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SUPPLY CHAIN 4.0 MATURITY, AGILITY, RESILIENCE AND ABSORPTIVE CAPACITY: AN EMPIRICAL STUDY IN INDONESIA

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Abstract

This study examines the effect of Absorptive Capacity on Supply Chain 4.0 Maturity (SC4.0) through the mediating role of Supply Chain Agility and Supply Chain Resilience. A quantitative research method was used by distributing an online survey, targeting supervisors and above in the supply chain field at companies that have adopted Industry 4.0 technologies. The study gathered responses from 94 participants; however, only 76 of them successfully completed the questionnaire. The data were analyzed using PLS-SEM. The research results show that Absorptive Capacity significantly influences Supply Chain 4.0 Maturity, with a path coefficient of 0,376 for Agility and 0,344 for Resilience, both categorized as moderate contributions. Agility and Resilience strongly impact Maturity, with coefficients of 0,413 and 0,414, highlighting their critical roles in digital transformation. Mediated effects through Agility and Resilience (0,298 each) emphasize the importance of Absorptive Capacity in achieving Supply Chain 4.0 Maturity. This study contributes to the understanding of factors affecting Supply Chain 4.0 Maturity and provides implications for organizations to adapt to the era of digitalization in Indonesia.

Keywords*:* *Absorptive Capacity; Supply Chain; Agility; Resilience; Maturity*

1. Introduction

Industry 4.0 in recent years has become a prominent topic not only in management circles, but also throughout the global community (Chauhan & Singh, 2020). The emergence of the Industry 4.0 revolution is attributed to the rapid development of information and communication technology in recent years, which has had a significant impact on integrating Industry 4.0 into supply chains (Alamsjah & Yunus, 2022). Industry 4.0 enables the creation of products and services as well as supply and delivery processes automatically with minimal human intervention, greatly accelerated by technological advancements such as the Internet of Things (IoT), Big Data Analytics (BDA), Artificial Intelligence (AI), and cloud computing (Hofmann *et al.*, 2019). Industry 4.0 is based on two dimensions of integration: horizontal and vertical integration of production systems driven by real-time data transactions and flexible manufacturing to enable customized production (Tiwari, 2021). The creation of value in the supply chain influenced by the advancements of Industry 4.0 which is known as Supply Chain 4.0 (SC4.0), which has fostered seamless connectivity in globalized supply chains, leading to improvements in the effectiveness and efficiency of operations within supply chains (Alamsjah & Yunus, 2022).

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The transition from traditional supply chains to digital supply chains is becoming increasingly important to support new production models, transportation modes, and customer experiences alongside the evolving technology in Industry 4.0. However, the implementation of Industry 4.0 is influenced by the level of development of a country. Industry 4.0 has already become a reality in advanced countries like Germany; however, there is still much that needs to be developed and implemented in industries, particularly in developing countries. Traditional supply chains in developing countries are considered inadequate in promptly responding to the growing demands of customers and the continuous advancements in technology brought about by Industry 4.0 (Alamsjah & Yunus, 2022; Choudhury *et al*., 2021; da Silva *et al*., 2019). One of the reasons for this is the limited financial resources available to subsidize industries and the lack of incentive policies to support them (Raj *et al*., 2020).

Supply Chain 4.0 has significant potential to help companies reduce lost sales by 65% to 75%, cut transportation and warehousing costs by 15% to 30%, decrease inventory by 35% to 75% and lower supply chain administrative costs by 50% to 80%, based on study by McKinsey & Company (Alicke *et al*., 2019). In SC4.0, digitalization, visibility, connectivity, and interoperability are integrated across the entire supply chain ecosystem, digitally linked and synchronized in real-time with a 360-degree view. Mutually beneficial partnerships are dynamic and sustainable, demonstrating resilience, flexibility, and responsiveness in facing uncertain market conditions (Yuan & Xue, 2023). However, the integration of SC4.0 technologies can be challenging for traditional organizations lacking the necessary knowledge for digital transformation. Even when such knowledge is readily accessible, these organizations may struggle to apply it to their routine tasks and activities. It can be said that these organizations exhibit low absorptive capacity or even deficiency in this regard (Siachou *et al*., 2021).

Implementing SC4.0 technology requires high capital investments (Makris *et al*., 2019). In developing countries like Indonesia, SC4.0 maturity entails not only technological readiness but also being flexible, innovative, and efficient in meeting customer demands through integrated digital business processes that enhance productivity systems and sustainability (Garcia-Reyes *et al*., 2022; Alamsjah & Yunus, 2022). However, in developing countries, SC4.0 growth across the nation can be hindered by social and geopolitical instability, making progress slow. Therefore, to effectively adopt Industry 4.0 technologies across all stages of the supply chain, it is crucial for Indonesia to achieve SC4.0 maturity (Supply Chain 4.0 Maturity) (da Silva *et al*., 2019; Hahn, 2020). Given the arguments above and limited studies on SC4.0 in Indonesia, we formulate the following research questions:

RQ1. How can absorptive capacity influence supply chain maturity in SC4.0, considering the mediating effects of supply chain resilience and supply chain agility?

RQ2. How does the implementation of Industry 4.0 technology influence the balance between exploration-exploitation in the supply chain in Indonesia?

Our research will address the research gap from previous studies by expanding understanding of the implementation of Industry 4.0 technology in one developing country, Indonesia (Raj *et al*., 2020; Zhao *et al*., 2023). We will also delve deeper into exploration-exploitation practices within the supply chain, providing a more profound understanding of the relationships and how Industry 4.0 technology can be optimized in the supply chain (Alamsjah & Yunus, 2022). Therefore, this study not only contributes theoretically to understanding factors influencing supply chain maturity such as absorptive capacity, supply chain resilience, and supply chain agility, but also holds implications for organizations and practitioners in their effort to adapt to the ongoing digitalization era in Indonesia.

Literature Review and Hypotheses

Absorptive Capacity

Absorptive Capacity (ACAP) is an organization's ability to absorb, integrate, transform, and apply external information to enhance performance, innovate, and adapt (Abourokbah *et al*., 2023). According to Cohen and Levinthal (1990), ACAP is defined as "the firm's ability to recognize the value of new external information, assimilate it, and apply it for commercial purposes". This definition was expanded by Zahra and George (2002), who defined ACAP as "the routines and processes within an organization by which it acquires, assimilates, transforms, and exploits knowledge to generate dynamic organizational capabilities" (Al-Hakimi *et al*., 2021). Introduced by Umam (2018), ACAP represents a crucial source of external knowledge in the process of organizational learning capability, enabling organizations to exploit external knowledge in enhancing their organizational learning capability (Sandy *et al*., 2023). Absorptive capacity within a company can shape innovative and exploitative strategies that leverage new information for internal use (Muller *et al*., 2021). Companies with higher ACAP are more likely to increase profitability and market share by acquiring external information that meets consumer expectations, innovating in technology, and responding to market cycle dynamics (Abourokbah *et al*., 2023).

Supply Chain Agility

Supply Chain Agility (SCA) is the ability possessed by an organization to respond adaptively to external changes (Tarigan *et al*., 2021), by adjusting tactics and operations within its supply chain (Abourokbah *et al*., 2023). The broad and multidimensional concept of SCA encompasses various strategic and disciplinary dimensions (Wong *et al*., 2022). The implementation of SCA by an organization demonstrates its capability to develop thinking, intelligence, and responsive processes across the entire supply chain when faced with external or environmental uncertainties (Tarigan *et al*., 2021). Therefore, an organization with high responsiveness is better equipped to address uncertainty situations (Wong *et al*., 2022). Research in supply chain management emphasizes the importance of implementing high responsiveness to uncertainty to minimize disruption risks and ensure service continuity (Braunscheidel & Suresh, 2008; Chen, 2019), enabling organizations to quickly align supply with demand and capitalize on changes more effectively (Wong *et al*., 2022). Supply chain managers can identify business operations requiring change to enhance SCA (Abourokbah *et al*., 2023). Studies conducted by Alamsjah and Yunus (2022) indicate that SCA significantly and positively impacts Supply Chain 4.0 Maturity. Additionally, research by Abourokbah *et al*. (2023), shows a positive impact of ACAP on SCA. Based on this, the proposed hypothesis is:

H_1 = Absorptive Capacity has a significant impact on Supply Chain Agility
H_3 = Supply Chain Agility has a significant impact on Supply Chain 4.0 Maturity

Supply Chain Resilience

Supply Chain Resilience (SCR) is the capability to return to normal operations and enhance performance after disruptions, measured by redundancy, real-time monitoring, visibility systems, and recovery plans (Tarigan *et al*., 2021; Ivanov & Dolgui, 2021). SCR represents an organization's ability to withstand disruptions and recover to its original state or even better than before (Aslam *et al*., 2020). As a supply chain system, supply chain resilience builds a company's ability to reduce the likelihood and consequences of disruptions, as well as shorten the time to restore normal business performance (Tarigan *et al*., 2021; GRUŽAUSKAS & VILKAS, 2017). Resilience capabilities in the supply chain enable recovery and adaptation when supply networks are exposed to and affected by environmental and operational changes (Ivanov *et al*., 2021). Organizations and supply chains must work to strengthen their dynamic capabilities, particularly their resilience capability, to mitigate the impact of any disruptions (Goaill & Al-Hakimi, 2021). Research by Abourokbah *et al*. (2023) indicates that ACAP enhances SCR. This research examines the concept of ACAP and its benefits to SCR, where ACAP can enhance SCR for sustained long-term advantage, allowing supply chains to innovate despite limitations imposed by disruptions in supply. Based on this, the proposed hypothesis is:

H_2 = Absorptive Capacity has a significant impact on Supply Chain Resilience
H_4 = Supply Chain Resilience has a significant impact on Supply Chain 4.0 Maturity

Supply Chain 4.0 Maturity

Supply chain maturity is a condition that can be measured in a supply chain, starting from its initial state to reaching a more advanced state (Done, 2011; Alamsjah & Yunus, 2022). The maturity model is a series of structured managerial capability levels that describe an organization's performance (Bititci *et al*., 2015; Alamsjah & Yunus, 2022). These maturity levels relate to stages of managerial capabilities implemented within an organization, where each level signifies gradual improvement in organizational performance. This maturity model helps identify areas needing improvement and highlights strengths and weaknesses (Reyes & Giachetti, 2010; Frederico *et al*., 2020). The concept of the supply chain 4.0 maturity framework was developed with four constructs as the core of each of the four maturity levels, along with corresponding dimensions as descriptors for each level (Frederico *et al*., 2020). Frederico *et al*. (2020) categorized the four SC4.0 maturity indicators forming the foundation of the SC4.0 framework; strategic outcomes, technological advancements, processes performance, and managerial capability. However, no research has yet been conducted on the mediation connecting ACAP and SC4.0 Maturity. Nevertheless, SCA and SCR have been mediated in several studies. For instance, the study conducted by Koc *et al*. (2022) showed positive mediation in SCA connecting environmental uncertainty and competitive advantage. Meanwhile, the study conducted by Bahrami *et al*. (2022) demonstrated a positive mediation in SCR connecting the variables of Big Data Analytics (BDA) capabilities and SC performance. Based on this, the proposed hypothesis is:

H_5 = Absorptive Capacity, through mediation of Supply Chain Resilience, has a significant impact on Supply Chain 4.0 Maturity
H_6 = Absorptive Capacity, through mediation of Supply Chain Agility, has a significant impact on Supply Chain 4.0 Maturity

2. Research Methods

This study is quantitative research. Data collection involved distributing an online survey using Google Form questionnaires aimed at supervisors and above who work in the supply chain domain, in companies that have implemented Industry 4.0 technology. Convenience sampling and snowball sampling methods were chosen due to limitations in direct access to companies. Convenience sampling occurs when participants who meet the study's criteria are recruited (Emerson, 2021). This involves contacting acquaintances working in the supply chain domain. The snowball sampling technique was used to assist in sample collection based on recommendations of names and information (Witjaksono, 2017).

The variables used to formulate this research model are Absorptive Capacity (ACAP), Supply Chain Resilience (SCR), Supply Chain Agility (SCA), and Supply Chain 4.0 Maturity (MAT). The instruments used to measure ACAP were obtained from Flatten *et al*. (2011), which measures a company's ability to recognize new information, assimilate it, and then apply it for commercial purposes. The ACAP indicators used in the research consist of Acquisition, Assimilation, Transformation, and Exploitation. The instruments used to measure SCR were obtained from

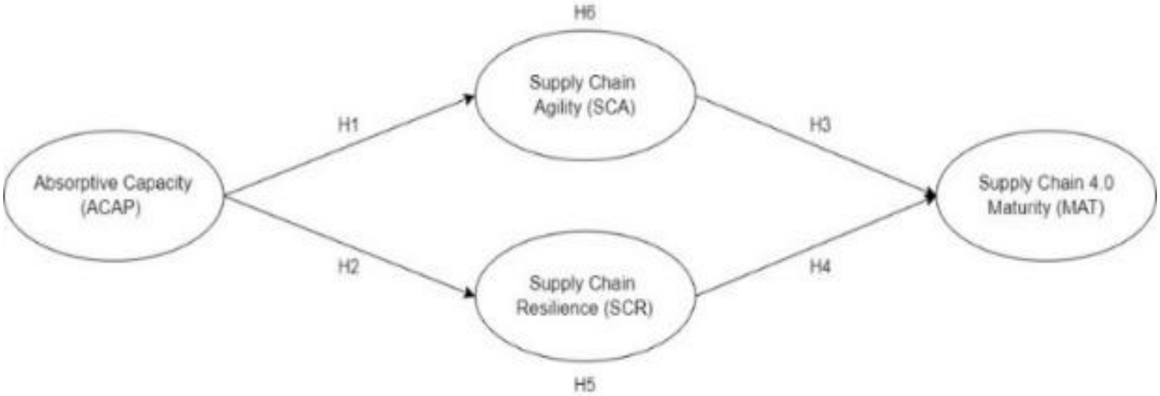

Figure 1. Theoretical Framework

Table 1. Test Model (Wiyono, 2011)

Test Model	Output	Criteria
Outer Model	Convergent Validity	Loading factors between 0,50 to 0,60 are considered sufficient.
	Discriminant Validity	Cross-loading values of latent variables should be greater than correlations with other latent variables.
	Average Variance Extracted (AVE)	AVE values should be above 0,50.
	Composite Reliability	Composite reliability values are considered good if ≥ 0,70.
Inner Model	R^2 for endogenous latent variables	R^2 results of 0,67; 0,30; 0,19 indicate a "good", "moderate", and "weak" model, respectively.
	Parameters and T-Statistics coefficients	Estimates of path coefficients in the structural model, which may need to be obtained through bootstrapping.

Table 2. Limits Score Reliability Cronbach's Alpha (Jogiyanto, 2011)

Score	Reliability
< 0,50	Low
0,50 – 0,60	Enough
0,70 – 0,80	High

Zouari *et al*. (2021), which measures the capacity of the supply chain to build preparedness, response, and recovery capabilities. The SCR indicators used in the research consist of Visibility, Adaptability, Recovery, Collaboration, and Anticipate. The instruments used to measure SCA were obtained from Alamsjah & Yunus (2022), which measures a company's ability to quickly adjust tactics and operations in the supply chain to respond to changes, opportunities, or threats. The SCA indicators used in the research consist of Lead Time, Cycle Time, Responsiveness, and Demand Flexibility. The instruments used to measure MAT were obtained from Frederico *et al*. (2020) and Alamsjah and Yunus (2022), which measured the state of supply chains from its initial state to a more advanced state. The MAT indicators used in the research consists of Strategic Outcomes, Technological Advancements, Processes performance, and Managerial Capability. All items were evaluated using a 6-point Likert scale. **Figure 1** is a graphical representation of the proposed research model.

Descriptive statistical data analysis employed PLS-SEM (Partial Least Squares Structural Equation Modeling) analysis with SmartPLS 4.0. PLS-SEM is a method capable of directly analyzing latent variables, variable indicators, and measurement errors (Hazriyanto *et al*., 2019). It possesses many characteristics that render it widely used in management research (Goaill *et al*., 2014). This method is considered suitable for small samples because it demonstrates greater statistical power when applied to complex models with limited sample sizes compared to covariance-based SEM (Henseler *et al*, 2009; Reinartz *et al*., 2009).

The model testing was conducted through the outer model and inner model. In the outer model, indicators were tested against latent variables to see the extent to which these indicators could explain the latent variables, using convergent validity, discriminant validity, Average Variance Extracted (AVE), and composite reliability. The inner model was used to test the influence of exogenous (independent) and endogenous (dependent) latent variables, as well as other hypotheses using R-Square. The stability of the estimates was tested using the T-test from bootstrapping (Hamid & Anwar, 2019). Detailed assessment criteria can be seen in the following **Table 1**.

Cronbach's Alpha is used to measure the reliability of indicators when assessing a construct, while Composite Reliability is considered a superior measure compared to Cronbach's Alpha (Hair *et al*., 2019). Reliability values between 0,50 and 0,60 are deemed adequate, whereas in most studies, accepted reliability values typically range from 0,70 to 0,80 (Jogiyanto, 2011). Limits Score Reliability Cronbach's Alpha are shown in **Table 2**.

Table 3. Respondents Characteristics

Respondent Profile	Frequency
Position	
Owner	-
Director	4
Senior Manager	15
Manager	29
Supervisor	28
Type of Company	
BUMN	17
BUMS	44
Foreign Company	15
Non-Profit Organization	1

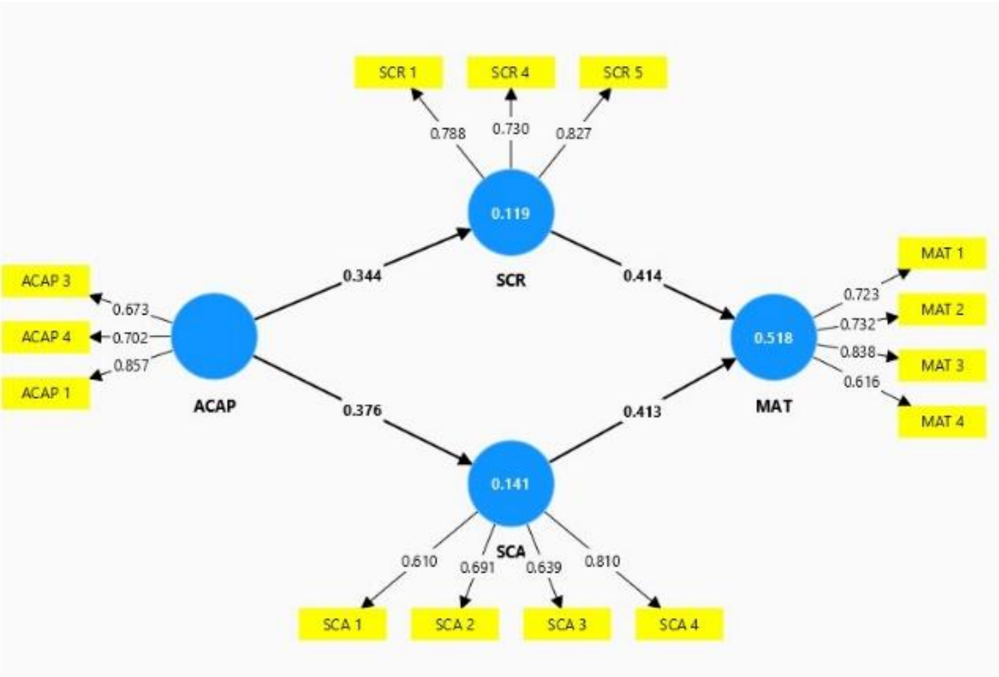

Figure 2. Outer Loadings Results

Table 4. Discriminant Validity Results

	ACAP	MAT	SCA	SCR
ACAP				
MAT	0,593			
SCA	0,608	0,838		
SCR	0,510	0,863	0,720	

3. Result And Discussion

3.1 Profile of Respondents

A total of 94 respondents were successfully collected during the survey, with 76 respondents completing the questionnaire. There were 19 other respondents who could not complete the questionnaire because the companies they work for have not yet adopted Industry 4.0 technology. Respondents' characteristics are shown in **Table 3**.

3.2 Validity and Reliability Testing

The test results showed that all indicators had sufficiently good outer loadings value, which were in the range of 0,60 indicating that the measurements were reliable. The test results are shown in **Figure 2**. Based on the results of the discriminant validity test that has been conducted, the highest correlation is found between MAT and SCR with a value of 0.863, indicating that the relationship between these two variables is quite strong. On the other hand, the lowest correlation is found between ACAP and SCR with a value of 0.510, indicating that the relationship between these two variables is weaker compared to the other variable correlations. The discriminant validity results are shown in **Table 4**.

The results of the Cronbach's Alpha test showed moderate reliability values, particularly for ACAP, SCA, and SCR, which were in the range of 0,60 while MAT had a good reliability value, indicated by a range of 0,70. Additionally, composite reliability showed good results with values above 0,70. The AVE results indicated good validity for ACAP, MAT, and SCR with

Table 5. Construct Reliability and Validity Results

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
ACAP	0,601	0,790	0,560
MAT	0,711	0,820	0,535
SCA	0,647	0,784	0,478
SCR	0,684	0,826	0,613

Table 6. R-Square Results

	R-Square
MAT	0,518
SCA	0,141
SCR	0,119

Table 7. Hypothesis Testing Results

Hypothesis	Path	Path Coefficients	T-Statistics	P-Values	Decisions
H1	ACAP → SCA	0,376	3,301	0,000	Accept H1
H2	ACAP → SCR	0,344	3,444	0,000	Accept H2
H3	SCA → MAT	0,413	4,091	0,000	Accept H3
H4	SCR → MAT	0,414	3,329	0,000	Accept H4
H5	ACAP → SCR → MAT	0,298	2,413	0,008	Accept H5
H6	ACAP → SCA → MAT	0,298	2,292	0,011	Accept H6

values above 0,50, whereas SCA was moderate with an AVE value slightly below 0,50. Construct reliability and validity results are shown in **Table 5**.

3.3 Hypothesis Testing

The R-Square test results for MAT showed a medium to high explanatory power, indicating that the model performs well in explaining MAT. In contrast, SCA and SCR had low explanatory power, suggesting that there are other factors that could play a role in mediating these relationships. R-Square Results are shown in **Table 6**.

The path coefficients from all hypotheses range from 0,20 to 0,40, indicating a strong positive relationship in those paths. The T-Statistics values for all hypotheses show significant relationships in the paths because they are greater than the critical value of 1,96 (5% significance level). The P-Values for all hypotheses also indicate values less than 0,05, indicating significant relationships. Based on these three values, the decision that can be made is that H1 to H6 are accepted. Hypothesis testing results are shown in **Table 7**.

3.4 Discussions

This study analyzes the influence of ACAP on the two mediating variables SCA and SCR, the influence of SCA and SCR on the dependent variable MAT, and the influence of ACAP on MAT mediated by SCA and SCR (as shown in Figure 1 Theoretical Framework). It was found that ACAP has a significant influence on SCA and SCR (H1 and H2), consistent with the findings of several previous studies. For example, in the research conducted by Sanchez and Leo (2018) dan Abourokbah *et al*. (2023), it was found that ACAP has a positive influence on SCA. ACAP can play an important role in supply chain relationships. High ACAP can provide a competitive advantage to companies due to their ability to effectively process new knowledge, which can enhance responsiveness to market changes and customer needs. In the supply chain, ACAP can help us improve our understanding of customers and suppliers, enhance synchronization and efficiency in resource management, and support information integration using the latest communication technology. This can strengthen relationships and coordination throughout the supply chain (Sanchez & Leo, 2018; Abourokbah *et al*., 2023; Whitehead *et al*., 2016). Research conducted by Golgeci & Kuivalainen (2020) and Abourokbah *et al*. (2023) found that ACAP significantly influences SCR. The supply chain can achieve SCR through strong relationships with customers and suppliers, well-integrated business process management, and by enhancing the skills and capabilities of workers to achieve better performance at lower costs but with higher quality (Abourokbah *et al*., 2023). In responding quickly to disruptions in the supply chain, the application of ACAP is crucial in developing, maintaining, and leveraging the capacities of SCA and SCR.

In this study, SCA and SCR were also tested to determine their relationship with MAT. It was found that both variables significantly influence MAT (H3 and H4). These results are consistent with the research conducted by Alamsjah and Yunus (2022), where SCA significantly influences supply chain 4.0 maturity and acts as a significant mediator between SC ambidexterity and SC4.0 maturity. In this context, SC ambidexterity and SCA can affect the maturity of digital supply chain innovation, which is adapted by the cultural dimensions of the organization (Alamsjah & Yunus, 2022). The study conducted by Nakandala *et al*. (2023) found an influence of SCR as a mediator, where Industry 4.0 technology positively impacts SCR, driving additional innovation in manufacturing companies in Australia.

The relationship between ACAP and MAT mediated by SCR and SCA produces significant outcomes (H5 dan H6) in this study, consistent with previous research by Abourokbah *et al*. (2023). In their study, SCA and SCR were found to have positive influence in mediating the relationship between ACAP and SC innovation performance. This is supported by agility aiding an organization in adapting and responding to changes according to customer needs and demands with innovative features (Sanchez *et al*., 2019). Meanwhile, SCR impacts digital technology innovation to enhance the supply chain performance of an organization (Bahrami *et al*., 2022). Therefore, building strong ACAP is crucial for companies, especially in Indonesia, to adapt effectively to the demands of Industry 4.0.

Companies in Indonesia need to focus more on improving ACAP in obtaining and assimilating external information to help facilitate the implementation of Industry 4.0 technology into the supply chain. ACAP can be improved by investing in digital skills training or education for employees within the company, enabling them to respond to challenges and seize opportunities in a dynamic business environment. Additionally, there is a need for investment in technology by adopting technologies such as IoT, AI and big data analytics, which are beneficial in improving efficiency, visibility and collaboration in the supply chain. This digital transformation is also the key to achieving Supply Chain 4.0 maturity. With a high level of ACAP, the strength of SCR and SCA will also increase, enabling companies to respond and overcome disruptions related to Indonesian market fluctuations more quickly, effectively, flexibly, and balance exploration opportunities with exploitation of existing resources.

4. Conclusion

This study concludes that there is a significant relationship between ACAP and SCR, and between SCR and SCA, as well as between SCR and SCA with MAT. Additionally, there is a mediated relationship between ACAP and MAT through SCR and SCA. High ACAP can strengthen SCR and SCA, thereby enhancing Supply Chain 4.0 maturity. In Indonesia, the adoption of Industry 4.0 technology in supply chains shows promise but faces challenges. Not all companies have implemented such technology due to uneven technological infrastructure, limited digital skills among the workforce, and regulatory issues. However, with the rapid growth of the digital economy and initiatives like Making Indonesia 4.0, there are significant opportunities to advance the transformation of supply chains towards Supply Chain 4.0 maturity.

Furthermore, this research emphasizes the importance of strategic collaboration among various stakeholders of companies to achieve a common goal, which is achieving Supply Chain 4.0 maturity. With effective collaboration among customers, suppliers, and distributors, information flow can be enhanced, reducing business uncertainty, and improving overall supply chain operational efficiency. Companies that can implement this will be more capable of building an integrated, responsive supply chain that provides greater value-added to customers. Therefore, companies in Indonesia can enhance their competitiveness in facing global market challenges and capitalize on opportunities arising from the development of Supply Chain 4.0 technologies.

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