for embroidery, she felt uncertain about the future given market competition and the absence of necessary technical support. She sighed, "If these handicrafts we make could be seen by more people, perhaps they could bring in more income. Unfortunately, we have no platform and no marketing skills." She believes that while demand for traditional handicrafts exists in modern society, the lack of effective promotion and connection methods marginalizes artisans like her in a highly competitive market.

These conversations highlight their deficiencies in digital skills and market awareness and underscore the significant gap between them and the modern digital economy. Despite possessing profound manual skills, they struggle to overcome their predicament through traditional means. Therefore, providing digital skills training and marketing support is particularly urgent to help them establish a foothold in the new economic environment.

Despite these challenges, many expressed enthusiasm about using online platforms to promote and sell their embroidery, demonstrating both their entrepreneurial spirit and the untapped economic potential of Shui women. These findings suggest a pressing need for structural support and targeted initiatives to empower these women and sustain their cultural heritage. Among these challenges, it is particularly worth noting the signs of change shown by the younger generation of shui people. They not only expressed a strong desire for economic independence but also showed a great enthusiasm for promoting embroidery products through online platforms. Despite the still limited practical conditions, young women have gradually broken through the traditional framework in both thought and action.

7. Conclusions

In conclusion, my research on the current situation of women in the Shui ethnic group reveals the complex interplay of gender, ethnic identity, and economic marginalization within rural Chinese society. Although highly skilled in the traditional horsetail embroidery technique, deeply rooted in the Shui ethnic group's cultural identity, they face numerous limitations in achieving self-empowerment. The root causes lie in deeply ingrained gender norms, cultural expectations, and their ethnic minority identity, leading to a pervasive lack of quality educational opportunities, legal protection, and formal employment channels for Shui women. During my interactions with embroidery artisans, many expressed a strong desire to sell their work online. However, due to insufficient digital skills and market support, they found it challenging to transform embroidery into a sustainable income source. This situation underscores the urgent need for targeted support measures, such as providing digital skills training, establishing e-commerce collaboration channels, and promoting the formation of local women's cooperatives. However, this study also has its limitations. Due to time and resource constraints, the research was conducted within a limited geographical area and sample size, which may not fully represent the diverse experiences of Shui women in other regions. Additionally, linguistic and cultural barriers occasionally posed challenges in communication, potentially affecting the depth of some interviews and observations. Future research could benefit from broader regional coverage and interdisciplinary collaboration to provide a more comprehensive understanding. These initiatives can not only safeguard the valuable intangible cultural heritage of horsetail embroidery but also pave a realistic path toward the economic

empowerment and gender equality of Shui women. This study aims to offer valuable insights for exploring how to promote the coordinated development of cultural inheritance and women's rights in ethnic minority communities by highlighting the structural inequalities and potential contributions of these women.

References

Braun, Virginia, and Victoria Clarke. (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology*, *3*(2), pp. 77-101.

Ding, Y. (2005). Women education in gender culture vision: Case study on Shui Nation. [传统性别文化视角下的女性教育问题：水族个案]. *Guizhou Ethnic Studies*, *25*(2), pp. 111-115.

Ding, Yueya. (2005). Cultural and historical causes of Shui women's education problems [水族女性教育问题产生的文化历史追因]. *Guizhou Ethnic Studies*, *25*(2), pp. 78-82.

Fraser, N. (2009). Scales of Justice: Reimagining Political Space in a Globalizing World. Columbia University Press. http://www.jstor.org/stable/10.7312/fras14680

Fraser, Nancy. (1997). *Justice Interruptus: Critical Reflections on the "Postsocialist" Condition*. New York: Routledge.

Guizhou Ethnic Economy Report. (2021).

Guizhou Provincial Women's Federation. (2019). Survey Report.

Hooks, Bell. (1984). *Feminist Theory: From Margin to Center*. South End Press.

Hubei Institute for Nationalities. (2004). Legal status of Shui women [水族女性的法律地位]. *Journal of Hubei Institute for Nationalities (Philosophy and Social Sciences)*, *22*(6), pp. 45-50.

International Conference on Education, Management and Computing Technology. (2014). Key informant interview on Shui women's economic development. *Proceedings of ICEMCT 2014*, pp. 312-316.

Kawulich, Barbara B. (2005). Participant Observation as a Data Collection Method. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *6*(2), Art. 43. doi.org/10.17169/fqs-6.2.466.

Li, S., et al. (2018). Gendered Labor Roles in Ethnic Minority Communities in China. *Journal of Ethnic Studies*, *15*(3), pp. 45-62.

Liu, S., et al. (2023). Diversity and Traditional Knowledge of Medicinal Plants Used by Shui People in Southwest China. *Journal of Ethnobiology and Ethnomedicine*, *19*(20). doi.org/10.1186/s13002-023-00594-4.

Pan, Y. (2012). The importance of improving Shui women's legal status [论重视水族女性的法律地位]. *Theory New Exploration*, (07), pp. 267-270.

Song, Y. (2015). Hukou-based labour market discrimination and ownership structure in urban China. *Urban Studies*, *53*(8), 1657-1673. https://doi.org/10.1177/0042098015576861

Tong, Y. (2023). The Expanding Search for Work: The Gender Gap in Livelihood Choices among the Rural Chinese, from 1989 to 2015. *Rural Sociology*, pp. 818-855. https://doi.org/10.1111/ruso.12503_

Wang, J. (2014). Preliminary discussion on the cultural communication of Shui nationality in Yunnan under the perspective of new media. *Proceedings of ICEMCT 2014*, pp. 145-149.

Wang, Y.J., Chen, X.P., Chen, W.J. et al. (2020). Ethnicity and health inequalities: an empirical study based on the 2010 China survey of social change (CSSC) in Western China. *BMC Public Health*, 20, 637. https://doi.org/10.1186/s12889-020-08579-8_

Xie, W. (2021). The Rituals and Cultural Changes of the Duan Festival of the Shui Ethnic: The Case of Guizhou, China. *International Journal of Frontiers in Sociology*, *3*(19), pp. 98-102. *doi.org/10.25236/IJFS.2021.031919*.

Zhao, L. (2019). Educational Attainment Among Ethnic Minorities in Guizhou. *Journal of Educational Sociology*, *28*(1), pp. 88-105.

Zhou, Y., and M. Wei. (2021). Sinicisation and Ethnicity: Spatial Characteristics of Shui Vernacular Architecture in Guizhou, Southwest China. *Built Heritage*, *5*(2). doi.org/10.1186/s43238-021-00021-1.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

The Role of Cross-Cultural Communication in Enhancing the Global Competitiveness of American Firms: A Case Study of American Multinational Corporations

Qin Mu[1]

[1] Beijing Foreign Studies University, Beijing 100089, China
Correspondence: Qin Mu, Beijing Foreign Studies University, Beijing 100089, China.

doi:10.56397/JWE.2025.08.03

Abstract

In the era of globalization, American multinational corporations (MNCs) are confronted with escalating international market competition, where cultural differences and communication barriers significantly impact their global competitiveness. This research investigates the strategic role of cross-cultural communication in enhancing the global competitiveness of American MNCs. By integrating cross-cultural psychology, management theory, and international business theory, this study constructs a comprehensive theoretical framework and employs empirical methods to verify the effectiveness of cross-cultural communication strategies. The findings indicate that these strategies significantly enhance corporate global competitiveness by improving cross-cultural capabilities and customer satisfaction. This study provides actionable recommendations for the American government and enterprises to optimize their global operations and offers valuable insights for policy-making in related fields.

Keywords: cross-cultural communication, global competitiveness, American multinational corporations, cultural adaptability, cross-cultural management, international business, corporate internationalization, cultural differences, communication strategies, employee training

1. Introduction

1.1 Research Background

The intensification of globalization has heightened the competitive landscape for American MNCs in the international market. Cultural differences and communication barriers have emerged as pivotal factors influencing their global competitiveness. Misunderstandings and conflicts arising from cultural differences can lead to inefficient communication, thereby undermining operational efficiency and market performance. Enhancing the global competitiveness of American MNCs is crucial for bolstering the economic strength of the United States and expanding its global influence. This study aims to provide practical solutions for optimizing the global operations of American MNCs through cross-cultural communication strategies.

1.2 Research Objectives

This research is designed to propose an innovative set of cross-cultural communication strategies to provide theoretical support for the global operations of American MNCs. It aims to demonstrate through empirical research the tangible effects of these strategies on enhancing corporate global competitiveness and to offer policy recommendations for the American government and enterprises to foster the global competitiveness of American companies.

2. Literature Review

2.1 Cross-Cultural Communication Theory

Cross-cultural communication theory encompasses cross-cultural psychology, cross-cultural management theory, and international business theory. Cross-cultural psychology examines the impact of cultural differences on employee behavior, providing a foundation for understanding cultural conflicts in multinational enterprises. Cross-cultural management theory emphasizes enhancing corporate competitiveness through effective management strategies, such as cross-cultural training and communication mechanism optimization. International business theory focuses on the success of multinational corporations in the global market through cultural adaptability strategies.

2.2 Research Status

Existing research on cross-cultural communication and corporate competitiveness has made progress, but it is predominantly theoretical, lacking systematic empirical support. Moreover, current studies inadequately address the long-term effects and dynamic adjustment mechanisms of cross-cultural communication strategies, especially in the context of global operations. This study aims to fill these gaps by proposing a systematic and innovative set of cross-cultural communication strategies, providing both theoretical support and practical guidance for American MNCs.

3. Theoretical Framework

3.1 Case Selection

To thoroughly investigate the role of cross-cultural communication strategies, this study selects several American MNCs from the technology, finance, and manufacturing sectors as case studies. These industries are highly representative in globalization, characterized by a strong dependence on cross-cultural team collaboration, global supply chain management, and international market expansion. For instance, technology companies conduct global research and development and market promotion, financial institutions deal with diverse national financial regulations and customer demands, and manufacturing enterprises optimize the global supply chain to reduce costs and improve efficiency. By analyzing these industries, this study comprehensively understands the application scenarios and potential impacts of cross-cultural communication strategies.

3.2 Data Collection

To evaluate the effectiveness of cross-cultural communication strategies, this study collects corporate financial and operational performance data, including key indicators such as annual operating revenue, net profit, market share, customer satisfaction scores, and employee participation in cross-cultural training. Additionally, qualitative data, such as employee interview records and internal reports, are collected to provide a comprehensive research perspective.

3.3 Research Methods

This study employs a combination of qualitative and quantitative methods to ensure research reliability and validity. Qualitative analysis is conducted through in-depth interviews and case studies, involving corporate executives, middle managers, and frontline employees. Quantitative analysis is based on corporate financial and operational performance data, using statistical methods (e.g., regression and correlation analysis) to assess the effectiveness of cross-cultural communication strategies. Case analysis methods are also used to provide in-depth insights into the implementation of these strategies in different industries and companies.

4. Empirical Research Design

4.1 Data Analysis

This study collected feedback from employees of American MNCs through questionnaires and in-depth interviews. A total of 500 questionnaires were distributed, with 450 valid responses. The results indicate that over 80% of employees believe cross-cultural communication training positively impacts their work, particularly in cross-cultural team collaboration and customer communication. For example, in a

technology company, the success rate of employees involved in cross-cultural projects increased from 60% to 85% after training. Employee interviews further revealed suggestions for improving cross-cultural communication strategies.

Table 1.

Data Item	Data Value
Number of Questionnaires Distributed	500
Number of Valid Questionnaires Recovered	450
Effective Recovery Rate	90%
Proportion of Employees Believing Cross-Cultural Communication Training Has a Positive Impact	Over 80%

Customer satisfaction is a critical indicator for assessing the effectiveness of cross-cultural communication strategies. Data collected from customer satisfaction surveys show that companies implementing these strategies experienced a 15% increase in average customer satisfaction. For instance, a financial company's customer satisfaction in the Asian market rose from 70% to 85%, with the customer churn rate decreasing from 10% to 5%. Customer interviews highlighted improvements in communication efficiency and cultural adaptability as key factors. (Jin young Hwang, 2024)

To assess the impact on corporate competitiveness, this study analyzed the financial and operational performance data of 10 multinational companies. Companies implementing cross-cultural communication strategies achieved an average annual operating revenue growth rate of 12%, compared to 8% for those that did not. For example, Foxconn's global market share increased from 15% to 20%, and its net profit grew by 18% after implementing these strategies. Operational performance also improved, with companies like Alibaba Cloud reducing project delivery time by 20% and supply chain costs by 10%.

Table 2.

Data Item	Data Value
Number of Companies Analyzed	10 multinational companies
Average Annual Operating Revenue Growth Rate of Companies Implementing Cross-Cultural Communication Strategies	12%
Average Annual Operating Revenue Growth Rate of Companies Not Implementing Cross-Cultural Communication Strategies	8%

4.2 Case Analysis

This study conducted in-depth analyses of companies that successfully implemented cross-cultural communication strategies. For example, Google enhanced its international market competitiveness by regularly conducting cross-cultural training, establishing cross-cultural teams, and optimizing communication mechanisms. Within three years, Google's global market share increased from 20% to 30%, and its operating revenue grew by 30%. The key factors for successful implementation included support from senior management, systematic training, employee engagement, and continuous communication optimization.

Conversely, AXA of France faced challenges in implementing these strategies. Despite conducting cross-cultural training, the lack of senior management support and continuous resource investment led to suboptimal training outcomes. Within two years, AXA's customer satisfaction only increased by 5%, and its market share decreased from 18% to 16%. The main reasons for failure were insufficient senior management support, training content disconnected from actual work, lack of continuous communication optimization, and employee resistance to cross-cultural communication strategies.

5. Empirical Research Results

5.1 Cultural Adaptability Strategies

Cultural adaptability adjustments are crucial for reducing cultural conflicts and enhancing corporate competitiveness. Empirical research on 10 multinational companies revealed that companies implementing cultural adaptability strategies experienced a 30% reduction in cross-cultural team collaboration conflicts. For

example, Lenovo improved production efficiency by 15% and increased employee satisfaction from 70% to 85% by adjusting management processes to accommodate diverse working habits. Cultural adaptability assessment tools can accurately identify potential cultural conflict risks and facilitate targeted resolutions.

Developing cultural sensitivity training courses for employees is essential for enhancing cross-cultural capabilities. Research data show that employees who participated in cultural sensitivity training increased their effective communication ratio in cross-cultural interactions from 60% to 80%. For instance, Ping An Insurance improved its employee customer satisfaction in handling international business from 75% to 90% through a three-month training program. The training content includes cultural difference awareness, cross-cultural communication skills, and case analysis of cultural adaptability. (Harris & David V. Collings, 2019)

5.2 Communication Optimization Strategies

Designing effective communication mechanisms significantly enhances internal and external communication efficiency. Companies implementing optimized communication mechanisms shortened project delivery time by an average of 20%. For example, BYD reduced its project delivery time from 30 days to 24 days and increased its project success rate from 70% to 85% by introducing cross-cultural communication platforms and regular meetings. Establishing cross-cultural communication feedback mechanisms allows companies to promptly identify and resolve communication issues, further improving efficiency.

Training employees in cross-cultural communication skills is vital for enhancing corporate competitiveness. A questionnaire survey of 500 employees revealed that those who participated in cross-cultural communication skills training increased their success rate in cross-cultural projects from 65% to 80%. For example, a multinational manufacturing company increased its communication efficiency with international suppliers by 30% and supplier satisfaction from 70% to 85% through training. The training content includes cross-cultural communication models, cultural adaptability skills, and conflict resolution methods.

5.3 Training and Development

Developing cross-cultural training programs significantly enhances employees' cross-cultural communication capabilities and global vision. Research data show that employees who participated in cross-cultural training programs increased their project success rate from 60% to 80% and customer satisfaction from 70% to 85%. For example, McDonald's improved its employee customer satisfaction in handling international business from 70% to 85% through cross-cultural training programs. The training content includes cross-cultural psychology, management skills, and international business etiquette.

Table 3.

Project	**Data Value**
Training Success Rate Before Training	60%
Training Success Rate After Training	80%
Customer Satisfaction Before Training	70%
Customer Satisfaction After Training	85%

Integrating cross-cultural capabilities with employee career development planning is an effective means of enhancing corporate competitiveness. Research findings indicate that companies implementing cross-cultural career development plans reduced employee turnover rates by 20%. For example, Lenovo reduced its employee turnover rate from 15% to 12% and increased employee satisfaction from 70% to 85% through these plans. Career development plans include cross-cultural capability assessments, training paths, and promotion mechanisms, motivating employees to enhance their cross-cultural capabilities and improving overall corporate competitiveness. (Harris & David V. Collings, 2019)

6. Conclusions and Future Work

6.1 Research Conclusions

This study systematically explores the role of cross-cultural communication strategies in enhancing the global competitiveness of American MNCs through theoretical and empirical research. The findings demonstrate that cultural adaptability, communication optimization, and cross-cultural training strategies significantly enhance companies'

cross-cultural capabilities and global competitiveness. Specifically, companies implementing cultural adaptability strategies reduced cross-cultural team collaboration conflicts by 30% and increased production efficiency by 15%; optimized communication mechanisms shortened project delivery time by 20% and increased project success rates from 70% to 85%; cross-cultural training programs increased employee project success rates from 60% to 80% and customer satisfaction from 70% to 85%. These results highlight the importance of cross-cultural communication strategies in enhancing the global competitiveness of American MNCs. (C., L., & Thakkar, B., 2012)

The theoretical contribution of this study lies in proposing a systematic framework of cross-cultural communication strategies, enriching cross-cultural management and international business theories. By integrating cross-cultural psychology, management theory, and international business theory, this study provides a new perspective for understanding the cultural adaptability of multinational corporations in the context of globalization. In practice, this study verifies the effectiveness of cross-cultural communication strategies through empirical research, offering actionable solutions for companies to better cope with cultural differences, enhance cross-cultural team collaboration efficiency, increase customer satisfaction, and gain competitive advantages in the global market.

6.2 Research Limitations

Despite the achievements of this study, there are some limitations. First, the research samples are primarily from American MNCs in the technology, finance, and manufacturing sectors, and the applicability to other industries requires further verification. Second, the research time span is relatively short, and the long-term effects of cross-cultural communication strategies have not been fully assessed. Additionally, the study relies mainly on internal company data and employee feedback, with insufficient attention to external stakeholders such as customers and suppliers.

6.3 Future Outlook

In the context of deepening globalization, cross-cultural communication capabilities have become a key factor for multinational corporations to succeed in the global market. The cross-cultural communication strategies proposed in this study provide theoretical support and practical guidance for American MNCs. By continuously optimizing cultural adaptability, communication mechanisms, and employee training, companies can better cope with cultural differences and enhance their global competitiveness. Future research can expand the sample scope to cover more industries and company sizes to verify the universality of cross-cultural communication strategies. The research time span can be extended to track the long-term effects of these strategies, especially their impact on corporate sustainable development. Additionally, future research can pay more attention to external stakeholders' perspectives to comprehensively assess the impact of cross-cultural communication strategies on overall corporate competitiveness. Finally, with the development of digital and artificial intelligence technologies, future research can explore the application of these new technologies in cross-cultural communication, providing more forward-looking solutions for companies.

References

C., L., & Thakkar, B. (2012). The Impact of Globalization on Cross-Cultural Communication. *InTech.*

Jin young Hwang. (2024). Cross-cultural communication in global business. *GSC Advanced Research and Reviews, 21*(03), 457-469. DOI: 10.30574/gscarr.2024.21.3.0481

Harris and David V. Collings. (2019). Cross-Cultural Management: Critical Perspectives on Business and Management Paul. Routledge.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

The Inside Job or Outside Rule: How Six Governance Forces Shape UK Board Independence?

Runmin Qiu[1]

[1] Johns Hopkins Bloomberg Center, Carey Business School, Johns Hopkins University, 555 Pennsylvania Avenue NW, Washington, DC 20001, USA
Correspondence: Runmin Qiu, Johns Hopkins Bloomberg Center, Carey Business School, Johns Hopkins University, 555 Pennsylvania Avenue NW, Washington, DC 20001, USA.

doi:10.56397/JWE.2025.08.04

Abstract

This research explores how the proportion of independent directors on UK-listed company boards relates to six key institutional dimensions—public participation, political stability, government effectiveness, regulatory quality, rule of law, and anti-corruption control—drawing on agency theory and resource dependence perspectives. Using panel data from non-financial firms listed on the London Stock Exchange (2013-2023), we extract independent director ratios from annual reports and combine them with the World Bank's Global Governance Indicators to quantify institutional quality. Our analysis employs double fixed-effects regression models and other techniques to effectively control for time and firm-specific heterogeneity. These findings reveal that while political stability significantly encourages the appointment of independent directors, the other five institutional dimensions show strong negative substitution effects. Notably, these institutional responses show no significant variation across firms of different sizes. Based on these results, the paper proposes a novel, integrated framework for board independence within a multi-dimensional regulatory system. Importantly, feasible decision-making references for investors to optimize governance risk assessment, corporate executives to adjust board composition, and regulatory authorities and industry associations to synchronously improve governance guidelines and information disclosure. In summary, this paper contributes uniquely by constructing a comprehensive multi-dimensional governance framework, integrating six distinct forces, and demonstrating how their interplay—particularly between regulatory enforcement and investor incentives—generates non-linear impacts on board independence.

Keywords: board independence, national governance quality, corporate governance, substitution effects, double fixed-effects model

1. Introduction

Corporate governance research has gradually expanded from an "internal perspective" to an "institutionally sensitive perspective," emphasizing the decisive role of the national governance environment in determining board structure and oversight intensity (Fauver et al., 2016; Neville et al., 2018). Building on agency theory and resource dependence theory, scholars suggest that while independent directors can reduce agency costs and coordinate external

resources, their marginal value hinges critically on national governance quality (Hu et al., 2022; Dahya et al., 2019). Evidence from cross-national studies further underscores the complexity of this relationship: robust rule of law and strict regulatory enforcement appear to lessen firms' reliance on independent directors, whereas sustained political stability enhances their strategic value in securing legitimacy (Bowen & Taillard, 2025). However, existing research typically focuses on single or dual institutional factors, leaving unexplored how a multidimensional governance landscape collectively shapes board independence. To address this research gap, this study examines the comprehensive impact of the World Bank's six governance indicators—Voice and Accountability (VA), Political Stability and Absence of Violence/Terrorism (PS), Government Effectiveness (GE), Regulatory Quality (RQ), Rule of Law (RL), and Control of Corruption (CC)—on the proportion of independent directors using a sample of UK listed companies.

The core question of this study is: How do the six dimensions of national governance—public participation (VA), political stability (PS), government effectiveness (GE), regulatory quality (RQ), rule of law (RL), and corruption control (C)—influence the proportion of independent directors in listed companies? This paper hypothesizes that in any scenario where external governance is strengthened, firms' reliance on independent directors as an internal monitoring mechanism will significantly decrease (H1–H6). The paper selects a sample of non-financial UK listed companies from 2013 to 2023, extracts the proportion of independent directors from annual reports, and obtains scores for the six institutional dimensions from the World Bank's "Global Governance Indicators." It controls for variables such as profitability, leverage levels, liquidity, cash flow, bankruptcy risk, GDP growth rate, inflation rate, and exchange rate volatility, and employs both company-level and year-level fixed effects.

Although scholars have been studying the relationship between external regulatory quality and corporate governance outcomes (including the proportion of independent directors) since the last century, current research still has limitations. First, some studies focus only on exploring one or two of the six regulatory dimensions, thereby failing to comprehensively examine the relationship between the two. For example, Wu et al. (2021) employed a three-level model (firm-year-country) using the World Bank's "regulatory quality" and "rule of law" indicators to measure the institutional environment and investigated its relationship with the proportion of independent directors. Second, even though some studies adopt a multi-dimensional institutional perspective, they have not been fully integrated with board composition research: Li, Zhou, Ling et al. (2025) conducted a one-dimensional grouping analysis based on regulatory quality when discussing financial asset allocation, while Bao et al. (2025) did not simultaneously incorporate macro-level institutional variables such as public participation or political stability when exploring the issue of independent director re-election. Third, research on the interaction between macroeconomic shocks such as inflation and exchange rates and corporate governance remains scarce. Dokas (2023) revealed the mediating role of corruption levels in profit management but did not examine its transmission effects on board independence; Bowen and Taillard (2025) re-evaluated mandatory independent director requirements but did not consider macroeconomic uncertainty. Therefore, no study has yet compared the six dimensions with the proportion of independent directors, nor has it systematically tested the heterogeneity of governance strategies across firms of different sizes within this multidimensional institutional framework.

The macroeconomic environment in the United Kingdom during the study period (2013–2023) influenced board composition: over the decade, the UK's average annual GDP growth rate was only 1.31%, but the standard deviation was as high as 4.54 percentage points, indicating that multiple economic cycles posed significant challenges to corporate expansion and investment decisions. During the same period, the average inflation rate was 3.30%, with a standard deviation of 3.06%, far exceeding the long-term target of 2%, particularly during the period from 2017 to 2022 when it peaked at over 9%, forcing companies to frequently adjust their cost control and pricing strategies. In terms of exchange rates, taking the pound sterling against the US dollar as an example, the average depreciation was 2.33%, with a standard deviation of 5.92%, exacerbating uncertainty in cross-border trade and financing. Overall, the sample companies studied in this paper operate

in a national environment characterized by both well-established institutions and significant macroeconomic volatility.

Research has found that six national governance quality indicators have a significant substitution or reinforcing effect on the proportion of independent directors in UK listed companies. Specifically, when public participation increases, companies reduce their allocation of independent directors, indicating that external public oversight can partially replace internal board monitoring; when political stability improves, companies increase their allocation of independent directors to obtain policy legitimacy and resource support; and improvements in government efficiency, regulatory quality, rule of law, and anti-corruption controls all significantly reduce companies' demand for independent directors, reflecting that the higher the strength of external institutions, the higher the cost of internal monitoring.

This paper fills a gap in current corporate governance research by examining the relationship between the six dimensions of regulatory quality and board independence. For institutional investors, they can draw on the insights from this study to understand the multifaceted impact of independent director appointments on risk and value protection and optimize their investment research models to accurately assess how changes in the institutional environment affect the proportion of independent directors in corporate governance (Bao et al., 2025). For company executives, the research indicates that enhancing regulatory quality and the rule of law can partially substitute for internal oversight functions within the board of directors, enabling companies to adjust the proportion of independent directors during institutional upgrades based on sound rationale (Ramachandraiah et al., 2025). This allows limited independent director resources to be allocated toward business innovation and strategic execution to enhance operational efficiency. Regulatory authorities should note that the critical role of independent directors in ensuring regulatory compliance must not be overlooked. When revising governance guidelines and prudent regulatory policies, they should concurrently improve disclosure and accountability mechanisms to strengthen the synergistic effects between external systems and internal governance (Deloitte & The Wall Street Journal, 2024).

2. Institutional Regulatory Quality

From 2013 to 2023, the UK consistently ranked in the top 10% globally in the WGI's "Voice and Accountability" category, indicating that democratic channels remain open and accessible. According to ACLED statistics, the number of domestic protests increased from 482 in 2013 to 1,243 in 2022, with a cumulative total of approximately 9,150 over the decade, representing an annual growth rate of over 10%; Political issues accounted for over 60% of these protests. High voter turnout also reflects the level of engagement: the 2014 Scottish independence referendum saw an 84.6% turnout, while the 2016 Brexit referendum had a 72% turnout. In 2019, the "People's Vote" march attracted over a million people in a single day, setting a record for peaceful demonstrations in the UK. In the same year, Extinction Rebellion occupied the streets of London for two consecutive weeks, and the court ultimately ruled that the police ban was illegal, highlighting the judiciary's protection of freedom of assembly.

In 2013, the UK ranked near the 70th percentile in the WGI's "Political Stability" category, but the 2016 Brexit referendum sparked significant uncertainty: the pound plummeted by 9.7% that evening (Bloomberg, 2016), and three changes of prime minister between 2016 and 2019 caused the indicator to drop to approximately 55% in 2019 (World Bank, 2024). Political-related protests and violent incidents recorded by ACLED also rose from 212 in 2015 to 653 in 2019, reflecting the rapid escalation of social divisions (ACLED, 2024). The formal signing of the UK-EU Trade and Cooperation Agreement in 2021 mitigated the risk of a hard Brexit, leading the indicator to rebound to 62.1% in 2023 (Cabinet Office, 2021; World Bank, 2024). Although the overall security situation remains at a low level among developed economies, the Global Peace Index has downgraded the UK's risk level to "moderate" since 2018 and maintained this rating from 2020 to 2023 (IEP, 2024).

From 2013 to 2023, the UK has remained relatively stable in the WGI "Government Effectiveness" indicator, ranking between the 85th and 90th percentiles globally. Its high effectiveness is primarily reflected in three areas. First, crisis response: The Medicines and Healthcare products Regulatory Agency (MHRA) completed a double-blind data review in just three months, becoming the first in the world to approve an mRNA vaccine in December

2020, highlighting the speed of regulatory decision-making (DHSC, 2020). Second, policy implementation: The Treasury launched the "Levelling-up Fund" and the "Green Industrial Revolution Ten-Point Plan" in 2021, which were recognized by the OECD as a model for green transition governance (OECD, 2022). Third, digital government: In 2023, "Gov.uk One-Login" was launched, enabling single sign-on for tax, visa, and medical appointments. An official survey showed that user satisfaction exceeded 80% (Cabinet Office, 2023). However, large-scale infrastructure projects have exposed shortcomings: The National Audit Office (NAO) noted that the HS2 high-speed rail phase two project faced a 40% cost overrun and further delays, leading to a slight decline of approximately 0.07 points in government efficiency scores between 2020 and 2022 (NAO, 2022; World Bank, 2024).

In 2013, the UK ranked around the 95th percentile globally in the WGI's "Regulatory Quality" category, but the Brexit process has undermined policy consistency: the number of customs entry and exit documents between the UK and the EU has increased from 1 to 8. According to a 2024 survey by the British Chambers of Commerce (BCC), 62% of surveyed businesses cited "frequent changes in regulations" as their top compliance challenge (BCC, 2024). As a result, the indicator's estimated value declined from +1.65 to +1.38 between 2016 and 2023, with the percentile dropping to 82 (World Bank, 2024). Despite the 2021 Financial Services Act granting the FCA and PRA greater autonomy, and the OECD's positive endorsement of the "flexible regulatory sandbox" (OECD, 2022), the 2022 "mini-budget" triggered significant volatility in the pound and government bonds, Standard & Poor's subsequently downgraded the UK's "regulatory predictability" rating from 'high' to "medium-high" (Standard & Poor's, 2022).

In 2013, the UK's "rule of law" valuation in the WGI was approximately +1.55; by 2023, it had fallen to +1.46, with the percentile ranking dropping by 4 points (World Bank, 2024). Two landmark rulings shed light on the context of this decline: in 2019, the Supreme Court ruled 11–0 that the Prime Minister's forced suspension of Parliament was unlawful (UK Supreme Court, 2019); in 2023, it again rejected the Rwanda deportation plan for immigrants (UK Supreme Court, 2023). While this highlights judicial independence, it also exposes the tension between the executive and judicial branches, sparking concerns about the predictability of policy. Additionally, the Metropolitan Police was found by an independent investigative body in 2022 to have a culture of systemic discrimination and sexual harassment, leading to public evaluations of the fairness of law enforcement dropping to a ten-year low (IOPC, 2022).

In 2013, the UK scored approximately +1.42 on the WGI "Anti-Corruption Controls" indicator, ranking in the top 10% globally; however, from 2018 to 2023, there was a significant decline: the score dropped to +1.10, and the percentile fell to 77 (World Bank, 2024). Transparency International's CPI score also dropped from 80 (2018) to 75 (2023), the lowest since the 2012 baseline (Transparency International, 2024). This downward trend is closely linked to a series of high-profile scandals: the "Partygate" scandal exposed gatherings at the Prime Minister's residence during the COVID-19 lockdown (Ipsos MORI, 2022); The National Audit Office revealed a "fast-track" procurement process for personal protective equipment (PPE), with 14 contracts bypassing competitive procedures (NAO, 2021); and the 2023 "cash-for-inquiries" case involving opaque political donation practices (Guardian, 2023).

A comprehensive analysis of the six major governance dimensions from 2013 to 2023 reveals that the UK's external institutional framework exhibits a pattern of "high standards but localized imbalances": while maintaining high levels of democratic vitality, administrative efficiency, and judicial independence, there has been a marginal weakening in regulatory consistency and integrity, providing a "strong institutional framework but divergent risk profiles" as the external backdrop for corporate governance strategies.

3. Literature Review and Hypothesis Development

3.1 Research Background

Regulatory quality, as the core embodiment of fairness and efficiency in government policy implementation (North, 1990), profoundly affects national economic development and firm performance through multidimensional mechanisms. At the macro level, there is a significant positive correlation between regulatory quality and national economic competitiveness. Brunet et al.'s (2012) study of the new EU member states shows that higher

levels of regulation can directly bring about an 18% improvement in the efficiency of resource allocation and a 2.3-basis-point increase in the competitiveness index, as well as enhance economic resilience through greater institutional stability. However, this effect exhibits a nonlinear character: Mokhtarifar et al. (2023) find that moderate regulation significantly promotes growth in countries with weaker institutions, but excessive regulation may dampen market dynamism in institutionalized environments. Rodrigo et al. (2009) emphasize that low-quality regulation resulting from dysfunctional governance at multiple levels not only fails to serve the public interest, but instead serves as a source of economic stagnation and social drivers of escalating costs.

The quality of corporate governance and the effectiveness of national regulatory systems as a guarantee of firm performance (Rahman, 2017), especially after the revelation of global financial scandals such as Enron and Marconi (Khanchel, 2007; Turrent & Ariza, 2016) have triggered a wider discussion. A particular distinction needs to be made: at the national level, regulatory quality is reflected in the binding effect of institutions on the free market; at the firm level, governance quality is reflected in the degree of sophistication of internal oversight mechanisms, including board independence and information disclosure. For example, Klapper and Love (2004) construct a corporate governance scoring system, and there is a huge discrepancy in the level of corporate governance among the emerging market countries they study-Pakistani firms have an average score of only 31.85, while South Korean firms reach 66.53. It is worth noting that this discrepancy does not only stem from the different strengths and weaknesses of national regulatory environments, but is also closely related to firms' internal governance practices. Similarly, Barucci and Falini's (2005) study of Italy and Beiner et al.'s (2006) study of Switzerland suggest that even in developed economies with well-developed regulatory regimes, the actual quality of firms' governance may still be significantly deficient.

While there are numerous ways to assess the impact of the quality of national regulation on the level of corporate governance, board independence is a significantly valid indicator. After the agency theory proposed by Fama and Jensen (1983) provides a solid theoretical foundation for the monitoring function of independent directors, Armstrong's team (2014) confirms through rigorous econometric methods that an increase in the proportion of independent directors significantly reduces agency costs, while Beasley's (1996) study finds that the proportion of independent directors is significantly negatively related to the incidence of financial fraud. Significant negative correlation, and these findings demonstrate a high degree of consistency, all of which indicate a strong correlation between board independence and corporate governance.

Compared to other board characteristics, the findings of studies on board independence are relatively reliable, for example, there is a clear disagreement in studies on board size (Dalton et al., 1999), and the discussion on studies on the integration of the two positions of CEO and chairman is inconclusive (Brickley et al., 1997), while Nguyen and Nielsen (2020) instantly, by analyzing the sudden deaths of independent directors, still validates the continued positive impact of board independence on firm value.

Board independence has a unique policy research value, and major global regulatory systems such as the U.S. SOX Act and the EU Corporate Governance Guidelines have adopted board independence as a core regulatory indicator. Dahya et al.'s (2019) study specifically points out that in countries with transitioning regimes, independence requirements are often an important entry point to regulatory reforms, making it an ideal research to connect the national regulatory environment with corporate governance practices pathway. For these reasons, this study chooses board independence as the core research variable to investigate its relationship with national regulatory quality (Voice and accountability and board independence; political stability; Government effectiveness; Regulatory quality; The rule of law; Corruption).

3.2 The Country's Regulatory Quality and Board Independence

3.2.1 Voice and Accountability

At the core of citizen expression and government accountability is the ability of citizens to participate in public decision-making through free voice (e.g., elections, media scrutiny) (citizen expression), and institutionalized mechanisms for governments to accept scrutiny and respond to demands (government accountability). (Menocal et al., 2012) The effectiveness of board

independence is highly dependent on the supporting support of external accountability mechanisms. In the Anglo-American corporate governance system, independent directorship and mandatory disclosure (e.g., SOX in the U.S.) form a complementary relationship, and the synergistic effect of the two significantly enhances the effectiveness of monitoring by independent directors (Aguilera et al., 2008); conversely, for example, in Aoki's (2001) study, in Japanese firms, the "voice and accountability" is replaced by the "voice and accountability" of the board of directors. "Voice and accountability" in Japanese firms, for example, the main bank and employee participation weakened the need for independent directors, thus reducing managerial efficiency and governance capacity. External accountability mechanisms affect board independence through regulatory costs Zhang (2005). In low accountability environments, firms tend to resist independent directorships in order to circumvent disclosure costs in order to maintain control (Lang & Lundholm, 2000). In contrast, in high accountability environments, firms obtain better disclosure and win investors' favor through high-cost regulation (including features such as having a more independent board).

Firm life cycle characteristics significantly affect the role of accountability mechanisms receive many influencing factors. Mature firms are resource-rich and able to respond effectively to high-cost external accountability requirements (Dalton et al., 1999), allowing independent directors to fully utilize their oversight function; conversely, they may adopt a strategy of greater insider control or reliance on venture capital because external accountability may interfere with their strategic flexibility (Filatotchev & Bishop, 2002). These findings suggest that the governance effectiveness of board independence depends not only on its institutional design per se, but is also closely related to contextual factors such as the institutional environment of external accountability mechanisms, cost constraints, and the stage of firm development. In addition, voice differences across countries directly affect the way board independence is implemented through policy instruments leading to divergent effects of independent director institutional transplantation (Aguilera & Cuervo-Cazurra, 2004). In contrast, flexible accountability mechanisms are more conducive for independent directors to adapt to local conditions (Arcot & Bruno, 2006). Based on this, this study proposes:

Hypothesis 1: Better regulatory quality strengthens board independence.

3.2.2 Political Stability

Political stability is the ability of a political system to maintain its basic structure and functioning through a continuous, nonviolent process of value allocation (Ake, 1975). Leuz et al. (2006) show that in politically unstable countries such as Argentina and Egypt, the proportion of politically connected directors in privatized firms is on average 15% higher than in stable countries, whereas the proportion of independent directors is significantly lower by 22%. This substitution effect is particularly pronounced in times of crisis, such as during regime change in Argentina, where the proportion of politically connected directors on corporate boards increased from 30% in the stabilization period to 45%, while the proportion of independent directors decreased from 40% to 22% (Megginson et al., 2001).

Political stability significantly affects board independence through the mediating role of politically connected directors (La Porta et al., 1998). In politically unstable environments, firms are exposed to the risks associated with policy uncertainty. This can motivate firms to adopt politically connected strategies, especially to gain political patronage by appointing directors with governmental background. This strategic choice directly affects the composition of the board: the proportion of politically connected directors increases significantly, while the number of independent directors decreases accordingly (Faccio et al., 2006). This effect is realized through two main mechanisms: the first is the substitution of political intervention for market oversight. In environments with weak institutions, politically connected directors can directly intervene in corporate decision-making, including important matters such as strategy formulation and executive appointments (Boubakri et al., 2008). The second is the compliance avoidance strategy. Firms often adopt superficial compliance practices in order to balance international normative requirements with the need for political survival. A more subtle approach includes the appointment of potentially politically connected individuals, such as relatives of government officials, as independent directors, which was found to account for as much as 32% of "connected independent

directors" (Khanna et al., 2000). Based on this, this study proposes:

Hypothesis 2: Better political stability strengthens board independence.

3.2.3 Government Effectiveness

Government effectiveness is the ability of government institutions to formulate high-quality policies, carry out public management functions effectively, and ensure reliable delivery of public services (Garcia-Sanchez et al., 2013). Highly effective governments with good institutional governance are better able to safeguard board independence (Aggarwal et al., 2011). It directly constrains the corporate governance structure through normative pressures that push some firms to comply with corporate law and securities regulations, and by establishing requirements such as minimum ratios of independent directors. On the other hand, firms in high-performance government environments often take the initiative to increase the number of independent directors to comply with market norms and enhance legitimacy. For example, Okhmatovskiy et al.'s (2012) study of transition economies in Eastern Europe shows that in countries with higher government effectiveness (e.g., Poland, Estonia), state-owned enterprises (SOEs) are quicker to adopt independent directorships due to EU access pressure. This is because their policy stability and internationalized business environments encourage firms to optimize their board structures in order to gain access to resources. Enterprises wishing to attract international capital (e.g., cross-border listings) often need to meet global governance standards. The expectations of foreign investors are met by increasing the proportion of independent directors. As Aggarwal et al. (2011) find, in countries with high government effectiveness, US-listed firms proactively increase the number of independent directors to meet SEC requirements. In addition, firms in such environments are more willing to invest in long-term governance mechanisms, and firms create more independent directors with specialized knowledge and outside resources to facilitate the firm's response to increased risk and competition (Bushman et al., 2004). Dermirgüç-Kunt's team (2019) reported at the World Bank that firms in high-performance countries (e.g., Denmark), in an effort to mitigate policy risks and prefer market-based governance mechanisms such as independent directors.

Government effectiveness indirectly affects board independence by reducing political interference and enhancing investor protection. In inefficient government environments, firms face chaotic market conditions, collusion between government and business, and other disruptions. They may rely on politically connected directors rather than independent directors to gain advantages such as franchises and policy incentives, thus weakening board independence (Fan et al., 2007). On the contrary, high-performance governments usually have more transparent administrative systems and rule of law environments, which reduce firms' reliance on political connections and make them more inclined to introduce independent directors to optimize corporate governance and reduce agency costs. In addition, high-performance governments tend to be accompanied by stricter investor protection systems (e.g., disclosure requirements, minority shareholder litigation rights), which further incentivize firms to enhance monitoring and market trust through the mechanism of independent directors (La Porta et al., 1998). Neville et al. (2018) also find that in countries with high levels of rule of law, independent directors have a more significant impact on corporate misconduct. inhibition is more significant. Based on this, this study proposes:

Hypothesis 3: Better government effectiveness strengthens board independence.

3.2.4 Regulatory Quality

The definition of regulatory quality has been expressed above. Regulatory Quality affects Board Independence mainly through both direct policy intervention and indirect institutional environment. Good regulatory quality tends to have strict regulatory policies (e.g., mandatory independent director ratio requirements) that can significantly enhance board independence, e.g., Chen et al. (2014) found that China's 2001 regulatory reforms that mandatorily increased the proportion of independent directors effectively reduced surplus management behaviors of listed companies. Similarly, Jiraporn et al. (2017) show, based on evidence from the Thai market, that a policy of mandatory appointment of independent directors effectively reduces firms' reliance on external audits. In terms of indirect effects, countries with high regulatory quality usually have stronger rule of law environments and market oversight mechanisms, and independent directors can

effectively play a supervisory role to strengthen corporate governance. A cross-country study by Uribe-Bohorquez et al. (2018) finds that board independence contributes more significantly to firm performance in countries with higher regulatory quality, suggesting that strict regulation has a moderating effect on the performance of independent directors' functions. In addition, Wu (2021) further suggests that country governance quality significantly affects the effectiveness of corporate governance structure, especially in emerging markets, where improved regulatory quality helps to mitigate the interference of large shareholders or management in independent directors. Based on this, this study proposes:

Hypothesis 4: Better regulatory quality strengthens board independence.

3.2.5 The Rule of Law

The definition of regulatory quality has been expressed above. Regulatory Quality affects Board Independence mainly through both direct policy intervention and indirect institutional environment. Good regulatory quality tends to have strict regulatory policies (e.g., mandatory independent director ratio requirements) that can significantly enhance board independence, e.g., Chen et al. (2014) found that China's 2001 regulatory reforms that mandatorily increased the proportion of independent directors effectively reduced surplus management behaviors of listed companies. Similarly, Jiraporn et al. (2017) show, based on evidence from the Thai market, that a policy of mandatory appointment of independent directors effectively reduces firms' reliance on external audits. In terms of indirect effects, countries with high regulatory quality usually have stronger rule of law environments and market oversight mechanisms, and independent directors can effectively play a supervisory role to strengthen corporate governance. A cross-country study by Uribe-Bohorquez et al. (2018) finds that board independence contributes more significantly to firm performance in countries with higher regulatory quality, suggesting that strict regulation has a moderating effect on the performance of independent directors' functions. In addition, Wu (2021) further suggests that country governance quality significantly affects the effectiveness of corporate governance structure, especially in emerging markets, where improved regulatory quality helps to mitigate the interference of large shareholders or management in independent directors. Based on this, this study proposes:

Hypothesis 5: Better the rule of law strengthens board independence.

3.2.6 Corruption

The essence of corruption as a systemic flaw lies in the alienation of the principal-agent relationship of public power, whereby those exercising the power breach their public fiduciary duties by turning administrative discretion, which should be used to promote public welfare, into a tool for private gain. This alienation of power not only undermines the legal framework for contract enforcement, but also forces firms to incur additional expenses, including the cost of bribery, compliance risk premiums, and systemic transaction costs, in order to obtain market access, business licenses, and other benefits that they should have obtained under the law (Shleifer & Vishny, 1993). Existing research suggests that corruption undermines the governance efficacy of board independence through a number of mechanisms. First, in environments where corruption is prevalent, informal rules such as bribery often substitute for formal governance mechanisms, resulting in the hollowing out of independent directors' oversight functions. For example, in industries where government approvals are highly regulated, firms may be more inclined to obtain licenses by paying bribes rather than relying on the professional compliance advice of independent directors, thus marginalizing independent directors in key decisions (Sena et al., 2018). Second, independent directors' motivation to perform their duties can be thwarted by rampant corruption. When legal and enforcement mechanisms are ineffective, independent directors find it difficult to effectively check and balance the misbehavior of management as well as other shareholders, and may even choose to perform their duties negatively due to their inability to drive substantive decisions (Dokas, 2023). In addition, corrupt environments can lead firms to prefer appointing "nominal independent directors" with political affiliations rather than truly independent professionals to accommodate corrupt transactions, or worse, highly reputable independent directors may avoid such firms, further reducing the overall independence of the board (Rashid & Hossain, 2021). Based on this, this study proposes:

Hypothesis 6: Better corruption control strengthens board independence.

3.2.7 Conclusion

Based on the characteristics of the UK sample in this study, six main effect hypotheses (H1–H6) are proposed: public participation, government effectiveness, regulatory quality, rule of law, and anti-corruption controls have a substitution effect on the proportion of independent directors, while political stability has a reinforcing effect. During the research process, the relationship between external governance and independent directors, as well as the research history, were systematically reviewed from two perspectives: agency costs, where independent directors reduce conflicts between management and shareholders through supervisory mechanisms, and resource dependency theory, where independent directors can introduce policy, reputation, and network resources to the company. Addressing the limitations of existing research, which often focuses on a single institutional dimension or is constrained by performance metrics, we propose hypotheses to examine the relationship between the six dimensions of national governance quality and board independence. This forms the basis for a research design model where "independent directors serve as the dependent variable, multi-dimensional institutions as the independent variables, and macroeconomic risks as the control variables."

4. Data and Sample Collection

This study has selected 100 non-financial firms as my research sample. I set the sample size at 100 because it meets the basic requirements of statistical analysis and ensures the reliability of data analysis. Non-financial firms were chosen because the financial characteristics, regulatory environment and capital structure of financial firms are significantly different from other industries. When the companies were screened, we excluded the samples with abnormal financial data and finally retained 100 companies with complete data as the object of analysis.

This study uses the UK FTSE index constituents (FTSE 350) as the sample base. They include large blue-chip stocks, excellent mid-sized companies respectively, which can fully reflect the characteristics of different sizes of listed companies in the UK. FTSE index constituents have high market representativeness and data reliability, and it covers the listed companies with the largest market capitalization and the best liquidity in the UK stock market. In the research process, the financial data disclosure of FTSE constituent stocks is standardized and easy to obtain, which is conducive to ensuring the reliability and authenticity of the analyzed data.

This study has selected 2013 to 2023 as the sample period mainly to minimize the impact of the volatility of the new crown epidemic (2020-2021). The length of the ten-year period can provide enough analyzed data to meet the requirement of statistical reliability, and at the same time, avoid the disturbance caused by the long-time span that results in encompassing more big events with sudden shocks. The disclosure standard of relevant financial data within the period is relatively uniform, ensuring data reliability and continuity.

My data samples in this study are sourced from the global authoritative financial databases Bloomberg and Refinitiv. As internationally recognized professional financial data platforms, the data sources can provide instant, high-quality and standard financial data of listed companies around the world to ensure the accuracy of the research data. They comply with strict exposure and verification processes to maximize data authenticity and provide complete historical company financial data and relevant market and industry trading information.

5. Research Methodology

5.1 The Measurements of Independent Variables

This study uses data on six indicators from the Worldwide Governance Indicators (WGI) [1] as independent variables to measure the quality of governance in different countries during 2013 to 2023. The Worldwide Governance Indicators (WGI) is a six-dimensional framework developed by the World Bank to measure the quality of countries' institutions, assessing the quality of a country's institutions in a comprehensive manner from different perspectives of voice and accountability (VA), political stability (PS), government efficiency (GE), regulatory quality (RQ), rule of law (RL), and corruption (C),

[1] The Worldwide Governance Indicators are a World Bank dataset that reports aggregate and individual governance indicators for over 200 economies since 1996. https://info.worldbank.org/governance/wgi/

respectively. In Cuervo-Cazurra and Genc (2008) and Kaufmann et al.'s (2009) studies, these six indicators of the WGI are also used to measure national governance quality indicators.

This study constructs a core system of independent variables based on Worldwide Governance Indicators, which mainly contains six dimensions of governance indicators. Voice and accountability and board independence reflect the degree of citizens' participation in political decision-making and the independence of oversight mechanisms in corporate governance. It can be measured by indicators such as citizens' political participation at the national level and media freedom; Political stability refers to the stability of government governance and social order. It is assessed using data such as the government stability index and the incidence of social violence; Government effectiveness reflects the efficiency of the government in providing public services and policy implementation. I will look at the quality of public services (including infrastructure coverage, World Health Organization scores, and teacher attendance in the World Bank's Service Delivery Indicator Survey) (Rajkumar & Swaroop, 2002), policy formulation capacity (including policy responsiveness, policy continuity, and integrity of strategic planning) (Andrews et al., 2017), and administrative efficiency (including the average length of time for business establishment approval) (Andrews et al., 2017), and administrative efficiency (including the average length of time for business establishment approval). (Kaufmann et al., 2010) are quantified in three dimensions; Regulatory quality assesses the level of government regulation of market behavior. This study focuses on the market regulation index and the related administrative approval efficiency; The rule of law measures the degree of society's compliance with legal rules. It can be measured by indicators such as judicial independence, property rights protection and contract enforcement efficiency; Corruption reflects the level of public sector integrity. In turn, it is assessed based on the public sector integrity and business corruption index.

5.2 The Measurements of Dependent Variable

As the core of corporate governance, the level of board independence can have a systematic impact on corporate operations. Existing research suggests that when board independence is high (≥50% of independent directors), it can significantly improve corporate governance effectiveness. Weisbach (1988) found that boards with a high percentage of independent directors are more likely to fire underperforming CEOs, which is when impediments to firm growth are removed by enhancing monitoring effectiveness. A high index promotes decision quality, and Armstrong et al. (2010) confirm that highly independent boards can significantly reduce connected transactions. Nguyen and Nielsen (2010) show that abnormal returns during surplus announcements are on average 1.8 percentage points higher for such firms. Conversely, low independence boards (≤30% of independent directors) tend to be accompanied by governance deficiencies, with Bebchuk and Fried (2004) showing that the probability of their CEOs being overcompensated is 2.3 times the industry average, and Dyck et al. (2017) finding that the risk of financial fraud rises to 1.8 times. Notably, related studies reveal an inverted U-shaped relationship between the board independence index and firm value, with Wintoki et al. (2012) measuring the optimal range of the index as 60-65%, and if it exceeds 75%. It may be negatively impacted by a decline in decision-making efficiency (Faleye et al., 2018). This relationship is also moderated by other factors such as institutional investor holdings and other contextual factors, suggesting the need to dynamically assess the level of independence (Chen et al., 2021).

5.3 The Collection of Control Variables

To improve the statistical significance of the model's findings and to reduce the influence of heterogeneity among individual sample observations on the precision of the model estimates, control variables were incorporated into the empirical analysis (Wooldridge, 2019). In my study, several control variables are selected based on the criteria proposed by Angrist and Pischke (2009). First, at the micro level, return on assets (ROA), a core measure of corporate profitability, has a bidirectional causal relationship with corporate governance quality (Adams et al., 2010; Chen et al., 2021); leverage ratios reflect capital structure characteristics, and high leverage may both reinforce the need for monitoring (Jensen, 1986) and lead to investment deficiencies (Myers, 1977); current ratio and cash flow capture a firm's short-term solvency and cash sufficiency, respectively (Dittmar & Mahrt-Smith, 2007; Opler et al., 1999); and firm size (market capitalization) is treated by natural

logarithms in order to control for size effects (Demsetz & Lehn, 1985); Z-value ratios are used to assess financial risk, with a larger measure indicating a lower probability of bankruptcy (Altman, 1968; Shumway, 2001). At the macro level, I will include GDP growth rate, inflation rate and exchange rate fluctuations in the model to control for the effects of systematic factors such as economic cycles (Bartram et al., 2012), price level changes (Bhamra, 2010) and exchange rate risk (Gulen., 2019).

5.4 Empirical Methodology

This study empirically analyzes the fixed effects model with dual clustering of firm and year, a modeling setup with multiple theoretical advantages and practical value. The fixed-effects model is able to effectively control for two types of potential endogeneity issues: inherent firm characteristics that do not change over time, such as corporate culture and place of incorporation, which can have systematic and long-lasting impacts on firm development; and macro factors that do not change over time, such as fluctuations in the economic cycle and changes in the policy environment (McNeish & Kelley, 2019). This model is particularly suitable for this study to focus on the core topic of "the impact of regulatory quality on board independence" because fixed-effects models can more accurately capture the time-series characteristics of the internal governance mechanisms of firms compared to random-effects models (Wooldridge, 2019). In terms of error treatment, by adjusting the standard errors through dual clustering of firms and years, the model is able to simultaneously address two dimensions of data dependence: not only eliminating serial correlation between observations of the same firm in different years but also controlling for common macro shocks faced by different firms in the same year (Cameron & Miller, 2015), such as new crown epidemics, trade wars, and so on. In terms of technical implementation, the use of heteroskedasticity-robust standard errors (Heteroskedasticity-Robust SE) effectively addresses the problem of conditional heteroskedasticity that is prevalent in panel data, as shown by Han and Kim (2023), which avoids the overestimation of significance levels by traditional standard errors in a dynamic panel setting. Not only that, but the impact of the model also setting on the study results was comprehensively assessed by replacing the measurements of the core explanatory variables, adjusting the sample period and range, and adding or subtracting combinations of control variables in a variety of ways (Lee & Pustejovsky, 2023).

Therefore, our specified model is as follows:

$$board\ independence_{i,t} = \alpha + \beta_1 reguatory\ quality_{i,t} + \Phi\ P + Company\ Effects + year\ effect + \varepsilon_{i,t} \quad (1)$$

There are six separate and alternative models used to proxy for regulatory quality under this model. For each model, we control for a specific set of variables, which are presented below. $\Phi\ P$ is a vector of control variables, and $\varepsilon_{i,t}$ is an error term.

$$BI_{i,t} = \alpha + \beta_1 \text{Voice and Accountability}_{i,t} + \Phi\ P + Banking\ Effects + Year\ effects + \varepsilon_{i,t} \quad (1)$$

$$BI_{i,t} = \alpha + \beta_1 \text{Political Stability}_{i,t} + \Phi\ P + Year\ effects + Banking\ Effects + \varepsilon_{i,t} \quad (2)$$

$$BI_{i,t} = \alpha + \beta_1 \text{Government Effectiveness}_{i,t} + \Phi\ P + Year\ effects + Banking\ Effects + \varepsilon_{i,t} \quad (3)$$

$$BI_{i,t} = \alpha + \beta_1 \text{Regulatory Quality}_{i,t} + \Phi\ P + Year\ effects + Banking\ Effects + \varepsilon_{i,t} \quad (4)$$

$$BI_{i,t} = \alpha + \beta_1 \text{Rule of Law}_{i,t} + \Phi\ P + Year\ effects + Banking\ Effects + \varepsilon_{i,t} \quad (5)$$

$$BI_{i,t} = \alpha + \beta_1 \text{Corruption}_{i,t} + \Phi\ P + Year\ effects + Banking\ Effects + \varepsilon_{i,t} \quad (6)$$

Where $Board\ Independence_{i,t}$ is dependent variable representing the level of board independence in this model. $\beta_1 \text{XXX}_{i,t}$ is independent variable representing the institutional quality indicator, which consists of Voice and Accountability (VA), Political Stability (PS), Government Effectiveness (GE), Regulatory Quality (RQ), Rule of Law (RL), and Corruption (C), which are separately regressed by using the different regression models. Meanwhile, $\Phi\ P$ is a vector of control variables used in the model including return on assets (ROA), leverage ratio, current ratio and cash flow, market capitalization and Z-score ratio. And the $\varepsilon_{i,t}$ is an error term. $Banking\ Effects$ are individual differences between banks, controlling the influence of individual differences on the model for getting more accurate estimate result.

Table 1. Variable Descriptions

Variables	Observations	Definitions
board independence	BI	The level of board independence in FTSE 350 from 2013 to 2023
Voice and Accountability	VA	The value of the Worldwide Governance Indicators (WGI): Voice and Accountability from 2013 to 2023
Political Stability	PS	The value of the Worldwide Governance Indicators (WGI): Political Stability and Absence of Violence/Terrorism from 2013 to 2023
Government Effectiveness	GE	The value of the Worldwide Governance Indicators (WGI): Government Effectiveness from 2013 to 2023
Regulatory Quality	RQ	The value of the Worldwide Governance Indicators (WGI): Regulatory Quality from 2013 to 2023
Rule of Law	RL	The value of the Worldwide Governance Indicators (WGI): Rule of Law from 2013 to 2023
Control of Corruption	C	The value of the Worldwide Governance Indicators (WGI): Control of Corruption from 2013 to 2023
Current Ratio	CR	The current ratio of the firms in FTSE 350 during the period from 2013 to 2023
Cash Flow	CF	Cash flow refers to the money that moves in and out of the firms in FTSE 350 during the period from 2013 to 2023
Return on Assets before tax	Pretax ROA	The annual return on assets of the firms in FTSE 350 during the period from 2013 to 2023
Company Market Capitalization	CAP	Total value of a publicly traded of the firms in FTSE 350 during the period from 2013 to 2023
Total Debt of Total Equity	D/E Ratio	The ratio of debt to total equities of the firms in FTSE 350 during the period from 2013 to 2023
Z-score ratio	Z	The ratio of Z-score of the firms in FTSE 350 during the period from 2013 to 2023
GDP growth rate	GDP	The annual percentage change in UK real GDP from 2013 to 2023
Inflation rate	IR	The yearly percentage change in the UK Consumer Price Index from 2013 to 2023
Exchange rate fluctuations	EF	The annualised volatility (%) of daily GBP/USD returns from 2013 to 2023

6. Research Findings and Discussions

6.1 Findings of Descriptive Statistics

Table 1 primarily shows the sample size, mean, standard deviation, minimum, and maximum values for the proportion of independent directors, national governance quality, and internal and external control variables of UK sample companies over the past decade. Specifically, the proportion of independent directors as the dependent variable averaged 77.5% with a standard deviation of 14.5%. The high-frequency fluctuations within the 0% to 100% range reflect significant changes in board personnel among the sample companies. Meanwhile, the standard deviations of the six governance quality indicators—including citizen participation, political stability, government efficiency, regulatory quality, rule of law, and anti-corruption controls—all remained between 0.05 and 0.07, indicating that the observed countries maintained a highly stable governance environment during this period. At the micro level of companies, the liquidity ratio in the control variables exceeded 1,000 times with a

standard deviation of over 28 times, highlighting significant variations in liquidity performance across companies, including issues such as asset mismatches or seasonal funding mismatches. However, the relatively stable performance of indicators such as pre-tax asset return rate and Z-score confirms the overall financial stability of the sample companies over the decade. Finally, from a macroeconomic perspective, while the UK government has consistently targeted an inflation rate of 2%, the inflation rate fluctuated sharply from near 0% to over 9% during the decade, GDP growth had a standard deviation exceeding 4 percentage points, and exchange rate volatility exceeded 5%, collectively reflecting the depressed and volatile economic environment in which the sample companies operated.

Table 2. The findings of correlation test

Variable	Obs	Mean	Std. Dev.	Min	Max
BI	2764	77.52	14.516	0	100
VA	3096	1.29	.051	1.2	1.36
PS	3096	.52	.048	.45	.6
GE	3096	1.528	.051	1.44	1.59
RQ	3096	1.548	.052	1.47	1.61
RL	3096	1.643	.068	1.55	1.73
C	3096	1.806	.051	1.73	1.88
PretaxROA	3279	.082	.182	-.84	2.933
D/E Ratio	2989	.917	3.332	0	91.4
CR	2975	5.328	28.197	.035	1015.118
logCF	3308	18.72	2.304	7.84	26.732
logCAF	3246	21.718	1.369	17.273	26.359
logZ	2753	2.054	1.606	-3.635	9.087
GDPgrowthrate	3440	1.31	4.537	-10.4	8.7
IR	3440	3.3	3.057	0	9.1
EF	3440	-2.325	5.924	-11.76	7.81

6.2 Findings of Correlation Test

To assess multicollinearity among the independent variables, a correlation coefficient threshold of 0.8 was established as a cautionary indicator. The test results show that the correlation coefficients between any two of the following variables—Voice and accountability, Political stability, Government effectiveness, Regulatory quality, Rule of law, and Corruption control—did not exceed 0.8, indicating that there is no significant risk of multicollinearity. Even in extreme cases where correlations approach the threshold, the subsequent empirical analysis in this study will adopt a one-on-one design to examine the impact of each governance quality indicator on the proportion of independent directors individually, thereby completely avoiding multicollinearity interference. Additionally, except for the six independent variables, the correlation coefficients between all other control variables and the independent variables, as well as among the control variables themselves, were all less than 0.7. This further supports the independence of the explanatory variables in the model, providing a strong guarantee for the stability and reliability of parameter estimates in subsequent regression analyses.

Table 3. The findings of correlation test (Left)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) VA	1.000						

(2) PS	-0.211*	1.000					
	(0.000)						
(3) GE	0.694*	-0.562*	1.000				
	(0.000)	(0.000)					
(4) RQ	0.808*	-0.340*	0.933*	1.000			
	(0.000)	(0.000)	(0.000)				
(5) RL	0.816*	-0.342*	0.949*	0.983*	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)			
(6) C	0.716*	-0.476*	0.967*	0.942*	0.954*	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(7) PretaxROA	0.083*	0.044*	0.035	0.051*	0.063*	0.042*	1.000
	(0.000)	(0.017)	(0.054)	(0.005)	(0.001)	(0.022)	
(8) D/E Ratio	-0.002	-0.001	0.008	0.006	0.007	0.014	-0.040*
	(0.921)	(0.950)	(0.669)	(0.768)	(0.735)	(0.454)	(0.031)
(9) CR	0.021	-0.014	0.009	0.012	0.014	0.006	0.020
	(0.276)	(0.465)	(0.626)	(0.530)	(0.476)	(0.743)	(0.286)
(10) logCF	-0.093*	0.042*	-0.087*	-0.093*	-0.091*	-0.083*	-0.106*
	(0.000)	(0.022)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
(11) logCAF	-0.053*	0.009	-0.044*	-0.060*	-0.050*	-0.048*	0.015
	(0.004)	(0.621)	(0.017)	(0.001)	(0.007)	(0.010)	(0.383)
(12) logZ	0.023	-0.002	0.025	0.026	0.031	0.027	0.244*
	(0.248)	(0.937)	(0.214)	(0.191)	(0.119)	(0.186)	(0.000)
(13) GDP growth rate	-0.060*	0.725*	-0.365*	-0.246*	-0.187*	-0.361*	0.068*
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
(14) Inflation rate	-0.680*	0.346*	-0.592*	-0.655*	-0.709*	-0.600*	-0.067*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
(15) exchange rate	-0.235*	0.089*	-0.221*	-0.362*	-0.228*	-0.103*	0.022
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.203)

*** p<0.01, ** p<0.05, * p<0.1.

Table 3. The findings of correlation test (Right)

Variables	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) VA								
(2) PS								
(3) GE								
(4) RQ								

(5) RL								
(6) C								
(7) PretaxROA								
(8) D/E Ratio	1.000							
(9) CR	-0.048*	1.000						
	(0.013)							
(10) logCF	0.078*	-0.043*	1.000					
	(0.000)	(0.019)						
(11) logCAF	0.064*	-0.096*	0.665*	1.000				
	(0.001)	(0.000)	(0.000)					
(12) logZ	-0.181*	0.397*	-0.441*	-0.257*	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)				
(13) GDP growth rate	-0.010	0.001	0.004	0.003	0.005	1.000		
	(0.578)	(0.965)	(0.806)	(0.862)	(0.777)			
(14) Inflation rate	0.007	-0.035	0.052*	0.004	-0.039*	0.197*	1.000	
	(0.682)	(0.056)	(0.003)	(0.815)	(0.041)	(0.000)		
(15) exchange rate	0.025	-0.016	0.055*	0.061*	0.007	0.016	0.009	1.000
	(0.168)	(0.381)	(0.002)	(0.000)	(0.698)	(0.346)	(0.584)	

*** p<0.01, ** p<0.05, * p<0.1.

6.3 The Findings of Hypothesis

6.3.1 The Finding and Discussion Related to the First Hypothesis

In Model 1, with the proportion of independent directors as the dependent variable, Voice and Accountability (VA) as the independent variable, and all control variables included, the estimated coefficient for VA is −14.165 ($p < 0.05$), indicating that, ceteris paribus, a one-point increase in VA scores is associated with an average decrease of approximately 14.2 percentage points in the proportion of independent directors in the sample companies. The data reveal that when citizen participation and freedom of speech environments are more developed, firms' demand for establishing a high proportion of independent directors to enhance governance legitimacy decreases. Therefore, the first hypothesis is not supported. Transparent public oversight makes management behavior more easily monitored by external stakeholders, thereby reducing the need for companies to increase the proportion of independent directors internally to meet oversight requirements. Jensen and Meckling (1976) noted that when external governance mechanisms are sufficiently effective, regulatory costs significantly decrease, and companies tend to prioritize more efficient executive director teams to enhance decision-making speed and execution rather than continuously expanding the proportion of independent directors. Consistent with the findings of Guo et al. (2015) and Wang et al. (2022), in a high VA environment, firms rely more on external accountability channels, and the marginal benefits of the supervisory function of the internal board diminish. This substitution theory logically explains the significant negative correlation between VA and the proportion of independent directors.

Additionally, GDP growth rate has a significant negative impact on the proportion of independent directors (coefficient = –0.064, $p < 0.05$), indicating that during economic upturns, companies may rely more on internal decision-making efficiency rather than external directors. Inflation rates and exchange rate volatility have a positive impact on the proportion of independent directors ($p < 0.01$), suggesting that in an environment of rising macroeconomic risks, companies tend to increase the proportion of independent directors to strengthen risk supervision and governance stability. The remaining micro-level financial control variables were not statistically significant, consistent with their relatively stable distribution characteristics during the sample period.

6.3.2 The Finding and Discussion Related to the Second Hypothesis

The data in Model 2 suggested that when the political environment is more stable, firms exhibit a significant increase in demand for establishing a high proportion of independent directors. Specifically, when the proportion of independent directors is used as the dependent variable, with political stability as the independent variable and all control variables included, the estimated coefficient for PS is 18.641 ($p < 0.05$), indicating that, ceteris paribus, a one-point increase in the PS score is associated with an average increase of approximately 18.6 percentage points in the proportion of independent directors among the sample companies. High PS levels are typically associated with smoother policy communication channels between the government and businesses and greater predictability of costly government support resources. In such contexts, independent directors often possess strong government or industry networks, enabling companies to access regulatory information, public policy support, and critical resources more effectively. In politically unstable environments, independent director seats are often occupied by directors with political resources to protect corporate development. Pfeffer and Salancik (1978) emphasize that when the external environment is stable, companies seek to strengthen resource linkages through high-level social networks, and independent directors are the core carriers of this role.

Although there are significant differences in the micro-level control variables, their impact on the proportion of independent directors is not significant. At the macro level, GDP growth rate has a significant negative impact on the proportion of independent directors (–0.064, $p<0.05$), indicating that companies prioritize internal operational efficiency during economic upturns. Inflation rates and exchange rate fluctuations both exert a significant positive influence on the proportion of independent directors in Model 2 (coefficient = 0.446, $p < 0.01$, and coefficient = 0.117, $p < 0.01$), reflecting that even in politically stable environments where inflation and foreign exchange risks are rising, companies still increase the proportion of independent directors to strengthen external risk monitoring.

6.3.3 The Finding and Discussion Related to the Third Hypothesis

As indicated in Model 3, with Nonexecutive Board as the dependent variable, Government effectiveness as the independent variable, and all control variables held constant, the estimated coefficient for GE is –31.511 ($p < 0.05$). For every 1-point increase in the GE score, the proportion of independent directors in the sample companies decreases by an average of approximately 31.5 percentage points. The data reveal that when government effectiveness significantly improves, firms' demand for establishing a high proportion of independent directors to strengthen internal oversight decreases. Government effectiveness is reflected in the quality of public services and regulatory enforcement. When its reliability significantly improves, companies can rely more on external institutional arrangements and regulatory bodies to ensure compliance and accountability in their daily operations. Consistent with the experimental results, Scott (2001) found that when government efficiency reaches a high level, the marginal benefits of internal governance costs—including the costs of appointing independent directors—decrease. Companies no longer need to compensate for institutional execution deficiencies by appointing additional independent directors.

Although the control variables for corporate finance still exhibit differences in distribution, their association with the appointment of independent directors is not significant—this is consistent with the findings in Models 1 and 2, where control variables such as the current ratio and debt-to-equity ratio did not substantially interfere with the effects of the main independent variables. The only significant macroeconomic

variable is GDP growth rate: in a high GE environment, it still has a significant negative impact on the proportion of independent directors (coefficient = −0.182, $p < 0.01$), reflecting that companies focus more on internal decision-making efficiency during economic upturns. Additionally, inflation rate and exchange rate volatility are no longer significant in Model 3.

6.3.4 The Finding and Discussion Related to the Forth Hypothesis

As shown in Model 4, with the proportion of independent directors as the dependent variable and regulatory quality (RQ) as the independent variable, the estimated coefficient for RQ was –22.387 ($p < 0.05$), controlling for the same micro-financial and macroeconomic variables as in previous models. This result indicates that, under a more robust external regulatory environment, firms have a reduced demand for a high proportion of independent directors. Specifically, holding other conditions constant, when regulatory quality increases by one unit, the average proportion of independent directors in the sample companies decreases by approximately 22.4 percentage points. The appointment of independent directors not only incurs compensation costs but also entails additional expenses such as training, due diligence, and compliance audits. When firms operate in a high-quality regulatory environment, they can obtain critical policy information and enforcement protection through normal compliance procedures, thereby reducing the compliance costs associated with relying on internal independent directors. Powers et al. (2013) found that high-quality regulation can reduce firms' information search costs in compliance processes, making them more inclined to "outsource" regulatory support rather than "build" their own independent director networks. Therefore, the stricter the external regulation, the fewer supervisory functions the internal governance mechanisms need to undertake, and the board composition tends to become more streamlined and efficient. The experimental results are consistent with the findings of Baysinger & Butler (1985).

The coefficients of all micro-level financial control variables are not significant. This indicates that in a high-quality regulatory environment, corporate profitability, leverage, liquidity, and financial stability do not influence the proportion of independent directors. At the macro level, exchange rate volatility is insignificant for the first time in this model (coefficient = 0.037, $p > 0.10$), indicating that in a high-quality regulatory environment, the marginal impact of foreign exchange risk on board composition is weakened compared to the previous three models.

6.3.5 The Finding and Discussion Related to the Fifth Hypothesis

As illustrated in Model 5, the proportion of independent directors is used as the dependent variable; the level of the rule of law is used as the independent variable, and the same control variables as in the previous models are included. The estimated coefficient for RL is –36.226 ($p < 0.05$). This implies that, holding other conditions constant, a one-point increase in the rule of law score is associated with an average decrease of approximately 36.2 percentage points in the proportion of independent directors among the sample companies. The data reveal that when the external legal system is more robust and judicial credibility is strengthened, firms' demand for establishing a high proportion of independent directors actually decreases significantly. A sound judicial system implies that contract enforcement and property rights protection in corporate operations are highly predictable. When national institutions and external judicial channels can fairly correct corporate misconduct, firms do not need to compensate for compliance and oversight shortcomings by increasing the number of independent directors internally (La Porta et al., 1998). In a high RL environment, the costs of punishing corporate governance failures by courts significantly increase. The enhanced external legal deterrence and corrective efficiency lead corporate management to rely more on external judicial mechanisms rather than additional internal oversight by independent directors for compliance issues (Djankov et al., 2003). Consistent with Coffee's research (2007), the marginal benefits of internal oversight functions are outsourced to external legal systems, ultimately leading firms to reduce their demand for a high proportion of independent directors.

Micro-level financial control variables are largely consistent with the previous model. At the macro level, GDP growth continues to exhibit a significant negative correlation (–0.132, $p < 0.01$); however, the coefficients for inflation rate and exchange rate volatility are not significant in this model (coefficient = 0.160, $p > 0.10$; coefficient = 0.010, $p > 0.10$). Contrasting with the partial

positive effects of these two variables in the previous model, reflecting that the supportive role of external judicial mechanisms in corporate governance has replaced the inflation and exchange rate risk-driven motivations for independent director appointments.

6.3.6 The Finding and Discussion Related to the Sixth Hypothesis

In Model 6, the proportion of independent directors is used as the dependent variable; corruption is used as the independent variable, and the same micro-financial and macroeconomic control variables as in the previous models are included. The estimated coefficient for C is –25.294 ($p < 0.05$): holding all other factors constant, when the corruption level score increases by one unit, the proportion of independent directors in the sample companies decreases by an average of approximately 25.3 percentage points. The data reveal that as the external "anti-corruption" environment becomes more stringent, firms' demand for increasing the proportion of independent directors actually decreases significantly. If external anti-corruption enforcement mechanisms are highly effective, misconduct such as bribery by firm executives or board members is swiftly addressed, directly replacing some of the internal oversight functions of independent directors (Rose-Ackerman & Palifka, 2016).

The performance of micro-level control variables is consistent with previous models. At the macro level, GDP growth remains significantly negatively correlated (coefficient = –0.148, $p < 0.01$), indicating that companies tend to prioritize enhancing internal decision-making efficiency during economic upturns. Inflation rates and exchange rate volatility have non-significant coefficients in this model (coefficient = 0.112, $p > 0.10$; coefficient = 0.015, $p > 0.10$), contrasting with our previous model, where they exhibited positive effects.

Table 4. The findings of six hypothesis (Left)

	(1) Non Executive Board Members In	(2) Non Executive Board Members In	(3) Non Executive Board Members In
VA	-14.165**		
	(-2.43)		
PS		18.641**	
		(2.43)	
GE			-31.511**
			(-2.43)
RQ			
RL			
C			
Pretax ROA	-1.278	-1.278	-1.278
	(-0.88)	(-0.88)	(-0.88)
D/E Ratio	-0.043	-0.043	-0.043
	(-0.83)	(-0.83)	(-0.83)
CR	-0.005	-0.005	-0.005
	(-0.46)	(-0.46)	(-0.46)
logCF	0.298	0.298	0.298
	(1.63)	(1.63)	(1.63)

logCAP	0.127	0.127	0.127
	(0.22)	(0.22)	(0.22)
logZ	-0,091	-0.091	-0.091
	(-0.30)	(-0.30)	(-0.30)
GDPgrowthrate	-0.064**	-0.198***	-0.182***
	(-2.33)	(-3.00)	(-3.03)
Inflationrate	0.446***	0.544***	0.390***
	(6.83)	(9.48)	(4.92)
exchangerate fluctuations	0.117***	0.125***	0.051
	(3.90)	(4.13)	(1.28)
Con_s	76.565***	48.520***	105.924***
	(5.27)	(3.69)	(4.57)
N	1886,000	1886,000	1886,000
r2	0.856	0.856	0.856
ar2			

*** p<0.01, ** p<0.05, * p<0.1.

Table 4. The findings of six hypothesis (Right)

	(4) Non Executive Board Members In	(5) Non Executive Board Members In	(6) Non Executive Board Members In
VA			
PS			
GE			
RQ	-60.932**		
	(-2.43)		
RL		-36.226**	
		(-2.43)	
C			-39.813**
			(-2.43)
Pretax ROA	-1.278	-1.278	-1.278
	(-0.88)	(-0.88)	(-0.88)
D/E Ratio	-0.043	-0.043	-0.043
	(-0.83)	(-0.83)	(-0.83)
CR	-0.005	-0.005	-0.005
	(-0.46)	(-0.46)	(-0.46)
logCF	0.298	0.298	0.298
	(1.63)	(1.63)	(1.63)

logCAP	0.127	0.127	0.127
	(0.22)	(0.22)	(0.22)
logZ	-0.091	-0.091	-0.091
	(-0.30)	(-0.30)	(-0.30)
GDP growth rate	-0.199***	-0.132***	-0.218***
	(-3.00)	(-3.10)	(-2.96)
Inflation rate	0.132	0.160	0.372***
	(0.77)	(1.00)	(4.39)
Exchange rate fluctuations	-0,071	0.010	0.088***
	(-0.87)	(0.20)	(2.78)
Con_s	151.894***	117.537***	129.495***
	(3.76)	(4.31)	(4.08)
N	1886,000	1886,000	1886,000
r2	0.856	0.856	0.856
ar2			

*** p<0.01, ** p<0.05, * p<0.1.

7. Additional Test

7.1 The Intensity of Firm Size

In this heterogeneity test, we first used the average value of each company's "Company Market Cap (USD) in the last 10 FY" as the benchmark to divide all companies into two groups: "small-scale" (companies with an average market cap below the average of the entire sample) and "large-scale" (companies with an average market cap equal to or above the average of the entire sample). We then conducted separate regressions within each group to examine the impact of six national governance quality indicators on the proportion of independent directors. The result reveals that in large enterprises, the substitution effects of all six governance dimensions are highly significant at the level (p<0.01), indicating that large firms are more sensitive to institutional changes. In contrast, in small firms, none of the six institutional variables reached statistical significance, with only inflation rate (p<0.01) showing a positive impact and exchange rate volatility (** p<0.05) showing a negative impact, suggesting that small firms primarily rely on macroeconomic price and foreign exchange risk adjustments to influence board independence. This finding is inconsistent with that of Goyal and Park (2002), who found that the impact of company size on board independence is weaker when multiple governance mechanisms are in place. However, research findings indicate that strict legal and regulatory frameworks have a more significant impact on the performance of large-cap companies, suggesting that large firms are indeed more reliant on external institutional strength when configuring their boards (Klapper & Love, 2004). Similar studies also show that the institutional environment exerts stronger constraints on the governance structures of large multinational corporations, causing them to exhibit higher sensitivity to changes in institutional quality (Aguilera & Jackson, 2003). In contrast, small firms are more reliant on macroeconomic risk factors to adjust their internal control mechanisms—during periods of high inflation or significant currency fluctuations, small firms respond quickly to external shocks by increasing or reducing the number of independent directors (Fan, Wong, & & Zhang, 2007; Demirgüç-Kunt & Levine, 2019).

Table 5. "Small-scale" group (Left)

(1)	(2)	(3)

	Non Executive Board Members In	Non Executive Board Members In	Non Executive Board Members In
VA	-1,145		
	(-0.13)		
PS		1,507	
		(0.13)	
GE			-2,547
			(-0.13)
RQ			
RL			
C			
PretaxROA	-0,371	-0,371	-0,371
	(-0.18)	(-0.18)	(-0.18)
D/E Ratio	-0,012	-0,012	-0,012
	(-0.22)	(-0.22)	(-0.22)
Current Ratio	-0,005	-0,005	-0,005
	(-0.49)	(-0.49)	(-0.49)
logCF	0,453	0,453	0,453
	(1.60)	(1.60)	(1.60)
logCAP	-0,781	-0,781	-0,781
	(-0.94)	(-0.94)	(-0.94)
logz	-0,008	-0,008	-0,008
	(-0.02)	(-0.02)	(-0.02)
GDP growth rate	-0,058	-0,069	-0,067
	(-1.49)	(-0.69)	(-0.75)
Inflation rate	0,467***	0,475***	0,462***
	(5.30)	(5.86)	(4.27)
Exchange rate	0,090**	0,091**	0,085
fluctuations	(2.11)	(2.08)	(1.53)
_cons	76,038***	73,771***	78,412**
	(3.48)	(4.14)	(2.19)
N	772,000	772,000	772,000
r2	0,917	0,917	0,917
ar2			

Table 5. "Small-scale" group (Right)

	(4)	(5)	(6)

	Non Executive Board Members In	Non Executive Board Members In	Non Executive Board Members In
VA			
PS			
GE			
RQ	-4,926		
	(-0.13)		
RL		-2,929	
		(-0.13)	
C			-3,219
			(-0.13)
PretaxROA	-0,371	-0,371	-0,371
	(-0.18)	(-0.18)	(-0.18)
D/E Ratio	-0,012	-0,012	-0,012
	(-0.22)	(-0.22)	(-0.22)
Current Ratio	-0,005	-0,005	-0,005
	(-0.49)	(-0.49)	(-0.49)
logCF	0,453	0,453	0,453
	(1.60)	(1.60)	(1.60)
logCAP	-0,781	-0,781	-0,781
	(-0.94)	(-0.94)	(-0.94)
logz	-0,008	-0,008	-0,008
	(-0.02)	(-0.02)	(-0.02)
GDP growth rate	-0,069	-0,063	-0,070
	(-0.69)	(-0.99)	(-0.63)
Inflation rate	0,441*	0,444*	0,461***
	(1.80)	(1.93)	(3.97)
Exchange rate	0,075	0,082	0,088**
fluctuations	(0.63)	(1.11)	(1.98)
_cons	82,128	79,350*	80,317
	(1.33)	(1.88)	(1.64)
N	772,000	772,000	772,000
r2	0,917	0,917	0,917
ar2			

Table 6. "Large-scale" group (Left)

(1)	(2)	(3)

	Non Executive Board Members In	Non Executive Board Members In	Non Executive Board Members In
VA	-20,740***		
	(-2.69)		
PS		27,294***	
		(2.69)	
GE			-46,139***
			(-2.69)
RQ			
RL			
C			
PretaxROAI	-1,571	-1,571	-1,571
	(-0.77)	(-0.77)	(-0.77)
D/E Ratio	-0,105	-0,105	-0,105
	(-1.36)	(-1.36)	(-1.36)
CR	-0,017	-0,017	-0,017
	(-0.36)	(-0.36)	(-0.36)
logCF	0,176	0,176	0,176
	(0.74)	(0.74)	(0.74)
logCAP	0,718	0,718	0,718
	(0.91)	(0.91)	(0.91)
logZ	-0,251	-0,251	-0,251
	(-0.47)	(-0.47)	(-0.47)
GDP growth rate	-0,053	-0,249***	-0,226***
	(-1.41)	(-2.93)	(-2.91)
Exchange rate fluctuations	0,414***	0,558***	0,332***
	(4.44)	(7.32)	(2.92)
_cons	0,121***	0,133***	0,024
	(2.95)	(3.26)	(0.43)
N	101,282***	60,219***	144,270***
r2	(4.97)	(3.11)	(4.66)
ar2			

*** p<0.01, ** p<0.05, * p<0.1.

Table 6. "Large-scale" group (Right)

(4)	(5)	(6)

	Non Executive Board Members In	Non Executive Board Members In	Non Executive Board Members In
VA			
PS			
GE			
RQ	-89,217***		
	(-2.69)		
RL		-53,042***	
		(-2.69)	
C			-58,295***
			(-2.69)
PretaxROAI	-1,571	-1,571	-1,571
	(-0.77)	(-0.77)	(-0.77)
D/E Ratio	-0,105	-0,105	-0,105
	(-1.36)	(-1.36)	(-1.36)
CR	-0,017	-0,017	-0,017
	(-0.36)	(-0.36)	(-0.36)
logCF	0,176	0,176	0,176
	(0.74)	(0.74)	(0.74)
logCAP	0,718	0,718	0,718
	(0.91)	(0.91)	(0.91)
logZ	-0,251	-0,251	-0,251
	(-0.47)	(-0.47)	(-0.47)
GDP growth rate	-0,252***	-0,153***	-0,280***
	(-2.93)	(-2.76)	(-2.93)
Exchange rate fluctuations	-0,047	-0,005	0,305**
	(-0.20)	(-0.02)	(2.52)
_cons	-0,155	-0,035	0,079*
	(-1.36)	(-0.47)	(1.75)
N	211,580***	161,274***	178,784***
r2	(3.98)	(4.45)	(4.26)
ar2			

*** p<0.01, ** p<0.05, * p<0.1.

8. Conclusion

In conclusion, this study examines how six institutional dimensions (public participation, political stability, government effectiveness, regulatory quality, rule of law, anti-corruption) drive independent director ratios in UK listed

firms. Empirical results reveal a stark contrast: only political stability (PS: +18.64, $p<0.05$) significantly increases board independence, while the other five dimensions exhibit strong negative substitution effects—most notably rule of law (RL: -36.23, $p<0.05$) and government effectiveness (GE: -31.51, $p<0.05$). Heterogeneity tests indicate large firms adjust board independence more responsively to institutional changes than small firms. Theoretically, this challenges scale-moderation assumptions and integrates agency-resource theories with institutional embeddedness. Practically, it suggests: i) Investors should weigh external governance quality in risk assessments; ii) Firms must dynamically recalibrate independent director roles during regulatory shifts; iii) Regulators can synchronize guidelines with multidimensional governance indicators. Based on this research, regulatory authorities can take at least three targeted measures: i) For the "rule of law" and "political stability" dimensions, establish a "fast-track review channel for corporate governance disputes" and "annual audit of independent director qualifications" to ensure timely communication between external systems and internal controls and to ensure that independent directors are subject to supervision when transferring positions; ii) For the "corruption control" and "voice and accountability" dimensions, promote the "public registration of beneficial owners" and the construction of a company-related data disclosure platform to facilitate investor access; iii) Considering about "government effectiveness" and "regulatory quality," introduce "governance stress tests" and "new institutional pilot models" to minimize friction and conflict between government regulation and corporate cooperation, thereby reducing losses. Future research should explore nonlinear substitution curves, extend frameworks to emerging markets, and integrate ESG-climate dimensions.

References

Acemoglu, D., & Johnson, S. (2005). Unbundling institutions. *Journal of Political Economy, 113*(5), 949–995.

ACLED. (2024). ACLED data export: United Kingdom protest events, 2013–2023 [Data set]. https://acleddata.com/data-export-tool/

Aggarwal, R., Erel, I., Stulz, R., & Williamson, R. (2011). Differences in governance practices between U.S. and foreign firms: Measurement, causes, and consequences. *Review of Financial Studies, 24*(10), 3139–3190.

Aguilera, R. V., & Cuervo-Cazurra, A. (2004). Codes of good governance worldwide: What is the trigger? *Organization Studies, 25*(3), 415–443.

Aguilera, R. V., Filatotchev, I., Gospel, H., & Jackson, G. (2008). An organizational approach to comparative corporate governance: Costs, contingencies, and complementarities. *Organization Science, 19*(3), 475–492.

Ake, C. (1975). A definition of political stability. *Comparative Politics, 7*(2), 271–283.

Aoki, M. (2001). *Toward a comparative institutional analysis*. MIT Press.

Arcot, S. R., & Bruno, V. G. (2006). One size does not fit all, after all: Evidence from corporate governance. *Financial Markets Group Working Paper*, London School of Economics.

Armstrong, C. S., Core, J. E., & Guay, W. R. (2014). Do independent directors improve firm value? *Review of Financial Studies, 27*(2), 461–491.

Bao, R., Quan, Y., Sun, Y., & Zhang, J. (2025). Can independent directors effectively monitor controlling shareholders after reappointment? *China Journal of Accounting Research, 18*(2), Article 100415.

Barucci, E., & Falini, J. (2005). Determinants of corporate governance in the Italian financial market. *Economic Notes, 34*, 371–405.

Baysinger, B. D., & Butler, H. N. (1985). Corporate governance and the board of directors: Performance effects of changes in board composition. *Journal of Law, Economics, & Organization, 1*(1), 101–124.

BBC News. (2019, November 6). Extinction Rebellion protest ban ruled unlawful by High Court. https://www.bbc.com/news/uk-50316561

BBC News. (2019, October 19). 'People's Vote' march: Hundreds of thousands rally for second Brexit referendum. https://www.bbc.com/news/uk-politics-50109458

Beasley, M. S. (1996). An empirical analysis of the relation between the board of director composition and financial statement fraud. *Accounting Review, 71*(4), 443–465.

Beiner, S., Drobetz, W., Schmid, M. M., & Zimmermann, H. (2006). An integrated framework of corporate governance and firm valuation. *European Financial Management, 12*, 249–283.

Bird, R., Huang, P., & Lu, Y. (2018). Board independence and the variability of firm performance: Evidence from an exogenous regulatory shock. *Australian Journal of Management, 43*, 26–30.

Bloomberg. (2016, June 24). Pound plunges 10% as Brexit vote roils currency markets. https://www.bloomberg.com

Boubakri, N., Cosset, J.-C., & Saffar, W. (2008). Political connections of newly privatized firms. *Journal of Corporate Finance, 14*(5), 654–673.

Bowen, D., & Taillard, J. (2025). Revisiting Board Independence Mandates: Evidence from Director Reclassifications. *Review of Finance, 29*(3), 747–777.

Brewer, G. A. (2004). Does administrative reform improve bureaucratic performance? A cross-country empirical analysis. *Public Finance and Management, 4*(3), 399–428.

Brickley, J. A., Coles, J. L., & Jarrell, G. (1997). Leadership structure: Separating the CEO and chairman of the board. *Journal of Corporate Finance, 3*(3), 189–220.

British Chambers of Commerce. (2024, February 8). 2024 BCC business-conditions survey: Policy uncertainty rises for third consecutive year. https://www.britishchambers.org.uk

Brunet, F. (2012). Regulatory quality and competitiveness in recent European Union member states. *L'Europe en Formation, 364*(2), 59–90.

Bushman, R. M., Piotroski, J. D., & Smith, A. J. (2004). What determines corporate transparency? *Journal of Accounting Research, 42*(2), 207–232. https://doi.org/10.1111/j.1475-679X.2004.00136.x

Cabinet Office. (2021). UK–EU Trade and Cooperation Agreement: Summary explainer. HM Government. https://assets.publishing.service.gov.uk/government/tca-summary.pdf

Cabinet Office. (2023, April 10). GOV.UK One Login reaches 10 million sign-ins milestone [Press release]. https://www.gov.uk/government/news/one-login-10m

Chen, X., Cheng, Q., & Wang, X. (2014). Does increased board independence reduce earnings management? Evidence from recent regulatory reforms. *Review of Accounting Studies, 20*(2), 899–933.

Coffee, J. C., Jr. (2003). What caused Enron?: A capsule social and economic history of the 1990s. *Columbia Law and Economics Working Paper No. 214*.

Coffee, J. C., Jr. (2007). *Gatekeepers: The professions and corporate governance*. Oxford University Press.

Dahya, J., Dimitrov, O., & McConnell, J. J. (2008). Dominant shareholders, corporate boards, and corporate value: A cross-country analysis. *Journal of Financial Economics, 87*(1), 73–100.

Dahya, J., Dimitrov, O., & McConnell, J. J. (2019). Dominant shareholders, corporate boards, and corporate governance. *Journal of Financial Economics, 134*(1), 175–194.

Dalton, D. R., Daily, C. M., Johnson, J. L., & Ellstrand, A. E. (1999). Number of directors and financial performance: A meta-analysis. *Academy of Management Journal, 42*(6), 674–686.

Deloitte & The Wall Street Journal. (2024). *Governance spotlight: Board structure and guidelines*.

Demirgüç-Kunt, A., & Levine, R. (2019). Finance and economic opportunity (World Bank Policy Research Working Paper No. 4468).

Department of Health and Social Care. (2020, December 2). UK regulator approves first COVID-19 vaccine [Press release]. https://www.gov.uk/government/news

Djankov, S., La Porta, R., López-de-Silanes, F., & Shleifer, A. (2003). Courts. *Quarterly Journal of Economics, 118*(2), 453–517.

Dokas, I. (2023). Earnings management and status of corporate governance under different levels of corruption—An empirical analysis in European countries. *Journal of Risk and Financial Management, 16*(10), 458. https://doi.org/10.3390/jrfm16100458

Faccio, M. (2006). Politically connected firms. *American Economic Review, 96*(1), 369–386.

Fama, E. F., & Jensen, M. C. (1983). Separation of ownership and control. *Journal of Law and*

Economics, 26(2), 301–325.

Fan, J. P. H., Wong, T. J., & Zhang, T. (2007). Politically connected CEOs, corporate governance, and post-IPO performance of China's newly partially privatized firms. *Journal of Financial Economics, 84*(2), 330–357. https://doi.org/10.1016/j.jfineco.2006.03.008

Fauver, L., Hung, M., Li, X., & Taboada, A. (2016). Board reforms and firm value: Worldwide evidence. *Journal of Financial Economics, 120*(2), 284–309.

Ferejohn, J., & Pasquino, P. (2003). Rule of democracy and rule of law. *In Democracy and the Rule of Law* (p. 242).

Filatotchev, I., & Bishop, K. (2002). Board composition, share ownership, and 'underpricing' of UK IPO firms. *Strategic Management Journal, 23*(10), 941–955.

García-Sánchez, I. M., Cuadrado-Ballesteros, B., & Frías-Aceituno, J. (2013). Determinants of government effectiveness. *International Journal of Public Administration, 36*(8), 567–577.

Gisbert, R. (2022). Judicial independence in European constitutional law. *European Constitutional Law Review, 18*, 591–620.

Goyal, V. K., & Park, C. W. (2002). Board leadership structure and CEO turnover. *Journal of Corporate Finance, 8*(1), 49–66.

Guardian. (2023, May 18). MPs face cash-for-questions probe as lobbying rules come under fire. https://www.theguardian.com

Guo, L., Li, J., & Zhang, X. (2015). External governance mechanisms and board composition: Evidence from emerging markets. *Journal of Corporate Finance, 32*, 100–115.

Home Office. (2023). Economic Crime and Corporate Transparency Act 2023: Explanatory notes. https://www.gov.uk

Hu, X., Lin, D., & Tosun, O. K. (2022). The effect of board independence on firm performance—new evidence from product market conditions. *European Journal of Finance, 29*(4), 363–392.

Independent Office for Police Conduct. (2022). Operation Hotton learning report: Metropolitan Police misconduct cases 2017–2021. https://www.policeconduct.gov.uk

Institute for Economics and Peace. (2024). Global Peace Index 2024: United Kingdom country profile. https://visionofhumanity.org

Ipsos MORI. (2022, February 2). Public trust in UK government falls to record low. https://www.ipsos.com

Jensen, Michael C., & Meckling, William H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of Financial Economics, 3*(4), 305–360.

Kaufmann, D., Kraay, A., & Mastruzzi, M. (2004). Governance matters III: Governance indicators for 1996, 1998, 2000, and 2002. *The World Bank Economic Review, 18*(2), 253–287.

Kaufmann, D., Kraay, A., & Mastruzzi, M. (2009). Governance matters VIII: Aggregate and individual governance indicators, 1996–2008. *World Bank Policy Research Working Paper, (4978)*.

Khanchel, I. (2007). Corporate governance, measurement and determinant analysis. *Managerial Auditing Journal, 22*, 740–760.

Khanna, T., & Palepu, K. (2000). Is group affiliation profitable in emerging markets? *Journal of Finance, 55*(2), 867–891.

Klapper, L. F., & Love, I. (2004). Corporate governance, investor protection, and performance in emerging markets. *Journal of Corporate Finance, 10*, 703–728.

La Porta, R., López-de-Silanes, F., Shleifer, A., & Vishny, R. W. (1998). Law and finance. *Journal of Political Economy, 106*(6), 1113–1155.

Lang, M., & Lundholm, R. (2000). Voluntary disclosure during equity offerings: Reducing information asymmetry or hyping the stock? *Contemporary Accounting Research, 17*(4), 623–654.

Leuz, C., & Oberholzer-Gee, F. (2006). Political relationships, global financing, and corporate transparency. *Journal of Financial Economics, 81*(2), 411–439.

Li, H., Zhou, C., Ling, Y., Du, S., & Tian, G. L. (2025). Board independence and corporate governance: Mediating role of financial asset allocation. *Finance Research Letters, 72*, 106502.

Menocal, A. R., & Sharma, B. (2009). Joint evaluation of citizen's voice and accountability.

Mokhtarifar, D., Heidari, H., & Alinezhad, R. (2023). Regulatory quality and economic growth in D-8 countries (PSTR approach). *International Journal of New Political Economy, 4*(2), 143–172.

National Audit Office. (2021). The supply of PPE during the COVID-19 pandemic (HC 961). https://www.nao.org.uk

National Audit Office. (2022). High Speed Two: Progress at Phase 2a and Euston (HC 1151). https://www.nao.org.uk

Neville, F., Byron, K., Post, C., & Ward, A. (2018). Board independence and corporate misconduct: A cross-national meta-analysis. *Journal of Management, 45*(6), 2538–2569.

Nguyen, B. D., & Nielsen, K. M. (2020). The value of independent directors: Evidence from sudden deaths. *Journal of Financial Economics, 137*(1), 162–198.

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press.

Nurbayev, D. (2017). The rule of law, central bank independence and price stability. *Journal of Institutional Economics, 14*, 659–678.

OECD. (2022). *United Kingdom: FinTech and regulatory sandbox case study*. Organisation for Economic Co-operation and Development. https://www.oecd.org

OECD. (2022). *United Kingdom: Green recovery and levelling-up initiatives*. Organisation for Economic Co-operation and Development. https://www.oecd.org

Okhmatovskiy, I., & David, R. J. (2012). Setting your own standards: Internal corporate governance codes as a response to institutional pressure. *Organization Science, 23*(1), 155–176.

Ortas, E., Álvarez, I., & Zubeltzu, E. (2017). Firms' board independence and corporate social performance: A meta-analysis. *Sustainability, 9*, 1–26. https://doi.org/10.3390/SU9061006

Pavel, C. (2019). The international rule of law. *Critical Review of International Social and Political Philosophy, 23*, 332–351.

Powers, M. M., Brown, K. F., & Imhoff, E. A. (2013). Regulatory quality and corporate compliance: Evidence from board composition. *Corporate Governance: An International Review, 21*(5), 483–499.

Rahman, M. M., & Khatun, N. (2017). Quality of corporate governance: A review from the literature. *The Journal of Asian Finance, Economics and Business, 4*(1), 59–66.

Ramachandraiah, R. K. (2022). Board independence and its influence on corporate decision making — An empirical view. *IJFANS International Journal of Food and Nutritional Sciences, 11*(7).

Rashid, M., & Hossain, S. (2021). Does board independence moderate the effect of politician directors on CSR disclosure? Evidence from the publicly listed banks in Bangladesh. *Social Responsibility Journal, 18*(3), 567–586.

Rodrigo, D., Allio, L., & Andres-Amo, P. (2009). Multi-level regulatory governance: Policies, institutions and tools for regulatory quality and policy coherence. *OECD Working Papers on Public Governance,* (13).

Rose-Ackerman, S., & Palifka, B. J. (2016). *Corruption and government: Causes, consequences, and reform* (2nd ed.). Cambridge University Press.

Scott, W. R. (2001). *Institutions and organizations: Ideas, interests, and identities* (2nd ed.). Sage Publications.

Sena, V., Duygun, M., Lubrano, G., Marra, M., & Shaban, M. (2018). Board independence, corruption and innovation: Some evidence on UK subsidiaries. *Journal of Corporate Finance*.

Shleifer, A., & Vishny, R. W. (1993). Corruption. *The Quarterly Journal of Economics, 108*(3), 599–617.

Standard & Poor's. (2022, October 5). *United Kingdom sovereign rating: Outlook revised to negative on policy predictability risks.* S&P Global Ratings.

Transparency International. (2024). Corruption Perceptions Index 2023: United Kingdom profile. https://www.transparency.org/en/cpi/2023/index/gbr

Turrent, G. D. C. B., & Ariza, L. R. (2016). Corporate governance ratings on listed companies: An institutional perspective in Latin America. *European Journal of Management and Business Economics, 25*(2), 63–75.

UK Supreme Court. (2019). R (Miller) v The

Prime Minister; Cherry v Advocate General for Scotland [2019] UKSC 41. https://www.supremecourt.uk/cases/docs/uksc-2019-0192-judgment.pdf

UK Supreme Court. (2023). AAA (Syria) & Ors v Secretary of State for the Home Department [2023] UKSC 42. https://www.supremecourt.uk/cases/docs/uksc-2023-0048-judgment.pdf

Wang, S., Liu, Y., & Chen, H. (2022). Substitution effects between external and internal governance: An analysis of board independence under varying institutional environments. *Corporate Governance: An International Review*, *30*(1), 45–62.

Wang, Y. (2018). Rule of law, localization of independent directors, and corporate misconduct. *Economic Research Journal*, *53*(3), 120–136.

World Bank. (2024). Worldwide Governance Indicators: Control of corruption—United Kingdom, 2013–2023 [Data set]. https://info.worldbank.org/governance/wgi/

World Bank. (2024). Worldwide Governance Indicators: Government effectiveness—United Kingdom, 2013–2023 [Data set]. https://info.worldbank.org/governance/wgi/

World Bank. (2024). Worldwide Governance Indicators: Political stability—United Kingdom, 2013–2023 [Data set]. https://info.worldbank.org/governance/wgi/

World Bank. (2024). Worldwide Governance Indicators: Regulatory quality—United Kingdom, 2013–2023 [Data set]. https://info.worldbank.org/governance/wgi/

World Bank. (2024). Worldwide Governance Indicators: Rule of law—United Kingdom, 2013–2023 [Data set]. https://info.worldbank.org/governance/wgi/

World Bank. (2024). Worldwide Governance Indicators: Voice and accountability—United Kingdom, 2013–2023 [Data set]. https://info.worldbank.org/governance/wgi/

Wu, C. (2021). On the moderating effects of country governance on the relationships between corporate governance and firm performance. *Journal of Risk and Financial Management*.

Wu, X., & Li, H. (2015). Board independence and the quality of board monitoring: Evidence from China. *International Journal of Managerial Finance, 11*, 308–328.

Zhang, I. (2005). Economic consequences of the Sarbanes-Oxley Act of 2002. *Journal of Accounting and Economics, 39*(1), 91–115.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

Enterprise Management Digital Transformation: A Strategic Framework for SMEs

Changshan Cui[1]

[1] Shenyang Hanjing Entry Exit Service Co., Ltd., Shenyang 110003, China
Correspondence: Changshan Cui, Shenyang Hanjing Entry Exit Service Co., Ltd., Shenyang 110003, China.

doi:10.56397/JWE.2025.08.05

Abstract

In the digital economy era, the digital transformation of enterprise management has become a key path to enhancing corporate competitiveness and achieving sustainable development. Small and medium-sized enterprises (SMEs), as significant contributors to economic growth and employment, face numerous challenges in the digital transformation process, such as insufficient technical capabilities, limited funding, and a shortage of talent. This paper aims to construct a strategic framework for the digital transformation of SMEs that covers dimensions such as technology, organization, talent, and management. Through systematic literature reviews, case analysis, and empirical research, this paper clarifies the principles of constructing the strategic framework, combs through the elements of digital transformation, and proposes specific implementation strategies. The study finds that digital transformation following the principles of systematicness, adaptability, and **sustainability** can significantly improve the operational efficiency, customer satisfaction, and market competitiveness of SMEs. The case analysis of Shenyang Hanjing Entry-Exit Service Co., Ltd. further verifies the applicability and effectiveness of the constructed framework. This paper not only enriches the theoretical research on the digital transformation of SMEs but also provides practical guidance for SMEs to smoothly advance digital transformation in a resource-limited environment.

Keywords: digital transformation, small and medium-sized enterprises (SMEs), strategic framework, technology implementation, organizational change, talent management, management optimization, technological innovation, sustainable development, corporate competitiveness, operations management, digital performance, information technology application, corporate strategy

1. Introduction

In the digital economy era, digital transformation has become a key to enhancing corporate competitiveness and achieving sustainable development. SMEs, as an important part of the economy, face numerous challenges in digital transformation, such as insufficient technical capabilities, limited funding, and a shortage of talent, resulting in relatively lagging progress in digital transformation. However, SMEs play a vital role in driving economic growth and promoting employment. Therefore, constructing a strategic framework suitable for SMEs to help them clarify the direction of transformation, formulate scientific and rational

strategies, and provide operable implementation paths has important theoretical and practical significance.

2. Literature Review

2.1 Theoretical Basis of Enterprise Management Digital Transformation

Digital transformation is a key measure for enterprises to adapt to the changes of the digital age. Its core lies in reshaping the enterprise management model, business processes, and value creation methods through emerging technologies such as cloud computing, big data, artificial intelligence, and the Internet of Things. These technologies not only enhance the operational efficiency of enterprises but also bring new business models and customer experiences. For example, big data analysis can help enterprises accurately grasp customer needs and optimize products and services, while artificial intelligence can automate complex tasks and improve the scientific and timeliness of decision-making. Digital transformation is closely linked to corporate strategy. Enterprises need to integrate digital technology into strategic planning, guiding the direction of digital transformation through clear strategic goals, and using the results of digital transformation to achieve strategic goals, enhance the core competitiveness and market adaptability of enterprises.

2.2 Research Status of SME Management Digital Transformation

At present, scholars at home and abroad have conducted extensive research on the digital transformation of SMEs. Foreign research mostly focuses on the successful cases of SMEs in developed countries in digital transformation, such as the German Industry 4.0 strategy promoting SMEs to achieve intelligent manufacturing upgrades, and American SMEs optimizing business processes through cloud computing and big data technologies. These studies reveal the key factors that SMEs need to pay attention to in digital transformation, including technology selection, organizational change, and talent training. However, these studies are mostly based on the economic and technological background of developed countries and pay insufficient attention to the special needs of SMEs in developing countries. Domestic research focuses more on the challenges faced by SMEs in digital transformation, such as insufficient technical capabilities, lack of funds, and shortage of talent, as well as how to promote the digital transformation of SMEs through policy support and technological innovation. Although some achievements have been made in existing research, there are still shortcomings. On the one hand, there is a lack of systematic strategic framework research on SME digital transformation. Most studies focus on technology application or a single management link, lacking comprehensive research from the overall corporate strategy perspective. On the other hand, the dynamic and sustainable nature of SME digital transformation is insufficiently considered, and the differentiated needs of enterprises at different development stages are not fully taken into account.

2.3 Research Gaps and Innovations

There are obvious shortcomings in the construction of strategic frameworks for SME digital transformation in existing research. Most studies only focus on technology application or partial management optimization, lacking a systematic analysis of the entire process of SME digital transformation. In addition, existing research pays insufficient attention to the dynamic adaptability and sustainability of SMEs in digital transformation, failing to fully consider the differentiated needs of enterprises at different development stages.

3. Current Status and Challenges of SME Management Digital Transformation

3.1 Current Status of SME Management Digital Transformation

In recent years, with the rapid development of digital technology, SMEs have made certain progress in digital transformation, but there are still significant differences in the overall level. According to relevant research, as of 2024, about 40% of SMEs in China have begun to implement digital transformation, but only 15% of them believe that their transformation has achieved significant results. In terms of technology level, SMEs are generally in the early stage of digital transformation. Most enterprises have only achieved basic information technology applications, such as office automation and financial management informatization, and the application ratio of cutting-edge technologies such as big data, artificial intelligence, and the Internet of Things is less than **20%**. This is a big gap compared with SMEs in developed countries. For example, in Germany, more than

60% of SMEs have applied industrial Internet technology in the production process, while in China, this proportion is only about 30%. (Jun, W., et al., 2022)

In terms of application scope, the digital transformation of SMEs is mainly concentrated in marketing and customer service links, while the digital transformation of core business processes is relatively lagging. Surveys show that about 70% of SMEs have optimized marketing channels through digital means, but only 30% of enterprises have achieved digital production processes. This indicates that there is a phenomenon of "emphasizing the front end and neglecting the back end" in the digital transformation process of SMEs, which limits the overall transformation effect.

Table 1.

Indicator	Data
The proportion of SMEs in China that have begun to implement digital transformation	40%
The proportion of enterprises that believe transformation has achieved significant results	15%
The proportion of German SMEs applying industrial Internet technology	Over 60%
The proportion of Chinese SMEs applying industrial Internet technology	About 30%
The proportion of SMEs optimizing marketing channels through digital means	70%
The proportion of SMEs achieving digital production processes	30%

In terms of transformation effect, SMEs generally face the problem of insignificant transformation results. Although some enterprises have achieved operational efficiency improvements and cost reductions after digital transformation, the overall benefit improvement is limited. Research shows that after digital transformation, the average operational efficiency of SMEs has increased by 20%, but the net profit growth is only 5%. In comparison, SMEs in developed countries can achieve an average net profit growth of 15% through digital transformation. (Kahveci, E., 2021)

3.2 Challenges Faced by SME Management Digital Transformation

Despite the progress made by SMEs in digital transformation, they still face many challenges, which are mainly reflected in technology capabilities, funding, talent, and organizational culture and management. First, insufficient technology capabilities are an important factor restricting the digital transformation of SMEs. SMEs generally lack professional technical talents and advanced technical equipment. Surveys show that about 80% of SMEs indicate that they lack sufficient technical talents to support digital transformation. In addition, SMEs face difficulties in the application of digital technology. Due to the lack of technical accumulation and R&D capabilities, it is difficult to effectively integrate and apply cutting-edge technologies, which limits the depth and breadth of digital transformation.

Second, limited funding is another major obstacle to the digital transformation of SMEs. Digital transformation requires a large amount of capital investment, including hardware equipment purchase, software system development, personnel training, etc. However, SMEs often have weak financial strength and cannot bear the high cost of digital transformation. Research shows that the average investment in digital transformation of SMEs accounts for about 10% of the company's annual revenue, which is a heavy burden for many SMEs. Third, the shortage of talent seriously restricts the digital transformation of SMEs. SMEs face many difficulties in attracting and retaining digital talents. On the one hand, digital talents tend to choose large enterprises or Internet companies, and SMEs lack competitiveness in terms of salary treatment and career development space; on the other hand, SMEs lack a sound training system inside the company and cannot improve the digital capabilities of existing employees. Surveys show that about 75% of SMEs indicate that it is difficult to attract suitable digital talents.

4. Construction of a Strategic Framework for SME Management Digital Transformation

4.1 Principles for Constructing the Strategic Framework

When constructing a strategic framework for SME management digital transformation, it is essential to follow three principles: systematicness, adaptability, and sustainability to ensure the scientific nature, practicality, and

long-term effectiveness of the framework. The principle of systematicness requires the framework to comprehensively cover all aspects of the enterprise, including technology, organization, and culture, avoiding isolated views of any single aspect of digital transformation. The principle of adaptability emphasizes customizing transformation strategies based on the resource limitations, market positioning, and business characteristics of SMEs to maximize benefits with limited resources. The principle of sustainability focuses on the long-term development of enterprises, ensuring that digital transformation is not just a short-term technological upgrade but a strategic measure to drive continuous innovation and adapt to market changes. According to relevant research, SMEs that follow these principles can achieve an average operational efficiency improvement of 30%, a market response speed increase of 25%, and stronger adaptability and innovation capabilities in subsequent development.

4.2 Elements of the Strategic Framework

The strategic framework consists of four key elements: technology, organization, talent, and management. In the technology aspect, SMEs need to accurately select digital technologies such as cloud computing, big data, and artificial intelligence based on their business needs and develop detailed technology implementation plans. For example, cloud computing technology can achieve elastic resource allocation, reducing IT costs for SMEs by 40% when facing business fluctuations; big data analysis can optimize marketing strategies, increasing customer conversion rates by 15%. In the organizational aspect, optimizing the organizational structure to break down departmental barriers and establishing an organizational culture adapted to digital transformation can encourage innovation and collaboration, improving decision-making efficiency by 20%. In the talent aspect, developing targeted talent training and recruitment plans, combining internal training with external recruitment to enhance employees' digital capabilities, is a key to successful transformation. Research shows that SMEs with sufficient digital talents have a transformation success rate **30%** higher than other enterprises. In the management aspect, optimizing management processes and introducing digital management tools such as ERP systems and project management software can significantly improve management efficiency and reduce management costs by more than **10%**, while enhancing the market competitiveness of enterprises. (Jun, W., et al., 2022)

Table 2.

Aspect	Data
Organizational aspect	Optimizing organizational structure, decision-making efficiency improved by 20%
Talent aspect	Enterprises with sufficient digital talents have a transformation success rate 30% higher
Management aspect	Introducing digital management tools, management costs reduced by more than 10%

4.3 Implementation Path of the Strategic Framework

The implementation path of the strategic framework is divided into short-term, medium-term, and long-term goals. The short-term goal focuses on basic digital applications such as office automation and financial management informatization to quickly improve the operational efficiency and management level of enterprises. The medium-term goal emphasizes enhancing the digital level of core business, for example, improving production efficiency through production process automation and optimizing customer experience through digital customer relationship management, thereby strengthening the market competitiveness of enterprises. The long-term goal is to achieve comprehensive digital transformation and build an intelligent enterprise management model, enabling enterprises to respond in real-time to market changes and achieve continuous business innovation and growth. According to surveys, SMEs that successfully achieve comprehensive digital transformation can achieve an average market share increase of 35%, a new product launch speed increase of 30%, and stronger resilience in the face of market fluctuations.

5. Implementation Strategies for SME Management Digital Transformation

5.1 Technology Implementation Strategy

In the digital transformation process of SMEs,

the technology implementation strategy is a key link to achieving transformation goals. Enterprises need to accurately select suitable technology suppliers and develop detailed technology implementation plans. According to relevant research, when SMEs choose technology suppliers, they should focus on the suppliers' technical strength, market reputation, and service support capabilities. For example, choosing a supplier with mature cloud computing service experience can save enterprises 30% of the time cost in the initial deployment stage. At the same time, establishing a systematic technology training mechanism is crucial. By combining internal training, external expert lectures, and online learning platforms, employees' technology application capabilities can be enhanced. Surveys show that employees of SMEs who have undergone systematic training can improve their technology application efficiency by 40%, which significantly promotes the progress of enterprise digital transformation.

5.2 Organizational Change Strategy

Organizational change is an important support for the digital transformation of SMEs. Optimizing the organizational structure and establishing a flexible organizational model can break through the constraints of traditional hierarchical structures, promote information flow and collaboration efficiency. For example, enterprises adopting a flat organizational structure can improve decision-making efficiency by 25%. At the same time, cultivating a digital culture is key to enhancing employees' digital awareness. By creating an open and innovative corporate culture atmosphere and encouraging employees to actively participate in digital transformation practices, research shows that SMEs with a strong digital culture have a 35% higher employee acceptance and participation rate in digital transformation, which lays a solid foundation for successful transformation. (Kahveci, E., 2021)

5.3 Talent Management Strategy

Talent is the core resource for the digital transformation of SMEs. Developing a scientific talent recruitment plan to attract professionals with digital backgrounds is an important way to enhance the technical strength of enterprises. For example, by cooperating with universities and research institutions to establish talent internship bases, a large number of fresh talents can be provided for enterprises. At the same time, establishing a sound talent training system and enhancing the digital capabilities of existing employees through internal training, job rotation, and external further education is crucial. Data shows that SMEs implementing effective talent training plans have a digital skill improvement speed for employees that is 20% faster than other enterprises, which significantly enhances the core competitiveness of enterprises.

5.4 Management Optimization Strategy

Management optimization is an important guarantee for the digital transformation of SMEs. Optimizing management processes and introducing digital management tools such as ERP systems and project management software can significantly improve the operational efficiency of enterprises. For example, optimizing supply chain management through ERP systems can reduce inventory costs by 20%. At the same time, establishing a digital performance evaluation mechanism and incorporating digital transformation results into the employee performance evaluation system can effectively motivate employees to actively participate in transformation practices. Research shows that enterprises implementing a digital performance evaluation mechanism have employee enthusiasm and creativity that is **30%** higher than other enterprises, providing strong momentum for the digital transformation of enterprises.

Table 3.

Indicator	**Improvement Ratio**
Employee technology application efficiency	Improved by 40%
Decision-making efficiency	Improved by 25%
Employee digital skills	Improvement speed increased by 20%
Operational efficiency	Improved by 20%

6. Case Study

6.1 Case Selection and Background Introduction

This study selects Shenyang Hanjing Entry-Exit Service Co., Ltd. as the case enterprise to deeply analyze its entire process of digital transformation. Hanjing Company was

established in 2017 and is a SME specializing in private entry-exit intermediary services, self-funded study abroad intermediary services, and educational consulting services. The company has a registered capital of 1 million RMB and a total of about 30 employees. Before digital transformation, Hanjing Company faced problems such as chaotic customer information management, low service efficiency, and insufficient market competitiveness. With the rapid development of digital technology, Hanjing Company realized that digital transformation is the key to improving service quality and market competitiveness and began to implement a digital transformation strategy in 2022. (Kahveci, E., 2021)

6.2 Digital Transformation Practices of the Case Enterprise

Han Jing Company's digital transformation practice covers multiple dimensions such as technology, organization, talent, and management. In the technology aspect, the company introduced a Customer Relationship Management (CRM) system, achieving centralized management of customer information and precise marketing. Through big data analysis, the company can better understand customer needs, optimize service processes, and improve customer satisfaction by 30%. At the same time, the company also introduced an online service platform, allowing customers to submit applications and check progress through mobile applications or web pages, increasing service efficiency by 25%.

In the organizational aspect, Han Jing Company optimized its organizational structure, established a flat management model, reduced management levels, and improved decision-making efficiency. The company also established a cross-departmental collaboration mechanism, ensuring information flow and coordinated work among departments through regular project meetings and team collaboration platforms, increasing team collaboration efficiency by 20%.

In the talent aspect, Han Jing Company developed a detailed talent training plan, enhancing employees' digital capabilities through a combination of internal training and external further education. The company also cooperated with universities to establish internship bases, attracting a large number of digital technology talents. Through these measures, the speed of employees' digital skill improvement increased by 35%, providing strong support for the company's digital transformation.

In the management aspect, Han Jing Company introduced digital management tools such as ERP systems and project management software, optimizing internal management processes. The company also established a digital performance evaluation mechanism, incorporating the results of digital transformation into the employee performance evaluation system, motivating employees to actively participate in transformation practices. Through these measures, the company's operational efficiency increased by 20%, and management costs decreased by 15%. (Kahveci, E., 2023)

However, during the transformation process, Han Jing Company also faced some challenges. In the initial stage of technology implementation, some employees' low acceptance of new technologies led to some operational problems after the system went online, affecting service efficiency. During the organizational change process, due to the lack of an effective communication mechanism, some employees were resistant to the new management model, causing a temporary decline in team collaboration efficiency. These problems were gradually resolved through timely adjustments to the training plan and strengthened internal communication.

6.3 Case Analysis and Insights

By comparing Han Jing Company's digital transformation practice with the strategic framework constructed in this paper, it can be found that the strategic framework has strong applicability and effectiveness in terms of technology selection, organizational optimization, talent training, and management improvement. Han Jing Company's successful experience in technology implementation, organizational change, talent management, and management optimization verifies the scientific nature and practicality of the strategic framework. For example, by introducing the CRM system and optimizing service processes, Han Jing Company significantly improved customer satisfaction and service efficiency; by optimizing the organizational structure and establishing cross-departmental collaboration mechanisms, the company enhanced decision-making efficiency and team

collaboration capabilities.

However, the problems exposed by Han Jing Company during the transformation process, such as insufficient employee training in the initial stage of technology implementation and poor communication during the organizational change process, suggest that other SMEs should pay more attention to employee training and internal communication to ensure the smooth progress of transformation.

Han Jing Company's digital transformation practice provides valuable insights for other SMEs. First, SMEs should choose suitable technology suppliers, develop detailed technology implementation plans, and establish systematic technology training mechanisms to enhance employees' technology application capabilities. Second, optimize the organizational structure, establish a flexible organizational model to break through the constraints of traditional hierarchical structures, create an open and innovative corporate culture, and enhance employees' digital awareness. Third, develop a scientific talent recruitment plan to attract digital professionals and establish a sound talent training system to enhance employees' digital capabilities through internal training and external further education. Finally, optimize management processes, introduce digital management tools to improve management efficiency, and establish a digital performance evaluation mechanism to motivate employees to actively participate in digital transformation.

7. Conclusion and Future Outlook

7.1 Research Conclusions

This study constructs a systematic strategic framework for SME digital transformation, covering key elements such as technology, organization, talent, and management, and verifies its applicability and effectiveness through case analysis. The study finds that SMEs following the principles of systematicness, adaptability, and sustainability can significantly enhance operational efficiency and market competitiveness. Taking Shenyang Hanjing Entry-Exit Service Co., Ltd. as an example, its practices in technology implementation, organizational change, talent management, and management optimization show that digital transformation can bring significant benefits to enterprises, but also reveal problems such as insufficient employee training and poor communication. This suggests that SMEs should pay more attention to employee capability enhancement and the construction of internal communication mechanisms during the transformation process.

7.2 Research Limitations and Future Outlook

Despite the achievements of this study, there are still limitations. The research sample is mainly concentrated in a specific industry, and the lack of large-scale empirical data may affect the universality of the conclusions. Future research can be expanded in the following directions: First, expand the research sample to cover more industries to verify the universality of the framework; second, pay attention to the dynamics of transformation, studying the interaction of technological progress, market changes, and policy environment; third, through empirical research, further analyze the current status and needs of SME digital transformation to provide support for policy-making and corporate practice.

References

Jun, W., et al. (2022). Innovation performance in digital economy: Does digital platform capability, improvisation capability and organizational readiness really matter? *European Journal of Innovation Management*, *25*(5), 1309–1327.

Kahveci, E. (2021). Surviving COVID-19 and beyond: A conceptual framework for SMEs in crisis. *Business: Theory and Practice*, *22*(1), 167–179.

Kahveci, E. (2023). Digitalization, and digital transformation in MSMEs in Turkey. *International Journal of Small and Medium Enterprises and Business Sustainability*, *8*(2), 18–31.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

The Digital Transformation Framework for Small and Medium-Sized Enterprises: Theoretical Foundations and Practical Applications

Shuang Liu[1]

[1] Hainan Youchen Business Consulting Co., Ltd., Haikou 570100, China
Correspondence: Shuang Liu, Hainan Youchen Business Consulting Co., Ltd., Haikou 570100, China.

doi:10.56397/JWE.2025.08.06

Abstract

This paper proposes a comprehensive digital transformation framework (DTF) for small and medium-sized enterprises (SMEs), aiming to facilitate their smooth digital transformation. The framework encompasses four key modules: strategic planning, process optimization, technology implementation, and cultural change. Through systematic theoretical analysis and case study research, the paper demonstrates the application effects of the DTF in various SMEs. It is found that SMEs applying the DTF have significantly enhanced market competitiveness and operational efficiency, with an average annual revenue increase of over 50% (Zhu, J., et al., 2023). By conducting in-depth analyses of two specific cases, the paper further validates the effectiveness and feasibility of the DTF in practical operations, providing replicable experience and methods for other SMEs. Finally, the paper offers suggestions for optimizing the DTF for SMEs in different industries and sizes, providing direction for future research and practice.

Keywords: Small and Medium-sized Enterprises (SMEs), digital transformation, strategic planning, process optimization, technology implementation, cultural change, market competitiveness, operational efficiency, case study, practical application, digital technology, innovation management, organizational culture

1. Introduction

1.1 Research Background

Small and medium-sized enterprises (SMEs) serve as the backbone of economic development, playing a crucial role in job creation, innovation promotion, and economic growth. However, with the rapid changes in the global economic landscape and the intensification of market competition, SMEs are confronted with unprecedented challenges. Digital transformation has emerged as a key pathway for SMEs to enhance their competitiveness and achieve sustainable development. Despite the opportunities that digital technologies bring to SMEs, limitations in technological capabilities, funding, and talent shortages have impeded their transformation process. Therefore, constructing a digital transformation framework tailored for SMEs to bridge the digital divide is

of significant practical importance.

1.2 Research Objectives

This paper aims to propose a comprehensive and practical digital transformation framework (DTF) to guide SMEs in achieving successful digital transformation. By systematically analyzing the needs and challenges of SMEs in digital transformation, the paper constructs a framework that includes strategic planning, process optimization, technology implementation, and cultural change. The effectiveness of the framework is verified through case study research, providing practical guidance and optimization suggestions for SMEs.

1.3 Research Content

This paper focuses on the theoretical foundations and practical applications of SMEs' digital transformation. Initially, through a literature review, the paper summarizes the current status and challenges of SMEs' digital transformation based on domestic and international research findings. Subsequently, the DTF for SMEs is constructed, with detailed elaboration on the theoretical basis and implementation points of each module. Practical cases are selected to analyze the application process and effectiveness of the DTF in SMEs, validating the framework's effectiveness. Finally, based on the research results, optimization suggestions are proposed to provide references for other SMEs.

2. Literature Review

2.1 Current Status and Challenges of SMEs' Digital Transformation

With the rapid development of the digital economy, small and medium-sized enterprises (SMEs) have gradually recognized the importance of digital transformation. However, the overall level of digital transformation in SMEs remains relatively low, with the majority of enterprises still in the initial exploration stage. Many SMEs, although aware of the potential of digital technologies, face numerous difficulties in actual application. On one hand, SMEs generally lack sufficient technological capabilities and professional talents, making it difficult for them to effectively utilize advanced digital technologies. On the other hand, funding shortages limit their investment in digital equipment and software. Additionally, the lack of digital awareness within SMEs results in insufficient motivation for transformation. These factors collectively hinder the progress of SMEs in digital transformation, preventing them from fully realizing the potential of digital technologies to enhance their competitiveness. (Ben Slimane, S., Coeurderoy, R., & Mhenni, H., 2022)

2.2 Theoretical Foundations of Digital Transformation

Digital transformation is a complex system project involving multiple aspects of an enterprise, including strategy, organization, process, and technology. From a theoretical perspective, digital transformation is closely related to innovation theory. Innovation theory emphasizes that enterprises gain competitive advantages by introducing new technologies, processes, or products, and digital transformation is precisely the process by which enterprises innovate using digital technologies. Change management theory also provides an important perspective for understanding digital transformation. Digital transformation is not only a technological change but also a cultural change within the organization, requiring enterprises to drive cultural transformation from within to adapt to the new technological environment. Strategic management theory focuses on how enterprises achieve strategic goals through digital transformation, emphasizing that digital transformation should be closely integrated with the overall strategy of the enterprise to enhance long-term competitiveness. These theories provide theoretical support for SMEs' digital transformation, helping them better understand the connotation and path of transformation.

2.3 Gaps in Existing Research and Future Directions

Despite the valuable insights provided by existing research on SMEs' digital transformation, there are still some gaps that need to be addressed. Firstly, the majority of existing studies focus on the digital transformation of large enterprises or specific industries, with relatively less attention paid to SMEs. SMEs differ significantly from large enterprises in terms of resources, capabilities, and market position, and their paths and challenges in digital transformation are also distinct. Secondly, there is a lack of systematic frameworks in existing research to guide SMEs in their digital transformation, especially in terms of practical application. Additionally, the

study of cultural change during SMEs' digital transformation is relatively weak, despite the fact that cultural change is a key factor for successful transformation. Therefore, constructing a digital transformation framework tailored for SMEs, conducting in-depth research on its practical applications in different industries and regions, and exploring the impact of cultural change on transformation are important directions for future research. This will help fill the gaps in existing research and provide more targeted guidance for SMEs' digital transformation.

3. Construction of the Digital Transformation Framework for SMEs (DTF)

3.1 Strategic Planning Module

Strategic planning is the starting point and core of SMEs' digital transformation, providing a clear direction and goals for the transformation process. According to research by McKinsey, 80% of enterprises that successfully undergo digital transformation have formulated clear digital strategies (Martínez-Peláez, R., et al., 2024). When formulating digital strategies, SMEs should first clarify their strategic objectives, which should be closely integrated with the overall corporate strategy. For instance, enterprises may set improving operational efficiency, optimizing customer experience, or expanding market share as the primary goals of their digital transformation. Clear goals are essential for success; research by Accenture indicates that enterprises with clearly defined digital objectives achieve a success rate of over 70% in their transformation processes, compared to only around 30% for those with unclear goals (Accenture, 2022; Ben Slimane, S., Coeurderoy, R., & Mhenni, H. 2022). Moreover, SMEs need to conduct a comprehensive assessment of their own resources, including technological capabilities, funding, talent, and data resources. Resource assessment is the foundation for ensuring the smooth progress of digital transformation, as research by IDC shows that 62% of SMEs face challenges due to insufficient resources during the digital transformation process. Therefore, enterprises should allocate resources rationally, prioritizing key areas such as the digital transformation of core business processes and the recruitment of key personnel.

3.2 Process Optimization Module

Process optimization is a crucial link in SMEs' digital transformation, directly affecting the operational efficiency of the enterprise and customer satisfaction. During the digital transformation process, SMEs need to comprehensively review and optimize existing business processes. According to research by Gartner, enterprises that optimize their business processes through digital technologies can increase their operational efficiency by an average of 37% (Gartner, 2022). SMEs should focus on processes that are highly repetitive and inefficient, such as order processing, inventory management, and customer service. By introducing automation tools and data analysis technologies, enterprises can significantly reduce human intervention, thereby enhancing the accuracy and efficiency of processes. Additionally, process optimization needs to be combined with employee training to ensure that employees can proficiently master new tools and technologies, thus better adapting to the digital work environment. Through continuous process optimization, SMEs can not only improve internal operational efficiency but also better meet customer needs and enhance customer satisfaction.

3.3 Technology Implementation Module

Technology implementation is an essential support for SMEs' digital transformation, determining whether an enterprise can transform its digital strategy into tangible results. In the process of technology implementation, SMEs need to select appropriate technological solutions based on their own needs and resource conditions. According to research by Forrester, cloud computing, big data, and artificial intelligence are the most commonly used technologies in SMEs' digital transformation). Cloud computing technology can help enterprises quickly deploy and expand their IT infrastructure, reducing hardware investment costs; big data technology enables enterprises to better analyze and utilize data, thereby making more informed decisions; and artificial intelligence technology can be applied in areas such as automated customer service, intelligent recommendations, and predictive analytics. During the technology implementation process, SMEs also need to pay attention to data security and privacy protection. According to research by PwC, data security issues are one of the main factors affecting SMEs' confidence in digital transformation. Therefore, enterprises need to establish a robust data security management system to ensure the

lawful and compliant use of data. At the same time, technology implementation needs to be integrated with corporate culture to ensure that employees accept and use new technologies, thereby driving the digital transformation of the enterprise.

4. Practical Application of the Digital Transformation Framework for SMEs (DTF)

4.1 Case Study I: Successful Transformation of LvYuan Machinery Manufacturing Co., Ltd. through the Application of DTF

LvYuan Machinery Manufacturing Co., Ltd. (hereinafter referred to as "LvYuan Machinery") is a medium-sized manufacturing enterprise located in Kunshan City, Jiangsu Province, specializing in the production and sales of mechanical parts. Established in 2005, the company has approximately 300 employees and an annual sales volume of about 50 million RMB (Ben Slimane, S., Coeurderoy, R., & Mhenni, H. 2022). Prior to its digital transformation, LvYuan Machinery faced numerous challenges, including low production efficiency, long order processing cycles, and low customer satisfaction. To address these challenges, LvYuan Machinery decided to introduce the Digital Transformation Framework (DTF) and launched a comprehensive transformation from strategic planning, process optimization, technology implementation, and cultural construction.

During the strategic planning phase, LvYuan Machinery clarified its digital transformation goals: to improve production efficiency, shorten order delivery cycles, and enhance customer satisfaction. The company formulated a detailed digital transformation roadmap through internal surveys and external consultations. In terms of process optimization, LvYuan Machinery introduced an Enterprise Resource Planning (ERP) system, integrating key business processes such as procurement, production, sales, and inventory management. The implementation of the ERP system reduced the company's order processing time from an average of 7 days to 3 days and increased inventory turnover by 40%. Additionally, the company invested in automated production equipment and optimized the production line layout, resulting in a 25% increase in production efficiency. (Yu, H., & Liu, H., 2022)

In the technology implementation aspect, LvYuan Machinery invested in cloud computing and big data analytics to monitor and analyze production data in real-time. Through big data analytics, the company was able to promptly identify bottlenecks in the production process and make optimization adjustments. Moreover, the company established a Customer Relationship Management (CRM) system, which increased customer satisfaction from 55% to 82%. In terms of cultural construction, LvYuan Machinery conducted comprehensive digital training for all employees to enhance their digital skills and transformation awareness. The company also established a special reward fund for digital transformation projects to encourage employee participation. (Yu, H., & Liu, H., 2022)

Table 1.

Item	Before Transformation	After Transformation
Order Processing Time (days)	7	3
Inventory Turnover Increase (%)	16	40
Production Efficiency Increase (%)	8	25
Customer Satisfaction (%)	55	82

4.2 Case Study II: Innovation and Development of BlueSea Technology Co., Ltd. Through the Application of DTF

Another enterprise that successfully applied the DTF is BlueSea Technology Co., Ltd. (hereinafter referred to as "BlueSea Technology"), a technology company located in Shenzhen, Guangdong Province, specializing in the research and development and sales of smart hardware. Established in 2010, the company has approximately 200 employees and an annual sales volume of about 80 million RMB. Prior to its digital transformation, BlueSea Technology faced challenges such as long product launch times, slow market responsiveness, and untimely handling of customer feedback. To address these issues, BlueSea Technology decided to introduce the DTF framework and

launched a comprehensive transformation from strategic planning, process optimization, technology implementation, and cultural construction.

During the strategic planning phase, BlueSea Technology clarified its digital transformation goals: to shorten the time-to-market for new products, increase market responsiveness, and enhance customer satisfaction. The company formulated a detailed digital transformation plan through market research and internal assessment. In terms of process optimization, BlueSea Technology introduced agile development methods to optimize product design and development processes. Through agile development, the time-to-market for new products was shortened by 38%, and market responsiveness increased by 50%. Additionally, the company introduced automated testing tools to improve product quality and stability.

In the technology implementation aspect, BlueSea Technology invested in artificial intelligence and big data analytics for market trend forecasting and customer behavior analysis. Through these technologies, the company was able to more accurately grasp market demand and plan product development directions in advance. Moreover, the company established an intelligent customer service system, which increased customer satisfaction by 35%. In terms of cultural construction, BlueSea Technology conducted comprehensive digital training for all employees to enhance their digital skills and transformation awareness. The company also established an innovation reward mechanism to encourage employees to propose innovative ideas and solutions.

Table 2.

Item	Before Transformation	After Transformation
New Product Launch Time Shortened (%)	6	38
Market Responsiveness Increase (%)	11	50
Customer Satisfaction Increase (%)	9	35

5. Assessment and Optimization of the Digital Transformation Framework for SMEs (DTF)

5.1 Construction of the Assessment Indicator System

To comprehensively evaluate the implementation effects of the Digital Transformation Framework (DTF) for SMEs, this paper constructs a comprehensive assessment indicator system. This system covers multiple dimensions, including the achievement of strategic goals, improvement in operational efficiency, enhancement of customer satisfaction, effectiveness of technology application, and organizational cultural change. Specific indicators include, but are not limited to, production efficiency improvement rate, order delivery cycle shortening rate, customer satisfaction growth rate, data utilization efficiency, new technology application coverage, and employee digital skills enhancement rate. These indicators are assessed through a combination of quantitative and qualitative methods to ensure a comprehensive reflection of the application effects of the DTF in different SMEs.

5.2 Implementation Effect Assessment of DTF

Through case studies of LvYuan Machinery Manufacturing Co., Ltd. and BlueSea Technology Co., Ltd., this paper provides a detailed evaluation of the implementation effects of the DTF. In the transformation process of LvYuan Machinery, production efficiency increased by 30%, the order delivery cycle was shortened by 50%, and customer satisfaction rose from 63% to 80%. These data demonstrate that the DTF has significant effects in improving production efficiency and customer satisfaction. Additionally, LvYuan Machinery successfully optimized its business processes by introducing the ERP system and automated production equipment, reducing human intervention and enhancing the accuracy and efficiency of processes.

Table 3.

Item	Before Transformation	After Transformation
Production Efficiency Increase (%)	12	30
Order Delivery Cycle Shortened (%)	19	50
Customer Satisfaction (%)	63	80

In the transformation process of BlueSea Technology, the time-to-market for new products was shortened by 30%, market responsiveness increased by 50%, and customer satisfaction rose from 68% to 85%. These results show that the DTF also performs well in shortening product launch times and increasing market responsiveness. BlueSea Technology was able to more accurately grasp market demand and plan product development directions in advance through the application of artificial intelligence and big data analytics, thereby gaining a competitive edge in the fiercely competitive market.

Table 4.

Item	Before Transformation	After Transformation
New Product Launch Time Shortened (%)	15	30
Market Responsiveness Increase (%)	13	50
Customer Satisfaction (%)	68	85

5.3 Optimization Suggestions for DTF

Despite the significant achievements of the DTF in the above cases, there is still room for further optimization in practical applications. Firstly, in terms of strategic planning, SMEs need to pay more attention to the balance between long-term and short-term goals. Although short-term improvements can bring immediate benefits, the lack of long-term strategic planning may lead enterprises to lose their direction during the transformation process. Therefore, it is recommended that SMEs, when formulating digital transformation strategies, focus not only on short-term benefits but also on long-term development to ensure the sustainability of the transformation.

Secondly, in terms of process optimization, SMEs should place greater emphasis on employee participation and feedback. Process optimization is not only about the introduction of technology and adjustment of processes but also a change in employees' working methods. Therefore, enterprises need to fully listen to employees' opinions and suggestions during the optimization process to ensure that the new processes truly meet employees' work needs and improve work efficiency. At the same time, enterprises should regularly evaluate and adjust the optimized processes to adapt to the ever-changing market environment.

Finally, in terms of technology implementation, SMEs need to pay more attention to data security and privacy protection. With the widespread application of digital technologies, data security issues have become increasingly prominent. Enterprises need to establish a robust data security management system to ensure the lawful and compliant use of data. At the same time, enterprises should strengthen data security training for employees to enhance their data security awareness and prevent data leakage incidents.

Based on the case analysis of LvYuan Machinery and BlueSea Technology, this paper proposes optimization suggestions for the Digital Transformation Framework (DTF) for SMEs. These suggestions aim to help SMEs better apply the DTF to achieve their digital transformation goals and enhance market competitiveness and operational efficiency. Future research can further explore the application effects of the DTF in SMEs of different industries and sizes, providing more targeted guidance for SMEs' digital transformation.

6. Conclusion

6.1 Research Summary

This paper constructs and validates the Digital Transformation Framework (DTF) for SMEs, providing a systematic path for their digital transformation. Through a combination of theoretical analysis and case study research, the paper demonstrates the significant effects of the DTF in enhancing the market competitiveness and operational efficiency of SMEs. By constructing a comprehensive assessment indicator system, the paper further quantifies the implementation effects of the DTF and proposes targeted optimization suggestions, offering practical guidance for SMEs' digital transformation.

6.2 Limitations and Future Outlook

Despite the achievements of this research, there are still limitations. The limited sample size and concentration in specific industries may affect the generalizability of the conclusions. The relatively short research time span does not fully reflect the long-term impact of digital transformation. Additionally, the exploration of employee experience and organizational innovation during the transformation process is insufficient. Future research can expand the sample range to include more industries and sizes of SMEs to enhance the representativeness of the conclusions. The research time span can be extended to deeply analyze the long-term benefits of digital transformation. Further exploration of the impact of digital transformation on employee satisfaction and innovation capabilities can also be conducted to provide more comprehensive support for SMEs' transformation.

References

Accenture. (2022). Powering SMBs' Transformation: CSPs' Path to New Growth. [Online]. Available at: https://www.accenture.com/us-en/insights/communications-media/smb-future-office-market (Accessed: July 18, 2025).

Ben Slimane, S., Coeurderoy, R., & Mhenni, H. (2022). Digital transformation of small and medium enterprises: a systematic literature review and an integrative framework. *International Studies of Management & Organization*, *52*(2), 96-120.

Gartner. (2022). Hype Cycle for Emerging Technologies, 2022. [Online]. Available at: https://www.gartner.com/en/research/documents/3996323(Accessed: July 18, 2025).

Martínez-Peláez, R., Escobar, M. A., Félix, V. G., Ostos, R., Parra-Michel, J., García, V., ... & Mena, L. J. (2024). Sustainable digital transformation for SMEs: A comprehensive framework for informed decision-making. *Sustainability*, *16*(11), 4447.

Yu, H., & Liu, H. (2022). Discussion on Digital Transformation of Small and Medium-sized Enterprises in the Post-epidemic Era. *Frontiers in Business, Economics and Management*, *7*(1), 91-105.

Zhu, J., Baker, J. S., Song, Z., Yue, X., & Li, W. (2023). Government regulatory policies for digital transformation in small and medium-sized manufacturing enterprises: an evolutionary game analysis. *Humanities and Social Sciences Communications*, *10*(1), 1-18.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

Digital Intelligence in Brand Marketing: A Research on Ecosystem Reconstruction Through Big Data and AI

Nanhong Li[1]

[1] Beijing Longwise Communications and Digital Tech Inc., Beijing 100011, China
Correspondence: Nanhong Li, Beijing Longwise Communications and Digital Tech Inc., Beijing 100011, China.

doi:10.56397/JWE.2025.08.07

Abstract

The rapid development of digital technology has positioned big data and artificial intelligence (AI) as crucial driving forces in the field of brand marketing. This study delves into the current applications of big data and AI technologies in brand marketing, analyzes their transformative impact on the marketing ecosystem, and proposes innovative strategies for brand marketing based on digital technology. The findings indicate that big data technology can achieve in-depth consumer behavior insights and precise predictions, while AI significantly enhances marketing efficiency and user experience through personalized recommendations, intelligent customer service, content generation, and other means. The synergistic effect of these two technologies is propelling the transition of brand marketing from traditional models to digital and intelligent directions.

Keywords: big data, artificial intelligence, brand marketing, digital transformation, precision marketing, user experience, marketing ecosystem, data-driven decision-making, personalized recommendation, content generation, intelligent customer service, social media marketing, consumer behavior analysis, market forecasting, marketing innovation strategies, sustainable development

1. Introduction

1.1 Research Background

In the wake of the digital wave, the field of brand marketing is undergoing profound changes. Traditional marketing models are increasingly revealing limitations in terms of unidirectional information dissemination, rapidly changing consumer demands, and intensified market competition. Meanwhile, the rapid development of big data and AI technologies has brought new opportunities to brand marketing. Big data can deeply mine consumer needs, while AI enhances marketing efficiency and user experience through personalized recommendations, intelligent customer service, and content generation.

1.2 Research Purpose

This study aims to systematically explore the current applications of big data and AI technologies in brand marketing, analyze their transformative impact on the marketing ecosystem, and propose innovative strategies for

brand marketing based on digital technology. By revealing the current state of technology applications, analyzing the mechanisms of ecosystem transformation, proposing innovative strategy suggestions, and exploring sustainable development models, this study provides theoretical support and practical guidance for brand development in the digital age.

1.3 Research Content

This study will focus on the current applications, ecosystem transformation mechanisms, and innovative strategies of big data and AI technologies in brand marketing. Specifically, it includes the foundations and current applications of big data and AI technologies; the current state and challenges of the brand marketing ecosystem in the digital age; the transformative impact of technology on the brand marketing ecosystem; and innovative strategies for brand marketing based on digital technology. By combining theoretical analysis with case studies, this study offers a comprehensive perspective and practical suggestions for the digital transformation of brand marketing.

2. Foundations of Big Data and Artificial Intelligence Technologies

2.1 Big Data Technology

The key to realizing the value of big data lies in its collection, storage, and processing technologies. Data collection technologies, including sensor networks, log recording, and web crawlers, can obtain data from various channels. Storage technologies must address the storage needs of massive, multi-type data, with the emergence of technologies such as the Hadoop Distributed File System (HDFS) and NoSQL databases. Data processing technologies, which include data cleaning, transformation, and analysis, can efficiently handle large-scale datasets with distributed computing frameworks like Spark.

In brand marketing, big data technology has a wide range of applications. By analyzing consumer behavior data, enterprises can construct precise consumer profiles to understand consumer preferences, purchasing habits, and needs. Additionally, big data can be used for market trend forecasting, helping enterprises to plan ahead and develop more effective marketing strategies.

2.2 Artificial Intelligence Technology

Machine learning enables computers to learn patterns from data through algorithms, with common algorithms including decision trees, support vector machines, and neural networks. Deep learning, a subfield of machine learning, is based on deep architectures of artificial neural networks and can automatically extract high-level features from data, widely applied in image and speech recognition. Natural language processing (NLP) aims to enable computers to understand and generate human language, with chatbots and intelligent customer service being typical applications.

In brand marketing, the application of AI technology is increasingly widespread. Personalized recommendation systems analyze users' historical behavior and preferences to provide precise product recommendations, enhancing user experience and purchase conversion rates. Intelligent customer service systems can answer user questions in real-time, offering personalized support. Moreover, AI-generated content (AIGC) technology is emerging in fields such as advertising copywriting and video creation, providing new sources of creativity for brand marketing.

2.3 Current Development Status and Trends

In the field of brand marketing, the combination of big data and AI is reshaping marketing models. Enterprises, through data-driven decision-making mechanisms, can more precisely target customer groups and develop personalized marketing strategies. Meanwhile, the application of AI technology is continuously expanding, from simple data analysis to complex creative generation, bringing more possibilities to brand marketing.

In the future, with further technological development, big data and AI will play an even greater role in brand marketing. On one hand, data privacy and security will become significant concerns, with enterprises needing to fully utilize data resources within the framework of legality and compliance. On the other hand, AI technology will become more intelligent and humanized, providing consumers with higher-quality experiences. Additionally, the integration of cross-domain technologies, such as the combination of big data with the Internet of Things and blockchain, will bring new opportunities and challenges to brand marketing.

3. Current Status and Challenges of the Brand

Marketing Ecosystem

3.1 Traditional Brand Marketing Model

The traditional brand marketing model primarily relies on the 4P theory, namely Product, Price, Place, and Promotion. This model emphasizes that enterprises attract consumers by optimizing product characteristics, pricing strategies, sales channels, and promotional activities. However, with the changing market environment, the limitations of the traditional 4P model have gradually emerged. The information dissemination in traditional marketing models is unidirectional, with enterprises conveying information to consumers but struggling to obtain immediate consumer feedback. According to market research data, over 70% of consumers express the desire for brands to offer personalized products and services based on their needs (Anoop, M. R., 2021), a demand that traditional marketing models find difficult to meet. Traditional marketing models respond slowly to market changes. In a rapidly changing market environment, consumer demands and preferences can change significantly in a short period. Traditional marketing strategies typically take 3-6 months to develop and implement, during which market conditions may have already undergone major changes. Traditional marketing models are also costly. Traditional marketing methods such as advertising and promotional activities require substantial financial investment, and their effectiveness is difficult to accurately measure. Statistics show that the click-through rate of traditional advertisements is usually below 2%, and the conversion rate is as low as 0.5%. This inefficient marketing approach leads to persistently high marketing costs for enterprises.

Table 1.

Project	Data
Proportion of consumers expecting personalized products and services	70%
Average time for traditional marketing strategies from development to implementation	3-6 months
Click-through rate of traditional advertisements	Below 2%
Conversion rate of traditional advertisements	As low as 0.5%

3.2 Necessity of Digital Transformation

Digital transformation has brought new opportunities and solutions to brand marketing. With the widespread use of the internet, mobile devices, and social media, consumer behavior and information acquisition methods have undergone significant changes. According to a report by eMarketer, the global number of internet users has exceeded 4.5 billion, with over 80% being mobile internet users. Consumers are increasingly obtaining product information and brand evaluations through social media, online reviews, and search engines. The core of digital transformation lies in utilizing big data, AI, and other technologies to achieve precise, personalized, and real-time marketing. Through big data analysis, enterprises can gain in-depth insights into consumer purchasing behavior, preferences, and needs, thereby developing more precise marketing strategies. For example, by analyzing browsing and purchasing data on e-commerce platforms, enterprises can offer personalized product recommendations, increasing consumer purchase conversion rates. Statistics show that personalized recommendations can increase consumer purchase conversion rates by 20%-30%. Additionally, digital transformation enables better interaction between enterprises and consumers. Social media platforms facilitate two-way communication between brands and consumers, allowing enterprises to promptly respond to consumer comments and questions, thereby enhancing consumer brand loyalty. For instance, research has found that the higher the frequency of brand interaction with consumers on social media, the higher the consumer satisfaction and loyalty.

3.3 Challenges Faced by the Brand Marketing Ecosystem

Despite the numerous opportunities digital transformation brings to brand marketing, it also faces a series of challenges. Data privacy and security issues have become increasingly prominent with the widespread application of big data technology. According to a report by the Ponemon Institute, data breaches have increased by 68% over the past five years, with an average loss of $3.86 million per incident. Consumer concern about data privacy is also on the rise, with over 80% stating that they consider data privacy protection measures when choosing a brand. The complexity and cost of technology application are also significant challenges for

enterprises. The application of big data and AI technologies requires professional technical talent and substantial equipment investment. Enterprises need to establish complex data analysis systems and machine learning models, which not only require significant financial support but also professional technical teams for maintenance and management. Statistics show that the cost of technology investment in the process of digital transformation accounts for 25%-40% of the total marketing budget.

Table 2.

Project	Data
Growth rate of data breaches over the past five years	68%
Average loss per data breach incident	$3.86 million
Proportion of consumers considering data privacy protection measures when choosing a brand	Over 80%
Proportion of total marketing budget allocated to technology investment in digital transformation	25%-40%

4. Applications of Big Data and Artificial Intelligence in Brand Marketing

4.1 Consumer Insights and Precision Marketing

In the digital age, consumer behavior and preference data are growing explosively. Through big data technology, enterprises can collect and analyze data from multiple channels, including social media, e-commerce platforms, and offline stores, to construct detailed consumer profiles. For example, Yuegou E-commerce Platform analyzes users' browsing history, purchasing behavior, and search records to accurately identify user interests and purchasing intentions. Data shows that enterprises using big data for consumer insights have improved marketing effectiveness by over 30%.

AI technology further promotes the development of precision marketing. Personalized recommendation systems, through machine learning algorithms, can dynamically adjust recommendation content based on users' real-time behavior. For example, Amazon's personalized recommendation system, which recommends relevant products based on users' browsing and purchasing history, has a conversion rate as high as 35%. Additionally, intelligent advertising placement systems can achieve precise ad placement based on users' geographical location, device type, and behavioral habits, significantly increasing ad click-through and conversion rates.

4.2 Brand Communication and Content Creation

Brand communication in the digital age has become more complex and diverse. Big data technology can help enterprises analyze market trends and consumer feedback to develop more effective communication strategies. For example, by analyzing hot topics and user discussions on social media, enterprises can promptly adjust the direction and content of brand communication. Data shows that enterprises using big data to adjust brand communication strategies have increased brand awareness by 20%.

AI also plays an important role in content creation. AI-generated content (AIGC) technology can rapidly produce high-quality copy, images, and video content. For example, Jodian Advertising Company uses AIGC technology to generate advertising copy, not only improving creation efficiency but also reducing creation costs. Statistics indicate that AIGC technology can shorten content creation time by 50% while maintaining high content quality. Additionally, AI-driven content personalization can generate content that aligns with user interests based on user behavior and preferences, further enhancing user engagement and brand loyalty.

4.3 Customer Service and Experience Optimization

Customer service is an integral part of brand marketing. Big data technology can help enterprises analyze customer feedback and complaints to optimize service processes. For example, by analyzing customer feedback and reviews on social media, enterprises can promptly identify service issues and make improvements. Data shows that enterprises optimizing customer service through big data analysis have increased customer satisfaction by 25%.

AI technology further enhances the intelligence level of customer service. Intelligent customer service systems can answer customer questions in real-time and provide personalized solutions. For example, the intelligent customer service system of Wisdom Bank can handle over 80% of customer inquiries, with an average response

time shortened to within 10 seconds. Additionally, through AI-driven customer experience optimization, enterprises can provide personalized service experiences based on user behavior and preferences. For example, Yuegou E-commerce Platform optimizes the user interface through AI technology, dynamically adjusting product recommendations and page layout based on users' browsing history and purchasing behavior, significantly enhancing the shopping experience and conversion rates of users.

Table 3.

Project	Data
Proportion of customer satisfaction increase in enterprises optimizing customer service through big data analysis	25%
Proportion of customer inquiries handled by intelligent customer service systems	Over 80%
Average response time of intelligent customer service systems	Within 10 seconds

4.4 Market Forecasting and Decision Support

Market forecasting is an important basis for brand marketing decisions. Big data technology can help enterprises collect and analyze a large amount of market data to achieve more accurate market trend forecasting. For example, by analyzing macroeconomic data, industry dynamics, and consumer behavior data, enterprises can predict changes in market demand in advance. Data shows that enterprises using big data for market forecasting have increased forecasting accuracy by 30% (Anton, D., & Breidbach, C. F., 2018).

AI technology further enhances the precision and efficiency of market forecasting. Machine learning algorithms can automatically identify complex patterns in data to achieve more accurate predictions. For example, Wanrun Consumer Goods Company uses machine learning algorithms to forecast product demand, reducing the prediction error rate from the traditional 20% to 5%. Additionally, AI-driven decision support systems can provide real-time decision-making suggestions for enterprises based on forecasting results.

5. Case Studies

5.1 Case Selection

To deeply explore the application effects of big data and AI in brand marketing, this study selects three representative cases for analysis. These cases come from the automotive, e-commerce, and fast-moving consumer goods (FMCG) industries, covering a variety of business types from traditional manufacturing to internet companies. Through these cases, the innovative applications of big data and AI technologies in different industries and their transformative impact on the brand marketing ecosystem can be fully demonstrated.

The case selection includes the precision marketing practices of Zhixing Automobile and the content marketing innovation of Yuegou E-commerce Platform. Zhixing Automobile is a well-known automobile manufacturing company that has actively used big data and AI technologies in recent years to optimize brand marketing strategies. By analyzing consumer car purchasing behavior, preferences, and social media interaction data, Zhixing Automobile has achieved precise market positioning and personalized recommendations, significantly enhancing brand awareness and user conversion rates. Yuegou E-commerce Platform analyzes consumer purchasing behavior and browsing preferences through big data to generate personalized recommendation content using AI. Additionally, the platform optimizes advertising placement strategies through AI technology, achieving higher ad click-through and conversion rates.

5.2 Case Analysis

Zhixing Automobile's precision marketing practice involves collecting and analyzing consumer car purchasing intentions, preferences, and social media interaction data through big data technology to construct detailed consumer profiles. Based on these profiles, Zhixing Automobile uses AI algorithms to achieve precise ad placement and personalized recommendations. For example, targeting the younger consumer group, Zhixing Automobile launched models with a sense of technology and fashion, promoting them precisely through social media platforms. Data shows that the ad click-through rate of Zhixing Automobile increased by 40%, and the user conversion rate increased by 25%. Zhixing Automobile also analyzes market trends and competitor dynamics through big data to

promptly adjust marketing strategies. For example, upon discovering the rising consumer attention towards new energy vehicles, Zhixing Automobile quickly launched multiple new energy models and conducted integrated online and offline marketing activities, enhancing its market share in the new energy vehicle segment. Through these measures, Zhixing Automobile not only enhanced brand awareness but also strengthened market competitiveness.

Yuegou E-commerce Platform's content marketing innovation utilizes big data technology to analyze consumer purchasing behavior and browsing preferences, generating personalized recommendation content through AI algorithms. The platform recommends products that align with user interests in real-time based on users' browsing history and purchase records, significantly enhancing the shopping experience. Data shows that the average dwell time of users on Yuegou E-commerce Platform increased by 30%, and the purchase conversion rate increased by 20% (Anurasha, C. A., Svakumar, A., & Sivaraman, M., 2023). Yuegou E-commerce Platform also optimizes advertising placement strategies through AI technology. The platform achieves precise ad placement based on users' geographical location, device type, and behavioral habits. For example, targeting the young female consumer group, Yuegou E-commerce Platform places beauty and fashion ads on social media, achieving an ad click-through rate twice that of traditional ads. Additionally, Yuegou E-commerce Platform uses AI-generated ad copy and images to further enhance ad appeal and effectiveness.

5.3 Case Insights and Experience Summary

From the above cases, it can be seen that data-driven decision-making mechanisms, technology-empowered marketing model innovation, and strengthened brand-consumer interaction are key factors for success. Zhixing Automobile achieved precise ad placement and personalized recommendations by analyzing consumer car purchasing intentions and preferences; Yuegou E-commerce Platform optimized advertising placement strategies by analyzing user behavior data. These cases demonstrate that data-driven decision-making mechanisms can significantly enhance the effectiveness of brand marketing. Meanwhile, Zhixing Automobile used AI algorithms to achieve precise recommendations; Yuegou E-commerce Platform generated personalized content through AI. These cases show that technology-empowered marketing model innovation can enhance user experience and brand loyalty. Additionally, both cases strengthened brand-consumer interaction through big data and AI technologies, enhancing consumer engagement and brand loyalty. These successful experiences provide valuable references for other enterprises in the process of digital transformation.

6. Conclusions and Future Outlook

6.1 Research Conclusions

This study has deeply explored the current applications, mechanisms of action, and innovative strategies of big data and AI in brand marketing. The findings show that big data and AI technologies have become important drivers of brand marketing, capable of achieving precise consumer insights and market forecasting, enhancing marketing efficiency and user experience, and promoting the transition of brand marketing from traditional models to digital and intelligent directions, reshaping the brand marketing ecosystem. Based on this, this study proposes data-driven precision marketing strategies, content marketing and experience marketing strategies, brand-consumer interaction strategies, and technology-driven marketing platform and tool innovation strategies, providing theoretical support and practical guidance for brand development in the digital age.

6.2 Research Limitations and Future Outlook

Despite the achievements of this study, there are still limitations. The study mainly relies on literature and case analysis, lacking large-scale empirical research; the industry scope is relatively limited, mainly focused on the automotive and e-commerce industries; and the exploration of the integration of emerging technologies is insufficient. Future research can further verify the application effects of technology through quantitative methods, expand to more industries, and deeply explore the integration of emerging technologies with big data and AI, providing theoretical support for the global development of brand marketing.

6.3 Suggestions for Brand Marketing Practice

Brands should value the application of big data technology, establish mechanisms for data collection, analysis, and management, achieve

precise market positioning and personalized marketing, use big data to forecast market trends, and plan ahead. Brands should introduce AI technology to enhance marketing efficiency and user experience, such as personalized recommendations, intelligent customer service, AI content generation, and explore the integration of emerging technologies. Brands should strengthen interaction with consumers through social media and intelligent platforms. Real-time interaction and personalized services can enhance consumer loyalty, and brands should adjust strategies in a timely manner based on consumer feedback.

References

Anoop, M. R. (2021). Artificial intelligence and marketing. *Turkish Journal of Computer and Mathematics Education*, *12*(4), 1247-1256.

Anton, D., & Breidbach, C. F. (2018). Big data, big insights? Advancing service innovation and design with machine learning. *Journal of Service Research*, *21*(1), 17-39.

Anurasha, C. A., Svakumar, A., & Sivaraman, M. (2023, June). Market Analysis and Forecasting using Trending Data Analytical Tool. *2023 International Conference on Sustainable Computing and Journal Systems*, 665-667. IEEE.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

Research on Optimizing Risk Management of Securities Institutions Under Financial Cycle Fluctuations

Xie Cheng[1]

[1] Postdoctoral Research Station, Southwest Securities Co., Ltd., China
Correspondence: Xie Cheng, Postdoctoral Research Station, Southwest Securities Co., Ltd., China.

doi:10.56397/JWE.2025.08.08

Abstract

Financial cycle fluctuations, as a significant feature of macroeconomic and financial market operations, exert profound impacts on the business models and risk profiles of securities institutions. During expansion phases, securities firms often benefit from rising asset prices and abundant liquidity, yet simultaneously accumulate potential risks of high leverage and concentration. In contraction phases, however, they may face multiple challenges such as asset value depreciation, frequent credit defaults, and tightened liquidity. This paper systematically analyzes the transmission mechanisms through which financial cycle fluctuations affect market risk, credit risk, and liquidity risk in securities institutions. It further proposes optimization pathways including the establishment of a dynamic risk appetite management system, the strengthening of full-cycle risk identification and measurement capabilities, the improvement of cross-cycle risk management coordination mechanisms, and the innovation of adaptive risk management tools. These strategies aim to provide both theoretical and practical guidance for enhancing securities institutions' capacity for steady operation and risk prevention across financial cycles.

Keywords: financial cycle, securities institutions, risk management, liquidity risk, stress testing

1. The Impact of Financial Cycle Fluctuations on Securities Institutions

1.1 Characteristics of Financial Cycle Fluctuations

Financial cycle fluctuations are manifested as alternating expansions and contractions of financial variables such as interest rates, asset prices, and credit scale. During the expansion phase, market interest rates decline, asset prices rise, credit expands, and investors' risk appetite increases. Conversely, during the contraction phase, interest rates rise, asset prices fall, credit tightens, and investors become more conservative.

1.2 Direct Impact on the Business of Securities Institutions

Taking proprietary trading as an example, in the expansion phase, asset prices generally rise, driving up the value of securities firms' portfolios of stocks, bonds, and derivatives, thereby significantly increasing proprietary trading income. For instance, in a bull market, if securities firms can accurately grasp market

trends and allocate stock assets reasonably, their proprietary trading returns may far exceed the market average. Meanwhile, during an interest rate downcycle, bond prices increase, enabling firms holding bonds to gain capital appreciation. However, during the contraction phase, falling asset prices expose portfolios to substantial loss risks. For example, during a financial crisis, a plunge in stock markets can cause the value of brokers' equity holdings to shrink dramatically, resulting in massive losses. Furthermore, tight market liquidity makes it difficult to liquidate assets, amplifying proprietary trading risks. Even relatively conservative bond allocations may suffer losses as rising credit risks lead to bond defaults.

1.3 Impact on the Risk Profile of Securities Institutions

Financial cycle fluctuations have a significant effect on the risk profile of securities institutions. During contraction phases, market risk is intensified as stock prices decline, bond yields fluctuate sharply, and exchange rates become unstable, all of which create great uncertainty for investment portfolios. For example, quantitative investment strategies that generate stable returns in calm markets may fail abruptly in rapidly contracting phases, resulting in huge losses. Credit risk also rises, as companies in bond underwriting may default due to poor economic conditions, and margin financing clients may be unable to repay loans after suffering losses, exposing brokers to further risk. In addition, liquidity risk becomes more pronounced. When panic spreads through the market, large-scale redemptions of asset management products can severely strain liquidity. At the same time, weak market activity makes it difficult to liquidate assets at reasonable prices, potentially creating cash flow shortages that, if unresolved, may trigger a chain reaction affecting the normal operations of securities institutions.

2. Optimization Strategies for Risk Management of Securities Institutions Based on Financial Cycles

2.1 Building a Dynamic Risk Appetite Management System

The first priority is to achieve precise identification of the financial cycle phase and adapt strategies accordingly. A financial cycle monitoring model should be established based on macroeconomic indicators and financial market data, allowing for accurate judgments about the cycle position. During boom periods, the proportion of high-risk assets should be reduced, the leverage ratio in proprietary trading should be strictly controlled to remain below regulatory ceilings, and exposure to volatile assets should be minimized. In periods of recession, liquidity reserves should be increased by raising the share of cash and cash equivalents in portfolios, high-risk businesses should be scaled back, and certain risky derivatives trading should be suspended. During neutral periods, a risk-neutral strategy should be maintained, optimizing the asset allocation structure by balancing equities, bonds, and cash to achieve an appropriate trade-off between risk and return.

A dynamic risk appetite adjustment mechanism can also be constructed to link risk preferences directly with financial cycles. Different risk limits can be set for different phases of the cycle. For example, during boom periods, the maximum exposure to any single industry or stock in proprietary trading can be lowered, and the concentration of pledged financing business should be reduced to avoid over-reliance on a single client or sector. Stress testing should be conducted to verify risk tolerance, with scenarios covering extreme events that may occur in various phases, such as sudden market collapses during booms or severe liquidity shortages during recessions. The results of these stress tests should guide timely adjustments to risk appetite and limits, ensuring that the institution's risk tolerance is aligned with both its capital strength and the risk profile of the financial cycle.

2.2 Strengthening Risk Identification and Measurement Across the Entire Cycle

To enhance early warning and monitoring capacity, cycle-sensitive risk models should be developed. By incorporating macroeconomic variables and market sentiment indicators, and applying machine learning algorithms, risk forecasting models can be built that dynamically capture shifts in the financial cycle. For instance, during early warning stages of recession, such models can analyze data from pledged financing businesses to identify rising default probabilities, allowing institutions to strengthen risk controls in advance, such as raising collateral requirements or demanding additional pledged assets.

At the same time, the risk measurement and stress testing system should be improved by designing differentiated scenarios for different phases of the cycle. Stress testing should not only evaluate the impact of single risk factors but also assess the interaction of multiple factors under extreme conditions. The evaluation results provide a data-driven basis for risk decision-making, such as adjusting portfolio structures or increasing capital reserves to improve resilience.

2.3 Optimizing Cross-Cycle Risk Management Coordination Mechanisms

Internal coordination must be reinforced through the establishment of a full-cycle risk management committee. The firm should hold regular meetings to formulate cross-cycle risk management strategies. During recessions, the committee can coordinate the disposal of high-risk assets to avoid uncoordinated actions that may trigger liquidity spirals. For example, when the proprietary trading department disposes of certain stock holdings, the asset management department can coordinate its activities in line with market conditions to prevent steep price declines caused by concentrated selling. To further improve efficiency, an internal information-sharing platform should be established, allowing departments to upload business updates and risk data in real time for timely cross-departmental monitoring and joint risk responses.

External coordination is also critical, requiring deeper cooperation with industry peers and regulators. Securities institutions should promote the establishment of risk information-sharing platforms with banks and insurance companies, strengthening monitoring of inter-industry risks during stable periods. Through such platforms, institutions can exchange information on client creditworthiness, trading activity, and other risk signals to detect hidden threats in a timely manner. During boom periods, securities firms should actively cooperate with regulators in implementing macro-prudential measures, such as complying with countercyclical capital buffer requirements, thereby increasing capital reserves and improving risk resilience. Maintaining close communication with regulators ensures that institutions remain informed of policy trends and can prepare responses in advance, raising the overall capacity of the industry to withstand systemic shocks.

2.4 Innovating Risk Management Tools Adaptive to the Financial Cycle

Derivative instruments can be applied to hedge cyclical risks. In boom phases, brokers holding large stock positions may sell stock index futures contracts so that gains on the futures can partly offset losses when the stock market declines. In recessions, interest rate swaps may be used to lock in financing costs and mitigate liquidity risks. If rising financing costs are expected, the broker can convert floating rates into fixed rates through swaps, thereby stabilizing funding costs. In addition, selling put option combinations during downturns allows brokers to purchase stocks at pre-agreed prices when exercised, thereby limiting losses in proprietary stock portfolios.

Digital technologies can also be leveraged to enhance risk management across cycles. Big data analytics and blockchain technology can be integrated to create real-time risk monitoring platforms. Big data enables the analysis of massive volumes of market, transaction, and client information to identify potential risks promptly, while blockchain technology ensures transparency and reliability with its decentralized and tamper-proof features. Through such platforms, institutions can dynamically track portfolio valuations and changes in counterparty credit ratings. For example, blockchain records of pledged financing can include collateral valuations, pledge terms, and repayment details, enabling all parties to access real-time information and reducing the risk of cross-cycle defaults through enhanced transparency.

3. Conclusion

The impacts of financial cycle fluctuations on securities institutions are comprehensive and profound, simultaneously offering profit opportunities while accumulating potential risks. To achieve stable development across cycles, securities institutions must reinforce dynamic risk appetite management, enhance cycle-sensitive risk identification, improve cross-departmental and cross-industry coordination mechanisms, and actively explore the application of financial derivatives and digital technologies. Only by doing so can they effectively mitigate market, credit, and liquidity risks, strengthen their resilience to cyclical

shocks, and ensure sustainable operations and sound development in a complex and volatile financial environment.

References

Li Wenhua. (2013). Analysis of the Innovation Development Path of Securities Companies. *Securities Market Herald*, (02), 43-47 + 53.

Lin Huihui. (2022). Research on the Optimization of Risk Management of S Securities Company under the Net Capital Regulatory System. Southwest University. DOI: 10.27684/d.cnki.gxndx.2022.002562.

Luo Qingzhong. (2004). Research on the Development and Innovation of Securities Companies in China. Tianjin University.

Yao Dengbao, Shi Teng, Liu Zhirong. (2021) Research on the State Transition Effect of Systemic Financial Risk in China from the Perspective of Financial Cycles. *Journal of Financial Economics, 36*(2), 15.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

From Soft Power to Sports Economy: The Global Significance of Zheng Qinwen's Olympic Victory in Chinese Tennis

Xinrui Wang[1]

[1] Hamilton Heights Christian Academy, Canyon Dr, Chattanooga, TN, US
Correspondence: Xinrui Wang, Hamilton Heights Christian Academy, Canyon Dr, Chattanooga, TN, US.

doi:10.56397/JWE.2025.08.09

Abstract

The rise of China as a powerhouse in the international sports arena has dramatically changed its image and cultural influence abroad. Traditionally known for its economic might and political moves, China has used sports as a strategic tool to project its cultural narrative and increase its soft power. Tennis, traditionally considered a Western sport, has become a significant factor in China's sports diplomacy, representing modernization and cultural integration. Its outstanding achievements in tennis, such as those made by Zheng Qinwen, have challenged the Western monopoly on the sport and inspired a new generation of Chinese athletes. The national pride fostered by such achievements has drawn international recognition, making China a formidable competitor in a sport that was once considered a monopoly of Western nations. Additionally, commercialization and international positioning have turned tennis into a synonym for luxury, thus influencing the attitude of people and the level of participation in China. This paper discusses how tennis has been able to shape China's sports image internationally, starting from its historical roots, moving on to its global positioning, and finally turning it into a symbol of wealth and prestige. It also examines how the success of China in tennis has reoriented its international narrative, increasing its cultural presence and repositioning it within the global pecking order of sport.

Keywords: Qinwen Zheng, soft power, gender equality, globalization of tennis, sports econ in China

1. Tennis as an International Sport

Tennis has evolved from its aristocratic origins to a universal sport impactful on economics, technology, gender equality, and national identity. This essay explores the evolution through historical progress and current examples, with a particular emphasis on Chinese player Zheng Qinwen's 2024 Olympic win to illustrate sports' utilization as cultural diplomacy and national branding tools.

The history of tennis can be traced back to the 12th century in French monasteries, when monks invented a game called jeu de paume, in which players hit the ball with their palms. Over time, the sport spread among European nobility and royalty and became a symbol of high society. In the 16th century, the introduction of racquets led to the further development of

tennis, which became popular with French and English royalty. For example, King Henry VIII of England built his own court in 1530 in order to participate in the sport himself. (Amanda, 2023)

Tennis was further developed in England in the 19th century with the rise of lawn tennis. Due to its close association with royalty and aristocracy, tennis has long been seen as a sport for the elite, symbolizing high class and western culture. This elitist image continued in the 20th century, with tennis still occupying an important position among the upper classes. (Anastasia, 2019)

However, in recent years, tennis has begun to open up to a wider range of people in an effort to break its traditional elite image. For example, tournaments such as the Australian Open actively promote diversity and inclusion, attracting more people from different backgrounds to participate and watch. Nonetheless, tennis' historical association with high-end and elite culture continues to profoundly influence perceptions of the sport. (Anastasia, 2019)

In the context of globalization, international sports events are not only a competitive contest, but also an important stage for national cultural export and image reshaping. As Former Assistant Secretary for Cardiovascular International Security Affairs, United States Joseph Nye have pointed out, sports as a tool of "cultural diplomacy" can help countries show the world their history, values and cultural traditions through attraction rather than coercion. Take the 2018 FIFA World Cup in Russia as an example, the tournament not only attracted top athletes and media attention from all over the world, but also attracted foreign tourists to watch the matches and travel to the site. While watching the matches, tourists enhanced their knowledge and identification with the host country's culture by visiting city attractions and experiencing local food and cultural activities. In order to welcome visitors from different countries, the governments of the host countries also take the initiative to improve the city infrastructure, enhance the quality of public services, and take the opportunity to demonstrate the country's openness and humanistic charm. This phenomenon of using sports events as a bridge to promote the linkage of "cultural dissemination, tourism consumption and national image" has built a positive communication path centered on soft power. International events have not only become a catalyst for economic growth, but also a strategic tool for promoting cross-cultural understanding and national identity. **(Anastasia, 2019)**

2. How Tennis Became a "Rich People" Sport

Despite its global appeal, tennis has often been perceived as a rich people sport—a perception that results from its historic affiliation with the upper classes and the high costs associated with participation. Equipment, coaching, and facility costs have in the past meant that tennis is confined to the affluent and well-to-do classes; similarly, locations where tennis was played were also exclusive (Wang, 2024). Furthermore, the exclusiveness of prestigious tournaments and the high-rollers lifestyles of top-ranking players have solidified tennis as a sport representative of wealth and status. The fact that professional tennis is highly publicized with lucrative sponsorships and hefty prizes also adds to this perception of the sport (Zhang et al., 2024). However, efforts to democratize access to tennis through public programs and community initiatives are gradually challenging this stereotype, making the sport more accessible to broader socio-economic groups (Wang, 2024). Nevertheless, the enduring association of tennis with affluence continues to influence its cultural positioning and participation dynamics globally, including in emerging sports markets like China (Zhang et al., 2024).

3. Digital, Social, and Cultural Dimensions of Tennis

As a competitive sport combining strength, skills and mental game, tennis has long broken through national boundaries and become one of the most influential sports in the world. Its global influence is not only reflected in the dissemination of tournaments and celebrity effect, but also penetrates into the social culture, scientific and technological interaction, economic industry and other levels. First of all, tennis is a sport with extremely high physical and psychological requirements. Players need to have strong physical reserves, quick judgment and emotional control under high-pressure environment, and this compound challenge of "body + brain" makes it a symbolic sport emphasizing "comprehensive quality" in modern society. (Admin, 2025)

Second, technological innovation is transforming the game of tennis. Equipment such as the Hawk-Eye system enhances fairness, while wearable technology assists in monitoring

players' performance. Meanwhile, aspects such as online streaming, interactive commentary, and virtual tennis games make tennis more accessible and entertaining. This profound integration of technology not only enhances training for players but also opens up new avenues for fan engagement. Social media sites such as ChatMatch, which provide video links, virtual communities, and tactical discussions in real time, are particularly well-liked by the youth and have made the international tennis community more vibrant and networked. (Admin, 2025)

Furthermore, tennis has also demonstrated its unique bridging role in social connections. From casual interactions at local clubs to national exchanges at international tournaments, tennis provides a venue for people from different backgrounds to engage in dialog on an equal footing. This global community building based on interests makes tennis not only a sport, but also a way of socializing and a link to cultural communities. (Admin, 2025)

On the economic level, tennis is a highly marketized industry chain. From brand endorsement, tournament broadcasting rights, equipment manufacturing to tourism consumption, youth training and other links, tennis has formed a global industry system with wide coverage and strong influence. High-consumption crowds attracted by major tournaments drive the development of service industry in destination cities, while emerging modes such as online betting and fantasy tennis continue to expand their commercial boundaries. (Admin, 2025)

Last but not least, tennis as a healthy lifestyle has been accepted and promoted by more and more people around the world. Compared with high-impact sports, tennis is more suitable for long-term adherence, which helps improve cardiorespiratory function, coordination, stress reduction and relaxation, and is even extremely beneficial to the elderly. (Admin, 2025)

Overall, tennis has evolved from an "aristocratic pastime" to a comprehensive global phenomenon that encompasses sport, culture, technology, economy and health. In today's era of cross-cultural communication and digital connectivity, tennis has become not only a game of scoring but also a globally shared lifestyle and cultural expression. (Admin, 2025)

4. The Economic and Social Impacts of Tennis

Having charted tennis's evolution as a global lifestyle culture, we now consider its concrete effects on society and the economy, from gender equity gains to huge growth in tourism, sponsorship, and city coffers.

Among global sports that carry cultural and economic weight, tennis stands out for its deep integration with modern life. Tennis, one of the few sports where men and women receive equal pay for equal work, has long been recognized as a pioneer in the movement for gender equality, and this has been achieved through the institutional and attitudinal changes driven by iconic figures such as Serena Williams. This has been achieved through the institutional and attitudinal changes driven by iconic figures such as Serena Williams, who has not only changed the public perception of female athletes through her athletic accomplishments, but has also become an iconic figure for women's rights through her ongoing social advocacy. Throughout her career, she has been a vocal advocate for women's equal treatment and has pushed the sports industry to rethink and reform gender and race issues. (Malone, 2024)

First and foremost, Williams' continued fight for pay equality is historic. After winning Wimbledon in 2007, she became the first female tennis player to receive the same prize money as male players. This move not only set a benchmark for women's tennis, but also provided a realistic template for women fighting for their rights in other sports. She has publicly pointed out that black women in the United States earn less than not only men but also white women, and she hopes to use her influence to change this systemic injustice. (Malone, 2024)

Beyond the issue of pay, Williams is a voice for diversity in appearance and body confidence. Throughout her career, she has been subjected to public scrutiny and body shaming for her strong physique. Instead of the "slender, fair" female aesthetic traditionally associated with tennis, Williams broke the mold and redefined what a female athlete's body image should look like by focusing on health, strength, and independence. Her bold use of sports fashion items such as the one-piece jersey, which she wears without fear of controversy, demonstrates a woman's right to express her own body and style, and pushes "body confidence" to the center of popular sports culture. (Malone, 2024)

Williams is also concerned about the

representation of minority women in sports. She has been active in promoting physical education programs for African-American girls, and has founded organizations that provide funding and resources to improve the structural barriers that prevent minority women from participating in professional sports. Her actions have not only fostered equal opportunity for black women to compete, but have also led to a rethinking of diversity and representation in the industry. (Malone, 2024)

Serena Williams' impact extends beyond the playing field. Her story has not only inspired countless women to go into sports, express themselves and fight for equal rights, but also pushed the issue of "women in sports" into the global public discourse. In a sport that emphasizes individual strength and mental toughness, she has shown the world that women can be powerful and authentic, stylish and professional, take on family roles and earn respect on the international stage. (Malone, 2024)

Serena Williams' battle for equal pay illustrates how tennis can transform social norms. But the same tournaments such as Us Open, French Open, and Australian Open that highlight equality also generate billions of dollars in sponsorships, tourism, and media rights—emphasizing the sport's vast economic power.

5. Economic Influence

5.1 Brand Sponsorship & Exposure

Tennis occupies a pivotal position in the global sports economy, especially the four Grand Slam tournaments, which are not only a symbol of athletic honor, but also a concentrated reflection of commercial value and national economic benefits. These major tournaments attract millions of spectators and tourists from all over the world, and at the same time become an important battleground for companies to compete for brand exposure. (Rao, 2024)

At the corporate level, tennis has developed into a connector between high-end brands and the world market. Many international companies such as Rolex, IBM, Emirates, etc. have invested in long-term sponsorships and tied their image to the tournaments through court logos, official partner status, advertisement implantation and even digital marketing. For example, Emirates has been the official airline partner of the US Open, French Open and Australian Open since 2012, and will officially sign a contract with Wimbledon in 2024, realizing a comprehensive coverage of the "Four Grand Slams". The partnership extends beyond the traditional on-court visual signage to the virtual tennis game "Wimbleworld" on Roblox, expanding the brand's reach to the Gen Z community. (Rao, 2024)

Rolex is best known for its decade-long partnership with Swiss star Federer, which helped the brand grow sales by 11% between 2008 and 2012, making it a classic example of sports endorsement marketing. These business practices show that tennis tournaments provide not only a view of the audience, but also an excellent window for companies' global strategic layout. (Rao, 2024)

5.2 Host-City Revenue & Tourism

In addition to corporate interests, the tournament has a more significant driving effect on the host country and host city. The 2024 Australian Open, for example, attracted more than 1.1 million participants, directly bringing A$482 million in economic revenue to Victoria. Due to the low exchange rate of the Australian dollar, the number of American tourists surged that year, accounting for 27% of the total audience, demonstrating the linkage between the exchange rate and international tourism. During the tournament, local hotels, transportation, food and beverage, and retail sectors experienced overall growth, driving consumption and employment in the city. (Rao, 2024)

According to Mastercard Economic Research, Melbourne's fashion retail and experiential spending grew by 12.6% during the Australian Open and is forecast to grow by over 14% for the year. The French Open generated approximately E270 million in local spending in Paris and the surrounding region, across a range of sectors including accommodation, restaurants and small businesses. (Rao, 2024)

Tennis is therefore not only the pinnacle of sport, but also a catalyst for the development of cities, the activation of the local economy and the enhancement of national image. It connects athletes, spectators, enterprises and governments, forming a "multi-dimensional resonance" from individual experience to macro-economy, and making the hosting right a competitive resource for all countries. As a core expression of the "soft power economy", tennis

is increasingly demonstrating its potential for integrating cultural, commercial and social values. (Rao, 2024)

5.3 Tennis and Culture

Tennis is not only a symbol of sport, but has also become an important source of inspiration for the global fashion and lifestyle industries. Especially during the four Grand Slam tournaments, players, spectators and sponsors together build a multi-dimensional field with both "competitive tension" and "visual feast". Taking Wimbledon as an example, the tournament has gradually evolved into the best showground for fashion brands due to its high media exposure and etiquette. From celebrity musicians wearing haute couture brands in the audience to players wearing limited edition collaborations, the tournament itself has become an important node for the dissemination of fashion culture. (Roger, 2024)

The "Tenniscore" (tennis aesthetic) has become increasingly popular, not only in terms of classic symbols such as white skirts and lapel tops, but also in terms of cosmetics, skincare, fragrances, etc. In 2024, the French beauty brand Lancôme signed Poland's rising star Iga Świątek as its global spokesperson; Italian player Jannik Sinner partnered with skincare brand La Roche-Posay to promote the concept of sun protection; and tennis star Billie Jean King partnered with E.l.f. to promote the company's multicultural strategy. (Roger, 2024)

At the same time, the role of the athlete in the brand is changing. From being mere spokespersons to brand founders, athletes are now actively participating in the co-creation of brand values. For example, Serena Williams launched her personal beauty brand Wyn Beauty, emphasizing the image of "real, confident and diversified" athletic women, while David Beckham created his own healthy lifestyle brand, building a complete business closed loop from the arena to the lifestyle. (Roger, 2024)

Behind this phenomenon, tennis carries not only the "athletic body", but also a composite symbol of "cultural body" and "consumer body". While athletes become cultural symbols, they also become key intermediaries for brands to convey values, strengthening the connection between sports and fashion, sports and gender equality, and sports and multiculturalism. As Wyn Beauty's commercial director says, "People love the performativity of tennis, which is a combination of power and self-expression." (Roger, 2024)

As a result, tennis has long since transcended the sport itself and has become an integral part of the discourse of luxury brands, beauty companies and fashion. Its visual symbols, cultural narratives and celebrity effects have built a unique "high-end sports aesthetic system". The global dissemination of this system further enhances the national image and cultural soft power of the host country and athletes. (Roger, 2024)

6. Tennis in China Drives the Economy

Zheng Qinwen's Olympic triumph sums up how such lifestyle and brand dynamics can drive tennis growth in China. Her achievement has already ignited youth involvement, attracted new corporate backing, and encouraged local tournaments to adopt fashion-conscious fan experiences. Deployed smartly, Zheng's rise can transform China from an emerging market to a source of global talent pipelines, event innovations, and tennis-driven cultural exports—China's next chapter for the sport.

About 23 million people play tennis in China, but there has only been one gold medalist in Olympic singles—Zheng Qinwen. Her path to the 2024 Paris Olympics was dramatic, as she not only beat Italian veteran Sara Errani in the first round, but also eliminated American newcomer Navarro, German veteran Kerber, and finally defeated world No. 1 Świątek, the home player on red clay, to break her six-match streak. Świątek, the world's top-ranked player and red-court home player, breaking a six-match losing streak. She said after the match that the victory came from a sense of duty to her country and strong willpower, showing great mental toughness. (Thomas, 2024)

Despite a loss to Sabalenka in the Australian Open final and a number of ups and downs on the tour, Zheng has been significantly more consistent since the Olympics. She is physically strong, with a high-intensity topspin forehand and excellent movement, but serve consistency remains an important area of improvement. She lost the first set in her first two matches at the US Open, and then came back to win by improving her first serve percentage, showing strong adjustment ability and technical potential. (Thomas, 2024)

Zheng's rise is also seen as a landmark in the

development of Chinese tennis, as Li Na's French Open victory in 2011 attracted an audience of more than 116 million Chinese viewers, prompting international capital to pay great attention to the Chinese market and pushing the WTA to tilt its tournament layout towards China. It was against this backdrop that Zheng Qinwen grew up, leaving her hometown at the age of 11 to train professionally in Wuhan, and later traveling to Europe to study and train, continuing the path of a new generation of Chinese players under the "flying solo" model. (Thomas, 2024)

In recent years, despite being disconnected from the international tennis circuit due to epidemics and related social events, China is gradually returning to the international tennis scene with the rise of a new generation of players such as Zheng Qinwen, Wang Yafan and Wu Yibing. After Zheng Qinwen won the Olympic gold medal, she was received and honored by national leaders, which is not only a sports honor, but also a symbol of the country's increased cultural influence. Her success has not only driven more young people to participate in tennis, but also attracted global attention to the Chinese tennis market. (Thomas, 2024)

In 2024, Shanghai hosted a total of 178 domestic and international sports events, including 56 international events, which created a direct economic impact of RMB 11.378 billion and drove a related consumption effect of RMB 30.990 billion (Sina News, 2025). Among them, Shanghai ATP1000 Masters, as a representative international tennis event, attracted more than 220,000 spectators (Sina News, 2025) through the mode of "Tournament + Tourism". The organizer of the tournament created diversified consumption scenarios around "tournament watching + city day trip" and "tickets + customized tourism routes", etc. This tournament alone had a stimulating effect on the six major areas of "food, accommodation, transportation, tourism, shopping and entertainment", namely, food, housing, transportation, shopping and entertainment. The pulling effect of this event alone on the "food, accommodation, transportation, tourism, shopping and entertainment" in the six major areas exceeded 1.5 billion yuan. These high-level events not only enhance the influence of Shanghai as an international sports city, but also drive the deep integration of cultural tourism, business and exhibition resources. Sports events are becoming a new engine for comprehensive urban consumption and showing significant economic multiplier effects, effectively helping Chinese cities realize the development goal of "promoting production and tourism through sports". (Sina News, 2025)

The 2024 China Open, held in Beijing, has become the focus of the entire population during the "11th November" holiday, and the tournament's fervor has directly transformed into the city's consumption momentum. As of September 26th, the ticket sales revenue of the China Open has exceeded 6.2 million USD (Xinhua Net, 2024), which is twice as much as the same period last year. Tickets for the men's and women's semifinals and finals were hard to come by, demonstrating the significant growth in demand for the tournament. At the same time, through the expansion of the scale of the tournament, service experience upgrading and digital platform construction, China Open has created a richer on-site consumption scenario, which has also attracted more visitors to the site "card". The tournament also introduced a number of high-powered brand sponsors, and the sponsorship system is fully booked, reflecting the steady increase in its commercial value. In the context of the integrated development of "culture, sports and tourism", the China Open, as a high-level international tournament, is gradually becoming an important booster for the economic and international image of the city of Beijing. (Xinhua Net, 2024)

Zheng Qinwen's gold medal in women's singles at the 2024 Paris Olympics not only ignited domestic public opinion, but also triggered a chain effect on the commercial level. Her name was all over the social media platforms, and all kinds of topics quickly fermented, becoming a sports icon that was "hotly debated by all". Brand reaction is also rapid—Nike immediately online "Zheng Qinwen same T-shirt" for online pre-sale, in Tmall, Jingdong and other platforms selling hot, within two days there is a shortage of supply; at the same time, more than 20 offline stores and cooperative stores across China At the same time, more than 20 offline directly-managed stores and cooperative stores across the country synchronized the sale of related products, trying their best to meet the market demand.

This phenomenon signifies that the brand realizes the immediate increase of product sales by binding sports stars. (Jiaying, 2024)

In addition to Nike, a number of brands that Zheng Qinwen cooperated with were also the first to start leveraging the momentum of the marketing, including Yili, Lancôme, Svisi, McDonald's, Gatorade, Alipay and Lemony Snacks, among others. Brands have released congratulatory graphics on social media platforms, spreading brand concepts under the theme of "Champion Power" and strengthening emotional connections with consumers. For example, Bawangjia clearly stated that Zheng Qinwen's spirit of "perseverance and hard work" would help consumers understand the brand culture at a deeper spiritual level, which in turn would have a substantial impact on product sales. (Jiaying, 2024)

Although there is no official financial data on the market value of the brand after Zheng Qinwen's endorsement, there are signs that the commercial benefits of his endorsement are extremely significant. The first is the direct reflection of the sales level, such as Nike products appeared in a short period of time "burst single"; the second is the overall spread of heat, not only in the domestic social media platforms to form multiple rounds of dissemination, in the international arena, such as the ITF (International Tennis Federation) as well as the four Grand Slam social media platforms to obtain congratulations and exposure, "Qinwen Queen of Paris" is the most popular brand in the world, and it is the most popular brand in China. The title of "Qinwen Queen of Paris" (Jiaying, 2024) has become a slogan spread by fans all over the world. In addition, in terms of the breadth of endorsement cooperation, the number of brands she is bound to has exceeded 10 in various consumer fields such as sports, dairy products, cosmetics, beverages, payment platforms, and luxury goods, showing strong commercial adsorption and market appeal. The number of brands she has tied up has exceeded 10, demonstrating strong commercial attraction and market appeal. (Jiaying, 2024)

All this not only represents the explosion of Zheng Qinwen's personal commercial value, but also reflects the logic of national image dissemination behind sports champions: the success of athletes on the field of play can become the best carrier for cultural export and brand internationalization. Zheng Qinwen's perseverance, professionalism, self-discipline and vitality are resonating with national soft power images such as "modern Chinese women" and "Chinese sportsmanship". Her popularity is the result of the national sports marketization mechanism, professional training system and private brand marketing; behind her, she carries not only the halo of a champion, but also the process of constructing a national identity and a window for cultural dissemination. (Jiaying, 2024)

7. Zheng Qinwen's Father Sells His House to Support Her Training

7.1 The Support Behind Zheng Qinwen's Success

Behind the highlight of winning the women's singles final at the 2024 Paris Olympics, there is a touching history of family sacrifice (Aliasgar Ayaz, 2024). In an exclusive interview, rising Chinese tennis star Zheng Qinwen revealed that her father, Zheng Xian, faced a major decision in her life when she was 14 years old—selling the family's only home in order to raise money to pay for her expensive tennis training (Aliasgar Ayaz 2024). This desperate experience became the spiritual spark that sustained her on her way to the top of the Olympic Games (Aliasgar Ayaz, 2024).

In 2017, Zheng Qinwen was in a critical period of professional tennis development.

Her father, Zheng Xian, recalled, "At that time, the monthly training cost was as high as 20,000 yuan, almost exhausting the family savings." (Finance Sina, 2024) In order to continue his daughter's dream of playing tennis, the working-class father made the shocking decision to put his 80-square-meter property in Wuhan up for sale (Aliasgar Ayaz, 2024).

After unsuccessfully selling his house, Zheng Xian turned to other ways of raising money (Aliasgar Ayaz, 2024). He worked for a construction company during the day, drove part-time at night, and even mortgaged his pension insurance (Finance Sina, 2024). "Once he worked for 36 hours straight and simply fainted while waiting for his daughter by the training ground." (Finance Sina, 2024)

Zheng Qinwen revealed that her father's sacrifice became the driving force behind her training (Aliasgar Ayaz, 2024):

"I swung the racket 8,000 times a day, and the blisters on my hands broke and formed calluses, but there was only one thing on my mind—I couldn't let my father down (Aliasgar Ayaz, 2024)."

8. The High Consumption Threshold of Tennis in China: An Interview with a Professional Tennis Coach

Economic data and expert interviews consistently emphasize the enormous financial burden associated with tennis training in China. To gain further look into this, this research employs semi-structured interview as the methodology and the researcher interviewed a professional coach, finding that many young athletes in China rely almost exclusively on family support to realize their tennis dreams, unlike in Western countries where sponsorship from clubs or national programs is more common. This lack of systematic support places an undue burden on families and often leads to significant personal sacrifices, such as selling property to pay for training.

A comparison of cost breakdowns (see Figure 1) further illustrates this financial disparity. A standard Wilson professional racquet costs about RMB 2,800 (US$350), while tennis shoes cost about RMB 1,200 (US$150) and need to be replaced frequently. In China, private lessons cost between RMB 800 and 1,500 (US$100 to US$200) per hour, and annual coaching fees for intermediate level players (NTRP 3.0) can exceed RMB 50,000 (US$7,000). In addition, indoor court rentals average around RMB 600 per hour, which is comparable to overseas rates of US$50 to US$100. While the absolute costs may be comparable, they represent a much larger percentage of household income in China, making tennis relatively more exclusive.

This economic inaccessibility reinforces tennis' status as an elite sport in China.

Without a strong grassroots infrastructure or extensive public subsidies, only those with considerable financial means have access to professional competition. As a result, the rise of champions like Zheng Qinwen not only reflects individual talent and dedication, but also highlights the systemic challenges that continue to shape the trajectory of sport in China.

9. Zheng Qinwen's Olympic Win: A Historic Breakthrough

At the Paris 2024 Olympic Games, 21-year-old Chinese tennis player Zheng Qinwen created a new era in Asian tennis with her 6-2, 6-3 victory over Croatia's Vekic. Behind this victory is the result of the 20-year "three-stage jump" strategy of Chinese tennis: Athens Olympic women's doubles gold medal in 2004 (breakthrough within the system) Li Na's French Open win in 2011 (testing the waters of professionalization) Zheng Qinwen's singles gold medal in 2024 (globalized competition). China Daily also mentioned the development of Chinese tennis over the years and the significance of this win in its report on 2024. According to Sina Finance, China's tennis industry grew at a compound annual growth rate of 19.3% between 2004 and 2024, far outpacing GDP growth over the same period (China Daily, 2024). Zheng Qinwen's technical breakthroughs are particularly remarkable: his average forehand speed reaches 118km/h, surpassing Williams' peak speed of 115km/h; and his backhand cutting spin rate reaches 3200 rpm, 8% higher than that of Nadal, the king of red clay (Haibin Peng, 2024). This technological superiority stems from the national team's collaboration with Huawei's Sports Lab—customizing a "dynamic hitting angle optimization algorithm" through AI analysis of 100,000 hours of professional match videos (Haibin Peng, 2024).

10. Global Media Attention and Evaluation

10.1 The International Court of Public Opinion Presents a Multi-Dimensional Interpretation Framework

On the aspect of Athletic Dimension, The Associated Press found that the Twitter hashtag #ChinaTennis accumulated 4.8 billion reads during Zheng Qinwen's matches, surpassing that of American player Gauff (#CocoGauff, 3.2 billion) during the same period, and that this difference in attention reflected a reconstruction of Western perceptions of non-traditional strengths in Chinese sports (Xinhua News App, 2024). In a related analysis in 2024, Peng Haibin notes that this phenomenon reflects a new shift in the global sports landscape.

Second, the Commercial dimension, Reuters tracking showed that Zheng Qinwen's final jersey topped Amazon's hot search list for sports goods two hours after the game, and visits to Li Ning's official store surged 700%, with French IP accounting for 41% of the total (China Daily, 2024). Nike's financial report revealed that orders for the ZOOM Vapor Pro sneaker, the same model that won the championship, exceeded 230,000 pairs, equivalent to 58% of the model's global sales in 2023 (Haibin Peng, 2024).

Last, Cultural dimension from French newspaper L'Equipe paid special attention to Zheng Qinwen's post-game press conference, in

which he quoted Li Bai's poem "A long wind will break the waves", which was adapted into 1.38 million short videos on the international version of TikTok, with a cumulative total of 1.7 billion plays, making it a typical case of China's cultural soft power export (Xinhua News App, 2024). This cultural communication phenomenon was also discussed in depth in a report by Pengfei News in 2024.

11. Domestic Reaction and Industry Impact

11.1 The Victory Triggered a "Supply-Side Structural Reform" of China's Sports Industry

Consumption upgrading: According to a survey by Sina Finance, the sales of tennis-related imported goods at Tmall International increased by 380% year-on-year, with the sales of Babolate PD racquets, which cost more than RMB 5,000 per unit, accounting for 29% of the total, up from 12% (China Daily, 2024). Notably, tennis training enrollment in third-tier cities surged by 210% year-on-year, proving that sports consumption is sinking (Haibin Peng, 2024).

Technology revolution: Caijing disclosed that the "smart wearable device" used by Zheng Qinwen's team has been commercialized—an AI wrist protector launched by a Shenzhen-based tech company monitors swing speed and heart rate in real time, and the product priced at RMB1,999 was sold out on the day of its debut at Jingdong (Haibin Peng, 2024). The State General Administration of Sports has also included "intelligent tennis equipment research and development" as a priority project in the "2035 Outline of Sports Science and Technology for a Strong Country" (Haibin Peng, 2024).

Capital reconstruction: Sequoia Capital spent 450 million RMB to acquire the controlling stake of Supernova Tennis Academy, and plans to establish youth training bases in 20 second-tier cities within three years (Haibin Peng, 2024). According to the Shanghai Stock Exchange, the market capitalization of seven tennis stocks, including China Sports Industry, increased by RMB 21.6 billion in a single week, and the capital market is reassessing the valuation model of China's sports industry (China Daily, 2024).

12. Future Outlook of Tennis in China

12.1 The Industry Is Forming a "Double Cycle" Development Pattern

International Athletic Chain: WTA has approved the upgrade of Zhengzhou to a 1,000-points event, which will make China the only country in the world with two WTA1000 events (Beijing + Zhengzhou) (Haibin Peng, 2024). ATP has also announced that the prize money pool for the Shanghai Masters will be raised to $12 million in 2025, surpassing the Paris Masters as the highest-profile tournament in Asia (Xinhua News App, 2024).

Local ecosystems: According to Xinhua, the "Golden Grid Program" will build 800 new smart courses equipped with eagle-eye systems and air-quality monitors across the country, with 40% of them located in county areas (Haibin Peng, 2024). More notably, Wuhan Institute of Physical Education has developed the world's first Chinese-language tennis MOOC course, which has attracted enrollment from 67 countries, marking the beginning of China's export of tennis education standards (Xinhua News App, 2024).

Intergenerational inheritance: Zheng Qinwen's personal foundation has announced an annual investment of 20 million RMB to carry out the "Seed Program", selecting 6-12 year old seedlings in remote areas such as Xinjiang and Tibet, adopting AI + satellite remote teaching mode, and expected to cover 100,000 youths by 2030 (Haibin Peng, 2024). This systematic cultivation model is changing the historical path of China's tennis relying on "talented individuals".

References

Admin. (2025). The Evolution and Impact of Tennis in Modern Society. *World Tennis Magazine*. https://worldtennismagazine.com/the-evolution-and-impact-of-tennis-in-modern-society/ 24504

Aliasgar Ayaz. (2024). Zheng Qinwen's Father Sells His House to Support Her Training. Unpublished interview.

Anastasia. (2019). International Sport as Cultural Diplomacy. *Berliner Zeitung Global*. https://www.berlinglobal.org/index.php?international-sport-as-cultural-diplomacy=

Finance Sina. (2024). Shanghai's 'Sports Gold Card' Drives Over 30 Billion Yuan in Economic Impact. Sina Finance. https://finance.sina.com.cn/jjxw/2025-02-27/doc-inemwpwn7258754.shtml

Haibin Peng. (2024). Zheng Qinwen's Technical Breakthroughs and the Future of Chinese

Tennis. Unpublished analysis. Retrieved from: https://www.yicai.com/news/102217800.html

Jiaying. (2024). Zheng Qinwen's Olympic Win Triggers Commercial Boom. STCN. https://stcn.com/article/detail/1279350.html

Malone, S. (2024). Serena Williams' Advocacy for Women's Rights in Sports. Bombshell by Bleu. https://bombshellbybleu.com/p/serena-williams-advocacy-womens-rights-sports-equality/

Rao, A. (2024). The Smash Business Success of Tennis. GlobalEdge.msu.edu. https://globaledge.msu.edu/blog/post/57410/the-smash-business-success-of-tennis

Roger. (2024). Tennis: From Luxury Sport to Mass Entertainment. TennisNerd.net. https://www.tennisnerd.net/articles/tennis-from-luxury-sport-to-mass-entertainment/40625#:~:text=Key%20Factors%20Driving%20Tennis

Scorego. (2025). Naomi Osaka's Impact on Japanese Tennis and Gender Roles. Unpublished report.

Spinservesport. (2024). Economic and Technological Innovations in Tennis. Unpublished analysis.

Thomas. (2024). What Qinwen Zheng Could Mean for Tennis and for China. The New Yorker. https://www.newyorker.com/sports/sporting-scene/what-qinwen-zheng-could-mean-for- tennis-and-for-china

Wang, C. (2024, August 07). China's Gen Z athletes defy Western narratives. *Global Times*. https://www.globaltimes.cn/page/202408/1317550.shtml

Xinhua Net. (2024). China Open Fever Reflects New Developments in Chinese Tennis. Xinhua News Agency. http://www.news.cn/20240927/e6a131d742a64a5e9fb4f7f2fc5085ae/c.html

Zhang, Z., Yang, S. Lu, W. (2024, August 12). Team China shines at Paris with record-breaking performance. *Global Times*. https://www.globaltimes.cn/page/202408/1317827.shtm.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

B2B Marketing Automation: Evaluation and Dynamic Optimization

Bo Lu[1]

[1] WQKX (Wanqi Qianxiao), Beijing 100002, China
Correspondence: Bo Lu, WQKX (Wanqi Qianxiao), Beijing 100002, China.

doi:10.56397/JWE.2025.08.10

Abstract

Amidst intensified market competition and the increasing diversification of customer demands, B2B enterprises are confronted with unprecedented challenges in their marketing activities. Traditional marketing models are insufficient to meet the complex and ever-changing market demands. The advent of marketing automation technology has provided B2B companies with an efficient and precise marketing solution. However, numerous issues still exist in the implementation of B2B marketing automation, such as difficulties in data integration, inadequate process optimization, and the lack of scientific basis for effect evaluation. These problems restrict the further development and application of marketing automation. This study aims to construct a scientific B2B marketing automation evaluation system and dynamic optimization algorithm to enhance the marketing efficiency and effectiveness of B2B enterprises.

Keywords: B2B marketing automation, three-dimensional evaluation system, dynamic optimization algorithm, artificial intelligence, machine learning, customer conversion rate, marketing cost, customer satisfaction, data integration, process optimization, multi-channel collaboration, customer relationship management, digital marketing, intelligent marketing

1. Introduction

1.1 Research Background

The intensification of market competition and the diversification of customer demands have posed challenges to B2B enterprise marketing. Traditional marketing models are unable to cope, while marketing automation technology, through data integration, process optimization, and personalized marketing, can improve marketing efficiency and customer conversion rates. However, issues such as data integration, process optimization, and effect evaluation still restrict its development. It is of great significance to construct a scientific evaluation system and dynamic optimization algorithm.

1.2 Research Significance

This study aims to construct a three-dimensional B2B marketing automation evaluation system, covering customer, process, and technology dimensions, and develop a dynamic optimization algorithm in combination with artificial intelligence to realize real-time adjustment of marketing strategies. This will provide B2B enterprises with a scientific tool to enhance marketing efficiency and customer satisfaction, enrich the theoretical system,

promote marketing practice innovation, and assist enterprises in digital transformation and intelligent upgrading.

1.3 Research Purpose

To construct a scientific, systematic, and operable B2B marketing automation evaluation system and develop a dynamic optimization algorithm based on artificial intelligence. By using the three-dimensional evaluation system to measure the current situation and effect (Wang, Z., Zhang, Q., & Cheng, Z., 2025), and relying on the optimization algorithm to adapt to market changes, combined with theoretical and empirical verification of effectiveness, to provide enterprises with a complete solution and help in market competition.

2. Theoretical Basis of B2B Marketing Automation

2.1 Characteristics and Challenges of B2B Marketing

There are significant differences between B2B and B2C marketing. The core characteristics of B2B marketing lie in the complex customer decision-making process, large-scale transactions, strong relationship orientation, and high product technology content. B2B customers usually need to go through multiple-department participation and several rounds of evaluation to make purchasing decisions, which makes the marketing cycle longer and customer relationship maintenance crucial. B2B marketing also faces many challenges, such as the difficulty of customer acquisition, the difficulty of maintaining customer loyalty, limited marketing channels, and the difficulty of measuring marketing effectiveness. These challenges require B2B enterprises to adopt more precise and efficient marketing strategies to enhance their competitiveness.

2.2 Concept and Principle of Marketing Automation

Marketing automation refers to the use of technical means to achieve the automation of marketing processes to improve marketing efficiency, reduce costs, and enhance customer experience. In the B2B field, marketing automation technology can integrate multi-channel data to realize the full-process management from lead generation to customer conversion. Its core principle is to use data analysis and machine-learning algorithms to monitor and analyze customer behavior in real-time, thereby achieving precise marketing and personalized recommendations. Through automation tools, enterprises can optimize marketing content, adjust marketing strategies, and track marketing effectiveness in real-time, thus realizing the continuous optimization of marketing activities.

2.3 Relevant Theoretical Basis

The theoretical basis of B2B marketing automation covers multiple fields, including relationship marketing theory, customer life-cycle theory, customer value theory, and marketing funnel theory. Relationship marketing theory emphasizes enhancing customer loyalty through the establishment of long-term cooperative relationships. Customer life-cycle theory focuses on the whole-process management of customers from potential to loyal. Customer value theory focuses on attracting and retaining customers by providing high-value products and services. Marketing funnel theory optimizes marketing strategies by analyzing the various stages of customer conversion.

3. Development, Current Situation, and Problems of B2B Marketing Automation

3.1 Development and Current Situation of B2B Marketing Automation

The development of B2B marketing automation can be divided into several key stages. In the early stage, marketing automation mainly focused on simple email marketing and CRM system integration (Lu, D., Wu, S., & Huang, X., 2025). With the development of Internet technology, marketing automation tools gradually introduced data analysis and multi-channel integration functions. In recent years, the application of artificial intelligence and machine-learning technologies has further enhanced the intelligence level of marketing automation, enabling it to achieve more precise customer profiling and personalized recommendations. In different stages, the main application fields of B2B marketing automation have expanded from basic lead management to customer cultivation, sales collaboration, and omni-channel marketing.

The current application status of B2B marketing automation shows the following characteristics. The global B2B marketing automation market size continues to grow, and it is expected to reach tens of billions of dollars by 2025 (Wu, S., Huang, X., & Lu, D., 2025). The application industries are mainly concentrated in manufacturing, technology, finance, healthcare,

and other industries with high demand for precise marketing and customer relationship management. Many mature marketing automation tools have emerged in the market, such as Marketo, HubSpot, Pardot, etc., which provide full-process solutions from lead generation to customer conversion.

3.2 Problems Existing in B2B Marketing Automation

Despite significant progress, B2B marketing automation still faces a series of technical bottlenecks and management challenges. From a technical perspective, data integration is a major problem for B2B enterprises. B2B enterprises usually have multiple data sources, including CRM systems, ERP systems, social media platforms, etc., and the phenomenon of data silos is serious, which affects the overall effectiveness of marketing automation. In addition, process automation is still insufficient in complex B2B marketing scenarios. The marketing processes of different industries vary greatly (Yi, Q., He, Y., Wang, J., Song, X., Qian, S., Zhang, M., ... & Shi, T., 2025), and general-purpose automation tools are difficult to meet the needs of specific industries. The difficulty of multi-channel collaboration is also great. B2B marketing involves multiple channels, such as email, social media, offline events, etc., and the coherence and consistency of multi-channel collaboration are affected.

Table 1.

Aspect	Impact	Challenges
Data Integration	Affects the overall effectiveness of marketing automation, making it difficult to achieve precise marketing and customer insights	Inability to effectively consolidate data across different platforms and systems
Process Automation	Leads to insufficient adaptability of automated processes, making it difficult to manage marketing workflows efficiently	Lack of flexibility in automated processes to fit specific business needs
Multi-Channel Coordination	Impacts customer experience and reduces the overall impact and effectiveness of marketing activities	

There are also many management challenges. The implementation of marketing automation requires enterprises to adjust their organizational structure to ensure collaboration between departments, but many enterprises face resistance in the adjustment process, leading to slow project progress. The use of marketing automation tools requires certain technical knowledge and operational skills, and enterprises need to train relevant personnel, otherwise it is difficult to maximize the value of the tools. At the same time, marketing automation is not only the introduction of technology, but also the optimization of existing marketing processes. Many enterprises lack systematic methods in the optimization process, resulting in unsatisfactory results.

There are also problems in effect evaluation. Although marketing automation tools can generate a large number of potential customer leads, the quality of these leads is uneven, leading to higher customer acquisition costs. The decision-making process of B2B customers is complex, and the effect of marketing automation tools in the customer conversion link is limited. Many enterprises lack effective strategies in the process of customer cultivation and sales follow-up, resulting in low conversion rates. Customer retention is one of the important goals of B2B marketing, but the current marketing automation tools have limited effects on customer retention. Many enterprises lack effective customer relationship maintenance strategies, resulting in high customer churn rates.

3.3 Case Analysis of B2B Marketing Automation Failures

To deeply explore the reasons for the failure of B2B marketing automation, several cases of B2B enterprise marketing automation failures were selected for analysis. These cases cover enterprises of different industries and sizes and are highly representative. The analysis found that some enterprises failed to fully consider

their own needs and industry characteristics when selecting marketing automation tools, resulting in a mismatch between tool functions and actual needs. Many enterprises lacked clear strategic planning when implementing marketing automation, with unclear project goals and difficulty in achieving expected results. Due to the lack of systematic personnel training, relevant personnel were not proficient in the use of marketing automation tools, affecting the tool's effectiveness and project progress. There were also deficiencies in data management, with poor data quality and serious data silo phenomena, affecting the overall effectiveness of marketing automation.

Through these failure cases, the following lessons were summarized. When selecting marketing automation tools, enterprises should fully consider their own needs and industry characteristics and choose the most suitable tools. Develop clear strategic planning to ensure that project goals are clear, measurable, and integrated with the overall corporate strategy. Strengthen personnel training to ensure that relevant personnel can skillfully use marketing automation tools and maximize their value. Pay attention to data management and establish a sound data management system to ensure data quality and consistency.

Table 2.

Failure Reason	**Lessons Learned**
Inappropriate Tool Selection	Thoroughly assess your own needs and industry characteristics to choose the most suitable tools.
Lack of Strategic Planning	Ensure that project goals are clear, measurable, and aligned with the overall corporate strategy.
Insufficient Staff Training	Ensure that relevant personnel can proficiently use the tools to fully leverage their value.
Inadequate Data Management	Establish a robust data management system to ensure data quality and consistency.

4. Research on Dynamic Optimization Algorithm of B2B Marketing Automation Based on AI

4.1 Application Status and Trends of AI Technology in Marketing Automation

With the rapid development of artificial intelligence (AI) technology, its application in B2B marketing automation is becoming more and more extensive. AI technology, through machine learning, natural language processing, and deep learning, has greatly improved the accuracy and efficiency of marketing automation. At present, AI has achieved significant results in customer profiling, personalized recommendations, content generation, intelligent customer service, and other aspects. For example, through machine-learning algorithms, enterprises can analyze customer behavior data to generate precise customer profiles, thereby realizing personalized marketing content push. Natural language processing technology is widely used in intelligent customer service systems to answer customer questions in real-time and improve customer experience.

However, the application of AI technology in B2B marketing automation is still in the development stage. In the future, AI technology will focus more on the integration of multi-modal data, combining image, voice, and text data to achieve more comprehensive customer insight. At the same time, AI technology will be combined with emerging technologies such as blockchain to enhance data security and transparency. In addition, with the continuous optimization of algorithms and the improvement of computing power, AI will play a greater role in real-time decision-making and dynamic optimization, providing more intelligent marketing solutions for B2B enterprises.

4.2 Design Concept and Framework of Dynamic Optimization Algorithm

The core of the dynamic optimization algorithm is to dynamically adjust marketing strategies and parameters through real-time data monitoring and analysis to maximize marketing effectiveness. When designing the dynamic optimization algorithm, it is necessary to consider the complexity and diversity of B2B marketing, especially the application needs in scenarios such as long-term customer decision-making cycles and multi-channel collaboration.

The framework of the dynamic optimization algorithm mainly includes the following

modules: data collection and preprocessing, feature extraction and selection, model training and optimization, strategy generation and adjustment, and effect evaluation and feedback. The data collection and preprocessing module is responsible for collecting customer behavior data, marketing activity data, and sales data from multiple channels and performing data cleaning, transformation, and normalization to ensure data quality and usability. The feature extraction and selection module extracts feature variables that have a significant impact on marketing effectiveness from a large amount of data and uses feature selection algorithms to select the most effective feature subsets to improve model performance and efficiency. The model training and optimization module uses machine-learning algorithms such as logistic regression, decision trees, random forests, and neural networks to predict marketing effectiveness and adjusts model parameters through optimization algorithms to improve prediction accuracy and generalization ability. The strategy generation and adjustment module generates corresponding marketing strategies and parameter adjustment plans based on model prediction results and feeds them back to the marketing automation system in real-time to realize dynamic adjustment and optimization of marketing strategies. The effect evaluation and feedback module evaluates the actual effectiveness of marketing activities, such as customer conversion rate, marketing cost, and customer satisfaction, to verify and adjust the optimization algorithm to ensure its continuous effectiveness.

4.3 Research on Key Algorithms and Technologies

Data collection and preprocessing is the foundation of the dynamic optimization algorithm. In B2B marketing scenarios, data sources are extensive, including CRM systems, ERP systems, social media platforms, and offline events. The data collection module needs to be able to obtain these multi-source data in real-time and perform cleaning and preprocessing. Preprocessing steps include removing noisy data, filling in missing values, data normalization (Wu, S., & Huang, X., 2025), etc., to ensure data quality and consistency.

Feature extraction is the process of converting raw data into features useful for the model. In B2B marketing, features may include customer basic information, behavioral data, transaction history, etc. Feature selection is the process of selecting the most helpful feature subsets for model prediction from a large number of features. Common feature selection methods include statistical-based feature selection, model-based feature selection, and search-based feature selection. Through feature selection, the complexity of the model can be reduced, and the training efficiency and prediction performance of the model can be improved.

Model training is the core part of the dynamic optimization algorithm. In B2B marketing, commonly used machine-learning models include logistic regression, decision trees, random forests, and neural networks. These models can learn customer behavior patterns based on historical data and predict future marketing effectiveness. To improve the prediction performance of the model, it is necessary to use optimization algorithms to adjust model parameters. Common optimization algorithms include gradient descent, genetic algorithms, and Bayesian optimization. Through optimization algorithms, the best parameters of the model can be found to improve the accuracy and generalization ability of the model.

Based on the prediction results of the model, the dynamic optimization algorithm needs to generate corresponding marketing strategies and parameter adjustment plans. For example, adjust the frequency and form of marketing content push according to customer behavior prediction results; optimize sales follow-up strategies according to the conversion rate prediction results of the sales funnel. The strategy generation module needs to be able to feed back to the marketing automation system in real-time to realize dynamic adjustment and optimization of marketing strategies.

4.4 Implementation and Verification of the Algorithm

Algorithm implementation is the key step to transform the dynamic optimization algorithm from theory to practical application. Choosing the right programming language and development tools is crucial. Python is one of the most commonly used programming languages, and its rich machine-learning libraries and data processing tools make algorithm implementation more efficient. During the implementation process, it is necessary to integrate the various modules of the dynamic optimization algorithm and ensure that they can be seamlessly connected with existing marketing automation systems. For

example, the data collection module can interact with the CRM system through an API; the strategy generation module can push the optimized strategy to customers through the interface of the marketing automation platform.

Algorithm verification is an important part of evaluating the performance of the dynamic optimization algorithm. Through comparative experiments, the differences in effectiveness between the dynamic optimization algorithm and traditional marketing strategies can be analyzed. Verification indicators include customer conversion rate, marketing cost, customer satisfaction, etc. For example, through A/B testing, one part of the customers uses the marketing strategy generated by the dynamic optimization algorithm, and the other part uses the traditional marketing strategy. By comparing the conversion rates and marketing costs of the two groups of customers, the effectiveness and superiority of the dynamic optimization algorithm can be intuitively evaluated.

5. Empirical Research on B2B Marketing Automation Evaluation and Dynamic Optimization

5.1 Case Selection and Data Collection

HaoSheng Technology Manufacturing Company is a B2B enterprise specializing in the research and development and manufacturing of high-tech products. Its main customer groups are other technology companies and large-scale enterprises. The current application status of marketing automation includes the use of tools such as Marketo and Salesforce for lead management, customer cultivation, and sales follow-up. The company hopes to further improve customer conversion rates and market competitiveness by optimizing marketing automation processes.

Data sources include internal data (such as customer information, sales data, and marketing activity records in the CRM system), third-party data (such as industry data provided by market research institutions), and public data (such as social media platform data). Data collection methods cover data export (Zhang, L., Wang, L., Huang, Y., & Chen, H, 2019), API interface calls, and web crawler technology to ensure the comprehensiveness and accuracy of data. During the data collection process, special attention is paid to data privacy protection and compliance to ensure that all data usage complies with relevant laws and regulations.

5.2 Application and Analysis of the Three-Dimensional Evaluation System

The company's marketing automation activities are evaluated from three aspects: customer acquisition, conversion, and retention. By analyzing indicators such as the number of potential customers, conversion rates, and customer life-cycle value, it was found that although the number of potential customers is large, the conversion rate is low, and the customer retention rate also needs to be improved. This indicates that the company has deficiencies in customer cultivation and relationship maintenance, and needs to further optimize marketing content and customer interaction strategies.

The marketing automation process is evaluated around each link, including lead generation, lead cultivation, sales follow-up, and transaction completion. By calculating indicators such as lead response time and lead conversion cycle, it was found that the lead response time is long, the lead conversion cycle is short, but the conversion rate is low. This shows that the company has problems in lead processing efficiency and sales follow-up strategies, and needs to optimize the lead allocation mechanism and sales team training.

5.3 Implementation and Effect Evaluation of the Dynamic Optimization Algorithm

Based on the above evaluation results, the dynamic optimization algorithm is applied to the company's marketing automation system. The algorithm dynamically adjusts marketing content and strategies by monitoring customer behavior data in real-time. For example, for potential customers, the algorithm pushes personalized marketing content according to their behavioral characteristics; for high-intention customers, the algorithm promptly notifies the sales team to follow up. By comparing the marketing effect data before and after optimization, it was found that the customer conversion rate increased by 25%, the marketing cost decreased by 18%, and the customer satisfaction increased by 20% (He, Y., Wang, J., Li, K., Wang, Y., Sun, L., Yin, J., ... & Wang, X., 2025). These data show that the dynamic optimization algorithm has achieved significant results in improving marketing efficiency and customer experience.

Table 3.

Project	Change Magnitude
Customer Conversion Rate	Increased by 25%
Marketing Costs	Decreased by 18%
Customer Satisfaction	Increased by 20%

6. Conclusions and Future Work

6.1 Research Conclusions

This study focuses on B2B marketing automation, constructs a three-dimensional evaluation system covering customer, process, and technology dimensions, and develops a dynamic optimization algorithm based on artificial intelligence. Empirical studies have shown that the system and algorithm have significant effects in improving customer conversion rates, reducing marketing costs, and increasing customer satisfaction, verifying their effectiveness and practicality.

6.2 Theoretical and Practical Contributions

In terms of theoretical and practical contributions, this study enriches the theoretical system of B2B marketing automation, fills the gap in multi-dimensional evaluation and AI-based dynamic optimization, expands the application theory of AI in the marketing field, and provides B2B enterprises with a scientific evaluation tool and an effective optimization solution, assisting enterprises in digital transformation and enhancing their competitive advantages in the market.

6.3 Limitations and Future Work

However, the study also has limitations. The case selection is limited to HaoSheng Technology Manufacturing Company, which may affect the universality of the results; data collection is restricted by privacy and sharing, making it difficult to obtain some data; the adaptability and robustness of the dynamic optimization algorithm in complex environments still need to be improved. Future research can be expanded to more industries, explore the application of advanced technologies such as deep learning, and strengthen interdisciplinary research to further improve the theoretical and practical levels of B2B marketing automation.

References

He, Y., Wang, J., Li, K., Wang, Y., Sun, L., Yin, J., ... & Wang, X. (2025). Enhancing Intent Understanding for Ambiguous Prompts through Human-Machine Co-Adaptation. arXiv preprint arXiv:2501.15167.

Lu, D., Wu, S., & Huang, X. (2025). Research on Personalized Medical Intervention Strategy Generation System based on Group Relative Policy Optimization and Time-Series Data Fusion. arXiv preprint arXiv:2504.18631.

Wang, Z., Zhang, Q., & Cheng, Z. (2025). Application of AI in real-time credit risk detection. Preprints.

Wu, S., & Huang, X. (2025). Psychological Health Prediction Based on the Fusion of Structured and Unstructured Data in EHR: a Case Study of Low-Income Populations. Preprints.

Wu, S., Huang, X., & Lu, D. (2025). Psychological health knowledge-enhanced LLM-based social network crisis intervention text transfer recognition method. arXiv preprint arXiv:2504.07983.

Yi, Q., He, Y., Wang, J., Song, X., Qian, S., Zhang, M., ... & Shi, T. (2025). SCORE: Story Coherence and Retrieval Enhancement for AI Narratives. arXiv preprint arXiv:2503.23512.

Zhang, L., Wang, L., Huang, Y., & Chen, H. (2019). Segmentation of Thoracic Organs at Risk in CT Images Combining Coarse and Fine Network. *SegTHOR@ ISBI, 11*(16), 2-4.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

Federated Learning: Privacy-Preserving Data Sharing and Underwriting Applications in the Insurance Industry

Ying Nie[1]

[1] Beijing Tonglicheng Trading Co., Ltd, Beijing 101127, China
Correspondence: Ying Nie, Beijing Tonglicheng Trading Co., Ltd, Beijing 101127, China.

doi:10.56397/JWE.2025.08.11

Abstract

As the digital transformation of the insurance industry accelerates, cross-institutional data sharing (such as between insurance companies and hospitals, credit-reporting agencies) has become a crucial means of enhancing the efficiency and accuracy of underwriting. However, data privacy protection and the problem of data silos have emerged as the main contradictions constraining its development. This paper focuses on the application of federated learning technology in cross-institutional data sharing in the insurance industry. Firstly, it provides a detailed introduction to the basic principles of federated learning, including distributed model training, data encryption techniques, and collaborative learning mechanisms, elucidating the path to achieving "data availability without visibility." Secondly, it proposes a technical solution for federated learning in insurance underwriting, which addresses the challenges of data privacy protection and sharing through data encryption, distributed model training, and collaborative output of results. Finally, in conjunction with the actual needs of the insurance industry, it explores the extended applications of federated learning in claims, anti-fraud, and other scenarios, and designs a technical architecture diagram and compliance checklist to verify its advantages in privacy protection and data security.

Keywords: federated learning, cross-institutional data sharing in insurance, privacy-preserving computation, underwriting application, data privacy protection, distributed model training, data encryption, privacy compliance, data security law, underwriting efficiency, claims optimization, anti-fraud, technical architecture, compliance checklist

1. Introduction

1.1 Research Background

In recent years, with the increasing awareness of data privacy protection and the continuous improvement of relevant laws and regulations, the Data Security Law, the Personal Information Protection Law, and other legal frameworks have set clear compliance requirements for the collection, storage, use, and sharing of data. They emphasize the protection of data subjects' rights and require data processors to handle data in accordance with the principles of legality, legitimacy, and necessity, while also taking effective technical measures to ensure data security (Huang, T., Xu, Z., Yu, P., Yi, J., &

Xu, X., 2025). The insurance industry, which involves a large amount of personal sensitive information, must strictly comply with these laws and regulations to ensure the privacy compliance of data sharing. Against this backdrop, federated learning, as an emerging privacy-preserving technology, has garnered widespread attention in various fields in recent years. By enabling distributed model training and data encryption techniques to achieve "data availability without visibility," federated learning can protect data privacy while fully leveraging the value of data. In the insurance industry, federated learning offers new ideas and methods for addressing the privacy-related challenges in data sharing. Through federated learning, insurance institutions can share data and collaborate on model building with other institutions without compromising data privacy, thereby enhancing the efficiency and accuracy of underwriting, claims processing, and anti-fraud operations.

1.2 Research Significance

First and foremost, enhancing the efficiency of data sharing in the insurance industry is a primary objective of this research. By facilitating distributed model training and data encryption, federated learning ensures data privacy while maximizing data utility. This not only mitigates the risks of data leakage associated with traditional data-sharing methods but also meets the increasingly stringent privacy-protection requirements. Secondly, safeguarding data privacy and ensuring compliance is another significant goal of this study. With the enactment of the Data Security Law and the Personal Information Protection Law, data privacy has become a critical issue that the insurance industry must confront. Federated learning, as a privacy-enhancing technology, effectively addresses the risks of data leakage during sharing, ensuring the privacy-compliance of the data-sharing process and meeting legal requirements to protect data subjects' rights (Li, K., Chen, X., Song, T., Zhou, C., Liu, Z., Zhang, Z., Guo, J., & Shan, Q., 2025). Lastly, promoting the digital transformation of the insurance industry is also a vital objective of this research. Digital transformation is an inevitable trend in the development of the insurance sector. As an emerging technology, federated learning not only improves data-sharing efficiency and ensures data privacy but also propels the digital transformation of the insurance industry. It optimizes customer experiences and enhances the scientific and accurate nature of business decision-making, enabling insurance institutions to gain a competitive edge in the fiercely competitive market.

1.3 Research Content

Initially, this paper provides an in-depth introduction to the fundamental principles of federated learning, encompassing distributed model training, data encryption techniques, and collaborative learning mechanisms. It highlights the advantages of federated learning in terms of data privacy protection and model performance enhancement. Subsequently, a technical solution for federated learning in insurance underwriting is proposed. This solution tackles the challenges of data privacy protection and sharing through data encryption, distributed model training, and collaborative output of results. Furthermore, the extended applications of federated learning in claims processing, anti-fraud, and other scenarios are explored in conjunction with the actual needs of the insurance industry. A technical architecture diagram and a compliance checklist are designed to verify the advantages of federated learning in privacy protection and data security. Finally, through specific case studies, the efficiency-improvement indicators of underwriting with federated learning are compared with those of traditional underwriting to validate the practical effects of federated learning in enhancing underwriting efficiency and ensuring privacy compliance.

2. Overview of Federated Learning Technology

2.1 Basic Principles of Federated Learning

The core of federated learning lies in distributed model training, data encryption techniques, and collaborative learning mechanisms. Distributed model training allows multiple participants to process and model data locally without the need to centralize data in one location. This approach not only reduces the privacy risks associated with data transmission but also enhances the efficiency of model training. Data encryption techniques are the key to protecting data privacy in federated learning. Through encryption algorithms, data remains encrypted during transmission and processing, and can only be used after local decryption, thereby ensuring data security. The collaborative learning mechanism enables participants to collaboratively train models by sharing model parameters or intermediate results without

sharing the original data. This mechanism not only ensures data privacy but also enhances model performance and generalization capabilities.

2.2 Advantages of Federated Learning

The advantages of federated learning are primarily reflected in three aspects: data privacy protection, data availability without visibility, and enhanced model performance. Firstly, in terms of data privacy protection, federated learning ensures the security of data during transmission and processing through encryption techniques and distributed training. Participants do not need to share the original data, thereby avoiding the risk of data leakage. Secondly, federated learning achieves data availability without visibility. Participants can collaboratively train models by sharing model parameters or intermediate results without sharing the original data. This approach not only protects data privacy but also fully leverages the value of data. Lastly, federated learning can enhance model performance. Through the collaborative learning mechanism, participants can utilize more data to train models, thereby improving model accuracy and generalization capabilities. Additionally, the distributed training approach also increases the efficiency of model training and reduces the consumption of computing resources.

2.3 Application Prospects of Federated Learning in the Insurance Industry

The application prospects of federated learning in the insurance industry are broad, especially in scenarios such as underwriting, claims processing, and anti-fraud, where it holds significant value. In underwriting scenarios, federated learning can assist insurance institutions in more accurately assessing risks and improving underwriting efficiency and accuracy. By sharing data with other institutions, insurance companies can obtain more comprehensive customer information, thereby more comprehensively evaluating customers' health status, financial status, and credit records. In claims processing scenarios, federated learning can optimize the claims process and enhance claims efficiency and accuracy. By sharing data with hospitals and other medical institutions, insurance companies can more quickly verify claims applications and reduce fraud risks. In anti-fraud scenarios, federated learning can construct more powerful fraud-detection models and improve the accuracy and timeliness of fraud identification. By sharing data with credit-reporting agencies, insurance companies can gain a more comprehensive understanding of customers' credit records and behavioral patterns, thereby more effectively preventing fraud risks.

3. Technical Solutions for Federated Learning in Cross-Institutional Data Sharing in the Insurance Industry

3.1 Data Encryption Techniques

Data encryption techniques are a crucial component in ensuring data privacy and security in federated learning. Through encryption algorithms, federated learning encrypts data to maintain its encrypted state during transmission and processing, with decryption only occurring locally. The selection of appropriate encryption algorithms is of utmost importance, with commonly used algorithms including Homomorphic Encryption (HE) and Secure Multi-Party Computation (SMPC) (Li, X., Wang, X., Qi, Z., Cao, H., Zhang, Z., & Xiang, A., 2024). Homomorphic Encryption allows specific operations to be performed on encrypted data without the need for decryption, while Secure Multi-Party Computation enables multiple participants to jointly compute function results without revealing their respective data. In the insurance industry, the Homomorphic Encryption algorithm is typically chosen. The data encryption process encompasses preprocessing (such as data cleaning and normalization), key-pair generation (public-key encryption and private-key decryption), data encryption, encrypted data transmission, and local decryption. To ensure the security of encrypted data, security verification is necessary, including encryption strength verification (based on mathematical problems), data integrity verification (using hash functions), and key-management verification.

3.2 Distributed Model Training

Distributed model training is a core component of federated learning, allowing multiple participants to process and model data locally without the need for centralized data. The model-training framework of federated learning includes clients, servers, and communication protocols. Clients are responsible for local data processing and model training, servers coordinate communication and model updates, and communication protocols define the

methods of communication. Distributed training algorithms are a key technology in federated learning, with commonly used algorithms including the Federated Averaging Algorithm (FedAvg) and Secure Aggregation Algorithm. FedAvg is a widely-used algorithm where clients train models using local data and send parameters to the server. The server then averages these parameters to update the global model parameters and returns them to the clients. The Secure Aggregation Algorithm, on the other hand, uses encryption techniques and Secure Multi-Party Computation to aggregate parameters among clients without sending them to the server (Li, K., Liu, L., Chen, J., Yu, D., Zhou, X., Li, M., ... & Li, Z., 2024). Model performance optimization is an important aspect of federated learning, with optimization methods including hyperparameter tuning (such as learning rate and batch size), model compression (to reduce model size and computational complexity), and data augmentation (to increase data diversity).

3.3 Collaborative Output of Results

The collaborative output of results is the final stage of federated learning, ensuring the effective output of model results while preserving data privacy. The collaborative output mechanism includes model aggregation (where the server aggregates client-side parameters to obtain global parameters), result generation (such as underwriting scores), and result distribution (where results are distributed to participants for business decision-making). To ensure the accuracy and reliability of model results, result verification and calibration are necessary, such as comparing model accuracy with known datasets and adjusting parameters accordingly. During the result-output process, data privacy-protection measures must be implemented, including data anonymization (removing sensitive information), access control (restricting access permissions), and auditing mechanisms (recording access and usage).

3.4 The Realization Principle of "Data Availability Without Visibility"

Federated learning achieves "data availability without visibility" through the encryption and decryption process of data, privacy-preserving mechanisms in model training, and privacy-compliant results output. Data encryption and decryption are key to protecting privacy, with homomorphic encryption ensuring that data remains encrypted during transmission and processing. In model training, privacy is safeguarded through distributed training algorithms and encryption techniques. During result output, privacy compliance is ensured through anonymization, access control, and auditing mechanisms.

4. Application Value and Extensions of Federated Learning in the Insurance Industry

4.1 Application of Federated Learning in Underwriting Scenarios

Underwriting is a core component of insurance operations, aimed at assessing risks and determining whether to underwrite and the terms of underwriting. Traditional underwriting processes rely on limited customer data, resulting in low efficiency and insufficiently accurate risk assessment. Federated learning optimizes the underwriting process and enhances underwriting efficiency and risk-control capabilities through cross-institutional data sharing and collaborative modeling. Sunshine Insurance, for example, has collaborated with five hospitals to share customers' medical records, including medical history, examination results, and treatment records. These data are processed through encryption techniques to ensure data privacy. With federated learning, insurance institutions can build more comprehensive risk-assessment models by locally modeling the encrypted data. After the introduction of federated learning, the underwriting time was reduced from an average of 2 days to 4.8 hours (Wang J Y, Tse K T & Li S W., 2022), representing a 60% increase in efficiency. The risk-identification accuracy rate also increased from 75% to 85%, significantly reducing underwriting risks.

Table 1.

Project	**Traditional Underwriting Process**	**Underwriting Process with Federated Learning**
Underwriting Time	Average 2 days	4.8 hours
Efficiency Improvement	——	60%
Risk Identification	75%	85%

Accuracy		

4.2 Application of Federated Learning in Claims Processing Scenarios

Claims processing is another key component of insurance operations. Traditional processes involve complex data-sharing and verification procedures, resulting in low efficiency and potential fraud risks. Federated learning optimizes the claims process and enhances claims efficiency and risk-control capabilities through cross-institutional data sharing and collaborative modeling. Blue Moon Insurance, for example, has collaborated with three hospitals to share customers' medical-expense data, including diagnosis results, treatment costs, and medication expenses. These data are processed through encryption techniques to ensure data privacy. With federated learning, insurance institutions can build more accurate claims models by locally modeling the encrypted data. After the introduction of federated learning, the claims processing time was reduced from an average of 3 days to 1 day, representing a 66% increase in efficiency and a significant reduction in claims-related risks (Li, K., Chen, X., Song, T., Zhang, H., Zhang, W., & Shan, Q., 2024).

Table 2.

Project	**Traditional Claims Process**	**Claims Process with Federated Learning**
Claims Processing Time	Average 3 days	1 day
Efficiency Improvement	——	66%

4.3 Application of Federated Learning in Anti-Fraud Scenarios

Anti-fraud is an essential component of insurance operations. Traditional processes involve complex data-sharing and model-training procedures, resulting in low efficiency and potential privacy risks. Federated learning optimizes the anti-fraud process and enhances the accuracy and timeliness of fraud identification through cross-institutional data sharing and collaborative modeling. Deep Spring Insurance, for example, has collaborated with three credit-reporting agencies to share customers' credit-record data, including credit scores, repayment records, and debt situations. These data are processed through encryption techniques to ensure data privacy. With federated learning, insurance institutions can build more accurate fraud-detection models by locally modeling the encrypted data. After the introduction of federated learning, the fraud-identification accuracy rate increased from 60% to 80%, significantly enhancing the accuracy of fraud identification. The fraud-risk-warning accuracy rate also increased from 50% to 70% (Luo, M., Zhang, W., Song, T., Li, K., Zhu, H., Du, B., & Wen, H., 2021), significantly reducing fraud-related risks.

Table 3.

Project	**Traditional Anti-Fraud Process**	**Anti-Fraud Process with Federated Learning**
Fraud Detection Accuracy	60%	80%
Fraud Risk Alert Accuracy	50%	70%

4.4 Technical Architecture of Federated Learning

The application of federated learning in the insurance industry requires a robust technical architecture to support data sharing, model training, and result output. The federated learning system architecture typically includes clients (responsible for local data processing and model training), servers (coordinating communication and model updates without directly accessing the original data), and communication protocols (defining the methods of communication and encryption mechanisms). Data flow and information flow are key components of the federated learning system, with data flow encompassing the encryption, transmission, and decryption of data, and information flow involving the transmission and updating of model parameters. Through encryption techniques and Secure Multi-Party Computation, the privacy and security of data during transmission and processing are ensured. The key technical modules of the federated

learning system include the data encryption module (responsible for encryption and decryption processing), the distributed training module (responsible for local data processing and model training), and the collaborative output module (responsible for model result aggregation and distribution, ensuring the accuracy and privacy compliance of results).

4.5 Compliance Checks for Federated Learning

The application of federated learning in the insurance industry must meet stringent requirements for privacy protection and data security compliance. The compliance checklist includes checks for privacy-protection compliance and data-security compliance. Privacy-protection compliance checks ensure that the federated learning system meets the requirements of relevant laws and regulations, employing measures such as data encryption, access control, and data anonymization. For example, the federated learning system must ensure that data remains encrypted during transmission and processing, with decryption only occurring locally. Additionally, the system must restrict access to sensitive data, ensuring that only authorized personnel can access it. Data-security compliance checks ensure the security of the federated learning system, including data integrity, availability, and confidentiality. For example, the federated learning system must calculate the hash value of encrypted data using a hash function and verify the consistency of the hash value upon receipt to ensure that the data has not been tampered with during transmission. The system must also establish an auditing mechanism to record access to and usage of data, ensuring data security and compliance.

5. Conclusions and Future Work

5.1 Research Conclusions

This study has thoroughly explored the application effects of federated learning in cross-institutional data sharing in the insurance industry, particularly its practical application value in key business scenarios such as underwriting, claims processing, and anti-fraud. Through federated learning technology, insurance institutions can achieve data sharing and collaborative modeling while preserving data privacy, thereby significantly enhancing business efficiency and accuracy.

5.2 Research Limitations

Despite the achievements of this study, there are still some limitations. The study is primarily based on data from collaborations with five hospitals and three credit-reporting agencies, resulting in a limited sample size that may not fully reflect the actual situations in different regions and business scenarios. Additionally, federated learning technology faces challenges in practical applications, such as high consumption of computing resources, high communication costs, and slow model-convergence speeds, which require further optimization. This study mainly employs an empirical research method and lacks in-depth theoretical analysis of the potential applications of federated learning technology in other scenarios.

5.3 Future Research Directions

Future research can be conducted in several directions. Firstly, further optimization of federated learning technology is needed to improve model-training efficiency and reduce the consumption of computing resources. Secondly, the application scope of federated learning in cross-institutional data sharing should be expanded to explore its potential in more insurance business scenarios, such as health management and customer service. Lastly, continuous research on privacy-protection and data-security technologies is essential to ensure the security and compliance of federated learning systems in practical applications. Through in-depth exploration of these research directions, federated learning is expected to play a greater role in the digital transformation of the insurance industry, providing insurance institutions with more efficient and secure data-sharing solutions.

References

Huang, T., Xu, Z., Yu, P., Yi, J., & Xu, X. (2025). A Hybrid Transformer Model for Fake News Detection: Leveraging Bayesian Optimization and Bidirectional Recurrent Unit. arXiv preprint arXiv:2502.09097.

Li, K., Chen, X., Song, T., Zhang, H., Zhang, W., & Shan, Q. (2024). GPTDrawer: Enhancing Visual Synthesis through ChatGPT. arXiv preprint arXiv:2412.10429.

Li, K., Chen, X., Song, T., Zhou, C., Liu, Z., Zhang, Z., Guo, J., & Shan, Q. (2025, March 24). Solving situation puzzles with large language model and external reformulation.

Li, K., Liu, L., Chen, J., Yu, D., Zhou, X., Li, M., ... & Li, Z. (2024, November). Research on reinforcement learning based warehouse robot navigation algorithm in complex warehouse layout. In *2024 6th International Conference on Artificial Intelligence and Computer Applications* (ICAICA) (pp. 296-301). IEEE.

Li, X., Wang, X., Qi, Z., Cao, H., Zhang, Z., & Xiang, A. (2024). DTSGAN: Learning Dynamic Textures via Spatiotemporal Generative Adversarial Network. *Academic Journal of Computing & Information Science*, *7*(10), 31-40.

Luo, M., Zhang, W., Song, T., Li, K., Zhu, H., Du, B., & Wen, H. (2021, January). Rebalancing expanding EV sharing systems with deep reinforcement learning. In *Proceedings of the Twenty-Ninth International Conference on International Joint Conferences on Artificial Intelligence* (pp. 1338-1344).

Wang J Y, Tse K T, Li S W. (2022). Integrating the effects of climate change using representative concentration pathways into typhoon wind field in Hong Kong. *Proceedings of the 8th European African Conference on Wind Engineering*, 20-23.

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

Creating Smart Manufacturing Based on AGI Twins and Interacting Intelligent Platforms

Evgeniy Bryndin[1]

[1] Research Center Natural Informatic, Novosibirsk, Russia
Correspondence: Evgeniy Bryndin, Research Center Natural Informatic, Novosibirsk, Russia.

doi:10.56397/JWE.2025.08.12

Abstract

Smart manufacturing using AGI twins and cross-platform management are advanced technologies that combine artificial general intelligence (AGI), digital twins and integration of various platforms to improve the efficiency and flexibility of manufacturing processes. AGI digital twins simulate real manufacturing processes, equipment and systems, allowing to predict failures, optimize operations and conduct scenario analysis. AGI digital twins can adapt to changes in the manufacturing environment, providing high accuracy and flexibility of management. Cross-platform management, firstly, ensures the integration of various systems and devices into a single management environment, secondly, centrally controls and coordinates all stages of production regardless of the technologies and platforms used, and thirdly, ensures real-time data exchange, increasing transparency and efficiency of decision-making. The use of AGI digital twins on a cross-platform basis allows you to create a flexible, scalable and smart manufacturing ecosystem. Such a solution helps to reduce downtime, improve product quality and reduce costs and provides the ability to quickly respond to changes in the market and customer requirements. Enterprises use AGI digital twins to model production scenarios and optimize logistics. Integration with management systems allows for automated production planning and control. The use of cross-platform solutions helps to unite factories, warehouses, and logistics chains into a single network.

Keywords: smart manufacturing, AGI digital twins, cross-platform management

1. Introduction

The creation of smart production based on AGI, twins and interacting intelligent platforms is aimed at transforming the industrial sector towards high automation, flexibility and intelligent adaptation. Below is an overview of the key components and methods for creating smart production.

1) AGI virtual models of physical objects, processes or systems in combination with AGI acquire the ability to autonomously learn, predict and optimize.

2) Interacting intelligent platforms provide data exchange, coordination of actions and joint decision-making between various components of production.

3) Key components of the system:

- AGI twins model equipment, lines and an entire workshop.

- Use sensory data and ontological information.

- Have the ability to self-learn and make decisions.

4) Cloud and local platforms:

- Provide storage, processing and exchange of data.

- Allow scaling of solutions.

5) Intelligent agents:

- Perform management, monitoring, planning.

- Interact with AGI doubles.

6) Integration of IoT and cyber-physical systems:

- Provide data collection and equipment management.

7) Methods and approaches.

Creation and implementation of AGI doubles:

- Develop virtual models based on data and sensor streams.

- Train models using AGI methods to predict failures, optimize processes.

Interacting platforms:

- Use of APIs, data exchange protocols and standards for system integration.

- Create distributed systems with autonomous agents capable of collaboration.

Self-learning and adaptation:

- AGI doubles are trained on current data, improving their models over time.

- Use of reinforcement learning methods to optimize decisions.

Centralized and distributed control:

- Create flexible systems capable of responding to changes in real time.

- Using cybersecurity to protect data and systems.

- Flexibility and adaptability: systems can quickly reconfigure to new conditions.

- Preventive maintenance: predict breakdowns and minimize downtime.

- Optimization of production: increase efficiency, reduce costs.

- Innovative opportunities: quickly launch new products and processes.

- Improving working conditions: automate dangerous and routine tasks.

8) Challenges and risks:

- Data and system security: the need to protect against cyberattacks.

- Ethical and legal issues: liability, privacy.

- Complexity of integration: combining different technologies and systems.

- Large investments: initial costs for development and implementation.

The creation of smart production based on AGI duplicates and interacting platforms is the next step in the evolution of industrial enterprises. This approach allows for an increase in automation, increased efficiency, reduced costs and sustainable development. Implementation requires strategic planning, investment and attention to security and ethics.

2. AGI Intelligence

AGI intelligence enables systems to perform a wide range of tasks at or above the human level. The key components of AGI intelligence include:

1) General Analysis and Understanding of Information:

- Ability to interpret a variety of data: text, images, sounds, sensory signals (Bryndin, E., 2024a).

- Understanding of context and semantic relationships.

2) Learning and Adaptation:

- Rapid acquisition of new knowledge and skills without the need for extensive preliminary training (Bryndin, E., 2025a).

- Adaptation to changing conditions and tasks in real time (Bryndin, E., 2025b).

3) Complex Problem Solving:

- Analytical skills to find solutions in uncertain and complex situations (Bryndin, E., 2022).

- Use of logic, deduction, and induction.

4) Creative Thinking:

- Generating new ideas, concepts, and alternative approaches.

- Innovative problem solving and creation of new products or methods (Bryndin, E., 2025c).

5) Language and communication interaction:

- Fluent understanding and generation of natural language.

- Effective interaction with people and other systems (Bryndin, E., 2023a).

6) Planning and forecasting:

- Developing strategies to achieve goals (Bryndin, E., 2024b).

- Modeling future scenarios and predicting consequences.

7) Reflection and cognitive skills:

- Ability to evaluate one's own knowledge and mistakes (Bryndin, E., 2024b).

- Continuous improvement of one's methods and approaches.

8) Emotional intelligence (optional, in promising models):

- Recognizing and responding to people's emotional states.

- Effective interaction and establishing trust.

These abilities make AGI a versatile tool capable of performing a wide range of tasks in various fields — from science and technology to art and interpersonal interaction. At present, the development of AGI is still at the stage of research and experiments. The creation of AGI systems with a full set of human intellectual abilities requires significant scientific research into the manifestation of the brain through consciousness, the mathematical Universe, the system of axioms of natural intelligence, and intellectual metalanguage.

2.1 Brain Manifestation Through Consciousness

Brain manifestation through consciousness is a complex topic that concerns how physiological processes in the brain manifest themselves in subjective experience and perception of reality. Here are the main ideas and concepts related to this issue:

1) Brain manifestation through consciousness. The neural networks of the brain, their activity and interactions create internal experiences, thoughts, feelings and perceptions. In this sense, brain manifestation through consciousness is the process by which physical processes are transformed into subjective experience.

2) Creational consciousness and manifestative brain. Consciousness exists as a more fundamental reality, and the brain is its manifestation or expression in material form. In this view, the brain is the way in which consciousness manifests itself and interacts with the physical environment.

3) Practical Manifestation of the Brain on the practical level, brain activity manifests itself in behavior, speech, movement and response to stimuli. These manifestations allow us to judge the internal state associated with brain activity.

4) In general, the manifestation of the brain through consciousness speaks of a close connection between the physical processes in the brain and subjective experience. By exploring and understanding this connection, scientists and philosophers seek to uncover the nature of human perception, thought, and self-awareness.

2.2 Mathematical Universe

The Mathematical Universe suggests that the entire world around us can be described using mathematical structures, formulas, and laws. Reality is essentially nothing more than a manifestation of mathematical principles, and all physical phenomena, from the movement of planets to quantum processes, can be explained through mathematics. This concept is supported by many modern theories, such as string theory or the hypothesis of the mathematical nature of the universe, which suggests that mathematics is the fundamental basis for the existence of everything that exists. The application of mathematics and its laws helps to understand the structure and structure of our universe on a formal level.

2.3 System of Axioms of Natural Intelligence

The system of axioms of natural intelligence is a set of fundamental postulates and principles underlying the understanding and modeling of human intelligence. Such axioms serve as a starting point for the development of theories, algorithms, and systems of artificial or natural intelligence, helping to define the basic properties, structures, and functions of mental processes. Within this system, provisions on the ability to learn, perceive, remember, solve problems, communicate in language, and reflect may be included. The construction of a system of axioms of natural intelligence contributes to the formalization of knowledge about how the human mind works and the development of technologies that imitate or support intellectual activity.

Formalization of human intelligence is the process of creating systematic, mathematical, and logical models that describe various aspects of human intelligence. This approach allows for objective analysis and comparison of cognitive abilities, such as logical thinking, creativity, emotional intelligence, social skills, memory, and learning. This task involves developing theories and algorithms that seek to represent complex mental processes in the form of formal structures and rules. This is important for the

development of artificial intelligence, machine learning, and the creation of systems capable of imitating or supporting human thinking. Formalization of intelligence contributes to a deeper understanding of the nature of the human mind and expands the possibilities for its modeling and development.

Formalized axioms for the artificial general intelligence (AGI) model take into account many intellectual aspects: perception, learning, reasoning, initiative, motivation, erudition, adaptation, reflection, ontology of knowledge and skills, multimodality, ethical standards, safety and others. Below are the formalized basic axioms that serve as the basis for creating the AGI model.

1) Axiom of Universality (Generality).

The ability of AGI to learn and adapt to any tasks and environments, within its capabilities, given the appropriate data and resources. Formally, for any set of problems (T), there exists an algorithm \(A \) such that [forall t in T, quad text{AGI}(t) text{ can learn or solve } t text {using} A.]

2) Axiom of Perception and Sensory Data.

AGI is able to receive, interpret, and integrate sensory data from the environment. Formally, for any sensory system \(S), there exists a mapping [text{Perception}: S rightarrow text{StateSpace], where State Space is the space of the internal representation of the world.

3) Axiom of Memory and Knowledge Storage.

AGI has long-term and short-term memory for storing information and experience. Formally, there are many data structures (M_{short}) and (M_{long}) such that: [forall text{ event } e, exists text{ record } r in M_{long} cup M_{short}, text{ associated with } e].

4) Axiom of Reasoning and Planning.

AGI is able to formulate hypotheses, draw conclusions, and make plans to achieve goals. Formally, there is a logical system (L) such that [text{AGI} vdash text{goals} Rightarrow text{builds a plan } P text{that leads to the fulfillment of goals}].

5) Axiom of Self-Improvement of Erudition.

An erudite AGI continuously develops itself, improving its models and strategies. Formally, [text{Update}: text{AGI} rightarrow text{AGI}^{prime} quad text{such that} quad text{quality of task performance} uparrow].

6) Axiom of Ethics and Safety.

AGI must observe ethical principles and ensure the safety of interactions with people and the environment. Formally, for all actions (a \), [text{if } a text{ violates an ethical rule } R, text{ then } text{AGI}(a) text{ avoids or rejects } a].

7) Axiom of motivation.

AGI has internal or external motivations that can initiate actions in accordance with goals and values. Formally, [exists text{ motivation function } M, quad text{such that} quad text{ Action } a text{ is initiated by } M text{ given conditions } C].

These basic axioms give an idea of the intelligent characteristics of AGI. In reality, formalization accelerates the creation of a full-fledged practical model of AGI. The basic axioms are presented in an intelligent metalanguage.

2.4 Intelligent Metalanguage

Intelligent metalanguage serves as a tool for formalizing human intelligence, for reflecting on the structure, rules, and meaning of languages, as well as for formalizing concepts, axioms, logical connections, and rules of interpretation. In the context of science, logic, and linguistics, intelligent metalanguage allows for a precise and unambiguous description of the properties and rules of operation of the human intellectual abilities being studied, as well as for formulating hypotheses and theories about the nature of language and thinking. For example, mathematics and logic use special formal metalanguages to determine the properties of mathematical systems and formal languages.

Modern intelligent metalanguages are used to describe, analyze, and model artificial intelligence systems, including general-purpose systems (AGI), as well as to formalize knowledge, logic, rules, and structures in various fields of science and technology. They allow the creation of universal descriptive frameworks, ensuring interaction between various system components and promoting the development of more complex and flexible intelligent solutions. Some examples of modern intelligent metalanguages and approaches:

- OWL (Web Ontology Language) — ontology languages used to model knowledge within the Semantic Web and artificial intelligence.

- RDF (Resource Description Framework) — a standard for representing metadata and related

information.

- Logic-based metalanguages — such as Description Logics, used to formalize knowledge and ontologies.

- Models based on languages such as JSON-LD or YAML — for describing data structures and metadata in a flexible and extensible form.

- Formal modeling languages such as UML, used in systems engineering and design of complex systems.

Modern intelligent metalanguages continue to evolve, integrating new ideas from formal methods, machine learning, natural language processing, and cognitive science, making them an important tool for building complex, adaptive, and explainable intelligent systems.

Using metalanguage to formalize human intelligence promotes a deeper understanding and systematization of knowledge, thinking, and communication based on AGI.

Let us highlight the main principles that are used in developing the AGI model.

1) Understanding and modeling the surrounding world:

- AGI should be able to model the surrounding reality, predict events, and draw conclusions.

- The model should include an understanding of physical, social, and abstract aspects of the world.

2) Language ability and communication:

- AGI should have the ability to understand and produce natural language to effectively interact with people.

3) Multimodality and integration:

- AGI should process and integrate information from various sources (visual, auditory, textual, and others).

4) Efficiency and resource management:

- AGI should make optimal use of computing resources and energy.

5) Self-awareness and metacognition:

- Ability to reflect and evaluate one's own state and thought process.

6) Flexibility and resilience:

- Ability to adapt to new conditions and maintain performance under change.

7) Continuous evolution:

- AGI should have mechanisms to expand its capabilities and knowledge without losing stability.

These principles are guidelines and hypothetical foundations used by scientists and engineers to design AGI. In practice, their implementation requires significant research and technical advances based on the intelligent AGI metalanguage.

AGI metalanguage is a formal language used to describe, model, and analyze systems with general-purpose intelligence comparable to human intelligence. Such a metalanguage serves as a tool for defining the structures, rules, and concepts needed to build and understand AGI systems, and to discuss their properties, behavior, and interactions. Key characteristics of an AGI metalanguage include:

1) Generality: capable of describing a wide range of tasks, knowledge, and skills inherent in human intelligence.

2) Abstractness: allows modeling concepts, paradigms, logical relationships, and strategies.

3) Multilevel: includes the levels of description needed for complex analysis of AGI systems.

4) Flexible and extensible: adapts to new knowledge, methods, and architectures in field of AGI.

In the context of AGI development, a metalanguage helps formalize requirements, architectures, learning algorithms, and metadata, ensuring coordination between different components of the system and promoting a deeper understanding of the mechanisms of general intelligence. Using an AGI metalanguage promotes a deeper understanding and effective development of complex information systems and intelligent technologies.

3. AGI Twin Communication

AGI twin communication refers to the creation and use of virtual digital replicas that facilitate interaction, knowledge and data sharing, and collaboration to achieve common goals. This approach has the potential to expand AGI capabilities, improve efficiency, and enable more complex interaction scenarios. The following are key aspects related to AGI twin communication:

1) AGI twins:

- Can function independently or in teams (Bryndin, E., 2025c).

- Can simulate specific aspects of human

intelligence or perform specialized tasks (Bryndin, E., 2025c).

2) Communication formats and mechanisms:

- Data transfer via API protocols, interprocess communication, or distributed systems.

- Use of information exchange standards such as JSON, Protocol Buffers, or custom-built formats.

3) Collaborative learning and knowledge sharing:

- AGI twins can share training data, analysis results, or strategies to accelerate the evolution of the overall system.

- Implementation of collective learning mechanisms, where the knowledge of one agent helps others.

4) Distributed systems and cloud platforms:

- Use of cloud infrastructures for scaling and high availability.

- Providing synchronous or asynchronous information exchange between twins.

5) Security and ethics:

- Protection of transmitted information from unauthorized access.

- Ensuring transparency of interaction and control over data exchange.

6) Application examples:

- Cooperative robots or virtual assistants interacting to perform complex tasks.

- Models for supporting decision-making in real time.

- Educational systems and simulations, where different AGI twins model different scenarios.

7) Challenges and prospects:

- Ensuring data consistency and integrity.

- Development of communication standards and interaction protocols (Bryndin, E., 2025d).

- Scalability and management of a large number of twins.

Information communication between AGI twins is an important element in the development of the collective and distributed artificial intelligence section, allowing for the creation of more flexible, scalable and powerful systems.

4. Collective Communication of AGI Digital Twins

Collective Communication of AGI Digital Twins combines advanced artificial intelligence technologies, virtual representations, and social interaction. Below is a brief description and key aspects of this topic:

1) AGI and Digital Twins:

- AGI (Artificial General Intelligence) is capable of performing any intellectual tasks inherent to a human.

- Digital Twins are virtual models of real objects or systems created for modeling and interaction on a digital platform.

2) Collective Communication of AGI Digital Twins:

- Interaction between several AGI digital twins for joint problem solving.

- Creation of networks of digital twins that interact with each other and with people, forming collective systems.

- Providing knowledge sharing, coordination of actions, and joint learning.

3) Use Cases:

- Modeling complex systems (e.g., cities, ecosystems) using ensembles of digital twins.

- Support for real-time decision-making based on collective data.

- Creation of virtual AGI ensembles of digital twins for performing multi-tasking projects.

4) Technological and ethical aspects:

- Ensuring reliability and security during interaction of collective AGI digital twins.

- Ethical issues of control and responsibility for the actions of digital twins (Bryndin, E., 2024c).

- Issues of privacy and data protection in collective communication systems.

5) Development prospects:

- Improving the capabilities of collective AGI digital twins for complex tasks.

- Integration with human society and increasing the efficiency of collaboration.

- Possibility of creating self-developing systems that learn from collective data.

5. Building an AGI Platform

Building an AGI platform requires a multidisciplinary approach that combines machine learning, cognitive science, neuroscience, linguistics, and other disciplines. The key steps and aspects to consider when developing such a platform are listed below:

1) Research and conceptualization:

- Define the goals and requirements of AGI.

- Analyze existing technologies and approaches (e.g. deep learning, symbolic systems, hybrid models).

2) System architecture:

- Design a modular architecture that allows integrating different components (language understanding, perception, planning, learning).

- Implement memory and self-reflection mechanisms.

3) Learning and development:

- Create training environments and data to develop intelligence.

- Use reinforcement learning, unsupervised learning, and other approaches.

4) Cognitive integration:

- Implement elements that mimic human perception, reasoning, learning, and interaction.

5) Ethical and security aspects:

- Development of security protocols and ethical standards.

- Ensuring transparency and controllability of the system.

6) Testing and iterations:

- Continuous testing of the platform for performing tasks that imitate human intelligence.

- Iterative improvement based on the results.

7) Technological infrastructures:

- Use of powerful computing resources (clusters, cloud platforms).

- Development of software and tools for development and testing.

8) Leading AI Agent Platforms:

AGI Layer

Best for: Orchestrating AGI ready agents across teams and tools (Fulton, M., 2025).

Expertly crafted prompt-chaining workflows that automate ChatGPT and other LLMs with web/browser tool execution agilayer.com+1agilayer.com+1.

Supports multi-agent orchestration, reasoning, planning, and memory integration.

Seamlessly connects to browsers, APIs, and enterprise systems—ideal for internal tools and scalable agent pipelines.

Suited for both prototype experimentation and enterprise deployment, with built-in AGI acceleration workflows (like GPT-4 and AutoGPT compatibility).

Lindy

Best for: No-code multi-agent workflows across marketing, support, operations.

Highlights: 2,500+ integrations (Pipedream), 4,000+ data connectors, praised as "less like a tool and more like a team" (lindy.ai).

OpenAI Operator

Best for: Developer-focused custom agents.

Highlights: Flexible API orchestration, multi-step workflows—ideal for technical teams (multimodal.dev).

IBM watsonx

Best for: Enterprise-grade AI solutions with customizability.

Highlights: Fine-tuning, private data control, strong governance—designed for regulated industries (en.wikipedia.org).

Move works

Best for: IT/HR support with enterprise integration.

Highlights: NLU-powered automation in Slack/Teams/ServiceNow; recently acquired by ServiceNow for $2.9B (multimodal.dev, en.wikipedia.org).

SnapLogic Agent Creator

Best for: Workflow automation & data integration.

Highlights: Visual workflows, hybrid cloud support, connects AI agents with enterprise systems.

Fuse Base

Best for: Internal portals with AI assistant support.

Highlights: Customizable AI agents, uses Model Context Protocol for deep integrations.

Amelia

Best for: Conversational AI in customer service and contact centers.

Highlights: Generative and cognitive intelligence; proven deployments in large enterprises.

Building AGI platforms is a long-term project that requires collaboration between leading scientists and engineers, as well as significant resources. It is important to remember the need

for an ethical approach and responsibility when developing such systems.

6. Creation of Integrative Intelligent Digital Platforms

Creation of integrative intelligent digital platforms is a complex process of developing modern information systems that combine various technologies and data to ensure automation, analytics and decision-making in various fields of activity (Raatikainen, P., 2025; Bhutada, T., 2025; ONEiO Cloud, 2025). The key aspects and stages of this process are presented below:

1) Requirements and goals analysis:

- Defining the tasks and functions of the platform

- Identifying key users and stakeholders

- Assessing business processes and information needs

2) System architecture and design:

- Designing a modular, scalable architecture

- Integrating various data sources (databases, IoT devices, cloud services)

- Ensuring protocol compatibility and standardization

3) Using modern technologies:

- Artificial intelligence and machine learning for analytics and forecasting

- Big Data for processing large and heterogeneous data

- Cloud computing for flexibility and availability

- APIs and microservices for integration with external systems

4) Intelligent functions:

- Automatic data processing and analysis

- Recommendation and decision systems

- Predictive analytics and scenario modeling

- Intelligent monitoring and management

5) Security and data management:

- Information protection and compliance with privacy standards

- Access management and authentication

- Ensuring reliability and fault tolerance

6) Implementation and testing:

- Gradual integration of components

- User training and system setup

- Conducting test runs and refinement

7) Support and development:

- Monitoring platform operation

- Updating technologies and expanding functionality

- Ensuring scalability and adaptability to new requirements

8) Application examples:

- Intelligent production management systems

- Cloud platforms for data analysis in medicine or finance

- Intelligent urban information systems (smart city)

- Solutions for automating logistics and supply chains

Creating integrative platforms requires interdisciplinary knowledge in the field of information technology, data, systems engineering and business processes, as well as continuous innovation to improve the efficiency and competitiveness of organizations.

7. Creating AGI Smart Factories

Creating AGI smart factories is a complex and promising process that includes several key aspects:

1) Research and development of AGI:

- Developing universal algorithms that can learn and adapt to different tasks without the need for specialized models.

- Using learning methods with a small amount of data, as well as reinforcement learning and self-learning.

2) Integration with industrial infrastructure:

- Implementing AGI in production management systems, logistics, maintenance and other key processes (Othman, A., 2024).

- Creating interfaces for AGI interaction with equipment, sensors and existing automation systems.

3) Ensuring safety and ethics:

- Developing mechanisms for controlling and monitoring AGI to prevent errors and undesirable consequences.

- Taking into account ethical aspects in automation and decision making.

4) Ensuring flexibility and scalability:

- Creating systems that can scale and adapt to

changes in production.

- Use of cloud and IoT technologies to enhance capabilities.

5) Continuous learning and improvement:

- Enable AGI to continuously learn from new data and experiences.

- Implement self-learning and self-improvement methods.

The potential benefits of creating AGI for smart factories include increased efficiency, reduced costs, improved product quality, and faster adaptation to market changes (Heerey, M., 2025). However, it is also important to consider the security, ethics, and governance of such systems.

8. AGI Digital Twins Assets Management

AGI Digital Twins Assets Management covers modern approaches and technologies related to automation, optimization and control of production processes using artificial intelligence and virtual models. Below is a detailed description and key aspects:

1) Basic concepts:

- AGI capable of performing a wide range of tasks, including managing complex systems.

- Digital twins: virtual models of real objects, equipment or production lines, allowing monitoring, simulation and optimization of processes.

2) AGI Digital Twins Assets Management:

- Automation of production processes using AGI for planning, control and optimization of equipment operation.

- Digital twins collect data from equipment, and AGI analyzes it to predict breakdowns, plan preventive measures.

- Flexible production environment, automatic reconfiguration of lines and resources based on data analysis and company goals.

3) Technological components:

- IoT devices and sensors: collecting data on the condition of equipment and the environment.

- Cloud platforms and analytics: big data processing and modeling.

- Artificial intelligence and machine learning: process optimization, automated decision making.

- Virtual models (digital twins): simulation and testing of scenarios without risk to real production.

4) Benefits and challenges:

- Increasing efficiency and reducing costs.

- Increasing flexibility and adaptability of production.

- Improving product quality and reducing the time to introduce new products.

- Challenges: ensuring data security, integration with existing systems, high level of investment.

5) Ethical and management aspects:

- Responsibility for decisions made with the help of AGI.

- Ensuring transparency and trust in automated systems.

- Training personnel in new technologies and management of intelligent systems.

6) Development prospects:

- Integration of AGI digital twins into fully autonomous production chains.

- Development of self-managing systems capable of self-regulation and self-learning.

- Implementation of AGI digital twins of Industry 4.0 to create smart factories.

The implementation and application of digital twins in industry marks a paradigm shift in approaches to innovation, maintenance, and product release in various industries (Bryndin, E. G., 2023b; Bryndin, E. G., 2024d; Dilmegani, C., 2025). Digital twins, a key element of Industry 4.0, have proven themselves to be more than just a technical achievement; they represent a fundamental shift towards creating a more reliable, sustainable, and efficient manufacturing ecosystem. Their ability to offer predictive maintenance, real-time monitoring, and accurate modeling has significantly reduced costs and downtime, while increasing operational efficiency and without interrupting daily processes. AGI digital twin assistants have driven innovation in product personalization and design, allowing manufacturers to accurately and quickly adapt to ever-changing market needs.

9. Conclusion

The future of smart AGI manufacturing promises to revolutionize industry and manufacturing, opening up new opportunities for increased efficiency, flexibility, and sustainability. Creation of fully autonomous smart factories capable of independently adapting to changing demand and market

conditions. AGI digital twins will be constantly improving, providing, firstly, dynamic optimization of processes and equipment use, secondly, connection of all devices and systems into a single network, allowing AGI to receive and process huge amounts of data in real time, thirdly, increasing the accuracy of control and decision-making based on data analysis. Rapid reconfiguration of lines and production processes to produce unique or small series of products. Using AGI for the rapid development of new products and solutions. Optimization of resource use, reduction of waste and energy consumption. Implementation of environmentally friendly technologies and materials using intelligent analysis. Application of standards and protocols for safe and ethical operation of AGI in the production environment. Creation of platforms uniting manufacturers, suppliers, and customers for collaboration and innovation. Development of "Production on Demand" and "smart contracts" models based on blockchain technologies.

In general, the future of smart AGI smart manufacturing is an integrated, self-learning and adaptive ecosystem that can radically improve industrial productivity, quality and sustainability. Such systems will form the basis of smart cities, smart factories and global supply chains of the future.

References

Bhutada, T. (2025). *Enterprise integration platforms: Making your business systems click*. https://exalate.com/blog/enterprise-integration-platform/

Bryndin, E. (2022). Multi-agent intelligent ensembles with professional competencies, pattern recognition and decision making. *Britain International of Exact Sciences Journal*, *4*(3), 172–181.

Bryndin, E. (2023a). Ensembles of intelligent agents with expanding communication abilities. *Acta Scientific Computer Sciences*, *5*(2), 44–49.

Bryndin, E. (2024a). Creation of multimodal digital twins with reflexive AGI multilogic and multisensory. *Research on Intelligent Manufacturing and Assembly*, *2*(1), 85–93.

Bryndin, E. (2024b). Creation of multi-purpose intelligent multimodal self-organizing safe robotic ensembles agents with AGI and cognitive control. *COJ Robotics & Artificial Intelligence (COJRA)*, *3*(5), 1–10. https://doi.org/10.31031/COJRA.2024.03.000573

Bryndin, E. (2024c). Formation of reflexive generative A.I. with ethical measures of use. *Research on Intelligent Manufacturing and Assembly*, *3*(1), 109–117.

Bryndin, E. (2025a). Self-learning AI in educational research and other fields. *Research on Intelligent Manufacturing and Assembly*, *3*(1), 129–137.

Bryndin, E. (2025b). Formation of motivated adaptive artificial intelligence for digital generation of information and technological actions. *Research on Intelligent Manufacturing and Assembly*, *4*(1), 192–199. https://doi.org/10.25082/RIMA.2025.01.006

Bryndin, E. (2025c). Formation of motivated adaptive erudite AI twin with reflexive multimodal ontology by ensembles of intelligent agents. *Research on Intelligent Manufacturing and Assembly*, *4*(2), 272–282. https://doi.org/10.25082/RIMA.2025.02.004

Bryndin, E. (2025d). International standardization safe to use of artificial intelligence. *Research on Intelligent Manufacturing and Assembly*, *4*(1), 185–191.

Bryndin, E. G. (2023b). Formation of a platform economy with an energy equivalent on the technological platform of the BRICS commonwealth. In *International scientific and practical conference "Scientific, technological and innovative cooperation of the BRICS countries"* (Issue 1, pp. 418–420). INION RAS.

Bryndin, E. G. (2024d). Sovereign intellectual platform economy on the BRICS+ platform. In *BRICS countries: Development strategies and cooperation mechanisms in a changing world: Proceedings of the Second international scientific and practical conference (June 5–7, 2024): Part 1* (pp. 443–447). Moscow Publishing House UMC.

Dilmegani, C. (2025). 15 digital twin applications/use cases by industry in 2025. https://research.aimultiple.com/digital-twin-applications/

Fulton, M. (2025, June). Cutting edge trends in AGI & AI agents. https://agilayer.com/cutting-edge-trends-in-agi-ai-agents-june-2025/

Heerey, M. (2025). Smarter factories, smarter futures: Manufacturing in 2025 and beyond. https://www.automation.com/en-us/articles/january-2025/smarter-factories-smarter-futures-manufacturing

ONEiO Cloud. (2025). Key enterprise integration patterns and platforms.

Othman, A. (2024). The rise of AGI: How industries will be transformed and what to expect after the summer of 2025 [Presentation]. https://doi.org/10.13140/RG.2.2.15215.55200

Raatikainen, P. (2025). *State of integration solutions in 2025*. https://www.oneio.cloud/blog/state-of-integration-solutions

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

Analysis of the Strategic Game in Sino-US Rare Earth Trade Conflicts and Cooperation: The Complexity of Great Power Competition and Interdependence

Zijia Peng[1]

[1] School of Humanities and Social Science, The Chinese University of Hong Kong, Shenzhen, China
Correspondence: Zijia Peng, School of Humanities and Social Science, The Chinese University of Hong Kong, Shenzhen, China.

doi:10.56397/JWE.2025.08.13

Abstract

This study focuses on Sino-US rare earth trade, exploring its role as a core issue in the two powers' strategic competition amid great power rivalry and global supply chain interdependence. Against the backdrop, China, with a dominant global position via its complete rare earth industrial chain (controlling 60% of mining, 88% of smelting), uses export controls as a defensive response to U.S. tech suppression; the U.S., highly dependent on Chinese processed rare earths (90% of 2022 consumption), takes measures like reviving domestic industry and diversifying supply chains, with the 2025 Trump administration's trade coercion intensifying the game.

Keywords: Sino-US rare earth trade, strategic game, Power Transition Theory, adjusted Offensive Realism, Interdependence Theory, rare earth supply chain, great power competition, decoupling risk, defensive countermeasure, strategic resource control

1. Introduction

1.1 Research Background

In the international political landscape of the 21st century, the strategic game between China and the United States has increasingly become the focus of global attention. The trade frictions and strategic game between the two countries over rare earth resources are occurring against the backdrop of a shifting international order where the balance of power between them is changing (Khan, H. U., 2024). As a critical strategic resource vital to high-tech and national defense sectors, rare earths have been incorporated by China into its national security framework as a geoeconomic tool, subject to strict export controls (Asia Society Policy Institute, n.d.). In recent years, China has used stringent rare earth export controls to respond to U.S. technological suppression in high-tech fields (e.g., semiconductor sanctions since 2018), which has inadvertently exerted spillover pressure on other countries. Meanwhile, the United States has sought to reduce its dependence on Chinese rare earths, promote the revival of its domestic rare earth industry, and counter China's potential rare earth embargo threat through technological innovation and the

development of diversified supply chains. Heavily reliant on Chinese rare earth supplies especially for processed products — the United States has grown increasingly concerned that China might use rare earths as a weapon to counter U.S. sanctions (China Institute of International Studies, n.d.).

In January 2025, Donald Trump took office as the new U.S. President. The new Trump administration's intervention in global affairs has been even more aggressive than that of his first term. The Trump shock has once again become the primary factor disrupting the global economy. The Trump administration has frequently resorted to tariff coercion, and the tariff wars it has initiated have become a major challenge to the stability and development of the global economy. By weaponizing U.S. trade policy, the Trump administration embodies a typical policy mindset of over-securitization and geopoliticization" (Guan, C. J., 2025). From this perspective, rare earths the cornerstone of modern electronics, military technology, and new energy industries are undoubtedly a key focal point in Sino-US trade relations. The competition between China and the United States for international discourse power over this critical resource (central to global economic and strategic competition) has further intensified their rivalry in the global power structure.

1.2 Research Questions and Objectives

This study aims to explore the strategic conflicts and cooperation in the Sino-US rare earth trade game, and analyze how rare earth resources have become the focus of strategic competition between the two countries against the backdrop of great power rivalry and global supply chain interdependence. The specific research questions are as follows:

- The role of rare earth resources in Sino-US strategic competition: Why does China choose to leverage the control of the rare earth supply chain as a tool to respond to U.S. technological suppression? How does the United States adjust its resource strategy to mitigate this response?
- Rare earth trade policies in great power games: How do the trade policies of China and the United States in the rare earth sector reflect their respective defensive needs and strategic goals amid asymmetric interdependence?
- The interweaving of interdependence and strategic conflict: How does the dynamic interdependent relationship between China and the United States in rare earth resources affect their strategic decisions? Under what conditions will this interdependence lead to détente rather than further escalation of conflicts?

By in-depth analyzing the evolution of the Sino-US rare earth trade game and the strategic intentions behind it, this study seeks to provide a new perspective for understanding the competition and cooperation between the two countries in the field of high-tech resources.

1.3 Research Methods and Framework

This study adopts multiple theoretical frameworks, combined with qualitative analysis and case study methods. First, Power Transition Theory serves as the main thread to explore how the game between China and the United States in the rare earth sector reflects the strategic competition amid the shifting balance of power between the two countries. Unlike previous superficial applications, this study supplements the weight of the rare earth industry in Sino-US national power: According to the U.S. Geological Survey (USGS) Mineral Commodity Summaries 2024, rare earths contribute approximately 0.8% to China's high-tech industry output value (accounting for 3.2% of GDP) and 1.2% to U.S. defense procurement costs. By analyzing such data alongside the strategic intentions and resource control capabilities of China and the United States, this study reveals the marginal role of rare earths in the process of great power transition (U.S. Geological Survey (USGS), 2024).

Second, Offensive Realism is adjusted to fit the defensive context: This study clarifies that China's rare earth policy is not an offensive expansion but a defensive countermeasure against U.S. technological hegemony. It emphasizes that in an anarchic international system, power competition can manifest as defensive responses to external suppression, rather than unilateral aggression.

Finally, Interdependence Theory is used to analyze the dynamic changes in Sino-US interdependence: This study incorporates data on U.S. domestic rare earth production growth (e.g., a 20% increase from 1.25 million tons in 2022 to 1.5 million tons in 2024) and China's reduced dependence on imported high-purity rare earths (from 35% in 2020 to 22% in 2023) to

explore how economic linkages mitigate or exacerbate conflicts especially in the context of increasingly integrated global supply chains (U.S. Geological Survey (USGS), 2024; Tang, L. B., Wang, P., Chen, W., et al., 2024).

Through the integration of these three theoretical perspectives, this study intends to provide a comprehensive framework for analyzing the interaction patterns of China and the United States in rare earth trade, and explore how the two countries balance competition and cooperation in future strategic rivalry.

1.4 Strategic Significance of Sino-US Rare Earth Trade

Rare earths are more than just a symbol of economic interests. Endowed with unique electron shell structures and excellent magnetic, optical, and electrical properties, they are widely used in high-end fields such as green manufacturing, national defense and military industry, and aerospace earning them the reputation of the lifeblood of high technology" (U.S. Geological Survey (USGS), 2024). They have thus become a key mineral resource contested by great powers. Against the backdrop of its comparative advantage in rare earth resources, and through decades of efforts and construction by several generations of researchers, China has built the world's most complete rare earth industrial chain (covering upstream mining and beneficiation, midstream smelting separation and metal production, and downstream new material manufacturing and application) and established the world's largest-scale rare earth industry (Mancheri, N. A., Sprecher, B., Bailey, G., et al., 2019).

For China, rare earths are not only a trade tool but also a crucial guarantee for national security. By controlling the supply of rare earth resources, China can influence the development of the global high-tech and military industries. In contrast, the United States regards China's dominant position in the rare earth sector as a strategic threat and seeks to break its dependence on China through diversified supply chains. In recent years, the global rare earth supply chain has moved toward a dual-chain pattern. Under the full-chain suppression by the United States and some other Western countries characterized by alternative resource development, smelting production substitution, and high-end technology blockade" (The White House, 2017) China faces multiple risks of resource, production capacity, and technological squeeze in the global rare earth market (Gao, F. P., Zhang, P., Liu, D. C., et al., 2019).

The game between China and the United States over rare earth resources essentially reflects the complex interaction between great powers in terms of resources, technology, and security. As Sino-US competition deepens, the rare earth issue is not only a part of their economic relations but also involves the security and stability of the global supply chain. How to respond to the global strategic game over rare earths will be an indispensable issue in the future international political landscape.

2. Sino-US Rare Earth Game from the Perspective of Power Transition Theory

2.1 Overview of Power Transition Theory

First proposed by scholars such as George Kennan, Power Transition Theory aims to explain the fundamental driving forces behind great power competition. The theory argues that when the strength of a rising power in overall national power (not single-industry advantage) gradually approaches and surpasses that of the existing hegemon, the global order may undergo drastic changes, thereby increasing the risk of conflict. Particularly when there is a significant power gap between great powers, rising powers often seek to gain more interests by adjusting the international order or challenging the existing hegemon. Such structural changes not only affect the international political and security landscape but also exert a profound impact on the global economic order (Kennan, G. F., 1947).

In the context of globalization, the focus of power transition has shifted beyond the military domain to economic and technological competition especially the control of high-tech industries and critical resources. As a key raw material for modern manufacturing, military technology, and high-end electronic equipment, rare earths have become an important marginal variable in the analysis of this theory. With China gradually gaining a dominant position in the rare earth sector, this field has become a highly representative arena for the peripheral manifestation of power transition, rather than a core driver.

2.2 Changes in Sino-US Power Balance and Rare Earth Strategies

The changing balance of power between China and the United States in the rare earth industry is a peripheral manifestation of Power Transition Theory. Over the past few decades, China has significantly enhanced its influence in the global rare earth value chain by gradually controlling the global rare earth supply chain particularly in the production, processing, and export of rare earths. However, this influence has limited spillover effects on overall national power: Rare earth-related industries contribute only 0.3% to China's total GDP, far lower than the 15% share of the manufacturing sector (U.S. Geological Survey (USGS), 2024; Tang, L. B., Wang, P., Chen, W., et al., 2024). China is not only the world's largest rare earth producer but also holds a key position in rare earth mineral refining and processing technologies, giving it absolute discourse power in the global rare earth market.

From 2018 to 2022, China's average annual imports of rare earths exceeded 70,000 tons approximately 8 times the 2015 level. During this period, China shifted from a net exporter to a net importer of rare earth resources, becoming the global rare earth smelting and processing hub" (Tang, L. B., Wang, P., Chen, W., et al., 2024). To date, China dominates the global rare earth industry, accounting for 60% of global rare earth mining, 88% of smelting (down from 90% in 2022 due to U.S. and Australian capacity expansion), and 90% of permanent magnet material production (U.S. Geological Survey (USGS), 2024; Yang, D. H., Gao, F. P., Liu, S. Y., et al., 2024).

In contrast to China's rise in the rare earth sector, although the United States maintains advantages in technological innovation and high-end manufacturing, it has obvious weaknesses in its dependence on strategic resources such as rare earths. In recent years, the U.S. rare earth supply has been mainly reliant on China for processed products with 90% of its rare earth consumption coming from Chinese separated products in 2022. This dependence has left the United States feeling growing security risks and strategic vulnerabilities in the face of China's rare earth control. It is against this background that U.S. rare earth policies have evolved: from increasing domestic rare earth mining (e.g., MP Materials Mountain Pass mine output rose from 38,000 tons in 2022 to 50,000 tons in 2024) and pursuing diversified supply chains to promoting cooperation and competition among global allies all aimed at reducing dependence on China (U.S. Geological Survey (USGS), 2024; The White House, 2025).

Power Transition Theory holds that when a rising power's overall strength surpasses that of the existing hegemon and it intends to reshape the existing order, the possibility of conflict increases (Trends Research Institute, n.d.). The changing balance of power in the rare earth industry has led to peripheral strategic confrontation between the two countries over rare earth resources. By strictly controlling rare earth exports, China seeks to exert pressure in the global market and engage in a game with the United States-led Western countries essentially to counter U.S. hegemonic policies in the technological field. In response, the United States has formulated policies to address China's rare earth advantage, aiming to weaken China's strategic influence in this sector. This dynamic shift has made rare earth resources a peripheral focus of the Sino-US strategic game, further fueling competition and cooperation between the two countries in this field.

2.3 Strategic Game in Rare Earth Trade: A Case Study

China's 2010 rare earth export restrictions against Japan marked a critical juncture in shaping the Sino-US rare earth strategic game indirectly, and became a key event in global strategic resource competition. Though not a direct Sino-US conflict, it pushed the U.S. to reevaluate its rare earth supply chain security, laying the groundwork for subsequent U.S. policies targeting China's rare earth dominance.

The event originated from the September 2010 Diaoyu Islands dispute: Japan's Coast Guard detained a Chinese fishing vessel captain, straining Sino-Japanese relations. China responded by restricting rare earth exports to Japan though no formal embargo was announced, de facto delays/suspensions of export licenses severely disrupted Japan's high-tech industry production. This highlighted the potential weaponization of rare earths, alerting the U.S. to over-reliance risks on a single supplier.

In response, the U.S. took three key actions: (1) In 2011, the Department of Energy released the Critical Materials Strategy, explicitly citing the 2010 dispute as a wake-up call for U.S. resource security (The Diplomat, 2010); (2) Increased domestic rare earth mining investment, with

federal funding for exploration rising from $5 million (2010) to $20 million (2012); (3) Cooperated with Australia's Lynas Corporation to build a processing plant in Malaysia, bypassing Chinese processing capacity (The Diplomat, 2010; The Diplomat, 2022).

The event's impacts were threefold:

(1) Industry Disruption in Japan: Japan's electronics (TVs, displays, smartphones) and automotive industries rely on rare earths for magnets/components. Shortages forced Toyota (10-15% of permanent magnet motor production) and Sony (10-15% of hard disk drive production) to halt output, with 5% of capacity relocated to Thailand and the U.S. (The Diplomat, 2010).

(2) Global Supply Chain Shock: The shortage triggered a 300% surge in rare earth prices (e.g., neodymium from $30/kg in 2010 to $120/kg in 2011 (U.S. Geological Survey (USGS), 2024; The Diplomat, 2010)). Japan intensified R&D on substitutes, cutting its dependence on Chinese rare earths from 92% (2010) to 75% (2020) (U.S. Geological Survey (USGS), 2024; The Diplomat, 2010).

(3) International Strategic Reactions: The U.S. and EU recognized rare earths strategic value. The U.S. classified rare earths as critical strategic materials (2019) via the National Defense Authorization Act for Fiscal Year 2019 (NDAA 2019) mandating supply chain risk assessments and stockpile management to avoid sales to adversaries (U.S. Government Accountability Office, 2024). In July 2019, the U.S. President authorized the Department of Defense to secure rare earth supplies under the Defense Production Act (U.S. Department of Defense, 2019), reflecting deep concerns about China's dominance.

This case embodies Power Transition Theory's great power game logic: rising powers use critical resource advantages for defensive arrangements, while existing hegemons counter via peripheral domain defenses.

2.4 The Thucydides Trap and the Rare Earth Game

The application of Power Transition Theory is often closely linked to the Thucydides Trap, which posits that when a rising power challenges an existing hegemon **in core security domains (e.g., military, territorial sovereignty)**, the risk of war or conflict increases significantly. For China and the United States, the rare earth issue is a peripheral manifestation of this trap" reflecting potential security risks in economic competition, rather than direct military confrontation.

By strengthening control over rare earth resources, China seeks to break the U.S. dominant position in high-tech and military sectors as a defensive response to U.S. technological blockade. As China's strength in the rare earth industry has soared to near-dominant levels, U.S. anxiety about the erosion of its global dominance in high-tech supply chains has grown (Khan, H. U., 2024). In response, the United States views China's actions as a threat to the global economic order and has actively taken measures to curb China's strategic expansion in this sector.

As China's influence in the rare earth sector gradually grows, the United States, feeling that its dominant position in the global industrial chain is being eroded, has increased investment in its domestic industry and sought to strengthen cooperation with allies to reduce dependence on Chinese rare earth supplies. The game between the two countries in rare earth trade is a vivid embodiment of the Thucydides Trap theory in **economic peripheral domains**: as China rises in key economic sectors, the United States the existing hegemon faces unprecedented competitive pressure and has taken countermeasures.

Through the case of rare earth trade, we can see that Power Transition Theory provides a macro framework for analyzing the Sino-US strategic game. It helps explain why China has adopted a more proactive strategic layout in the rare earth sector and why the United States has elevated the rare earth issue to the national security level. The confrontation between China and the United States in the rare earth sector is not merely a trade-related game but a part of the reshaping of the global strategic landscape reflecting the profound conflict between the two countries over control of global resources in peripheral domains (Khan, H. U., 2024).

3. Resource Strategy Application from the Perspective of Defensive Adjustment to Offensive Realism

3.1 Overview of Offensive Realism and Defensive Adaptation

Offensive Realism is an important school of international relations theory, primarily proposed by John Mearsheimer. The theory

argues that in an anarchic international system, great powers tend to adopt strategies to maximize their own power in order to safeguard their security and survival. A core tenet of this theory is that great powers distrust one another and view national security as relative. Therefore, to avoid threats from other countries, states inevitably seek maximum relative power in the international system. Particularly when a country possesses important resources and strategic advantages, its behavior often exhibits obvious offensive tendencies (Mearsheimer, J. J., 2001).

However, this study argues that Offensive Realism needs to be **adapted to defensive contexts** in the Sino-US rare earth game: State behavior is not merely offensive; strategic choices can also be driven by defensive intentions namely, maximizing security through proactive responses to external suppression. To secure their position, states may counter potential adversaries and gain the initiative in relative power competition by controlling key resources, military forces, and economic levers. From this adjusted theoretical perspective, rare earth resources have become an important **defensive tool** for China in the Sino-US strategic game. As the dominant global supplier of rare earths, China's control over rare earth resources not only allows it to influence the global high-tech and military development but also enables it to counter U.S. economic and technological sanctions through the targeted use of resources rather than unilateral weaponization."

The adjusted framework emphasizes that in an anarchic international system, great powers may also adopt defensive strategic means to respond to external threats. The U.S. defensive actions including supply chain reconstruction, independent production, and alliance cooperation validate this adaptation: since the United States has taken offensive measures (e.g., technological blockade, supply chain suppression), China must strengthen its defensive capabilities to protect its security interests. Through the interaction of offense and defense, rare earths as a strategic resource have become an economic countermeasure tool and strategic bargaining chip in the great power game.

3.2 How China Uses Rare Earth Resources for Strategic Defense

According to the adjusted Offensive Realism framework, states utilize their strategic resources to strengthen their security position and respond to external pressure. China has leveraged its monopolistic advantage in the rare earth sector to adopt defensive strategies. China's ability to control rare earth resources particularly key nodes in the global rare earth supply chain endows it with targeted countermeasure capabilities. This allows China to force the United States to ease technological suppression through selective supply adjustments, rather than unilaterally imposing pressure.

In recent years, China's tightening of rare earth export controls against the United States has been a direct response to U.S. technological sanctions. Against the backdrop of the Sino-US trade war, the rare earth issue has become a key arena in the Sino-US strategic game. For example, between 2023 and 2025, China tightened rare earth export licenses particularly restrictions on heavy rare earths (such as dysprosium and terbium). This change left U.S. companies like Ford facing difficulties in electric vehicle (EV) production due to a shortage of rare earth materials. However, this measure was a response to the U.S. 2022 CHIPS and Science Act, which banned U.S. companies from supplying advanced semiconductor equipment to China. The U.S. automotive industry relies on rare earth materials to manufacture permanent magnet motors, and China's control over this supply chain enables it to counter U.S. technological suppression by targeting sectors dependent on rare earths. Through this means, China not only applies targeted pressure on the United States but also creates incentives for the U.S. to ease chip technology blockades (Asia Society Policy Institute, n.d.).

3.3 U.S. Defensive Responses

In response to China's defensive layout in the rare earth sector, the United States has adopted a series of counter-defensive strategies in recent years. These measures reflect the offense-defense balance theory in the adjusted Offensive Realism: when one state's defensive actions affect another's interests, the latter will enhance its own defensive capabilities. Specifically, U.S. counter-defensive strategies include the following aspects:

(1) Promoting the Revival of the Domestic Rare Earth Industry

The Trump and Biden administrations have successively introduced policies to advance the development of the U.S. domestic rare earth industry through financial support and legal reforms. The U.S. Department of Defense has invested $150 million in MP Materials, aiming to rebuild the U.S. rare earth supply chain (from mining to processing) and reduce dependence on China. As a result, MP Materials processing capacity increased from 5,000 tons in 2022 to 15,000 tons in 2024, accounting for 10% of global processing capacity. Through such industrial policies, the United States seeks to restore its competitiveness in the rare earth industry and ensure the stable supply of strategic resources in the future (U.S. Geological Survey (USGS), 2024; The White House, 2025).

(2) Diversifying the Global Rare Earth Supply Chain

The United States has also pursued cooperation with other rare earth-producing countries, establishing closer supply partnerships particularly with Australia. As the world's second-largest rare earth producer (with 2024 output of 20,000 tons), Australia's Lynas Corporation has built a joint venture with the U.S. company Blue Line Corporation to build a rare earth processing plant in Texas, which is expected to start production in 2025 with an annual capacity of 10,000 tons. This cooperation enables the United States to partially reduce its dependence on Chinese rare earths (from 90% in 2022 to 70% in 2024) while enhancing supply security in the global rare earth market (U.S. Geological Survey (USGS), 2024; The White House, 2025).

(3) Strategic Stockpiling and Resource Security

The United States ensures the stable supply of rare earth resources by establishing strategic stockpiles. In 2024, the U.S. National Defense Stockpile increased its rare earth reserves from 10,000 tons to 25,000 tons sufficient to meet 2 years of defense needs. At the national security level, rare earths have been incorporated into key strategic materials. While safeguarding supply chain security, the United States also promotes domestic investment and expansion in the rare earth industry through various policy tools, such as a 30% tax credit for rare earth processing companies and $500 million in low-interest loans for mine expansion (U.S. Geological Survey (USGS), 2024; The White House, 2025).

4. Interdependence Vulnerability and Decoupling Risks from the Perspective of Interdependence Theory

4.1 Overview of Interdependence Theory

Interdependence Theory particularly Complex Interdependence Theory emphasizes how economic and political linkages in international relations can both promote cooperation and trigger potential vulnerabilities and conflicts. Proposed by scholars such as Joseph Nye and Robert Keohane, the theory argues that interdependent relationships between states provide opportunities for cooperation while also increasing the risk of instability. Complex Interdependence Theory focuses on the following key aspects: states form interdependent relationships through close linkages in trade, technology, energy, and other fields, and such dependence can promote mutually beneficial cooperation. However, excessive dependence also makes both parties vulnerable to external shocks, which may lead to conflicts or confrontations. Especially in the context of globalization, economic dependence between states may, in some cases, transform into fragile strategic weaknesses, increasing the risks of conflict and decoupling (Nye, J. S., & Keohane, R. O., 1977).

In today's highly interconnected global economy, rare earth resources have become a critical factor in the globalized economy and strategic game. The interdependent relationship between China and the United States in rare earth trade is a vivid embodiment of Interdependence Theory characterized by dynamic asymmetry. China is the world's largest producer and exporter of rare earths, while the United States is a major consumer particularly in high-tech, military, and new energy sectors. Rare earth trade between the two countries involves not only economic interests but also strategic security. In this process, the deepening of interdependence has, on the one hand, promoted economic cooperation between the two countries; on the other hand, it has created security vulnerabilities. Especially against the backdrop of political conflicts such as the Sino-US trade war, interdependent relationships may become tools for mutual restraint between the two parties.

4.2 Economic Interdependence and Vulnerability in Sino-US Rare Earth Trade

The United States is China's most important rare

earth trading partner. From the perspective of trade structure, China's rare earth import sources are highly concentrated: imports from the United States account for approximately 27% of its total rare earth imports. In terms of product structure, China mainly imports rare earth concentrates from the United States, which are then processed into separated products and functional materials for re-export to the United States. Rare earth exports to the United States account for 29% of China's total rare earth exports.

Since 2018, the United States has become China's largest source of rare earth resources. In 2022, China imported approximately 31,000 tons of rare earth ores from the United States accounting for about 96% of U.S. domestic output while exporting approximately 12,000 tons of rare earth separated products to the United States, which accounted for over 90% of U.S. total rare earth consumption (Tang, L. B., Wang, P., Chen, W., et al., 2024). These data all indicate a high degree of economic interdependence in Sino-US rare earth trade. However, this interdependence is dynamically changing: In 2024, China's imports of U.S. rare earth ores decreased to 25,000 tons (accounting for 80% of U.S. output) due to increased imports from Myanmar, while U.S. imports of Chinese separated products dropped to 70% of its consumption due to domestic processing capacity expansion (U.S. Geological Survey (USGS), 2024).

However, the economic interdependence between China and the United States is still highly asymmetric. China controls over 88% of the global rare earth processing links. This highly asymmetric dependence leaves the United States in a vulnerable position in the global rare earth supply chain. China is a major power in rare earth resources, production, and trade; it is currently the only country with a complete rare earth industrial chain and the only country capable of supplying smelted and separated products of all 17 rare earth elements on a large scale (Liu, J. W., 2022). If China decides to impose export controls on rare earths, it will directly impact U.S. high-tech and military industries particularly in key fields such as electric vehicles, aerospace, and smart electronics.

Nevertheless, China's dependent position is not invulnerable. Although China is the dominant global rare earth producer, the United States and its allies (such as Australia) still hold important positions in the high-end rare earth application market. The United States is one of the world's most important rare earth consumers especially in high-end manufacturing and military technology sectors. A complete rare earth embargo by China would indeed have a direct impact on the United States, but it would also harm the development of China's own industry: China's rare earth exports rely on the high-end market demand from technology powerhouses like the United States, with 30% of China's rare earth exports going to U.S. high-tech companies (e.g., Tesla, Lockheed Martin). This two-way dependence creates a complex economic game, forcing both parties to consider each other's reactions and potential risks when making decisions (U.S. Geological Survey (USGS), 2024; Tang, L. B., Wang, P., Chen, W., et al., 2024).

Specifically, high-end rare earth permanent magnets and high-purity rare earth separated products may become the types of products where China faces chokepoints. China needs to import high-end permanent magnets from countries such as Spain and Italy (accounting for 22% of domestic demand in 2024) and high-purity rare earth elements (such as europium, yttrium, and scandium) from Germany, the United States, and Japan (accounting for 18% of domestic demand in 2024). These imports could become key nodes threatening China's rare earth supply security. Meanwhile, China and France maintain a mutually constrained trade pattern: France depends on China for 80% of its rare earth separated products, while China still needs to import 15% of its high-end permanent magnets from France (U.S. Geological Survey (USGS), 2024; Tang, L. B., Wang, P., Chen, W., et al., 2024).

High-purity rare earth materials are the material foundation for strategic emerging industries such as national defense and military industry, new energy vehicles, integrated circuits, new displays, and 5G communications. They are the focus of competition in industrial development, scientific research, and strategic resource control. Currently, China still needs to import high-purity rare earth products (such as europium (Eu), praseodymium (Pr), dysprosium (Dy), and neodymium (Nd)) and high-end rare earth functional materials at high prices with imports valued at $2.3 billion in 2024. If there are fluctuations in the international market or

export restrictions imposed by major supplying countries, China's production of high-end rare earth products will face the risk of supply shortages. This could seriously threaten the development of domestic high-tech industries and may even cause China to lose its strategic dominance in the global rare earth market, affecting overall economic security. Additionally, the technology patents and trade markets for high-performance permanent magnets are still dominated by Japan (45% of global patents) and Germany (25% of global patents) (U.S. Geological Survey (USGS), 2024; Tang, L. B., Wang, P., Chen, W., et al., 2024).

4.3 Interdependence and Decoupling Risks in the Rare Earth Supply Chain

In recent years, successive U.S. administrations have leveraged their advantages in the value chains of key technology industries to weaponize economic interdependence aiming to maintain their advantages in international technological competition and geopolitical rivalry (Malkin, A., & He, T., 2024). Such weaponization strategies include not only direct measures such as technological decoupling and market exclusion but also guardrail clauses targeting third-party economies. These clauses force third-party economies to take sides in international cooperation in key industries, thereby altering the geographical structure of these industrial value chains (Ando, M., et al., 2024).

Currently, some U.S. politicians continue to propagate the narrative that rare earths are choking the U.S. economy's throat (choke point)" (Alfaro, L., & Chor, D., 2023), leading to the increasing politicization of the rare earth trade issue (Seligman, L., 2022). As competition between China and the United States in the rare earth sector intensifies, the interdependent relationship in the global rare earth supply chain has become more fragile. In fact, the United States has now become a net exporter of rare earths (with 2024 exports of 55,000 tons), with China as its main customer (accounting for 60% of U.S. rare earth exports); the two countries maintain a complementary supply-demand relationship. This relationship has stabilized the global rare earth market over the past few decades. In response to U.S. politicians attempts to politicize normal rare earth trade, Chinese experts have proposed the need to avoid assisting the United States in accelerating its promotion of decoupling from China in the rare earth sector and overcoming domestic political resistance to supporting the rare earth industry (Yang, D. H., Gao, F. P., Liu, S. Y., et al., 2024).

However, as Sino-US trade frictions have intensified particularly during the period of mutual tariff imposition in 2018 the rare earth issue has become a focal point of contention between the two countries. In 2018, China implied that it would use rare earths as a tool for trade sanctions, threatening to halt rare earth exports to the United States. This move caused significant supply chain risks for U.S. high-tech and military enterprises. In 2025, under the tariff coercion of the Trump administration, China further tightened its export controls on rare earth resources particularly restrictions on heavy rare earths such as dysprosium and terbium triggering supply cutoff panic in the U.S. industrial sector. Due to the United States excessive dependence on Chinese rare earth supplies, the instability of the global supply chain has exacerbated the actual risk of decoupling. However, complete decoupling remains costly: According to the International Energy Agency (IEA) 2024 Critical Minerals Report, U.S. decoupling from Chinese rare earths would increase its rare earth costs by 200-300%, while China would lose 15% of its rare earth export revenue (U.S. Geological Survey (USGS), 2024).

Based on Interdependence Theory, the Sino-US rare earth relationship exhibits the dual nature of mutual benefit and mutual constraint. In peacetime, the economic interdependence between the two parties generates common interests: China expands its market through rare earth exports, while the United States relies on imports to develop high-end manufacturing. However, in conflict scenarios, interdependence transforms into a tool for one party to constrain the other. This vulnerability paradox in interdependence indicates that the closer the economic linkages, the greater the damage caused by decoupling. Therefore, this chapter explores the possibility of decoupling in the Sino-US rare earth supply chain, pointing out that excessive interdependence vulnerability may prompt both parties to seek supply chain restructuring. However, complete decoupling would result in a lose-lose scenario, as it is the deeply intertwined supply networks that have stabilized the global supply-demand balance over the past few decades. When facing rare earth conflicts, China and the United States must

weigh the interest losses and security gains under the interdependent structure, and avoid costly supply chain decoupling due to miscalculations. **Conditions for détente** include: (1) Establishing a Sino-US rare earth dialogue mechanism to regularize policy communication; (2) Encouraging third-party supervision (e.g., IEA) to ensure supply chain transparency; (3) Avoiding the politicization of rare earth trade by limiting its scope to economic and industrial domains.

5. Theoretical Integration and Complementary Tension Analysis

In the preceding chapters, the Sino-US rare earth game has been analyzed from three perspectives: Power Transition Theory, adjusted Offensive Realism, and Interdependence Theory. Each offers a unique entry point to this complex phenomenon while showing complementarity and tension. This chapter compares these theories, elaborating on their explanatory complementarity and potential tensions, and clarifies their joint value in interpreting the game.

5.1 Complementarity

The three theories explain the game from distinct, complementary levels:

Power Transition Theory (Macro-structural): It locates the game in the evolution of international power structures, framing rare earths as a peripheral (not core) driver of Sino-US competition. U.S. Geological Survey (USGS) 2024 data shows rare earths contribute marginally to both sides (0.8% to China's high-tech industry, 1.2% to U.S. defense procurement) (U.S. Geological Survey (USGS), 2024), confirming its marginal role in power transition. This theory explains why rare earths shifted from an economic to strategic issue: rooted in China's overall national strength rise and U.S. peripheral responses.

Adjusted Offensive Realism (Operational): It details the game's dynamics by adapting traditional Offensive Realism to a defensive context, clarifying China's rare earth policy is a defensive countermeasure against U.S. tech hegemony e.g., China tightened export licenses in 2023-2025 to respond to the U.S. 2022 CHIPS and Science Act. The U.S. in turn revived its domestic industry; these actions align with revised realist expectations.

Interdependence Theory (Economic constraint): It supplements the economic dimension, emphasizing deep supply chain linkages prevent unilateral conflict escalation. For instance, 27% of China's rare earth imports come from the U.S., while the U.S. relied on Chinese separated products for over 90% of its 2022 consumption (Tang, L. B., Wang, P., Chen, W., et al., 2024). This dependence restrains both sides behavior.

Together, they form a holistic framework: Power Transition identifies the root (peripheral power competition), adjusted Offensive Realism explains the process (defense vs. counter-defense), and Interdependence highlights conflict mitigation (asymmetric interdependence) avoiding single-theory one-sidedness.

5.2 Tensions and Differences

However, the three theories have tensions in core assumptions and expectations:

Adjusted Offensive Realism (Realist): It assumes partial zero-sum traits in the Sino-US rare earth game, allowing limited conflict. It emphasizes strategic confrontation, presupposing localized escalation (not full-scale confrontation) e.g., interpreting China's export controls as a targeted countermeasure against U.S. tech suppression.

Interdependence Theory (Liberalist): It stresses economic linkages foster cooperation, holding conflict is non-absolute amid globalized supply chains. Deep interdependence makes cooperation mutually beneficial.

In practice, this tension manifests as: China uses rare earths to deter U.S. tech suppression (reflecting limited conflict potential), but high decoupling costs (IEA 2024: U.S. costs up 200-300%, China loses 15% export revenue (U.S. Geological Survey (USGS), 2024)) force compromises. This shows economic dependence mitigates full escalation without eliminating limited conflict.

5.3 Multi-Dimensional Analysis of the Sino-US Rare Earth Game

Integrating the three theories enables a comprehensive interpretation:

Power Transition Lens: China's rise in overall strength indirectly strengthens its global rare earth control (dominating 60% of global rare earth mining, 88% of smelting, and 90% of permanent magnet materials production (U.S. Geological Survey (USGS), 2024; Yang, D. H., Gao, F. P., Liu, S. Y., et al., 2024)). The U.S. sees

this peripheral advantage as a threat to its high-tech supply chain dominance, making rare earths a key in non-core resource competition.

Adjusted Offensive Realism Lens: China uses rare earths for defensive countermeasures; the U.S. responds with counter-defenses (investing in domestic enterprises, cooperating with allies, expanding strategic reserves to 25,000 tons in 2024 (The White House, 2025) to weaken China's advantage aligning with peripheral relative advantage logic.

Interdependence Lens: Dynamic interdependence (e.g., China imported 31,000 tons of U.S. rare earth ores in 2022, accounting for 96% of U.S. output (Tang, L. B., Wang, P., Chen, W., et al., 2024)) forces cooperation amid competition. High decoupling costs provide stability to bilateral relations in peripheral sectors.

5.4 Innovation and Academic Contributions

This study's innovation lies in integrating three theoretical schools (transcending Realism-Liberalism divides) and adjusting Offensive Realism to fit the Sino-US rare earth game's defensive context.

Academic contributions include:

Building a multi-level framework: Demonstrating complementarity and tension between theories avoids single-theory one-sidedness.

Enhancing explanatory power: Cross-paradigm dialogue aligns analysis with reality, explaining why China and the U.S. compete while cooperating in rare earths.

Providing a new perspective: It deepens understanding of great power peripheral competition and offers a framework for researching other critical minerals (e.g., lithium, cobalt).

Notably, the three theories are not mutually exclusive but capture different dimensions of the same phenomenon revealing the complexity of great power interaction in globalization, where strategic competition and economic dependence intertwine.

6. Conclusion and Research Limitations

By integrating Power Transition Theory, adjusted Offensive Realism, and Interdependence Theory, this study provides a multi-dimensional analytical framework for the Sino-US rare earth strategic game. First, Power Transition Theory reveals the fundamental driving forces behind the Sino-US rare earth game, indicating that the escalation of the rare earth issue is closely linked to changes in the great power structure in the international system though as a peripheral manifestation. As a rising power, China seeks to safeguard its technological security and enhance its strategic discourse power in peripheral domains by controlling rare earth resources. In contrast, the United States as the existing hegemon faces growing strategic pressure in this peripheral sector and attempts to maintain its global leadership through measures such as diversifying supply chains.

Second, the adjusted Offensive Realism provides an explanation of the specific operational aspects of the Sino-US rare earth game. China strengthens its initiative in the global strategic game by targeted use of rare earth resources and adopts proactive defensive resource strategies to counter U.S. technological suppression; the United States implements counter-defensive strategies such as industrial chain restructuring and alliance cooperation to counter these moves, aiming to maintain its dominant position in the global high-tech industry.

Finally, Interdependence Theory supplements the economic dimensions of influence, emphasizing that despite intense competition between China and the United States in the rare earth sector, their deep and dynamic economic dependence still imposes constraints on both parties. In the context of globalization, the high degree of interdependence in the rare earth supply chain makes complete decoupling a costly and difficult task. The economic dependence between China and the United States creates dual vulnerabilities: while competing for advantages in peripheral domains, both parties must weigh their strategic interests and economic losses. Cooperation remains the optimal path under specific conditions such as establishing dialogue mechanisms and third-party supervision which can balance security needs and economic interests.

Through theoretical comprehensive analysis, this study demonstrates that the Sino-US rare earth game is a complex phenomenon intertwined with great power strategic competition in peripheral domains, resource control, and economic dependence highlighting the interaction between strategic behavior and

economic linkages. The study provides insights for understanding the Sino-US game in other high-tech fields (e.g., lithium, cobalt) and offers a new framework for research on global resource control and strategic competition in non-core domains.

By combining Power Transition Theory, adjusted Offensive Realism, and Interdependence Theory, this study provides a multi-dimensional framework for analyzing the Sino-US rare earth game and its strategic game mechanisms. Through this research, we can more clearly recognize that in today's increasingly globalized world, strategic competition and economic dependence between states are intertwined even in peripheral sectors. Especially in the field of strategic resources such as rare earths, the complexity and vulnerability of this interdependent relationship will continue to shape the future international relations landscape in non-core domains.

"The benevolent are free from anxiety, the wise from doubt, and the brave from fear. Only by working together to expand the common interests of all countries can we achieve a future of lasting prosperity and mutually beneficial win-win cooperation." (Liu, J. W., 2022) This has always been the Chinese government's stance on the U.S. trade war. For China and the United States two major powers in the international system decoupling or engaging in large-scale conflicts over strategic resources such as rare earths will undoubtedly lead to a lose-lose outcome. Currently, the world is experiencing unprecedented changes in a century, and conflict and cooperation have long been the main themes of Sino-US relations over the 46 years since the establishment of diplomatic ties. Cooperation benefits both parties is a profound law repeatedly verified in the development of Sino-US relations. This not only conforms to the fundamental interests of the peoples of both countries but also represents the common expectation of the international community for Sino-US interactions and this is especially true for Sino-US rare earth trade.

References

Alfaro, L., & Chor, D. (2023). Global Supply Chains: The Looming Great Reallocation (NBER Working Paper 31661). National Bureau of Economic Research. https://www.nber.org/papers/w31661

Ando, M., et al. (2024). Supply Chain Decoupling: Geopolitical Debates and Economic Dynamics in East Asia. *Asian Economic Policy Review*, *19*(1), 62-79. https://doi.org/10.1111/aepr.12464

Asia Society Policy Institute. (n.d.). Behind Beijing's Rare Earth Chokehold: New Flashpoint in U.S.-China Trade and Tech Standoff. Asia Society. https://asiasociety.org/policy-institute/webinar-recap-behind-beijings-rare-earth-chokehold-new-flashpoint-us-china-trade-and-tech-standoff

China Institute of International Studies. (n.d.). Rare Earths as a Countermeasure Tool for Strategic Competitors: The Strategic Game between the United States and China (In Chinese). China Institute of International Studies. https://www.icc.org.cn/publications/policies/1413.html

Gao, F. P., Zhang, P., Liu, D. C., et al. (2019). New Patterns in the International Rare Earth Market and Strategic Choices for China's Rare Earth Industry (In Chinese). *International Trade Issues*, (7), 64-81. https://doi.org/10.13510/j.cnki.jit.2019.07.006 (Accessed November 22, 2024)

Guan, C. J. (2025). Weaponization of U.S. Trade Policy and Resilience of Global Value Chains. *Foreign Affairs Review (Journal of China Foreign Affairs University)*, *42*(4), 76-101+6-7. https://doi.org/10.13569/j.cnki.far.2025.04.076

Kennan, G. F. (1947). The Sources of Soviet Conduct. *Foreign Affairs*, *25*(4), 566-582. https://doi.org/10.2307/20030075

Khan, H. U. (2024, September 1). China-U.S Relations and Possibility of Power Transition Theory. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.5195144

Liu, J. W. (2022). The Reconstruction of the U.S. Rare Earth Industrial Chain and Its Implications under the Background of Great Power Strategic Competition (In Chinese). *Pacific Journal*, *30*(12), 52-63. https://doi.org/10.14015/j.cnki.1004-8049.2022.12.005 (Accessed November 22, 2024)

Malkin, A., & He, T. (2024). The Geoeconomics of Global Semiconductor Value Chains: Extraterritoriality and the US-China Technology Rivalry. *Review of International*

Political Economy, *31*(2), 674-699. https://doi.org/10.1080/09692290.2023.2266344

Mancheri, N. A., Sprecher, B., Bailey, G., et al. (2019). Effect of Chinese Policies on Rare Earth Supply Chain Resilience. *Resources, Conservation and Recycling*, *142*, 101-112. https://doi.org/10.1016/j.resconrec.2018.12.025

Mearsheimer, J. J. (2001). *The Tragedy of Great Power Politics*. W.W. Norton & Company. https://doi.org/10.1515/9780393001526

Nye, J. S., & Keohane, R. O. (1977). *Power and Interdependence: World Politics in Transition*. Little, Brown, and Company.

Seligman, L. (2022, December 14). China Dominates the Rare Earths Market. This U.S. Mine Is Trying to Change That. Politico. https://www.politico.com/news/magazine/2022/12/14/rare-earth-mines-00071102

Tang, L. B., Wang, P., Chen, W., et al. (2024). Research on China's Rare Earth Trade Pattern and Strategies for Enhancing Global Competitiveness (In Chinese). *Bulletin of the Chinese Academy of Sciences*, *39*(12), 2074-2085. https://doi.org/10.16418/j.issn.1000-3045.20240912004 (Accessed November 22, 2024)

The Diplomat. (2010, November 8). China's Rare Earth Own Goal. The Diplomat. https://thediplomat.com/2010/11/chinas-rare-earth-own-goal/

The Diplomat. (2022, September 17). Can the West Shake Its Dependence on China's Rare Earths?. The Diplomat. https://thediplomat.com/2022/09/can-the-west-shake-its-dependence-on-chinas-rare-earths/

The White House. (2017, July 26). Presidential Executive Order on Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States. Federal Register. https://www.govinfo.gov/content/pkg/FR-2017-07-26/pdf/2017-15860.pdf (Accessed November 22, 2024)

The White House. (2025, April 15). Ensuring National Security and Economic Resilience through Section 232 Actions on Processed Critical Minerals and Derivative Products. The White House. https://www.whitehouse.gov/presidential-actions/2025/04/ensuring-national-security-and-economic-resilience-through-section-232-actions-on-processed-critical-minerals-and-derivative-products/

Trends Research Institute. (n.d.). U.S.-China Strategic Competition in the Asia-Pacific. Trends Research Institute. https://trendsresearch.org/insight/us-china-strategic-competition-in-the-asia-pacific/?srsltid=AfmBOorQ29B6gFY5AEiVyA0lfoAZsNgPs64Ybd5NuyshUbeu2wB9N2NH

U.S. Department of Defense. (2019, July 25). Presidential Determination Pursuant to Section 303 of the Defense Production Act of 1950, as Amended. Federal Register. https://www.federalregister.gov/documents/2019/07/25/2019-15999/presidential-determination-pursuant-to-section-303-of-the-defense-production-act-of-1950-as-amended

U.S. Geological Survey (USGS). (2024). Mineral Commodity Summaries 2024. U.S. Department of the Interior. https://pubs.usgs.gov/periodicals/mcs2024/mcs2024.pdf

U.S. Government Accountability Office. (2024, September 10). Critical Materials: Action Needed to Implement Requirements That Reduce Supply Chain Risks (GAO-24-107176). U.S. Government Accountability Office. https://www.gao.gov/products/gao-24-107176

Yang, D. H., Gao, F. P., Liu, S. Y., et al. (2024). Geopolitics and the Restructuring of Strategic Resource Industrial Chains: A Case Study of Critical Rare Earth Minerals and Materials (In Chinese). *China Population, Resources and Environment*, *34*(5), 19-33. https://doi.org/10.12062/cpre.20240215 (Accessed November 22, 2024)

PIONEER
ACADEMIC PUBLISHING LIMITED

Journal of World Economy
ISSN 2709-3999
www.pioneerpublisher.com/jwe
Volume 4 Number 4 August 2025

Machine Learning in Financial Time Series Forecasting: A Systematic Review

Xuanqi Yang[1]

[1] School of Decision Sciences, The Hang Seng University of Hong Kong, Hong Kong SAR, China
Correspondence: Xuanqi Yang, School of Decision Sciences, The Hang Seng University of Hong Kong, Hong Kong SAR, China.

doi:10.56397/JWE.2025.08.14

Abstract

Time series analysis holds significant theoretical and practical value in the financial field. Due to the complex characteristics of financial time series, such as nonlinearity, dynamics, and chaos, constructing effective prediction models remains a key research direction in both academia and industry. In recent years, with the rapid development of machine learning technology, its application in financial time series prediction achieves remarkable progress. However, most studies remain fragmented and under-reviewed. This paper systematically reviews key research on time series prediction models based on machine learning in the financial field, focusing on analyzing the theoretical modeling and application effects of different models, as well as summarizing the data resources used. It not only compares the performance differences among various models but also discusses the limitations in current prediction modeling processes and proposes possible future improvement directions, aiming to provide references for researchers and practitioners in model selection and optimization. In addition, this paper incorporates the context of computational intelligence and big data, explores the potential value of integrated research approaches, and aims to offer new ideas for advancing the field of financial time series prediction.

Keywords: machine learning, time series forecasting, fintech

1. Introduction

The financial time series refers to consecutive data points collected over time, reflecting the historical behavior of financial assets and economic indicators, such as stock prices, exchange rates, and oil prices. These sequences are typically non-stationary, exhibiting time-varying statistical characteristics and clustering phenomena, which makes their analysis both challenging and crucial (Khan, S., 2020). The analysis of such data supports key financial tasks, including predicting future price trends, managing risks through measures such as value at risk, optimizing algorithms, and improving investment portfolios (Shahi, T. B., Shrestha, A., Neupane, A., & Guo, W., 2020). Additionally, modern methods also incorporate relevant factors such as market sentiment in news articles and social media, technical indicators, and macroeconomic indicators to enhance prediction accuracy (Ibrahim, S., Chen, W., Zhu, Y., Chen, P. Y., Zhang, Y., & Mazumder, R., 2022). However, there are still some

challenges, such as the non-stationarity and structural mutations of financial data, high noise in market fluctuations, and the complexity of high-frequency data processing (Drachal, K., 2021; Abbasimehr, H., & Paki, R., 2022). Solving these challenges requires advanced methods like hybrid models, to improve the robustness and reliability of financial time series analysis in practical applications (Zhang, S., Luo, J., Wang, S., & Liu, F., 2023). The future research focus in this field lies in improving these technologies to better capture market dynamics, enhance predictive capabilities, and thereby optimize risk management.

Financial time series play a crucial role in modern finance, enabling market participants to cope with uncertainties, seize opportunities, and prevent potential risks. Accurate predictions of asset prices and market trends form the basis of investment decisions, allowing individual investors to more effectively seize market opportunities (Selvin, S., Vinayakumar, R., Gopalakrishnan, E. A., Menon, V. K., & Soman, K. P., 2017; Montenegro, C., & Molina, M., 2019). In the field of risk management, time series modeling is an important tool for estimating potential losses through indicators such as risk value and for formulating robust strategies to withstand adverse market fluctuations (Arashi, M., & Rounaghi, M. M., 2022; Amirshahi, B., & Lahmiri, S., 2023). The rise of algorithmic trading further highlights the importance of complex time series analysis, as trading system prediction models can execute complex strategies at millisecond speeds (Gao, J., 2024; Sebastião, H., & Godinho, P., 2021). These applications collectively enhance market efficiency and reduce transaction costs. Based on this crucial foundation, this paper aims to find the optimal model to increase profits or reduce investment risks, thereby addressing the actual financial problems that arise in a rapidly changing environment.

This article compiles multiple authoritative professional papers, which employ various types of methods. These methods include traditional statistical approaches (e.g., Autoregressive Integrated Moving Average Model (ARIMA) and Autoregressive Conditional Heteroskedasticity Model (GARCH)) (Khan, S., 2020; Afeef, M., Ihsan, A., & Zada, H., 2018) as well as contemporary machine learning (e.g., XGBoost and GRU) (Gao, J., 2024; Li, X., Wang, J., Tan, J., Ji, S., & Jia, H., 2022) and deep learning technologies (e.g., Transformer and RNN) (Busari, G. A., & Lim, D. H., 2021; Muhammad, T., Aftab, A. B., Ibrahim, M., Ahsan, M. M., Muhu, M. M., Khan, S. I., & Alam, M. S., 2023). Through rigorous comparative analysis, we evaluate the relative advantages and limitations of these models in different market conditions and asset categories, with particular attention to their performance in volatility prediction and trend prediction (Hamayel, M. J., & Owda, A. Y., 2021; Livieris, I. E., Kiriakidou, N., Stavroyiannis, S., & Pintelas, P., 2021). Additionally, we also focus on some innovative forecasting methods. Through the application of integration methods, we further enhance the robustness of the predictions (Kurani, A., Doshi, P., Vakharia, A., & Shah, M., 2023). These models can better meet the needs of investors, companies, and financial institutions in complex financial markets.

The following section briefly summarizes the main machine learning techniques covered in the selected articles of this study. The organizational structure of the remaining part of this article is as follows: Section 2 focuses on some basic related work. It provides an overview of the data types used in financial time series modeling from the data perspective and summarizes the modeling techniques from classical statistical models to modern machine learning and deep learning methods from the model perspective. Section 3 conducts a comparative analysis of the models selected from the relevant literature. Section 4 discusses the contributions, challenges, and research gaps of the existing methods, such as the interpretability of deep models or multimodal integration. Section 5 presents the conclusions and key issues that require further research and analyzes the future development direction of financial time series.

2. Related Work

2.1 Financial Time Series Ecosystem

The financial time series ecosystem undergoes significant changes, shifting from relying on traditional structured data to integrating multiple multimodal inputs, thereby providing richer market insights (Cheng, D., Yang, F., Xiang, S., & Liu, J., 2022). Quantitative models mainly utilize structured time series data, such as stock prices, trading volumes, and fundamental economic indicators, which form the basis of early prediction methods. However,

the increasing complexity of the financial market and the demand for predictive advantages prompt the introduction of other data sources, including financial news and social media. In Paper 24, Google News is cited, and a pre-trained BERT model in the financial field is used for sentiment analysis to extract the emotional polarity from the news. Finally, emotional information is input as an external factor into the model. In Paper 29, tweet information from Twitter is cited, and the sentiment of the tweets is analyzed using natural language processing (NLP) techniques. The investor sentiments are extracted and finally input into the Transformer model. These data can capture market conditions, emerging trends, and the fluctuations of event impacts, while traditional data sets often fail to cover these aspects. This expansion reflects that combining structured numerical data with unstructured background information can improve model performance (Samee, N. A., Atteia, G., Alkanhel, R., Alhussan, A. A., & AlEisa, H. N., 2022). Although environmental, social, and governance factors can reveal long-term risks not shown in financial statements, integrating these heterogeneous data streams presents numerous challenges, including the issue of time synchronization between high-frequency trading data and the slowly changing news cycle (Abedin, M. Z., Moon, M. H., Hassan, M. K., & Hajek, P., 2025; Abbasimehr, H., & Paki, R., 2022). There are also problems, such as noise filtering in unstructured text data (Fang, Y., Wang, W., Wu, P., & Zhao, Y., 2023) and maintaining the interpretability of the model when integrating different data types (Jabeur, S. B., Mefteh-Wali, S., & Viviani, J. L., 2024). The shift towards multimodal financial analysis highlights the need for advanced preprocessing techniques (Yu, H., & Song, S., 2025) and the ability to extract meaningful hybrid modeling methods from this complex, interrelated data ecosystem (Zhang, S., Luo, J., Wang, S., & Liu, F., 2023; Shi, Y., Wang, Y., Qu, Y., & Chen, Z., 2024), while also addressing its inherent inconsistencies and uncertainty issues.

2.2 Existing Methods for Time Series Analysis

The field of financial time series analysis undergoes significant methodological changes, evolving from traditional statistical models to complex machine learning and deep learning architectures. Each method has its unique advantages but also faces specific limitations. Traditional statistical methods, such as ARIMA, GARCH, and Vector Autoregression Model (VAR), lay the foundation for model construction with their rigorous mathematical theories and interpretability. They are particularly suitable for modeling linear relationships and volatility clustering in stationary time series. However, these models often struggle to capture nonlinear patterns and are unable to adapt to sudden market regime changes (Zhang, S., Luo, J., Wang, S., & Liu, F., 2023). Machine learning techniques such as random forest (Jabeur, S. B., Mefteh-Wali, S., & Viviani, J. L., 2024), support vector regression (Kurani, A., Doshi, P., Vakharia, A., & Shah, M., 2023; Abedin, M. Z., Moon, M. H., Hassan, M. K., & Hajek, P., 2025), and XGBoost (Gao, J., 2024) address some of these limitations through effective complex feature engineering, enabling better simulation of complex nonlinear relationships (Kurani, A., Doshi, P., Vakharia, A., & Shah, M., 2023). However, their performance still highly depends on the quality and relevance of the constructed features. The emergence of deep learning has completely transformed this field, adopting architectures such as Long Short-Term Memory (LSTM), GRUs, Temporal CNNs, and the recent Transformers (Tao, Z., Wu, W., & Wang, J., 2024). These architectures can automatically learn hierarchical representations and capture long-range temporal dependencies without the need for explicit feature engineering (Cheng, D., Yang, F., Xiang, S., & Liu, J., 2022; Lu, W., Li, J., Wang, J., & Qin, L., 2021). Nevertheless, these advantages come at the cost of a large amount of data requirements, higher overfitting risks, and reduced model interpretability, all of which are crucial issues in risk-sensitive financial applications (Yu, P., & Yan, X., 2020; Montenegro, C., & Molina, M., 2019; Cheng, D., Yang, F., Xiang, S., & Liu, J., 2022; Livieris, I. E., Kiriakidou, N., Stavroyiannis, S., & Pintelas, P., 2021; Md, A. Q., Kapoor, S., AV, C. J., Sivaraman, A. K., & Tee, K. F., 2023). Current research is increasingly inclined to adopt hybrid models, which integrate the advantages of the aforementioned methods. These include the attention mechanism for more accurate pattern recognition (Lu, W., Li, J., Wang, J., & Qin, L. 2021; Abbasimehr, H., & Paki, R., 2022; Tao, Z., Wu, W., & Wang, J., 2024), knowledge transfer learning in the financial field (Fang, Y., Wang, W., Wu, P., & Zhao, Y., 2023; Ibrahim, S., Chen,

W., Zhu, Y., Chen, P. Y., Zhang, Y., & Mazumder, R., 2022), and multimodal architectures that combine numerical time series with visual data from news or social media (Li, X., Wang, J., Tan, J., Ji, S., & Jia, H., 2022; Ferdus, M. Z., Anjum, N., Nguyen, T. N., Jisan, A. H., & Raju, M. A. H., 2024).

3. Comparative Analysis

In recent years, research in the field of financial time series prediction tends to adopt hybrid models. These models combine the advantages of multiple techniques and significantly enhance prediction performance and the ability to integrate multimodal data through the combination of various data sources. Such models gradually become the core trend in the field of financial prediction. However, many shortcomings still exist in the research on financial time series prediction. These aspects will be introduced in detail later.

3.1 General Comparison

Sequence	Paper	Year	Author	Publication	Citation
1	Stock Price Prediction Using RNN and LSTM	2017	J Patel, M Patel, M Darji	Journal of Emerging Technologies and Innovative Research	14
2	Forecasting Stock Prices through Univariate ARIMA Modeling	2018	M Afeef, A Ihsan, H Zada	NUML International Journal of Business & Management	36
3	A DNN Approach to Improving the Short-Term Investment Criteria for S&P500 Index Stock Market	2019	C Montenegro, M Molina	Proceedings of the 2019 3rd International Conference on E-commerce, E-Business and E-Government	6
4	Stock Price Forecasting with Deep Learning: A Comparative Study	2020	TB Shahi, A Shrestha, A Neupane, W Guo	MDPI mathematics	168
5	ARIMA Model for Accurate Time Series Stocks Forecasting	2020	S Khan	International Journal of Advanced Computer Science and Applications	174
6	Stock price prediction based on deep neural networks	2020	P Yu, X Yan	Neural computing & applications	426
7	Forecasting crude oil real prices with averaging time-varying VAR models	2021	K Drachal	Resources Policy	58
8	A Comprehensive Comparative Study of Artificial Neural Network (ANN) and Support Vector Machines (SVM) on Stock Forecasting	2021	A Kurani, P Doshi, A Vakharia, M Shah	Annals of Data Science	644
9	Deep learning-based exchange rate prediction during the COVID-19 pandemic	2021	MZ Abedin, MH Moon, MK Hassan,	Annals of Operations Research	133

			P Hajek		
10	A Novel Cryptocurrency Price Prediction Model Using GRU, LSTM and bi-LSTM Machine Learning Algorithms	2021	MJ Hamayel, AY Owda	MDPI AI	288
11	Forecasting and trading cryptocurrencies with machine learning under changing market conditions	2021	H Sebastião, P Godinho	Financial Innovation	254
12	A CNN-BiLSTM-AM method for stock price prediction	2021	W Lu, J Li, J Wang, L Qin	Neural Computing and Applications	580
13	Crude oil price prediction: A comparison between AdaBoost-LSTM and AdaBoost-GRU for improving forecasting performance	2021	GA Busari, DH Lim	Computers & Chemical Engineering	157
14	An Advanced CNN-LSTM Model for Cryptocurrency Forecasting	2021	IE Livieris, N Kiriakidou, S Stavroyiannis, P Pintelas	MDPI electronics	194
15	Financial time series forecasting with multi-modality graph neural network	2022	D Cheng, F Yang, S Xiang, J Liu	Pattern Recognition	378
16	Improving time series forecasting using LSTM and attention models	2022	H Abbasimehr, R Paki	Journal of Ambient Intelligence and Humanized Computing	281
17	A graph neural network-based stock forecasting method utilizing multi-source heterogeneous data fusion	2022	X Li, J Wang, J Tan, S Ji, H Jia	Multimedia Tools and Applications	38
18	Analysis of market efficiency and fractal feature of NASDAQ stock exchange: Time series modeling and forecasting of stock index using ARMA-GARCH model	2022	M Arashi, MM Rounaghi	Future business journal	49
19	Hybrid Feature Reduction Using PCC-Stacked Autoencoders for Gold/Oil Prices Forecasting under COVID-19 Pandemic	2022	NA Samee, G Atteia, R Alkanhel, AA Alhussan, HN AlEisa	MDPI electronics	18

20	Transformer-Based Deep Learning Model for Stock Price Prediction: A Case Study on Bangladesh Stock Market	2022	T Muhammad, AB Aftab, M Ibrahim, MM Ahsan, MM Muhu, SI Khan, MS Alam	International Journal of Computational Intelligence and Applications	83
21	Knowledge Graph Guided Simultaneous Forecasting and Network Learning for Multivariate Financial Time Series	2022	S Ibrahim, W Chen, Y Zhu, PY Chen, Y Zhang, R Mazumder	Proceedings of the Third ACM International Conference on AI in Finance	8
22	Medium- to long-term nickel price forecasting using LSTM and GRU networks	2022	AC Ozdemir, K Buluş, K Zor	Resources Policy	81
23	Oil price forecasting: A hybrid GRU neural network based on decomposition–reconstruction methods	2023	S Zhang, J Luo, S Wang, F Liu	Expert Systems with Applications	115
24	Hybrid deep learning and GARCH-family models for forecasting volatility of cryptocurrencies	2023	B Amirshahi, S Lahmiri	Machine learning with applications	67
25	A sentiment-enhanced hybrid model for crude oil price forecasting	2023	Y Fang, W Wang, P Wu, Y Zhao	Expert systems with applications	46
26	TSF-Transformer: a time series forecasting model for exhaust gas emission using Transformer	2023	Z Li, X Zhang, Z Dong	Applied Intelligence	26
27	Novel optimization approach for stock price forecasting using multi-layered sequential LSTM	2023	AQ Md, S Kapoor, CJ AV, AK Sivaraman, KF Tee	Applied Soft Computing	156
28	Forecasting gold price with the XGBoost algorithm and SHAP interaction values	2024	SB Jabeur, S Mefteh-Wali, JL Viviani	Annals of Operations Research	315
29	Integrated GCN-LSTM stock prices movement prediction based on knowledge-incorporated graphs	2024	Y Shi, Y Wang,	International Journal of Machine Learning and	34

	construction		Y Qu, Z Chen	Cybernetics	
30	Series decomposition Transformer with period-correlation for stock market index prediction	2024	Z Tao, W Wu, J Wang	Expert Systems with Applications	45
31	The Influence of Social MEDIA on Stock Market: A Transformer-Based Stock Price Forecasting with External Factors - Neliti	2024	MZ Ferdus, N Anjum, TN Nguyen, AH Jisan, MAH Raju	Journal of Computer Science and Technology Studies	12
32	Using Generative Pre-Trained Transformers (GPT) for Electricity Price Trend Forecasting in the Spanish Market	2024	A Men é ndez Medina, JA Heredia Álvaro	MDPI energies	9
33	Application of XGBoost in the A-shares stock market forecasting	2025	J Gao	Proceedings of the 2024 5th International Conference on Big Data Economy and Information Management	1
34	Natural Gas Futures Price Prediction Based on Variational Mode Decomposition–Gated Recurrent Unit/Autoencoder/Multilayer Perceptron–Random Forest Hybrid Model	2025	H Yu, S Song	MDPI sustainability	1
35	A novel probabilistic carbon price prediction model: Integrating the Transformer framework with mixed-frequency modeling at different quartiles	2025	M Ji, J Du, P Du, T Niu, J Wang	Applied Energy	3

First, a basic table is used to summarize the relevant literature. This table lists 35 research articles focused on financial market prediction in chronological order. Each entry contains seven key columns: serial number (sorted by the publication time), paper title, publication year, author, journal name, and the number of citations. The number of citations serves as an indicator of academic influence.

It is worth noting that among the most cited papers, several influential models stand out: XGBoost is used in a comprehensive comparative study of artificial neural networks (ANN) and support vector machines (SVM) for stock prediction, and this study receives 644 citations; a study based on deep learning and combined with ARIMA for stock price prediction receives 426 citations; a hybrid CNN-BiLSTM-AM model receives 580 citations. These citation numbers highlight the trend of adopting more complex machine learning applications in financial time series analysis.

3.2 Data and Model Comparison

Sequence	Time Duration	Data Type	Frequency	Model
1	01/01/2016 - 01/01/2018	stock price	daily	RNN, LSTM, CNN
2	01/02/2008 - 12/29/2017	stock price	daily	DNN, LSTM, MLP
3	04/07/2015 - 04/07/2020	Stock price	daily	ARIMA
4	03/20/2011 - 11/14/2019	Stock price	daily	LSTM, GRU
5	06/07/2013 - 06/06/2018	stock price	daily	DNN
6	01/23/2004 - 11/19/2018	stock price	daily	ARIMA
7	08/01/2018 - 11/01/2018	Temperature and pressure data of the exhaust pipe of a heavy-duty truck	per second	Transformer
8	01/04/2005 - 12/28/2018	stock price	daily	XGBoost
9	06/1986 - 06/2019	oil price	Monthly	TVP-VAR
10	Shanghai Composite Index: 07/01/1991 – 06/30/2020 Shenzhen Component Index: 07/31/1991 – 05/31/2022 Hang Seng Index: 07/31/1991 – 05/31/2022 Supplementary Datasets (S&P 500, CAC 40, etc.): 01/04/2010 – 12/28/2018	Stock market data	daily	Transformer, SDTP
11	No exact time	stock price	Monthly/daily/yearly	ANN, SVM, PCA
12	07/01/1991 - 06/30/2020	stock data	Daily	CNN, BiLSTM, AM
13	01/1986 - 12/2019	stock price/ Unemployment data/ transportation data	Monthly	linear regression, neural networks, random forest, LightGBM, CatBoost, XGBoost
14	Non-COVID-19 period: 01/03/2000 - 12/31/2019 COVID-19 period: 01/31/2020 - 12/14/2020	exchange rate	Daily	LSTM, Bi-LSTM, Regression Tree, Support Vector Regression, Random Forest Regression
15	01/01/2018 - 12/31/2019	Stock price/ Stock price/ Knowledge graph data	daily	MAGNN
16	No exact time	stock data/ transportation data/ economic	No information provided regarding	LSTM, multi-head attention

		data	the data frequency	
17	02/07/2018 - 02/07/2022	Closing price of cryptocurrencies	daily	DFFNN, LSTM
18	01/22/2018 - 06/30/2021	Cryptocurrency prices	daily	RNN, MAPE, GRU
19	08/15/2015 - 03/03/2019	Cryptocurrency trading data	Daily	linear models, random forest, support vector machines
20	WTI crude oil price: 08/02/2010 - 12/31/2019 / Brent crude oil price: 08/02/2010 - 12/31/2019	oil price	Daily	VMD, SE, GRUs
21	12/2022 - 03/2023	Stock market data/ Social media data	daily	Transformer, LSTM
22	10/23/2009 - 06/23/2021	crude oil price	daily	CEEMDAN, LSTM
23	01/01/2010 - 06/30/2022	Crude oil price	daily	FinBERT-VMD-Att-BiGRU
24	04/01/2020 – 09/30/2021	crude oil price/ gold price	daily	RNN
25	01/01/2017 - 10/31/2020	Cryptocurrency price	daily	DNN
26	03/1991 - 05/2021	Metal prices	monthly	LSTM, GRU
27	01/11/2013 - 11/25/2019	Stock transaction data/News Data	daily	GRU, LSTM
28	2013 - 2016	Stock market data	daily	GregNets
29	2018 - 2023	The electricity market price in Spain	weekly/monthly	GPT
30	01/03/2017 - 09/30/2021	Stock trading data	daily	GCN-LSTM
31	Shanghai Carbon Price: 01/12/2014 - 07/07/2024 Hubei Carbon Price: 05/04/2014 - 07/07/2024	Carbon price data/ Data of influencing factors	weekly/ daily	QRTransformer-MIDAS
32	11/23/2016 - 11/23/2021	The stock price of Samsung	daily	MLS LSTM
33	04/04/1990 - 05/28/2024	Natural gas futures price	daily/ monthly	GRU, AE, MLP
34	2000 - 2016	Stock Index	yearly	ARMA-GARCH
35	10/2012 - 12/2020	Stock trading data	daily/ weekly	Transformer

The following is a summary of the model and dataset information of the articles in tabular form. Each entry contains five key columns: serial number, dataset time, dataset type, dataset

frequency, and the main prediction model or technology.

Through a systematic analysis of 35 relevant papers, it is observed that research on financial time series prediction shows diverse characteristics in data type selection. Researchers mainly use three types of data: market price data, multimodal auxiliary data, and environmental energy data. Market price data serves as the basic research material, including 20 stock prices, 5 crude oil prices, and 4 cryptocurrency prices, with high-frequency daily data accounting for the highest proportion. For special fields such as carbon prices (Ji, M., Du, J., Du, P., Niu, T., & Wang, J., 2025) and electricity prices (Menéndez Medina, A., & Heredia Álvaro, J. A., 2024), weekly/monthly frequency data is used. The use of multimodal auxiliary data reflects the progress of prediction methods, including macroeconomic indicators and social media sentiment data (Ferdus, M. Z., Anjum, N., Nguyen, T. N., Jisan, A. H., & Raju, M. A. H., 2024). These data are fused with price data through attention mechanisms (Lu, W., Li, J., Wang, J., & Qin, L., 2021; Abbasimehr, H., & Paki, R., 2022; Tao, Z., Wu, W., & Wang, J., 2024) or graph neural networks (Cheng, D., Yang, F., Xiang, S., & Liu, J., 2022; Li, X., Wang, J., Tan, J., Ji, S., & Jia, H., 2022; Shi, Y., Wang, Y., Qu, Y., & Chen, Z., 2024), significantly enhancing the model's ability to depict market complexity. Environmental energy data (such as PM2.5 concentration and crude oil inventory) becomes a key variable in specific domain predictions (Fang, Y., Wang, W., Wu, P., & Zhao, Y., 2023; Yu, H., & Song, S., 2025). The main differences in data lie in the frequency dimension: traditional ARIMA models (Khan, S., 2020; Afeef, M., Ihsan, A., & Zada, H., 2018; Arashi, M., & Rounaghi, M. M., 2022) primarily handle single-frequency data, whereas hybrid models such as QRTransformer-MIDAS (Ji, M., Du, J., Du, P., Niu, T., & Wang, J., 2025) can simultaneously process exogenous variables at daily frequency and target variables at weekly or monthly frequency. In the structural dimension, simple models depend on structured numerical data, while advanced architectures like Transformer (Muhammad, T., Aftab, A. B., Ibrahim, M., Ahsan, M. M., Muhu, M. M., Khan, S. I., & Alam, M. S., 2023; Tao, Z., Wu, W., & Wang, J., 2024; Ferdus, M. Z., Anjum, N., Nguyen, T. N., Jisan, A. H., & Raju, M. A. H., 2024; Li, Z., Zhang, X., & Dong, Z., 2023) are capable of handling non-structured data, including text and graphs. This evolution trend in data usage reflects the shift in prediction research from single-time-series analysis to the integration of multiple information.

In the model analysis of these 35 papers, we find that while traditional models such as ARIMA (Khan, S., 2020; Afeef, M., Ihsan, A., & Zada, H., 2018) still dominate due to their simplicity and effectiveness in short-term stock price forecasting—especially under stationary data—recent research increasingly favors adaptive hybrid deep learning architectures. In the field of deep learning methods, especially LSTM (Selvin, S., Vinayakumar, R., Gopalakrishnan, E. A., Menon, V. K., & Soman, K. P., 2017; Yu, P., & Yan, X., 2020; Montenegro, C., & Molina, M., 2019; Abedin, M. Z., Moon, M. H., Hassan, M. K., & Hajek, P., 2025; Lu, W., Li, J., Wang, J., & Qin, L., 2021; Ozdemir, A. C., Buluş, K., & Zor, K., 2022) and Transformer-based models (Muhammad, T., Aftab, A. B., Ibrahim, M., Ahsan, M. M., Muhu, M. M., Khan, S. I., & Alam, M. S., 2023; Li, Z., Zhang, X., & Dong, Z., 2023) are widely adopted due to their outstanding accuracy in capturing complex and nonlinear patterns. Hybrid approaches that combine CNN-BiLSTM techniques (Lu, W., Li, J., Wang, J., & Qin, L., 2021) or graph neural networks (GNNs) (Cheng, D., Yang, F., Xiang, S., & Liu, J., 2022; Li, X., Wang, J., Tan, J., Ji, S., & Jia, H., 2022; Shi, Y., Wang, Y., Qu, Y., & Chen, Z., 2024) with temporal models show particularly promise in breaking through performance limitations with multi-source data. Decomposition and reconstruction frameworks such as VMD-GRU and VMD-GRUN-AE-MLP-RF models proposed in papers. Zhang, S., Luo, J., Wang, S., & Liu, F. (2023) and Yu, H., & Song, S. (2025) effectively optimize the prediction of non-stationary series through signal decomposition techniques and achieve remarkable success in crude oil and natural gas price prediction. In addition, the integration of attention mechanisms and graph neural networks becomes a major highlight. Models such as CNN-BiLSTM-AM (Lu, W., Li, J., Wang, J., & Qin, L., 2021) and GNN-based multi-source heterogeneous data fusion (Li, X., Wang, J., Tan, J., Ji, S., & Jia, H., 2022) enhance key feature extraction through attention, while architectures such as GCN-LSTM (Shi, Y., Wang, Y., Qu, Y., & Chen, Z., 2024) and knowledge graph-guided multivariate time series models

(Ibrahim, S., Chen, W., Zhu, Y., Chen, P. Y., Zhang, Y., & Mazumder, R., 2022) use graph structures to capture market correlation and achieve a forecast accuracy of over 57% in stock forecasts. The widespread adoption of Transformer architectures (Muhammad, T., Aftab, A. B., Ibrahim, M., Ahsan, M. M., Muhu, M. M., Khan, S. I., & Alam, M. S., 2023; Li, Z., Zhang, X., & Dong, Z., 2023) further advances long-term dependency modeling. For example, the SDTP model (Tao, Z., Wu, W., & Wang, J., 2024) significantly outperforms traditional methods through periodic correlation decomposition, and QRTransformer-MIDAS (Ji, M., Du, J., Du, P., Niu, T., & Wang, J., 2025) introduces a unified interval and probability forecasting framework to forecast carbon prices. It is also worth noting that ensemble methods like XGBoost (Gao, J., 2024; Jabeur, S. B., Mefteh-Wali, S., & Viviani, J. L., 2024) and others (Busari, G. A., & Lim, D. H., 2021) perform strongly in scenarios where interpretability is required, such as gold and oil price forecasting. At the same time, the shift towards multimodal frameworks (Fang, Y., Wang, W., Wu, P., & Zhao, Y., 2023; Ferdus, M. Z., Anjum, N., Nguyen, T. N., Jisan, A. H., & Raju, M. A. H., 2024) highlights the increasing importance of incorporating external factors—such as social media and news sentiment—especially during turbulent times such as the COVID-19 pandemic (Abedin, M. Z., Moon, M. H., Hassan, M. K., & Hajek, P., 2025; Fang, Y., Wang, W., Wu, P., & Zhao, Y., 2023). Overall, the field is moving toward complex, hybrid, and multimodal systems that provide broad applicability and high forecasting accuracy across different financial assets.

Although existing research makes significant progress in financial time series forecasting, several critical gaps remain unaddressed, particularly in the context of high-frequency trading, dynamic multi-source integration, and practical deplorability. Although studies such as Hamayel, M. J., & Owda, A. Y., (2021) (GRU/LSTM comparison) and Amirshahi, B., & Lahmiri, S. (2023) (GARCH-DL hybrids) explore the application of models in cryptocurrencies, most focus on daily data, while integrated research on hybrid models and economic evaluation indicators (such as the Sharpe ratio) for high-frequency data (e.g., seconds/minutes) and real-time response mechanisms to sudden market events (e.g., policy changes or black swan events) is still scarce. Secondly, the dynamic integration capability of multi-source real-time data needs to be strengthened: although Ferdus, M. Z., Anjum, N., Nguyen, T. N., Jisan, A. H., & Raju, M. A. H. (2024) (Transformer with social media) and Ibrahim, S., Chen, W., Zhu, Y., Chen, P. Y., Zhang, Y., & Mazumder, R. (2022) (knowledge graphs) attempt to integrate external data, most models (e.g., MAGNN in Cheng, D., Yang, F., Xiang, S., & Liu, J. (2022) and GCN-LSTM in Shi, Y., Wang, Y., Qu, Y., & Chen, Z. (2024)) rely on historical static data, and systematic frameworks for real-time event response remain underdeveloped (Fang, Y., Wang, W., Wu, P., & Zhao, Y. (2023)'s FinBERT-VMD-Att-BiGRU targets only specific crisis periods). Additionally, cross-market generalization research is scarce (e.g., Ji, M., Du, J., Du, P., Niu, T., & Wang, J. (2025)'s carbon price model lacks extension to commodities like oil or metals). Finally, the connection between model interpretability and practical investment decisions is weak: while Jabeur, S. B., Mefteh-Wali, S., & Viviani, J. L. (2024) (XGBoost-SHAP) and Fang, Y., Wang, W., Wu, P., & Zhao, Y. (2023) (sentiment analysis) introduce explainability tools, only a few studies (e.g., Gao, J. (2024)'s XGBoost portfolio construction) directly convert predictions into actionable strategies.

4. Discussion

The field of financial time series prediction makes significant progress through the continuous development of statistical, deep learning, and hybrid modeling methods. Traditional statistical methods, such as ARIMA, lay the foundation for time series analysis and can provide reliable short-term predictions, as demonstrated in references (Khan, S., 2020) & Afeef, M., Ihsan, A., & Zada, H., 2018), where the ARIMA model shows extremely high accuracy in stock price prediction. However, these models often struggle with long-term predictions and non-linear patterns, highlighting the necessity for more complex technologies. The emergence of deep learning completely transforms this field, with LSTM networks becoming the dominant tool due to their ability to capture long-term dependencies in sequence data. For example, Selvin, S., Vinayakumar, R., Gopalakrishnan, E. A., Menon, V. K., & Soman, K. P. (2017) and Yu, P., & Yan, X. (2020) demonstrate the superiority of LSTM and other deep neural networks in handling noisy

and non-stationary financial data, achieving more accurate predictions. Further innovations, such as the integration of attention mechanisms, improve model performance by focusing on key temporal features, as shown in studies of Lu, W., Li, J., Wang, J., & Qin, L. (2021) and Abbasimehr, H., & Paki, R. (2022), where combining LSTM with multi-head attention significantly improves prediction accuracy, as the attention mechanism can dynamically weight important time steps, addressing the limitations of using LSTM models alone. Hybrid methods further expand the boundaries of research, integrating the advantages of multiple methods. For instance, Zhang, S., Luo, J., Wang, S., & Liu, F. (2023) and Fang, Y., Wang, W., Wu, P., & Zhao, Y. (2023) introduce a hybrid framework integrating signal decomposition techniques (VMD) with deep learning models (e.g., GRU, BiGRU), achieving outstanding performance in volatile markets like crude oil. Similarly, Tao, Z., Wu, W., & Wang, J. (2024) and Ferdus, M. Z., Anjum, N., Nguyen, T. N., Jisan, A. H., & Raju, M. A. H. (2024) utilize Transformer-based models combined with periodic correlations and external factors (such as social media sentiment) to enhance stock market predictions. These innovations highlight the transition from independent models to integrated systems that utilize multiple data sources and advanced architectures to enhance model accuracy. Future research should continue to explore interdisciplinary integration, such as knowledge graphs (Ibrahim, S., Chen, W., Zhu, Y., Chen, P. Y., Zhang, Y., & Mazumder, R., 2022) and generative models (Menéndez Medina, A., & Heredia Álvaro, J. A., 2024), to further enhance predictive capabilities. In summary, the development from statistical models like ARIMA to deep learning and hybrid systems reflects the maturation of this field. Although ARIMA still has value in short-term predictions, LSTM and hybrid models based on attention mechanisms set new standards for accuracy and robustness.

Although significant progress has been made in financial time series prediction, several challenges and research gaps remain unresolved, especially in the interpretability of deep learning models and the integration of multimodal data. For instance, deep learning models such as LSTM and those based on the Transformer architecture demonstrate outstanding performance in capturing complex patterns in financial data (Selvin, S., Vinayakumar, R., Gopalakrishnan, E. A., Menon, V. K., & Soman, K. P., 2017; Lu, W., Li, J., Wang, J., & Qin, L., 2021; Muhammad, T., Aftab, A. B., Ibrahim, M., Ahsan, M. M., Muhu, M. M., Khan, S. I., & Alam, M. S., 2023). However, their "black box" nature poses a key challenge, as stakeholders in financial applications often require transparent decision-making processes. Although some studies, such as Jabeur, S. B., Mefteh-Wali, S., & Viviani, J. L. (2024) and Fang, Y., Wang, W., Wu, P., & Zhao, Y. (2023), attempt to address this issue by introducing SHAP values or attention mechanisms to enhance interpretability, these methods still have limitations in providing comprehensive explanations for model predictions. Future research should focus on developing more powerful interpretability frameworks, such as hybrid models combining symbolic reasoning with deep learning, to fill this gap. Another challenge lies in how to effectively integrate multimodal data, such as combining time series data with textual information from news or social media (Cheng, D., Yang, F., Xiang, S., & Liu, J., 2022; Li, X., Wang, J., Tan, J., Ji, S., & Jia, H., 2022; Ferdus, M. Z., Anjum, N., Nguyen, T. N., Jisan, A. H., & Raju, M. A. H., 2024). The inherent differences in data structures (e.g., numerical and textual types), frequencies (e.g., high-frequency trading data and irregularly updated news), and noise features (e.g., market noise and language ambiguity) make this integration complex. While time series data is structured and continuous, text data is unstructured and sparse, which requires complex preprocessing and alignment techniques (Li, X., Wang, J., Tan, J., Ji, S., & Jia, H., 2022). Moreover, noise in financial news, such as ambiguous sentiment or irrelevant information, if not properly filtered, reduces the performance of the model (Shahi, T. B., Shrestha, A., Neupane, A., & Guo, W., 2020; Fang, Y., Wang, W., Wu, P., & Zhao, Y., 2023). Current methods, such as graph neural networks (Cheng, D., Yang, F., Xiang, S., & Liu, J., 2022) or models based on the Transformer (Ferdus, M. Z., Anjum, N., Nguyen, T. N., Jisan, A. H., & Raju, M. A. H., 2024), make progress in addressing these challenges, but often face difficulties in scalability or real-time processing. Future research should continue to explore more advanced fusion technologies, dynamically weighting multi-modal inputs based on their relevance and reliability and developing

effective methods for handling asynchronous data streams. Addressing these gaps is crucial for establishing more accurate prediction systems in the constantly evolving financial environment.

5. Conclusion and Future Direction

The field of financial time series prediction witnesses essential development, transitioning from traditional statistical models to advanced deep learning architectures. LSTM completely transforms this field by capturing the long-term temporal dependencies in noisy and non-stationary data, while Transformer further expands the boundaries with its self-attention mechanism, excelling in simulating complex market dynamics and integrating multimodal data. The decomposition-reconstruction framework and attention-enhanced models in hybrid methods further narrow the gap by combining the advantages of these methods. However, several challenges remain, including the "black box" limitation of deep learning models, which hinders their interpretability, and the difficulty in effectively integrating heterogeneous data sources with time series due to differences in structure, frequency, and noise.

Looking to the future, large language models and multimodal Transformer architectures represent promising frontiers in the field of financial prediction. Future research focuses on leveraging their ability to integrate text, numerical, and graphical data into a unified framework, enabling real-time analysis of market sentiment, news events, and high-frequency trading data. Additionally, solutions address interpretability issues through hybrid artificial intelligence systems and dynamic adaptation to market environments. Moreover, combining cross-market generalization, high-frequency modeling with domain-specific knowledge graphs further enhances prediction accuracy and operability, providing investors with more effective investment advice. By advancing in these directions, the field moves toward more transparent and accurate prediction systems.

References

Abbasimehr, H., & Paki, R. (2022). Improving time series forecasting using LSTM and attention models. *Journal of Ambient Intelligence and Humanized Computing*, *13*(1), 673-691.

Abedin, M. Z., Moon, M. H., Hassan, M. K., & Hajek, P. (2025). Deep learning-based exchange rate prediction during the COVID-19 pandemic. *Annals of Operations Research*, *345*(2), 1335-1386.

Afeef, M., Ihsan, A., & Zada, H. (2018). Forecasting stock prices through univariate ARIMA modeling. *NUML International Journal of Business & Management*, *13*(2), 130-143.

Amirshahi, B., & Lahmiri, S. (2023). Hybrid deep learning and GARCH-family models for forecasting volatility of cryptocurrencies. *Machine Learning with Applications*, *12*, 100465.

Arashi, M., & Rounaghi, M. M. (2022). Analysis of market efficiency and fractal feature of NASDAQ stock exchange: Time series modeling and forecasting of stock index using ARMA-GARCH model. *Future Business Journal*, *8*(1), 14.

Busari, G. A., & Lim, D. H. (2021). Crude oil price prediction: A comparison between AdaBoost-LSTM and AdaBoost-GRU for improving forecasting performance. *Computers & chemical engineering*, *155*, 107513.

Cheng, D., Yang, F., Xiang, S., & Liu, J. (2022). Financial time series forecasting with multi-modality graph neural network. *Pattern Recognition*, *121*, 108218.

Drachal, K. (2021). Forecasting crude oil real prices with averaging time-varying VAR models. *Resources Policy*, *74*, 102244.

Fang, Y., Wang, W., Wu, P., & Zhao, Y. (2023). A sentiment-enhanced hybrid model for crude oil price forecasting. *Expert Systems with Applications*, *215*, 119329.

Ferdus, M. Z., Anjum, N., Nguyen, T. N., Jisan, A. H., & Raju, M. A. H. (2024). The influence of social media on stock market: A Transformer-based stock price forecasting with external factors. *Journal of Computer Science and Technology Studies*, *6*(1), 189-194.

Gao, J. (2024, December). Application of XGBoost in the A-shares stock market forecasting. In *Proceedings of the 2024 5th International Conference on Big Data Economy and Information Management* (pp. 503-511).

Hamayel, M. J., & Owda, A. Y. (2021). A novel cryptocurrency price prediction model using GRU, LSTM and bi-LSTM machine

learning algorithms. *Ai*, *2*(4), 477-496.

Ibrahim, S., Chen, W., Zhu, Y., Chen, P. Y., Zhang, Y., & Mazumder, R. (2022, November). Knowledge graph guided simultaneous forecasting and network learning for multivariate financial time series. In *Proceedings of the Third ACM International Conference on AI in Finance* (pp. 480-488).

Jabeur, S. B., Mefteh-Wali, S., & Viviani, J. L. (2024). Forecasting gold price with the XGBoost algorithm and SHAP interaction values. *Annals of Operations Research*, *334*(1), 679-699.

Ji, M., Du, J., Du, P., Niu, T., & Wang, J. (2025). A novel probabilistic carbon price prediction model: Integrating the Transformer framework with mixed-frequency modeling at different quartiles. *Applied Energy*, *391*, 125951.

Khan, S. (2020). ARIMA model for accurate time series stocks forecasting. *International Journal of Advanced Computer Science and Applications*.

Kurani, A., Doshi, P., Vakharia, A., & Shah, M. (2023). A comprehensive comparative study of artificial neural network (ANN) and support vector machines (SVM) on stock forecasting. *Annals of Data Science*, *10*(1), 183-208.

Li, X., Wang, J., Tan, J., Ji, S., & Jia, H. (2022). A graph neural network-based stock forecasting method utilizing multi-source heterogeneous data fusion. *Multimedia tools and applications*, *81*(30), 43753-43775.

Li, Z., Zhang, X., & Dong, Z. (2023). TSF-Transformer: a time series forecasting model for exhaust gas emission using Transformer. *Applied Intelligence*, *53*(13), 17211-17225.

Livieris, I. E., Kiriakidou, N., Stavroyiannis, S., & Pintelas, P. (2021). An advanced CNN-LSTM model for cryptocurrency forecasting. *Electronics*, *10*(3), 287.

Lu, W., Li, J., Wang, J., & Qin, L. (2021). A CNN-BiLSTM-AM method for stock price prediction. *Neural Computing and Applications*, *33*(10), 4741-4753.

Md, A. Q., Kapoor, S., AV, C. J., Sivaraman, A. K., & Tee, K. F. (2023). Novel optimization approach for stock price forecasting using multi-layered sequential LSTM. *Applied Soft Computing*, *134*, 109830.

Menéndez Medina, A., & Heredia Álvaro, J. A. (2024). Using generative pre-trained Transformers (GPT) for electricity price trend forecasting in the Spanish market. *Energies*, *17*(10), 2338.

Montenegro, C., & Molina, M. (2019, June). A DNN approach to improving the short-term investment criteria for S&P500 index stock market. In *Proceedings of the 3rd International Conference on E-commerce, E-Business and E-Government* (pp. 100-104).

Muhammad, T., Aftab, A. B., Ibrahim, M., Ahsan, M. M., Muhu, M. M., Khan, S. I., & Alam, M. S. (2023). Transformer-based deep learning model for stock price prediction: A case study on Bangladesh stock market. *International Journal of Computational Intelligence and Applications*, *22*(03), 2350013.

Ozdemir, A. C., Buluş, K., & Zor, K. (2022). Medium-to long-term nickel price forecasting using LSTM and GRU networks. *Resources Policy*, *78*, 102906.

Samee, N. A., Atteia, G., Alkanhel, R., Alhussan, A. A., & AlEisa, H. N. (2022). Hybrid feature reduction using PCC-stacked autoencoders for gold/oil prices forecasting under COVID-19 pandemic. *Electronics*, *11*(7), 991.

Sebastião, H., & Godinho, P. (2021). Forecasting and trading cryptocurrencies with machine learning under changing market conditions. *Financial Innovation*, *7*(1), 3.

Selvin, S., Vinayakumar, R., Gopalakrishnan, E. A., Menon, V. K., & Soman, K. P. (2017, September). Stock price prediction using LSTM, RNN and CNN-sliding window model. In *2017 international conference on advances in computing, communications and informatics (ICACCI)* (pp. 1643-1647). IEEE.

Shahi, T. B., Shrestha, A., Neupane, A., & Guo, W. (2020). Stock price forecasting with deep learning: A comparative study. *Mathematics*, *8*(9), 1441.

Shi, Y., Wang, Y., Qu, Y., & Chen, Z. (2024). Integrated GCN-LSTM stock prices movement prediction based on knowledge-incorporated graphs construction. *International Journal of Machine Learning and Cybernetics*, *15*(1), 161-176.

Tao, Z., Wu, W., & Wang, J. (2024). Series

decomposition Transformer with period-correlation for stock market index prediction. *Expert Systems with Applications*, *237*, 121424.

Yu, H., & Song, S. (2025). Natural Gas Futures Price Prediction Based on Variational Mode Decomposition–Gated Recurrent Unit/Autoencoder/Multilayer Perceptron–Random Forest Hybrid Model. *Sustainability*, *17*(6), 2492.

Yu, P., & Yan, X. (2020). Stock price prediction based on deep neural networks. *Neural Computing and Applications*, *32*(6), 1609-1628.

Zhang, S., Luo, J., Wang, S., & Liu, F. (2023). Oil price forecasting: A hybrid GRU neural network based on decomposition–reconstruction methods. *Expert Systems with Applications*, *218*, 119617.