

Governance System, Dynamic Capability, Digital Transformation, Environmental Uncertainty of Supply Chain Affecting Competitive Advantages of Manufacturing Industry in China

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Abstract

This dissertation investigates the impact and mechanisms of supply chain digital transformation on the competitive advantage of manufacturing enterprises in an uncertain environment. It aims to address three key objectives: (1) To explore the relationship between supply chain digital transformation and the competitive advantage of enterprises; (2) To determine the role of supply chain dynamic capability as a mediator between supply chain digital transformation and competitive advantage; and (3) To propose a model that incorporates environmental uncertainty, supply chain digital transformation, supply chain dynamic capability, and competitive advantage. The research adopts a mixed-methods approach, combining quantitative and qualitative methodologies. The quantitative component involves a survey of 220 manufacturing enterprises in China, while the qualitative component consists of semi-structured interviews with sixteen industry experts. The findings reveal that supply chain digital transformation significantly enhances the competitive advantage of manufacturing enterprises. Digital technologies improve supply chain performance by increasing visibility, stability, efficiency, and flexibility, while also helping to prevent supply chain disruptions. Furthermore, supply chain management is identified as a critical link in the development process of manufacturing enterprises. The study also confirms that supply chain dynamic capability plays a mediating role in the relationship between supply chain digital transformation and competitive advantage, enabling enterprises to effectively leverage digital technologies. Additionally, environmental uncertainty is found to moderately influence the relationship between digital transformation and competitive advantage. These findings provide valuable

insights for industry professionals and policymakers in overcoming challenges and seizing opportunities associated with digital transformation in the manufacturing sector.

Keywords: Digital Transformation of the Supply Chain; Environmental Uncertainty; Supply Chain Dynamic Capability; Competitive Advantages

Introduction

In the era of Industry 4.0, digital transformation has become a strategic imperative for manufacturing enterprises seeking to sustain competitive advantages in a rapidly changing global landscape. China, as a leading manufacturing power, has strongly promoted digital industrialization through national initiatives such as Made in China 2025 and the 14th Five-Year Plan, aiming to integrate advanced technologies like AI, IoT, and big data into traditional manufacturing systems (State Council of China, 2021; Zhang, 2023).

The COVID-19 pandemic has further accelerated this shift, revealing vulnerabilities in global supply chains and emphasizing the need for increased agility, visibility, and resilience through digital transformation (Ju et al., 2016). Traditional supply chains, often fragmented and rigid, are being replaced by digital supply chains that allow real-time monitoring, automated decision-making, and intelligent collaboration across the entire network (Nasiri et al., 2020; Wu et al., 2016).

However, while many studies have focused on the internal digital transformation of enterprises, limited research has examined the role of digital supply chain transformation in enhancing competitive advantage, particularly under conditions of environmental uncertainty (Oh et al., 2018). Moreover, the dynamic capability of supply chains—the ability to integrate, reconfigure, and optimize resources—has been identified as a crucial mediator in converting digital transformation into tangible business performance (Teece, 2019; Beske et al., 2017).

Therefore, this study aims to explore the interplay among supply chain digital transformation, dynamic capabilities, and environmental uncertainty in shaping the competitive advantage of manufacturing enterprises in China.

Research Objective

1. What is the impact of digital transformation of supply chain of manufacturing enterprises on competitive advantage of enterprises
2. What role does supply chain dynamic capacity of manufacturing enterprises play
3. How environmental uncertainty regulates the relationship between digital transformation of supply chain, supply chain dynamic capacity and competitive advantage of enterprises

Research Hypothesis

H1: Digital transformation of supply chain of manufacturing enterprises has a impact on competitive advantage of enterprises.

H2: Digital transformation of supply chain of manufacturing enterprises has a impact on supply chain dynamic ability.

H3: Supply chain dynamic ability has a impact on competitive advantage of enterprises.

H4: Environmental uncertainty mediating the relationship between digital transformation of supply chain and supply chain dynamic ability.

H5: Environmental uncertainty mediating the relationship between supply chain dynamic ability and competitive advantage of enterprises.

Literature Review

This study is grounded in several theoretical frameworks and key concepts that explain how digital transformation in supply chains influences the competitive advantage of manufacturing enterprises, particularly in the context of environmental uncertainty. The theoretical foundation includes Dynamic Capability Theory, Resource-Based View (RBV), Contingency Theory, and Competitive Advantage Theory.

1. Dynamic Capability Theory

Dynamic Capability Theory provides a basis for understanding how firms adapt, integrate, and reconfigure internal and external resources in response to rapidly changing environments (Teece, 2019). Dynamic capabilities are essential for managing digital transformation effectively, particularly in supply chain contexts where flexibility and responsiveness are required (Eisenhardt & Martin, 2000).

2. Resource-Based View (RBV)

RBV emphasizes the role of valuable, rare, inimitable, and non-substitutable resources in achieving sustainable competitive advantage (Barney, 1991). In digital supply chains, these resources may include proprietary digital platforms, data analytics capabilities, and innovation processes that enable firms to outperform competitors (Wernerfelt, 1984).

3. Contingency Theory

Contingency Theory asserts that there is no single best way to manage an organization; rather, the optimal course of action depends on the external environment (Lawrence & Lorsch, 1967). In this study, environmental uncertainty acts as a moderator, influencing how digital transformation and dynamic capabilities translate into competitive outcomes.

4. Competitive Advantage Theory

Porter (1985) argues that firms gain competitive advantage through cost leadership, differentiation, or focus strategies. In the digital era, leveraging advanced technologies in supply chains contributes to differentiation and operational efficiency, which in turn enhances competitive positioning.

5. Empirical Research

Numerous studies have supported the relationships among these constructs. For instance, Oh et al. (2018) found that digital supply chain capabilities significantly impact firm performance when dynamic capabilities are present. Nasiri et al. (2020) demonstrated that digital transformation enables real-time responsiveness and supply chain integration. Furthermore, Beske et al. (2017) emphasized that supply chain agility and collaboration are enhanced by digital initiatives under conditions of environmental uncertainty.

Conceptual Framework

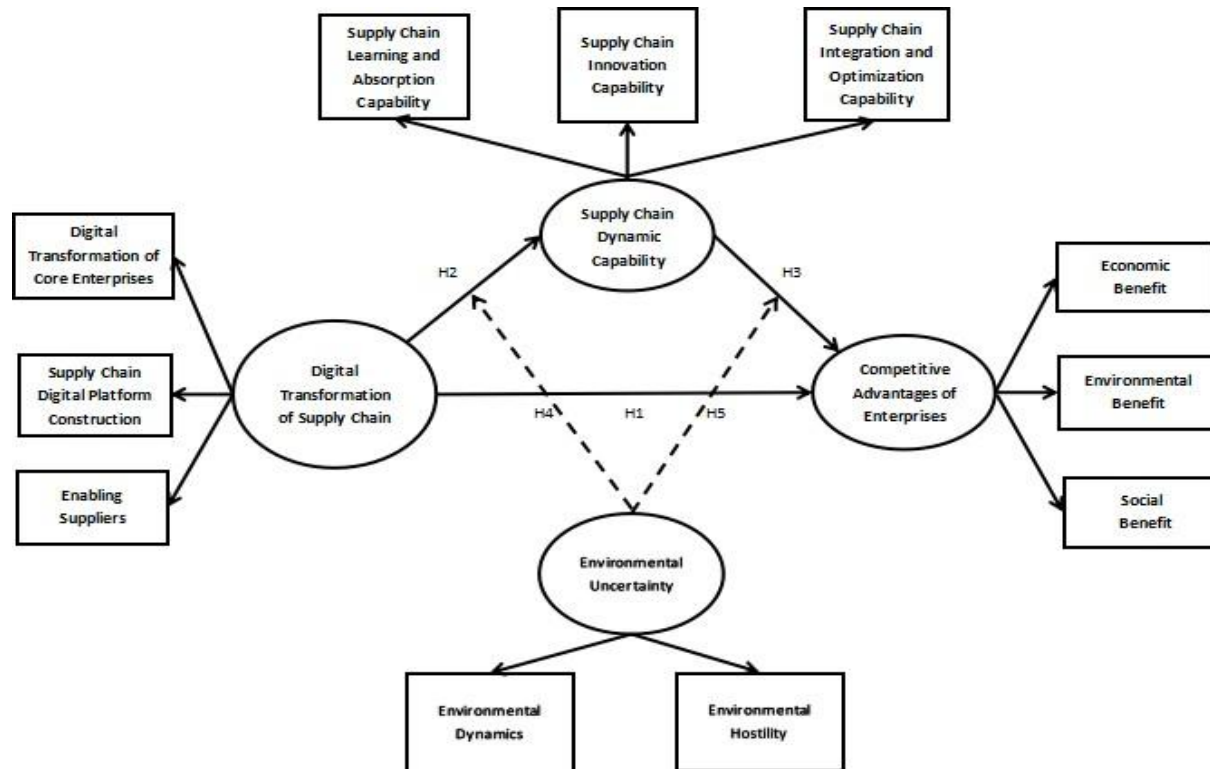


Figure 1 Conceptual Framework

Research Methodology

This study employs a mixed-methods research design following an explanatory sequential approach, which integrates quantitative and qualitative methodologies to comprehensively investigate how supply chain digital transformation (DT), dynamic capability (SC), and environmental uncertainty (EU) affect the competitive advantage (CA) of manufacturing enterprises in China. This design was chosen to ensure both the generalizability of findings through statistical analysis and the depth of understanding through expert insights.

Research Design

The research process is structured in two sequential phases:

1. **Quantitative Phase** – A large-scale survey was conducted to empirically test the hypothesized relationships between digital transformation, supply chain dynamic capability, environmental uncertainty, and competitive advantage. The purpose of this phase was to provide measurable evidence of direct, indirect, and moderating effects using advanced statistical techniques.

2. Qualitative Phase – Semi-structured interviews with industry experts were conducted after the quantitative analysis. This phase aimed to explain, refine, and validate the statistical results, thereby ensuring triangulation and enhancing the validity of the overall findings.

The explanatory sequential design was selected because it allows the researcher to first establish causal relationships statistically and then enrich the interpretation of results through qualitative evidence, addressing the research gap in prior studies that focused only on either quantitative or qualitative methods.

Quantitative

Population and Sample The target population consists of manufacturing enterprises in China that are actively engaged in digital transformation initiatives. The study used stratified random sampling to ensure representation from diverse regions and industry segments. Data were collected from 220 valid respondents across the Guangdong–Hong Kong–Macao Greater Bay Area and Northeastern China, which are both strategic hubs of industrial and technological development.

Data Collection Instrument A structured questionnaire was developed based on validated scales adapted from previous studies (e.g., Nasiri et al., 2020; Wu et al., 2016). The instrument consisted of five-point Likert scale items (ranging from 1 = strongly disagree to 5 = strongly agree) measuring the four major constructs:

Digital transformation of the supply chain (DT)

Supply chain dynamic capability (SC)

Environmental uncertainty (EU)

Competitive advantage (CA)

The questionnaire was pre-tested with ten experts and twenty managers to ensure clarity, reliability, and contextual appropriateness for the Chinese manufacturing environment.

Data Collection Procedure Survey data were collected via both online distribution (e-mail and professional networks) and field visits to industrial parks. To improve response rates, confidentiality was assured, and participation was voluntary.

Data Analysis Techniques The quantitative data were analyzed in several steps:

1. Descriptive statistics were computed to summarize the profile of respondents and general trends.

2. Reliability and validity tests were conducted, including Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE).

3. Confirmatory factor analysis (CFA) was performed to assess measurement validity.

4. Structural Equation Modeling (SEM) using AMOS/SmartPLS 3.0 was employed to test direct, indirect (mediation), and moderating relationships among the constructs.

The use of SEM was appropriate because it enables simultaneous estimation of multiple dependent relationships and provides robust testing of the conceptual model.

Qualitative

Participants For the qualitative phase, sixteen industry experts and senior managers were purposively selected from manufacturing enterprises across different sectors (electronics, automotive, machinery, and consumer goods). Selection criteria included direct involvement in supply chain management, digital transformation projects, or strategic decision-making roles.

Interview Design A semi-structured interview guide was developed to explore three main areas:

1. The real-world application and challenges of digital transformation in supply chains.
2. The role of dynamic capabilities in facilitating transformation and maintaining competitiveness.
3. The impact of environmental uncertainty (e.g., policy shifts, market fluctuations, supply disruptions) on supply chain strategies and competitive outcomes.

Interviews were conducted face-to-face or via online platforms, each lasting 45–60 minutes, and were recorded with participant consent.

Data Analysis The qualitative data were analyzed using thematic analysis. The process included transcription, coding, categorization, and synthesis of themes. NVivo software was used to manage the data and ensure systematic coding. The analysis focused on identifying patterns and illustrative examples that corroborated or expanded upon the quantitative findings.

Triangulation and Validity

To ensure credibility and reliability of findings:

Methodological triangulation was achieved by combining quantitative surveys and qualitative interviews.

Data triangulation was obtained from multiple respondents across different sectors and regions.

Expert validation was conducted by sharing preliminary results with selected industry experts for feedback.

Ethical Considerations

All participants were informed of the research purpose and gave informed consent. Anonymity and confidentiality were strictly maintained. Data were used solely for academic purposes, in compliance with ethical research standards.

Research Results

This section presents the findings of the study according to the three stated research objectives. Both quantitative results from Structural Equation Modeling (SEM) and qualitative evidence from expert interviews are reported and integrated.

Objective 1: To examine the impact of digital transformation (DT) on competitive advantage (CA)

Quantitative Results The SEM results show that digital transformation has a significant and positive effect on competitive advantage. The path coefficient for $DT \rightarrow CA$ was $\beta = 0.282$, $p = 0.000$, confirming that supply chain digitalization enhances firms' ability to achieve efficiency, agility, and differentiation.

Qualitative Results Experts emphasized that digital transformation not only involves technology but also organizational restructuring and cultural change. A senior electronics manager explained:

“By using digital platforms, our supply chain achieves end-to-end visibility. This allows us to respond faster to market changes and reduce the risks of disruptions.”

This reinforces the quantitative results by illustrating how digital adoption directly improves responsiveness and competitiveness.

Table 1 Results for Objective 1 (Impact of DT on CA)

Hypothesis	Path	SEM Results	Qualitative Evidence	Interpretation
H1	DT → CA	$\beta = 0.282$, $p = 0.000$	<i>“Our supply chain achieves end-to-end visibility, allowing faster responses and fewer disruptions.”</i>	DT significantly enhances CA by increasing agility, efficiency, and resilience.

Objective 2: To determine the role of supply chain dynamic capability (SC) as mediator

Quantitative Results Mediation analysis revealed that SC plays a critical role in transmitting the impact of DT to CA:

DT → SC: $\beta = 0.394$, $p = 0.000$

SC → CA: $\beta = 0.377$, $p = 0.000$

Indirect effect (DT → SC → CA): 0.090, CI [0.059, 0.133], $p = 0.008$

These results confirm that supply chain dynamic capability is a significant mediator in the relationship between DT and CA.

Qualitative Results Interviewees highlighted that dynamic capabilities are reflected in learning, innovation, and integration:

Learning new digital tools and absorbing technologies.

Innovating processes such as logistics optimization.

Integrating supply chain partners more effectively.

An automotive supply chain director stated:

“Digital tools are important, but what really makes the difference is how quickly we learn, adapt, and apply them. That is where our competitive strength comes from.”

Table 2 Results for Objective 2 (Role of SC as Mediator)

Hypothesis	Path	SEM Results	Qualitative Evidence	Interpretation
H2	DT → SC	$\beta = 0.394$, $p = 0.000$	<i>“We adapt quickly to digital tools, which strengthens our supply chain.”</i>	DT positively enhances SC capabilities.

Hypothesis	Path	SEM Results	Qualitative Evidence	Interpretation
H3	SC $\rightarrow$ CA	$\beta = 0.377$, $p = 0.000$	<i>"Integration across suppliers builds resilience and competitiveness."</i>	SC significantly improves CA.
H6	DT $\rightarrow$ SC $\rightarrow$ CA (Mediation)	Indirect effect $= 0.090$, CI [0.059, 0.133], $p = 0.008$	<i>"Competitive strength comes when digital adoption is combined with adaptive processes."</i>	SC mediates the relationship between DT and CA.

Objective 3: To assess the role of environmental uncertainty (EU) as moderator

Quantitative Results The moderation effects of environmental uncertainty were both significant:

$$EU \times DT \rightarrow SC: \beta = 0.140, p = 0.000$$

$$EU \times SC \rightarrow CA: \beta = 0.138, p = 0.000$$

This indicates that under conditions of high uncertainty, the benefits of digital transformation and supply chain capabilities are amplified.

Qualitative Results Managers confirmed that uncertainty creates pressures but also drives faster innovation. For instance, a machinery manufacturer commented:

"We face unpredictable shortages and policy changes. Firms without digital readiness suffered, but uncertainty pushed us to innovate faster and collaborate more closely with our partners."

Table 3. Results for Objective 3 (Role of EU as Moderator)

Hypothesis	Path	SEM Results	Qualitative Evidence	Interpretation
H4	EU $\times$ DT $\rightarrow$ SC	$\beta = 0.140$, $p = 0.000$	<i>"Uncertainty forced us to adopt digital tools faster to stabilize operations."</i>	EU strengthens the effect of DT on SC.
H5	EU $\times$ SC $\rightarrow$ CA	$\beta = 0.138$, $p = 0.000$	<i>"Market volatility made dynamic capability essential to maintain competitiveness."</i>	EU amplifies the impact of SC on CA.

The integrated results confirm that:

1. Digital transformation directly enhances competitive advantage (Objective 1).
2. Supply chain dynamic capability mediates the DT–CA relationship (Objective 2).
3. Environmental uncertainty moderates the effects of both DT on SC and SC on CA (Objective 3).

By combining SEM evidence with expert insights, the study provides a comprehensive understanding of how digital transformation, dynamic capability, and environmental uncertainty jointly determine competitive advantage.

Hypotheses Test

Table 3 Hypotheses Test Results

No.	Hypothesis	Results
H1	DT → CA	Supported
H2	DT → SC	Supported
H3	SC → CA	Supported
H4	EU × DT → SC	Supported
H5	EU × SC → CA	Supported

This study proposes five interrelated hypotheses to examine how digital transformation, dynamic capability, and environmental uncertainty influence the competitive advantage of manufacturing enterprises:

H1: Digital transformation of the supply chain positively affects enterprise competitive advantage by enabling smarter, more efficient operations.

H2: Digital transformation enhances the dynamic capabilities of the supply chain, improving flexibility, responsiveness, and adaptability.

H3: Dynamic capability of the supply chain contributes significantly to enterprise competitive advantage through better market adaptation and cost efficiency.

H4: Environmental uncertainty moderates the relationship between digital transformation and supply chain dynamic capability—its effect is stronger under high uncertainty.

H5: Environmental uncertainty also moderates the relationship between dynamic capability and competitive advantage—conversion of capability to advantage is more difficult under unstable conditions.

Together, these hypotheses form a comprehensive framework illustrating how digital transformation drives competitive advantage, both directly and indirectly through dynamic capabilities, with environmental uncertainty shaping the strength of these effects.

Discussion

The findings of this study provide strong empirical evidence for the proposed conceptual framework, highlighting the relationships among digital transformation (DT), supply chain dynamic capability (SC), environmental uncertainty (EU), and competitive advantage (CA). In this section, the discussion focuses on the most significant results and their theoretical and practical implications.

1. Digital Transformation and Competitive Advantage

The results confirm that digital transformation has a significant positive effect on competitive advantage ($DT \rightarrow CA: \beta = 0.282, p = 0.000$). This finding aligns with Nasiri et al. (2020), who demonstrated that digitalization improves visibility, integration, and responsiveness in supply chains, ultimately enhancing firm performance.

What this study adds is evidence from Chinese manufacturing enterprises, which operate under unique policy-driven and competitive environments. Unlike many prior studies focused on Western contexts, this research shows that in China, the adoption of IoT, cloud platforms, and big data analytics is strongly linked to cost efficiency, agility, and product differentiation. The results therefore strengthen the argument that digital transformation is not just a technological upgrade but a strategic enabler of long-term competitive advantage.

2. Supply Chain Dynamic Capability as a Mediator

The mediating effect of supply chain dynamic capability ($DT \rightarrow SC \rightarrow CA$: indirect effect = 0.090, $p = 0.008$) validates the Resource-Based View (Barney, 1991) and Dynamic Capability Theory (Teece, 2019). The results confirm that firms cannot achieve sustainable advantage merely by adopting digital technologies; instead, they must develop organizational capabilities that enable the learning, integration, and reconfiguration of resources.

This finding extends prior studies by demonstrating that Chinese firms, especially in the manufacturing sector, leverage digital transformation to build dynamic capabilities that allow them to adapt rapidly to volatile market conditions. The evidence provides a contextual contribution, showing

that the mechanism of mediation is particularly critical in emerging economies, where the gap between technological investment and practical application is often wide.

3. Moderating Role of Environmental Uncertainty

The study also confirmed the moderating effects of environmental uncertainty:

$$EU \times DT \rightarrow SC (\beta = 0.140, p = 0.000)$$

$$EU \times SC \rightarrow CA (\beta = 0.138, p = 0.000)$$

These results support Contingency Theory (Lawrence & Lorsch, 1967), which posits that organizational effectiveness depends on the fit between external conditions and internal strategies. In highly uncertain environments—marked by policy shifts, supply disruptions, and fluctuating demand the positive effects of digital transformation and supply chain capabilities are amplified.

The contribution of this study is the provision of empirical evidence from China, where environmental uncertainty is not only a market-driven factor but also heavily influenced by government regulation and global trade dynamics. This finding enriches the literature by showing that uncertainty in China does not only create risks but also acts as a catalyst for innovation and faster digital adoption.

4. Theoretical and Practical Contributions

This research contributes to the literature in three main ways:

Theoretical Integration – By linking digital transformation, dynamic capability, and environmental uncertainty within one model, the study integrates RBV, Dynamic Capability Theory, and Contingency Theory into a unified framework, demonstrating how these perspectives complement each other.

Contextual Contribution – While prior studies have been dominated by Western contexts, this research extends knowledge to the Chinese manufacturing sector, offering localized evidence of how digital transformation drives competitive advantage under uncertainty.

Practical Insight – The findings highlight that managers should not only invest in digital tools but also focus on capability building and scenario planning in uncertain environments. Policymakers should recognize the role of uncertainty as a driver for transformation and provide supportive infrastructure and policies.

5. Knowledge Expansion

Overall, the study expands existing knowledge by demonstrating that:

Digital transformation directly enhances competitive advantage, consistent with global evidence, but the China-specific findings show stronger emphasis on policy-driven adoption.

Supply chain dynamic capability is a key mediating mechanism, reinforcing that technological investment must be matched with organizational learning and integration.

Environmental uncertainty acts as an amplifier rather than just a threat, turning volatility into an opportunity for capability development.

These contributions add new insights to the global literature, particularly where empirical evidence from the Chinese manufacturing context has been scarce.

Conclusions

This study examined how digital transformation (DT), supply chain dynamic capability (SC), and environmental uncertainty (EU) influence the competitive advantage (CA) of Chinese manufacturing enterprises. The results demonstrate three key findings: (1) DT directly enhances CA, (2) SC mediates the relationship between DT and CA, and (3) EU positively moderates both $DT \rightarrow SC$ and $SC \rightarrow CA$ relationships. Together, these findings confirm that digital transformation drives competitiveness, but its full impact depends on capability development and the external environment.

Recommendations

For Manufacturing Enterprises

Invest in digital transformation (IoT, cloud, AI, big data), while building the dynamic capabilities to learn innovate and integrate at pace.

Encourage cross-functional collaboration and develop a culture of digital thinking that can convert technology prospects into best-practice advantages.

For Supply Chain Managers

Leverage contingency and responsive supply chain structures as a means to move skillfully through environmental uncertainty.

Leverage digital capabilities to improve transparency and responsiveness while enabling zero-latency decision-making.

For Policymakers

Policies to encourage and fund SMEs from the adoption of digital supply chain technologies.

Build national digital infrastructure and standards that will help us to interact easily with each other and share data across sectors.

For Future Research

Explore applications of Theorem \ref{thm:main} in different industrial domains such as healthcare, agriculture and logistics.

Use longitudinal studies to investigate the sustained effect of DT.

Add more factors (i.e., organizational culture, leadership style and technological readiness) to enhance the explanatory power of the model.

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