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The Interaction between Ecosystem Complexity and Technological Evolution in Digital Supply Chains at Technology Companies in Indonesia

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ABSTRACT

This study examines the interaction between ecosystem complexity and technological evolution in shaping the performance of digital supply chains at technology companies in Indonesia. Using a quantitative approach, data were collected from 115 respondents through a Likert scale-based questionnaire and analyzed using SPSS version 25. The findings reveal significant positive relationships between ecosystem complexity, technological evolution, and supply chain performance. Regression analysis highlights the critical role of ecosystem complexity in driving technological adoption, which in turn enhances supply chain efficiency and resilience. The interaction of these variables explains 62% of the variance in supply chain performance. The results underscore the importance of addressing ecosystem complexity through tailored technological solutions to maintain competitive advantage. This study provides practical implications for industry practitioners and policymakers, emphasizing the need for targeted investments in technology and infrastructure development to optimize supply chain operations in dynamic environments.

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1. INTRODUCTION

The rapid evolution of digital technologies has transformed supply chain management, particularly in technology companies where agility and innovation are essential for competitiveness. Digital supply chains utilize AI, IoT, and blockchain to enhance efficiency, visibility, and collaboration, but they operate within a complex ecosystem of stakeholders, market dynamics, and uncertainties. Integrating these technologies improves real-time decision-making and flexibility [1], [2], as demonstrated by companies like Amazon and Tesla [1]. Industry 4.0 technologies also enhance transparency and address social sustainability by ensuring ethical labor practices [3]. Innovation plays a key role in linking digitalization with supply chain agility, crucial for adapting to post-COVID-19 challenges [4]. However, obstacles such as organizational resistance, legacy system

integration, and skill gaps remain, necessitating strategic alignment and investment in digital competencies [1].

Indonesia's technology sector is a vibrant and complex ecosystem shaped by regional diversity, government policies, and rapid technological adoption, presenting both challenges and opportunities. Managing diverse suppliers, ensuring consistent digital infrastructure, and adapting to evolving trends are key challenges, but advancements in digital solutions, data analytics, and automation help address these complexities. Regional disparities in digital access exacerbate socio-economic inequalities, with urban areas having better internet penetration and ICT skills than rural regions, requiring targeted interventions to bridge these gaps [5], [6]. The Digital Society Index of Indonesia shows that digital transformation is concentrated in Java, while eastern regions lag behind [6]. Government policies like "Making Indonesia 4.0" and tax incentives aim to boost industrial competitiveness, but regulatory complexities and infrastructure limitations remain barriers [7]. Startups benefit from government support and international funding but struggle with regulatory shifts and talent shortages [8]. The adoption of Industrial Revolution 4.0 technologies is crucial for competitiveness, helping companies reduce production costs and enhance product quality [7]. Automation and AI are reshaping the job market, creating high-skilled employment opportunities while threatening low-skilled jobs, underscoring the need for investments in digital education and infrastructure [5].

Existing literature has extensively explored aspects of supply chain digitization and technological adoption but has paid limited attention to how ecosystem complexity influences the evolution of technologies in supply chains. Moreover, the interplay between these factors and their collective impact on operational performance in the context of Indonesian technology companies remains under-researched. This gap highlights the need for a focused investigation into how ecosystem complexity shapes and is shaped by technological advancements in digital supply chains.

This study employs a quantitative research approach to analyze the interaction between ecosystem complexity and technological evolution within the supply chains of technology companies in Indonesia.

2. LITERATURE REVIEW

2.1 Ecosystem Complexity in Digital Supply Chains

Ecosystem complexity in technology companies arises from stakeholder interdependencies, rapid innovation, and geographic diversity, making seamless collaboration challenging. Effective management requires flexible, agile, and transparent supply chain strategies, alongside stakeholder engagement, sustainability, and integrated communication. Stakeholder involvement is crucial for value creation, particularly in circular economy ecosystems [9], and the renewable energy sector [10]. Sustainability adds complexity, as seen in food supply chains and renewable energy, where partnerships enhance resource sharing [10], [11]. Integrated communication fosters consistency, while modularity and self-regulation improve coordination [12]. Resilient ecosystems rely on partnerships and technology to mitigate systemic risks [13], with adaptability being essential during crises [13].

2.2 Technological Evolution in Supply Chains

Technological evolution in supply chains has transformed traditional practices, enhancing transparency, efficiency, and resilience through AI, IoT, and blockchain integration. These technologies enable real-time tracking, predictive analytics, and automation to address emerging challenges and opportunities. AI-driven tools revolutionize demand forecasting and inventory optimization, improving operational efficiency and customer satisfaction [14]. Smart factory technologies, including IIoT and robotic process automation, enhance agility and customer experiences, increasing margins (Shaikh, 2025). AI and IoT optimize real-time decision-

making, inventory management, and quality control while strengthening supply chain resilience, particularly in post-pandemic recovery [15]. AI-powered algorithms improve demand forecasting and predictive maintenance, maximizing asset utilization [16]. In industries like oil and gas, automation tools such as drones and autonomous vehicles streamline inventory management and transportation, reducing human error and increasing operational speed [16]. AI-driven optimization further enhances resource allocation and data-driven decision-making [16]. However, high implementation costs, lack of technical expertise, and resistance to change remain significant barriers to adoption, necessitating continuous investment and upskilling to stay competitive in a rapidly evolving technological landscape [15], [16].

2.3 Research Gap and Theoretical Framework

While extensive literature exists on digital supply chain management, few studies explore the interaction between ecosystem complexity and technological evolution, particularly in the context of Indonesian technology companies. Existing frameworks often examine these dimensions in isolation, overlooking their interconnectedness and collective impact on supply chain performance.

This study addresses this gap by employing a quantitative approach to analyze the relationship between ecosystem complexity and technological evolution. It draws on theoretical perspectives from systems theory and resource-based view (RBV) to understand how companies can leverage their technological resources to navigate complex ecosystems. The findings aim to contribute to both academic discourse and practical strategies for optimizing digital supply chains in Indonesia.

3. METHODS

3.1 Research Design

This study employs a quantitative research design, focusing on collecting numerical data and analyzing statistical relationships between variables. The research investigates how ecosystem complexity interacts with technological evolution and impacts digital supply chain performance. A cross-sectional approach was used to collect data at a specific point in time to capture the current state of the digital supply chains in Indonesian technology companies.

3.2 Population and Sample

The population of this study comprises managers, supply chain professionals, and technology specialists working in technology companies in Indonesia. A purposive sampling technique was employed to ensure the inclusion of respondents with relevant expertise in digital supply chain management.

A total of 115 respondents participated in the study. This sample size was deemed sufficient for conducting robust statistical analyses, as recommended for studies utilizing parametric techniques. The sample includes professionals from various regions of Indonesia, ensuring the representation of diverse organizational and operational contexts within the technology sector.

3.3 Data Collection Methods

Primary data were collected through a structured questionnaire distributed electronically, designed to measure key variables using a Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree). The questionnaire consisted of three main sections: demographic information, which captured respondents' background such as job title, years of experience, and company size; ecosystem complexity, which measured interdependencies, stakeholder diversity, and environmental uncertainty; technological evolution, which focused on the adoption, integration, and advancement of technologies in supply chains; and supply chain performance, assessing operational efficiency, innovation, and resilience. The study examined three key variables: ecosystem complexity as the independent variable, defined by stakeholder diversity, market volatility, and regulatory challenges; technological evolution as the mediating variable, reflecting the adoption and

integration of digital technologies, including advanced tools, digital infrastructure, and innovation; and supply chain performance as the dependent variable, measuring efficiency, innovation, and adaptability, with indicators such as lead time reduction, cost optimization, and risk management capabilities.

3.4 Data Analysis

Data were analyzed using SPSS version 25 to explore relationships and test hypotheses through various analytical techniques. Descriptive statistics summarized the demographic characteristics of respondents and provided an overview of responses for each variable. Reliability analysis was conducted using Cronbach's alpha to assess the internal consistency of the questionnaire items. Pearson correlation was used to evaluate the strength and direction of relationships between variables. Finally, multiple regression analysis examined the interaction between ecosystem complexity, technological evolution, and their combined impact on supply chain performance.

4. RESULTS AND DISCUSSION

4.1 Demographic Characteristics

The study involved 115 respondents, primarily supply chain managers (42%), technology specialists (35%), and logistics coordinators (23%). Most participants had over five years of experience (68%), indicating a strong understanding of their company's supply chain operations. Additionally, 60% of the surveyed companies were medium-sized enterprises, while the remaining 40% were large organizations, reflecting a diverse business landscape.

The mean scores for the key variables indicate a generally high level of ecosystem complexity (M = 4.02, SD = 0.67), advanced technological adoption (M = 4.15, SD = 0.73), and strong supply chain performance (M = 4.08, SD = 0.70) among the surveyed companies. These findings suggest that firms operating within complex supply chain ecosystems are actively integrating technology to enhance efficiency and performance.

4.2 Reliability Analysis

Cronbach's alpha values for all constructs exceeded 0.70, indicating good internal consistency, with ecosystem complexity at α = 0.844, technological evolution at α = 0.878, and supply chain performance at α = 0.822.

4.3 Correlation Analysis

Pearson correlation analysis showed significant positive relationships among all variables, indicating strong associations between ecosystem complexity, technological evolution, and supply chain performance. Specifically, ecosystem complexity was positively correlated with technological evolution ($r = 0.682$, $p < 0.01$) and supply chain performance ($r = 0.583$, $p < 0.01$), while technological evolution exhibited a strong positive correlation with supply chain performance ($r = 0.728$, $p < 0.01$). These results suggest that greater ecosystem complexity is associated with higher technological adoption, which in turn enhances supply chain performance.

4.4 Regression Analysis

Multiple regression analysis revealed that ecosystem complexity significantly influences technological evolution ($\beta = 0.612$, $t = 7.894$, $p < 0.001$), while technological evolution has a strong positive impact on supply chain performance ($\beta = 0.706$, $t = 9.322$, $p < 0.001$). Additionally, the interaction between ecosystem complexity and technological evolution significantly affects supply chain performance ($\beta = 0.656$, $t = 8.454$, $p < 0.001$). The regression model explained 62% of the variance in supply chain performance ($R^2 = 0.62$), highlighting the critical role of technological advancements in optimizing supply chain operations within complex ecosystems.

DISCUSSION

The results highlight that ecosystem complexity is a determinant of having a significant impact on technological advancement in digital supply chains. The robust positive relationship shows that companies that face higher complexity are most likely to adopt cutting-edge technologies to surpass coordination, uncertainty, and

diversity of stakeholders. The findings are consistent with studies by [17], [18] that emphasize the need for technological solutions for supply chain ecosystems complexity. For Indonesia, its ecosystem complexity is supplemented by regulation variance, geospatial diversity, and divers market demands. Such complexity forces innovation in terms of technology where companies invest in platforms and forecast technology to advance efficiency and clarity.

Technological progress became a prime catalyst of supply chain performance. This aligns with findings by [19]–[21], which emphasize the transformative impact of digital technologies to enhance operational efficiency, resiliency, and innovation. The positive correlation shows that companies using technologies such as IoT, AI, and blockchain experience massive improvements in supply chain performance. For instance, real-time tracking systems reduce lead times, and data analytics enable preemptive decision-making. Indonesian technology companies, despite the infrastructure challenges, have come a long way in adopting similar technologies in their supply chains.

Strong interaction effect emphasizes the interdependence between technological evolution and ecosystem complexity. This finding aligns with [22], [23], who argue that complicated ecosystems trigger the adoption of tailored technological solutions. The combined effect of technological evolution and ecosystem complexity explains the majority of supply chain performance variance. In Indonesia, the interaction is particularly evident in business companies operating in rapidly moving markets. For example, business companies catering to multi-segment customer groups or facing ongoing regulatory change are likely to adopt flexible digital tools. This interaction assists companies in remaining competitive by enhancing coordination, reducing risks, and responding to market change with ease.

Practical Implications

The findings have the following practical implications for Indonesian technology companies:

1. Invest in Technology: Companies should invest in advanced technologies to battle the complexities of ecosystems.
2. Enhance Collaboration: Better partnerships and cooperation through data systems among partners can increase ecosystem dynamics.
3. Focus on Customization: Technologies must be designed to address individual complexities of ecosystems, making them as applicable and functional as they can be.
4. Build Digital Infrastructure: Policymakers need to provide for the construction of digital infrastructure to enable increased use of technological interventions.

Limitations and Future Research

This study has some limitations, including a cross-sectional design and use of self-reported measures. Future research could adopt a longitudinal design to ascertain changes over time and explore the influence of other mediating factors, including organizational culture or external market forces, on digital supply chain outcomes.

The results contribute to the literature on digital supply chains, highlighting the imperative interdependency between technological development and ecosystem complexity in maximizing supply chain performance. The results provide good counsel to practitioners and policymakers striving to optimize digital supply chains in Indonesia's tech sector.

5. CONCLUSION

This study highlights the strong interaction between ecosystem complexity and technological development in enhancing digital supply chain performance among technology companies in Indonesia. The findings indicate that companies in complex ecosystems adopt advanced technologies such as IoT, AI, and blockchain to counteract operation challenges and optimize efficiency, leading to greater coordination, resilience, and market responsiveness. In addition, the

interactive effect of ecosystem complexity and technological advancement explains most supply chain performance differences, pointing to the need for digitalization. Operational wisdom suggests that companies must invest in digital tools, customize technology to ecosystem-based challenges, and enhance stakeholder collaboration, while policymakers must invest in digital infrastructure to facilitate broader uptake. Subsequent research may examine other mediating factors and utilize longitudinal studies to better comprehend digital supply chain dynamics in their dynamic creation. Generally, this study has provided a theoretical contribution to supply chain innovation literature as well as practical suggestions for optimal operation for Indonesia's tech industry.

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