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The effect of supply chain resilience on supply chain performance of chemical industrial companies

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A B S T R A C T

The aim of this study is to identify the effect of supply chain resilience as measured by supply chain flexibility, supply chain collaboration, and supply chain agility on supply chain performance. A sample consisting of employees from chemical industrial companies in Jordan was selected to collect data using an electronic questionnaire. Analyzing data via SmartPLS 3.0, the results showed that supply chain collaboration and supply chain agility as key dimensions of supply chain resilience had significant effects on supply chain performance, while supply chain flexibility exerted insignificant effect on supply chain performance. Therefore, managers are recommended to improve their firms' abilities to carry out effective work with partners and to enhance firms' abilities to respond quickly to unpredictable changes. Scholars are also requested to conduct further studies such as investigating the effect of supply chain redundancy on supply chain performance.

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1. Introduction

Supply chain disruption due to numerous factors such as technology innovation, globalized supply chains, and enlarged outsourcing is a key driver of firms' need to develop supply chain resilience (Pettit, Fiksel & Croxton, 2010). Resilience in the literature of supply chain refers to a capability of a firm to recover from disruptions based on a quick response to unpredictable conditions (Tukamuhabwa et al., 2015; Christopher & Da Silva, 2014). For firms to achieve effective supply chain resilience, some strategies are suggested like supply chain flexibility, supply chain collaboration, supply chain redundancy, and supply chain agility. Flexibility in this regard assumes that firms should have the ability to cope with changes and uncertainty in business environments such as changes in customers' requirements (Tukamuhabwa et al., 2015; Scholten & Schilder, 2015). Collaboration emphasizes a firm's capability to develop and implement mutual objectives based on strategies such as reward and risk sharing (Mandal et al., 2016). Redundancy refers to having numerous options during supply chain disruptions, e.g., alternative suppliers (Tan, Zhang & Cai, 2019), while agility describes a firm's ability to adjust its work processes to adapt to changes in business environment (Dhaigude & Kapoor, 2017). The impacts of these capabilities on other constructs such as supply chain performance are mixed in the literature. Some studies (e.g., Bevilacqua et al., 2020) indicated that supply chain flexibility plays a significant role in supply chain performance and other studies (e.g., Saglam, Çankaya and Sezen, 2020) showed insignificant effects of supply chain flexibility on supply chain performance. Mandal et al. (2016) recognized a specific importance of supply chain collaboration for supply chain performance while Botes, Niemann and Kotzé (2017) found a non-significant effect of supply chain collaboration on supply chain performance. Furthermore,

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supply chain agility is significantly related to supply chain performance (Abdallah, Alfar & Alhyari, 2021). Therefore, the study aims at exploring the effects of three dimensions of supply chain resilience (supply chain flexibility, supply chain collaboration, and supply chain agility) on supply chain performance.

The contribution of this study is that it highlights some key drivers of supply chain performance, which in turn influence the overall performance of the firm. It instructs managers that supply chain resilience should be a strategic goal to ensure an excellent organizational performance with a specific focus on supply chain performance. The study calls scholars to investigate factors affecting supply chain performance using different samples from diverse industries.

2. Literature review and hypotheses development

2.1 Definition of supply chain resilience

Based on a review of the literature, Tukamuhabwa et al. (2015: 8) defined supply chain resilience as "the adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost effective recovery, and therefore progress to a post disruption state of operations – ideally, a better state than prior to the disruption". For Pereira, Christopher and Da Silva (2014: 627), supply chain resilience refers to "the capability of supply chains to respond quickly to unexpected events so as to restore operations to the previous performance level or even to a new and better one". In their framework on supply chain resilience, Pettit, Fiksel and Croxton (2010) indicate that supply chain resilience is positively influenced by capabilities (e.g., efficiency, adaptability, and recovery) and negatively affected by vulnerabilities (e.g., external pressures and resource limitations), therefore, resilience results in two unbalanced states, i.e., high vulnerabilities and capabilities, or low vulnerabilities and high capabilities, as well as one balanced state, i.e., capabilities match vulnerabilities.

2.2 Strategies of supply chain resilience

The most common strategies of supply chain resilience include supply chain flexibility, supply chain collaboration, supply chain redundancy, and supply chain agility (Tukamuhabwa et al., 2015).

2.2.1 Supply chain flexibility

Flexibility in the context of supply chain refers to a firms' ability to adjust to changes in business environment and stakeholders' requirements consuming least time and dedicating minimum effort (Tukamuhabwa et al., 2015). The benefits of flexibility for supply chains include enabling firms to adapt to unexpected changes, allowing firms to show effective responses to supply chain disruptions, and facilitating firms' abilities to cope with supply chain uncertainty (Scholten & Schilder, 2015). Operationally, supply chain flexibility refers to a firm's ability to modify supplier's orders, delivery time and schedules and production capacity to mitigate supply chain disruptions (Mandal et al., 2016).

2.2.2 Supply chain collaboration

Collaboration in supply chain literature describes a firm's ability to achieve mutual benefits through effective work with other firms (Tukamuhabwa et al., 2015). It has been defined as achieving mutual benefits through developing and attaining strategic mutual objectives as well as reward and risk sharing (Mandal et al., 2016). Supply chain collaboration leads to many benefits such as enhancing firms' responsiveness to changes in supply chain requirements, improving supply chain capabilities like demand planning and knowledge creation, improving supply chain flexibility, and increasing synergies of supply chain members (Scholten & Schilder, 2015).

2.2.3 Supply chain redundancy

Redundancy in supply chain research assumes alternative suppliers, hence, supply chain redundancy refers to availability of redundant suppliers during crises (Tukamuhabwa et al., 2015). In this regard, redundancy can be achieved through keeping an emergency stock of raw materials and finished products, protecting suppliers from disruption by increasing redundancy in their operations, and maintaining back-up plants to be used during disruptions (Tan, Zhang & Cai, 2019).A key aim of supply chain redundancy is to reduce supply chain costs and increasing service delivery during supply chain disruption (Kamalahmadi, Shekarian, & Parast, 2022).

2.2.4 Supply chain agility

An agile supply chain is the one that is able to show quick responses to sudden changes in demand and supply (Tukamuhabwa et al., 2015). It has been described as a firm's ability to modify its operations to changes in business environment (Dubey et al., 2018). In the context of supply chain resilience, supply chain agility refers to a quick satisfaction of customers based on a quick response to short term changes (Charles, Lauras & Van Wassenhove, 2010). Generally, the focus of supply chain literature is divided into three main categories: supply chain responsiveness, supply chain speed, and firm's awareness of changes (Dhaigude & Kapoor, 2017).

2.3 Supply chain performance

Approaches to assess supply chain performance include three key approaches; process-based approaches (i.e., integrated processes from suppliers to end customers), perspective-based approaches (i.e., balanced scorecard models, and supply chain operations reference model), and hierarchal-based approaches (strategic, tactical, and operational level), on the other hand, techniques of supply chain performance measurement involve e analytic hierarchy process, data envelopment analysis, and

simulation (Reddy, Rao & Krishnanand, 2019). Examples of supply chain performance measures in some previous works embrace customer satisfaction, enhanced process transparency, reduced errors in supply chain processes, eliminated work redundancies, and compacted administration costs (Ul-Hameed et al., 2019).

2.4 Supply chain resilience and supply chain performance

2.4.1 Supply *chain flexibility and supply chain performance*

Testing the influence of supply chain capabilities (i.e., flexibility, velocity, visibility, and collaboration) on supply chain resilience, Mandal et al. (2016) indicate that all these capabilities have significant influences on supply chain resilience. Examining supply chain resilience using three key forms of resilience, i.e., engineering, ecological, and evolutionary resilience, Adobor and McMullen (2018) indicated that all these three forms are essential for a supply chain to recover after a disruption or in other words resilience. According to the authors, ecological resilience is a function of adaptive capabilities such as flexibility, adaptive capacity and functions redundancy. On the other hand, Saglam, Çankaya and Sezen (2020) found that supply chain flexibility had no significant effect on supply chain performance. Generally, supply chain flexibility is a critical dimension to ensure supply chain performance (Al-Nawafah et al., 2022; Alshawabkeh et al., 2022; Bevilacqua et al., 2020). It was expected based on these results that supply chain flexibility has a significant effect on supply chain performance, hence, the following hypothesis was suggested:

H_1: *Supply chain flexibility has a significant effect on supply chain performance.*

2.4.2 Supply chain collaboration and supply chain performance

Investigating the role of collaboration in supply chain resilience using multiple case studies from the food industry in The Netherland, Scholten & Schilder (2015) found that collaboration activities such as joint relationship efforts, mutually created knowledge, collaborative communication, and information sharing are key antecedents of supply chain resilience. Some studies (e.g., Al-khawaldah et al., 2022; Aityassine et al., 2021; Mandal et al., 2016) indicate that supply chain capabilities such as collaboration, flexibility, velocity, and visibility have significant effects on supply chain resilience, which in turn significantly affects supply chain performance. Other studies (e.g. Botes, Niemann & Kotzé, 2017) found that supply chain collaboration has no direct effect on supply chain resilience but on the antecedents of supply chain resilience such as flexibility, velocity, and visibility. Using current data, this study assumes the following effect between supply chain collaboration and supply chain performance as stated in the following hypothesis:

H_2: *Supply chain collaboration has a significant effect on supply chain performance.*

2.4.3 Supply chain agility and supply chain performance

Altay et al. (2018) indicates that agility is one key capability of supply chains and exerts a significant direct effect on pre-disaster supply chains. Abdallah, Alfar and Alhyari (2021) reported a significant mediating influence of supply chain agility on the effect of supply chain management quality on supply chain performance. This result assumes that supply chain agility has a direct significant influence on supply chain performance. In a study on the mediating role of supply chain agility on the relationship between supply chain orientation and supply chain performance, Mukhsin et al. (2022) found that both supply chain flexibility and supply chain agility are significantly and positively related to supply chain performance. Therefore, it was hypothesized that:

H_3: *Supply chain agility has a significant effect on supply chain performance.*

3. Research methodology

3.1 Sample and data collection

One hundred and fifty employees were selected from 15 chemical industrial firms IN Jordan to gather research data using an electronic questionnaire distributed to employees of the supply chain department. One hundred and fourteen questionnaires were received valid for data analysis.

3.2 Research model

This research assumes three hypotheses, i.e., H1, H2, and H3, to estimate the effect of the dimensions of supply chain resilience (supply chain flexibility, supply chain collaboration, and supply chain agility) on supply chain performance.

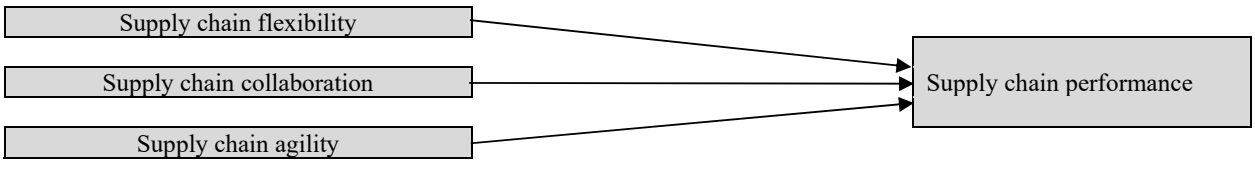

Fig. 1. Research theoretical model

3.3 Research instrument

Supply chain flexibility (3 items) and supply chain collaboration (4 items) are measured using items adopted from Mandal et al. (2016); Al-Hawary et al. (2017). Supply chain agility (4 items) adopted from Eckstein et al. (2015). Additionally, supply chain performance was evaluated using 4 items adopted from Ul-Hameed et al. (2019). All items were designed to assess the latent constructs based on Likert five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree).

3.4 Common method bias

The current self-reported data are gathered using a single source, hence, common method bias is possible. Based on the results of exploratory factor analysis (EFA), which was carried out by IBM SPSS version 25.0, the total variance of one factor un-rotated matrix is less than 50 percent, which means that the common method bias had on influence on the current data (AlTaweel, I. R., & Al-Hawary, 2021; Bag, Gupta & Foropon, 2018).

3.5 Model quality

The predictive relevance of the endogenous constructs was evaluated using Stone-Geiser's (Q^2) to assess the quality of the model. Its value should be higher than zero (Ul-Hameed et al., 2019). Moreover, the explanatory power of the model was judged using R^2 of the dependent construct (Dubey et al., 2021; Al-Alwan et al., 2022a,b; Al-Shormana et al., 2021). The results showed that the value of Q^2 is 0.104 and the value of R^2 is 0.170, which represent a good model quality.

4. Results and discussion

4.1 Reliability and validity

Cronbach's alpha (α) and composite reliability (CR) are used to test an item's reliability. Values of these two measures should be greater than 0.70. Validity, on the other hand, is measured using convergence through items' standardized loadings, and discriminant validity by the average variance extracted (AVE). Standardized loadings should be higher than 0.70 and AVE values should be higher than 0.50 (AlHamad et al., 2022; Tariq et al., 2022; Mandal et al., 2016). The results in Table 1 confirm that the criteria of reliability and validity are met. Both Cronbach's alpha and composite reliability values were higher than 0.70, all factor loadings were greater than 0.70 except two items close to this threshold value, i.e., 0.666 and 0.682. as well, AVE values were greater than 0.611. In terms of collinearity statistics as measured by variance inflation factor (VIF), the results indicate that VIF values for supply chain flexibility, supply chain collaboration, and supply chain agility were less than 5, i.e., 1.140, 1.103, and 1.082, respectively.

Table 1
Results of reliability and validity

Factors	Items	VIF	Standardized loadings	Cronbach's alpha	Composite reliability	AVE values
Supply chain flexibility	SCF1	1.140	0.830	0.800	0.873	0.697
	SCF2		0.904			
	SCF3		0.765			
Supply chain collaboration	SCC1	1.103	0.907	0.901	0.931	0.772
	SCC2		0.807			
	SCC3		0.946			
	SCC4		0.849			
Supply chain agility	SCA1	1.082	0.745	0.796	0.861	0.611
	SCA2		0.805			
	SCA3		0.892			
	SCA4		0.666			
Supply chain performance	SCP1	-	0.932	0.868	0.906	0.711
	SCP2		0.952			
	SCP3		0.682			
	SCP4		0.776			

4.2 Descriptive statistics and correlations

The results in Table 2 show that the total degree of supply chain resilience is moderate (M = 2.83, SD = 0.68). Specifically, the total degrees of supply chain flexibility (SCF), supply chain correlation (SCC), and supply chain agility (SCA) are moderate (M_{SCF} = 2.48, SD_{SCF} = 0.77, M_{SCC} = 2.99, SD_{SCC} = 0.871, M_{SCA} = 3.02, SD_{SCA} = 0.941). As well, the degree of supply chain performance is moderate (M = 3.66, SD = 0.873). The results of Pearson's correlation coefficients indicate that supply chain flexibility is significantly correlated to supply chain correlation (r = 0.285) and supply chain agility (r = 0.252) and supply chain collaboration is significantly correlated to supply chain agility (r = 0.178). On the other hand, supply chain flexibility has insignificant correlation to supply chain performance, while both supply chain correlation and supply chain

agility are significantly correlated to supply chain performance (r = 0.330, 0.299). These results signify a statistically significant correlation between supply chain collaboration as well as supply chain agility and supply chain performance.

Table 2
Descriptive statistics and correlation coefficients

Variables	Mean	SD	Degree	1	2	3	4
1. SCF	2.48	0.770	Moderate	-			
2. SCC	2.99	0.871	Moderate	0.285**	-		
3. SCA	3.02	0.941	Moderate	0.252**	0.178**	-	
4. SCP	3.66	0.873	Moderate	0.178	0.330**	0.299**	-

SCR: Mean = 2.83, SD = 0.68.
**. Correlation is significant at the 0.01 level (2-tailed).

4.3 Research structural model

Fig. 2 shows a research structural model in which three dimensions of supply chain resilience (supply chain flexibility, supply chain collaboration, and supply chain agility) were linked to supply chain performance. Statistics of model fit indicate that the current model fits the current data well. Standardized Root Mean Square Residual (SRMR) is less than 0.10 and Normed Fit Index (NFI) is greater than 0.9. In terms of the effects of supply chain resilience dimensions on supply chain performance. It can be noted that the total effect of supply chain performance on supply chain performance is weak (β = 0.039). Detailed results of hypothesis testing are shown in Table 3.

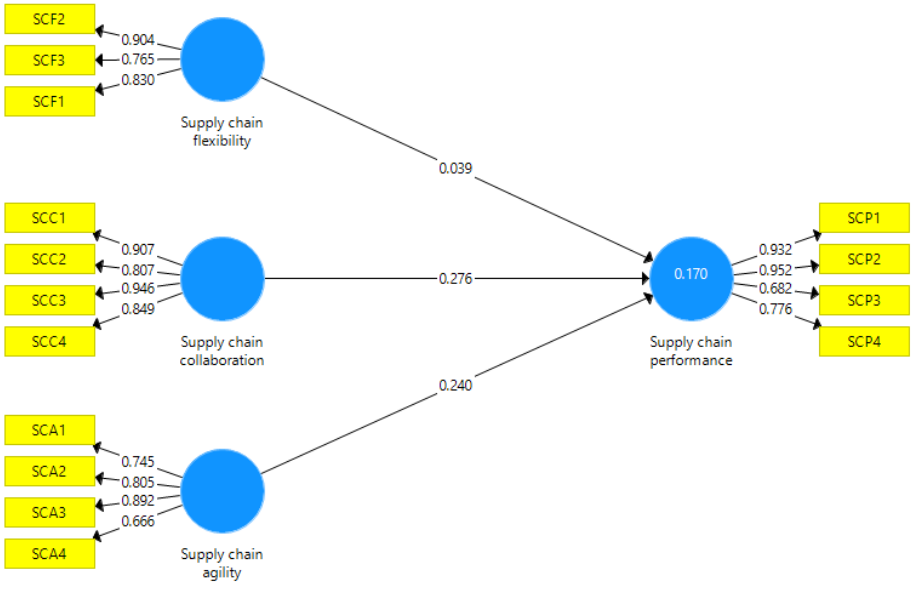

Fig. 2. Research structural model

Results of hypotheses testing as depicted in Table 3 suggest that supply chain flexibility dose not exert a significant effect on supply chain performance (β = 0.039, t-statistics = 0.333, P = 0.739) while supply chain collaboration is significantly and positively related to supply chain performance (β = 0.276, t-statistics = 0.3.274, P = 0.001), additionally, supply chain agility is significantly and positively linked to supply chain performance (β = 0.240, t-statistics = 0.3.034, P = 0.003). Based on these results, H1 was rejected, H2 and H3 were accepted. The reason behind these results may be the conviction of the sample members that the firms under study, although they are characterized by flexibility, cooperation and agility to a moderate degree, but their ability to adjust their production capacity or delivery time and schedules as suggested by flexibility does not mean their ability to face unexpected events because facing such events require collaboration with partners and the ability to respond quickly to changes as agility suggests.

Table 3
Results of hypotheses testing

Constructs and paths			β	T statistics	P value	R^2
SCF	→	SCP	0.039	0.333	0.739	
SCC	→	SCP	0.276	3.274	0.001	0.170
SCA	→	SCP	0.240	3.034	0.003	

The current results are echoed in some previous works and inconsistent with other results. The results of Mandal et al. (2016) confirm that supply chain capabilities like supply chain flexibility and supply chain collaborations have significant effects on

supply chain performance. For Mukhsin et al. (2022), both supply chain flexibility and supply chain agility have significant effects on supply chain performance. Saglam, Çankaya and Sezen (2020) highlight an insignificant effect of supply chain flexibility on supply chain performance. Abdallah, Alfar and Alhyari's (2021) results refer to a significant effect of supply chain agility on supply chain performance.

5. Conclusion and implications

The aim of this study is to investigate the effect of supply chain resilience as measured by supply chain flexibility, supply chain collaboration, and supply chain agility on supply chain performance. Therefore, the study is concerned with testing three hypotheses on the effects of the dimensions of supply chain resilience on supply chain performance. Hypothesis 1 (H1) was rejected, which means that supply chain flexibility had an insignificant effect on supply chain performance. Hypotheses 2 and 3 (H2 & H3) were supported by the current data, that is, there are significant effects of supply chain collaboration and supply chain agility on supply chain performance. Basically, it was concluded that some characteristics such as a firm's effective work with its partners to achieve mutual benefits, a firm's ability to respond quickly to unpredictable changes such as changes in demand and supply enhance its ability to satisfy its customers, to reduce process errors, improve process transparency and decrease administration costs. This conclusion advises supply chain managers to consider collaboration through its supply chain and to improve responsiveness, speed and awareness of unexpected changes. In other words, managers are required to design the supply chain to a resilient one based on collaboration and agility. Scholars, on the other hand, are requested to reassess the effect of supply chain flexibility on supply chain performance as the current study found that supply chain flexibility had no effect on supply chain performance.

6. Limitations and future work directions

The study is limited to a sample of supply chain employees from industrial firms, as well as investigating the effect of three dimensions of supply chain resilience (supply chain flexibility, supply chain collaboration, supply chain agility) on supply chain performance. Therefore, further studies are required to examine the effect of supply chain resilience using other dimensions such as supply chain redundancy on supply chain performance collecting data from other samples from different industries.

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