WEP
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Publishing

Transactions on Economics, Business and Management Research
ISSN: 2960-1789, eISSN: 2960-2254 | Volume 8
EMEHSS 2024

Study on the Impact Mechanism of Supply Chain Integration on Supply Chain Resilience

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Abstract. In recent years, the auto parts manufacturing industry has been facing multiple challenges, such as economic fluctuations, technological changes, etc. Improving SCR has become an urgent need for the development of the industry. This paper explores how automotive parts manufacturing companies can enhance supply chain resilience by optimizing SCI and analyze how this relationship changes in the context of market turbulence. The study shows that all three dimensions of SCI, namely supplier integration, internal integration and customer integration, can significantly enhance supply chain resilience. Relational capital and supply chain agility play an important role as mediating variables, while MT negatively moderates the supply chain integration and resilience relationship. This study not only deepens the theoretical understanding, but also provides new perspectives for practice, emphasizing that when formulating supply chain strategies, firms need to consider the multidimensional impact of integration to ensure the sustained stability and long-term competitiveness of the supply chain.

Keywords: supply chain resilience (SCR), supply chain integration (SCI), mediating effect, moderating effect

1. Introduction

In a globalized economy, the automotive parts manufacturing industry faces numerous challenges: economic volatility, rising environmental standards, accelerating technology iterations, smart and electrified transformation, and the global ravages of the global pandemic (Soares, Ferreira, and Murari 2021). These factors intertwine into a complex web of risks, intensifying the urgency of building an efficient supply chain resilience (SCR) system.

Research on SCR has explored factors from both internal and external dimensions. Internally, technological advancements like blockchain (Al-Swidi et al. 2024) , digital transfer of supply chains (Zhao, Hong, and Lau 2023) are pivotal. Organizational resilience is also crucial for mitigating external shocks (Lin and Fan 2024). Externally, the importance of social capital in inter-firm networks for enhancing SCR is recognized (Golgeci and Kuivalainen 2020), alongside the varying impacts of channel integration across different contexts (Wu, Li, and Zhu 2023). However, current studies often focus on singular aspects rather than the interaction between internal and external factors in building SCR (Ji et al. 2020). They also lack depth in analyzing how external factors affect supply chain integration (SCI) dynamics in resilience building. (Yuan, Tan, and Liu 2024). This study aims to address these gaps by examining the roles of relational capital (RC) and supply chain agility (SCA) as mediators, with market turmoil (MT) as a moderating factor, in the SCI-SCR relationship. It offers three contributions:

Firstly, this paper carefully analyzes the diversified influence paths of SCI on SCR. By refining SCI into three dimensions, namely, supplier Integration (SI), internal integration (II), and customer integration (CI), it systematically evaluates the different strengths of each dimension's effect on SCR. Secondly, this study constructs a multilevel theoretical framework and comprehensively examines for the first time how the dimensions of SCI affect SCR through the dual mediating mechanisms of RC and SCA. Thirdly, this study innovatively introduces MT as a moderating variable. It reveals how external environmental fluctuations become a key factor affecting SCR, which makes the study's conclusions go beyond the static perspective and enhances the dynamic adaptability and practical guidance of the model.

2. Theoretical background and assumptions

2.1. Supply chain integration and supply chain resilience

Supply chain integration involves strategic collaboration with key partners to coordinate activities across organizations (Jajja, Chatha, and Farooq 2018; Zhang et al. 2023), positively impacting supply chain resilience (Zahid et al. 2020). In order to explore the mechanism of the influence of SCI on SCR, each of the three dimensions of SCI is viewed as three separate factors to be explored in this study (Flynn, Huo, and Zhao 2010).

Supplier Integration includes information sharing, joint decision-making, system coupling, and strategic cooperation with key suppliers (Jajja, Chatha, and Farooq 2018), enhancing resilience against disruptions through collaboration (Lin and Fan 2024). Internal integration is an important factor in SCI and refers to the degree of information sharing and synergy between departments and functions within an organization (Tarigan, Siagian, and Jie 2021). Enhancing intra-company coordination benefits and supply chain transparency can promote the construction of supply chain resilience (Zahid et al. 2020). Customer Integration focuses on information exchange and cooperation with key customers, helping responsiveness and accuracy through timely market information (Flynn, Huo, and Zhao 2010). These interactions help adjust products and services, address supply chain issues, and bolster resilience (Zahid et al. 2020). Therefore, the following hypotheses are proposed:

H1: SCI positively affects SCR

H1a: SI positively affects SCR

H1b: SI positively affects SCR

H1c: SI positively affects SCR

2.2. The mediating role of relationship capital

Relational capital is a close cooperative relationship between members of an alliance formed by efficient cooperation and governance (Xue, Lei, and Yi 2010). SI strengthens the robustness of RC by integrating firms' strategies, processes, practices, and behaviors, resulting in cooperative, synchronized, and consistent activities (Flynn, Huo, and Zhao 2010). II promotes information fluency among firms' departments, which helps firms to build a more stable market relationships, thereby increasing RC. CI deepens RC by engaging key customers, raising mutual value and strengthening the closeness of the organization to its customers (Jajja, Chatha, and Farooq 2018).

Enhanced integration in the supply chain boosts mutual trust, facilitating quick information and resource exchange during risks, and improving risk control and emergency response (Nahapiet and Ghoshal 1998). RC can significantly improve the quality of ties within the supply chain network in three aspects: promoting trust building, optimizing cooperative relationships, and ensuring commitment fulfillment, and contributing to the formation of shared values and goals among supply chain actors (Chowdhury et al. 2023). This RC-based cooperation makes supply chain parties more inclined to make shared investments and joint research and development, which in turn strengthens the resilience of the supply chain in the face of uncertainty and complexity challenges (Yu and Huo 2018). Therefore, the following hypotheses are proposed:

H2a: RC mediates between SI and SCR

H2b: RC mediates between II and SCR

H2c: RC mediates between CI and SCR

2.3. The mediating role of supply chain agility

Supply chain agility is a company's ability to quickly and effectively respond to short-term changes in the supply chain and market (Dubey et al. 2018). Supply chain integration establishes a solid and close connection between supply chain actors, optimizing information sharing, knowledge exchange and trading activities among supply chains, which reinforces SCA in response to market changes (Zhuo, Ji, and Yin 2021). Moreover, Tarigan et al. (Tarigan, Siagian, and Jie 2021) noted that post-COVID-19, manufacturing firms should form good collaborative relationships with their supply chain partners through SCI in order to strengthen SCA to enhance SCR to achieve a more sustainable competitive advantage. Therefore, the following hypotheses are proposed:

H3a: SCA mediates between SI and SCR

H3b: SCA mediates between II and SCR

H3c: SCA mediates between CI and SCR

2.4. The moderating role of market turbulence

Market turbulence is defined as the rate of change in customer composition and preferences (Hanvanich, Sivakumar, and Hult 2006). Empirical studies show that turbulent market environments diminish the effectiveness of SCI capabilities (Chen et al. 2023; Hendijani and Saeidi Saei 2020). Highly integrated supply chains may be more vulnerable to MT (Peck 2005). But in some cases, even with the disruption of MT, stronger SCI capabilities can improve SCR (Ambulkar, Blackhurst, and Grawe 2015). Therefore, the following hypotheses are proposed:

H4: MT attenuates the impact of SCI on SCRs

3. Data and methods

3.1. Sample and data collection

I conducted the survey in May 2024 and targeted the automotive parts manufacturing industry in China. After pilot-testing the survey on 50 participants, the official survey was conducted via SoJump (http://www.wjx.cn/)(Liao and Xing 2023a). For accurate collection of content, it was also necessary to screen all the scales recovered, and 520 valid questionnaires were finally obtained. Of these respondents, over half (54.23%) of the participants worked as general staff. State-owned enterprises (SOEs) comprised 44.81% of respondents. Nearly half (43.46%) of the companies have been established for 5-10 years, and have been working with their main suppliers for mostly 3-5 years (46.54%).

3.2. Measures

The scale items were selected from previous studies and modified for this research to ensure the credibility and robustness. First, the metrics for SCI were adapted from Jajja et al. (Jajja, Chatha, and Farooq 2018). The RC assessment was based on Chowdhury et al. (Chowdhury et al. 2023) with revisions. The measurement tool for SCA was developed based on the scales of Shukor, AAA et al. (Shukor et al. 2021). MT measurements were adapted from Wilden, R. et al. (Wilden and Gudergan 2015). The measurement tool for supply chain resilience was developed based on studies by Ismail Gölgeci et al. (Golgeci and Kuivalainen 2020). Items were quantified using a five-point Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

3.3. Methods of analysis

In this study, I used Structural Equation Modeling (SEM) with Partial Least Squares (PLS) for data processing (Liao and Xing 2023b). PLS-SEM was chosen because it handles non-normally distributed data effectively (Fornell and Bookstein 1982), and is suitable for complex models with mediating or moderating variables (Hair 2017). SmartPLS version 4.0 software was used to validate the model.

4. Data analysis and results

4.1. Common method variance

Common Method Variance (CMV) occurs when the same respondent completes the entire questionnaire, potentially reducing the reliability of research results (Fuller et al. 2016). The general method for testing CMV is the Harman one-factor method (Golgeci and Kuivalainen 2020). In this study, the first factor accounted for 35.36% of the total variance, below the critical value of 50%. Thus, I believe CMV does not significantly affect the reliability and validity of the study results.

4.2. The measurement model

I built a measurement model to test data reliability and validity. Table 1 shows that all Average Variance Extracted (AVE) scores were above the critical value of 0.5, indicating good model convergence. Cronbach's alpha and Composite Reliability (CR) values were all above 0.7, demonstrating good internal consistency (Nunally 1978). Additionally, I applied the Fornell-Larcker criterion and the HTMT ratio to determine validity. Table 2 shows that the square roots of the AVEs (on the diagonal) exceed the inter-structural correlations (other values in the matrix), , indicating good discriminant validity. All values in Table 2 are below 0.9, confirming test validity for all items (Henseler, Ringle, and Sarstedt 2015).

Table 1. Reliability and validity tests of the constructs.

Construct	Items no.	Standard loadings	Cronbach's α	CR	AVE
SI	SI1	0.810			
	SI2	0.794	0.743	0.745	0.661
	SI3	0.835			
II	II1	0.765			
	II2	0.806	0.795	0.795	0.620
	II3	0.800			
	II4	0.777			
CI	CI1	0.749			
	CI2	0.858	0.757	0.774	0.673
	CI3	0.850			
RC	RC1	0.800			
	RC2	0.821			
	RC3	0.818	0.864	0.866	0.648
	RC4	0.802			
	RC5	0.784			
SCA	SCA1	0.734			
	SCA2	0.775			
	SCA3	0.763			
	SCA4	0.774	0.873	0.877	0.568
	SCA5	0.721			
	SCA6	0.745			
	SCA7	0.762			
SCR	SCR1	0.740			
	SCR2	0.748			
	SCR3	0.829	0.846	0.852	0.619
	SCR4	0.815			
	SCR5	0.797			
MT	MT1	0.798			
	MT2	0.827	0.841	0.842	0.677
	MT3	0.824			
	MT4	0.842			

Note: CR is short for Composite Reliability; AVE is short for Average Variance Extracted; SI1-MT4 are measured items. SI=Supplier Integration; II=Internal integration; CI=Customer Integration; RC=Relational capital; SCA=Supply Chain Agility; SCR=Supply Chain Resilience; MT=Market Turmoil.

Table 2. Heterotrait-Monotrait Ratio (HTMT) and confidence interval.

	SI	II	CI	RC	SCA	SCR
II	0.781 [0.692,0.866]					
CI	0.805 [0.720,0.887]	0.615 [0.519,0.708]				
RC	0.656 [0.566,0.746]	0.563 [0.468,0.655]	0.735 [0.656,0.809]			
SCA	0.536 [0.436,0.638]	0.479 [0.390,0.570]	0.435 [0.339,0.530]	0.532 [0.450,0.615]		
SCR	0.704 [0.614,0.796]	0.627 [0.546,0.703]	0.680 [0.589,0.771]	0.699 [0.621,0.774]	0.621 [0.549,0.693]	
MT	0.519 [0.426,0.609]	0.473 [0.383,0.559]	0.522 [0.425,0.617]	0.430 [0.343,0.515]	0.376 [0.286,0.467]	0.752 [0.693,0.805]

Note: The diagonal (bold) elements are the square roots of AVEs, the off-diagonal elements are the correlations among constructs and the confidence interval of the value is in parentheses. SI=Supplier Integration; II=Internal integration; CI=Customer Integration; RC=Relational capital; SCA=Supply Chain Agility; SCR=Supply Chain Resilience; MT=Market Turmoil.

4.3. Path relationship evaluations

The evaluation algorithm I used for the structural model was PLS-SEM and the significance of the coefficients was calculated by bootstrap self-sampling method (5000 self-samples).

Table 3 and figure 1 demonstrate the hypothesis testing and path structure. From the table, it can be seen that SI ($\beta = 0.094$, $p < 0.05$), II ($\beta = 0.088$, $p < 0.05$), and CI ($\beta = 0.084$, $p < 0.05$) positively affect SCR in favor of H1a, H1b, and H1c. In addition, SI ($\beta = 0.243$, $p < 0.001$), II ($\beta = 0.198$, $p < 0.001$), CI ($\beta = 0.127$, $p < 0.05$) had a significant positive effect on SCA. Similarly, SI ($\beta = 0.183$, $p < 0.01$), II ($\beta = 0.160$, $p < 0.01$), and CI ($\beta = 0.418$, $p < 0.001$) had significant positive effects on RC. Consistent with expectations, SCA ($\beta = 0.183$, $p < 0.001$), RC ($\beta = 0.223$, $p < 0.001$) positively influenced SCR, while MT ($\beta = -0.398$, $p < 0.001$) negatively influenced SCR.

Table 3. Results of algorithm and bootstrapping tests.

Hypothesis	β	T-value	p-value
SI -> SCA	0.243^{***}	3.877	0.000
SI -> SCR	0.094^{*}	2.023	0.043
SI -> RC	0.183^{**}	3.381	0.001
II -> SCA	0.198^{***}	3.838	0.000
II -> SCR	0.088^{*}	2.218	0.027
II -> RC	0.160^{**}	3.330	0.001
CI -> SCA	0.127^{*}	2.200	0.028
CI -> SCR	0.084^{*}	2.014	0.044
CI -> RC	0.418^{***}	8.539	0.000
SCA -> SCR	0.183^{***}	4.733	0.000
RC -> SCR	0.223^{***}	4.941	0.000
MT -> SCR	-0.398^{***}	11.181	0.000

Note: SI=Supplier Integration; II=Internal integration; CI=Customer Integration; RC=Relational capital; SCA=Supply Chain Agility; SCR=Supply Chain Resilience; MT=Market Turmoil.
*p<0.05; **p<0.01; ***p<0.001

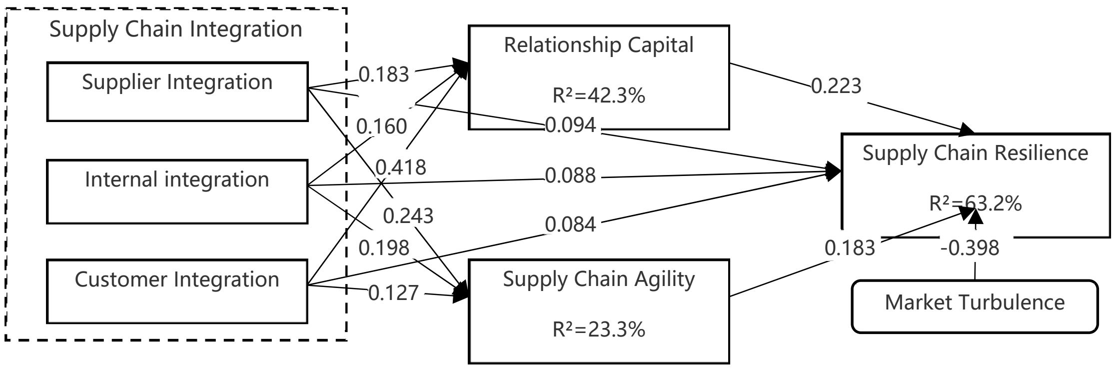

Figure 1 Results of the structural model

4.4. Mediating effect analysis

The mediation effect test I used was bootstrap self-sampling. T-values and 95% confidence intervals were used to measure the significance of profile effects (Hair 2017). Table 4 demonstrates the specific indirect, direct, and total effects of SCI vs. SCR. With all T-values exceeding 1.96 and the absence of 0 values within the 95% confidence intervals, I conclude that RC and SCA are significant mediators of SCI->SCR, supporting H2a, H2b, H2c, H3a, H3b, and H3c.

Table 4. The results of mediating effect analysis.

Hypothesis	Specific indirect effects			Direct effects			Total effects		
	β	T-value	Confidence intervals	β	T-value	Confidence intervals	β	T-value	Confidence intervals
SI -> RC -> SCR	0.041**	2.878	[0.016,0.071]	0.094*	2.023	[0.614,0.796]	0.085***	4.079	[0.047,0.129]
SI -> SCA -> SCR	0.044**	3.085	[0.019,0.075]						
II -> RC -> SCR	0.036**	2.750	[0.014,0.064]	0.088*	2.218	[0.546,0.703]	0.072***	3.852	[0.039,0.112]
II -> SCA -> SCR	0.036**	2.757	[0.014,0.065]						
CI -> RC -> SCR	0.093***	4.221	[0.053,0.138]	0.084*	2.014	[0.589,0.771]	0.117***	4.573	[0.069,0.169]
CI -> SCA -> SCR	0.023*	2.005	[0.003,0.049]						

Note: SI=Supplier Integration; II=Internal integration; CI=Customer Integration; RC=Relational capital; SCA=Supply Chain Agility; SCR=Supply Chain Resilience; MT=Market Turmoil
*p<0.05; **p<0.01; ***p<0.001

4.5. Analysis of moderating effects

The moderating effect test I used was the product indicator method. As shown in Table 5, as hypothesized, the moderating effect of MT pair on SCI and SCR is significant and negative, confirming H4.

Figure 1 illustrates the findings. R2 is used to measure the overall explanatory power of the model (Wieland and Wallenburg 2013), with all endogenous variables take R2 values above 0.23, indicating substantial effect (Cohen 1992). Besides, I derived the Stone-Geisser test value (Q2) via the Blindfolding algorithm to evaluate the relative predictive relevance of the structural models (GEISSER 1974; Stone 1986). A Q2 value of 0.109 for Supply Chain Agility is the minimum, indicating acceptable predictive relevance of the PLS-SEM model (Sarstedt et al. 2014).

Table 5. The results of moderating effect analysis.

Moderator variable	Interacting	β	T-value	p-value
MT	MT × SI -> SCR	-0.163***	5.024	0.000
	MT × II -> SCR	-0.100**	3.072	0.002
	MT × CI -> SCR	-0.166***	5.026	0.000

Note: SI=Supplier Integration; II=Internal integration; CI=Customer Integration; SCR=Supply Chain Resilience; MT=Market Turmoil.
*p<0.05; **p<0.01; ***p<0.001

5. Discussion

First, SCI positively impacts SCR , with each dimension having distinct effects. This positive effect corresponds to the findings of N. Zhuo et al. (Zhuo, Ji, and Yin 2021; Zahid et al. 2020; Wieland and Wallenburg 2013). In manufacturing, SCI improves the speed of information flow by rationally integrating key suppliers, intra-firms, and customers (Zahid et al. 2020), enhancing collaboration, resource utilization, and allocation. This bolsters firms' ability to handle supply chain emergencies and uncertainties (Lii and Kuo 2016). Among SCI dimensions, SI has the most significant positive impact on SCR due to the diversified and volatile nature of suppliers in the automotive parts manufacturing industry. Optimizing supplier selection, information sharing, and collaboration buffers against market shocks, such as raw material price fluctuations and logistical delays, ensuring stable operations (Fartaj et al. 2020). In contrast, CI’s contribution to enhancing adaptive capacity and resilience is more limited compared to SI and II due to the relatively stable and predictable demand patterns in the automotive industry (Belhadi et al. 2021).

Second, RC and SCA are mediating variables of SCI to SCR. The indirect effect of RC is slightly lower than SCA in the SI to SCR impact path, as the automotive parts manufacturing industry is particularly dependent on a diverse network of suppliers, making SCA crucial for continuous supply and efficient operations. Specifically, SCA enables firms to quickly switch unstable or underperforming suppliers, preventing production disruptions (Lummus et al. 2003). Conversely, RC's direct role is limited in a situation where there are numerous suppliers and the market is highly competitive. However, RC's indirect effect is significantly higher than SCA in the CI to SCR path, because in the automotive parts manufacturing industry, stable customer demand reduces reliance on agility. Trust, shared values, and long-term cooperation intentions established with customers enable companies to rely on solid customer relationships for more support and resources when facing supply chain disruptions, thus effectively enhancing supply chain resilience (Mei et al. 2011).

MT significantly weakens the impact of SCI on SCR by increasing uncertainty (Koc, Delibas, and Anadol 2022). This forces firms to spread their resources and attention in multiple directions to cope with change, which inevitably reduces SCI's focus and effectiveness. At the same time, the demand for quick response and flexibility in turbulent environments can make even tightly integrated supply chains less resilient by not adapting fast enough (Angkiriwang, Pujawan, and Santosa 2014).

6. Conclusion

This study verifies the hypothesized proposed in the previous section and deeply explores the mechanism of SCI's influence on SCR in auto parts manufacturing companies. First, SCI has a differential positive impact on SCR. Second, RC and SCA play a mediating effect between supply chain integration and supply chain resilience. Third, MT as a significant moderator exerts differential negative effects on the three paths of SCI's impact on SCR.

7. Inspiration

This study has several implications for automotive parts manufacturing industry and the supply chain field.

First, firms should focus on various dimensions of SCI, especially SI. Specific actions include establishing a diversified supplier network, making a list of alternative suppliers (Wagner and Bode 2006). Meanwhile, organizational flatness should be enhanced to accelerate decision-making and responsiveness by streamlining the decision-making process and reducing the number of layers, to satisfy customers' needs more effectively and adapt quickly to market changes (He et al. 2014).

Second, focus on RC and SCA. In terms of relational capital, it is critical to select partners that complement the firm's values and business (Barroso-Méndez et al. 2020). Trust can be enhanced and supply chains stabilized through long-term contracts that cover price, quality assurance, and joint development. To increase agility, adopt a modular design strategy. That is, by allowing automotive components to be produced at different times and locations, it ensures that firms are able to quickly adjust their production and distribution strategies in the event of supply chain disruptions.

Finally, recognize that MT, an external factor, can weaken the positive impact of SCI on SCR. Construct a comprehensive risk assessment system with regular reviews, continuous analysis, and timely adjustments to ensure that entrepreneurs are sensitive to potential risks (Tummala and Schoenherr 2011). Further, formulate detailed emergency plans and conduct simulation drills for different scenarios, which will greatly enhance the resilience of enterprises to deal with emergencies (Sheffi 2005).

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