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Article

Achieving Supply Chain 4.0 and the Importance of Agility, Ambidexterity, and Organizational Culture: A Case of Indonesia

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Abstract: This study explores the key determinants of Supply Chain 4.0 (SC4.0) maturity in the context of a developing country by examining the relationships between supply chain ambidexterity, supply chain agility, and the maturity of SC4.0. The study was carried out using the survey method involving 154 managers from Indonesian manufacturing companies. The SC4.0 maturity model was developed and tested using structural equation modeling. From our analysis, it was found that supply chain ambidexterity emphasizing on innovation positively influences the companies' agility and SC4.0 maturity levels, and supply chain agility partially mediates supply chain ambidexterity. This paper contributes to the operationalization of SC4.0 maturity determinants that incorporate innovation and technological aspects and extends the extant literature by empirically elaborating the determinants and antecedents of SC4.0 maturity that may expedite the achievement of SC4.0 maturity. This implies that companies and supply chain professionals aiming at achieving their SC4.0 maturity should do so by being outward-looking and, at the same time, foster supply chain collaboration with external networks. This paper is pioneering the empirical study on SC4.0 and offers a means to achieving SC4.0 maturity through SC ambidexterity and SC agility, particularly in the context of a developing country.

Keywords: supply chain ambidexterity; supply chain agility; Supply Chain 4.0 maturity; organizational culture; open innovation

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1. Introduction

The rapid development of information and communication technologies over the last few years has resulted in the emergence of the fourth industrial revolution—Industry 4.0—and had a significant impact on their integration into supply chains [1,2]. Technology advancements such as the Internet of Things (IoT), big data analytics (BDA), and blockchains have accelerated the shift to Industry 4.0 [3–6]. Supply chains benefit from Industry 4.0 in three distinct ways: vertical integration, horizontal integration, and end-to-end engineering [7]. These can be enabled by real-time data analysis, autonomous monitoring and control, and logistics and supply chain control towers, allowing dynamic product creation and development, improved visibility in supply networks, and increased process efficiency [1]. People, machines, and data can now be integrated to create supply chains that are more agile and responsive [8]. The technological advancements in supply chain, also known as Supply Chain 4.0 (SC4.0), have improved seamless interconnection in supply chain globalization, leading to improvements in the effectiveness and efficiency of their operations [3,9,10].

As the traditional supply chains will eventually shift to digital supply chains to support new production models, transportation modes, customer experiences, and relationships,

the implementation of SC4.0 is somewhat influenced by the state of development of a country, and this is particularly apparent in developing countries. Despite the aforementioned benefits, traditional supply chains, especially in the developing world, have not been able to quickly keep up with escalating breakthrough innovations brought by the advancement in Industry 4.0 technologies [11]. This is because developing countries often have limited financial resources to subsidize the industry and do not have supportive incentive policies. Furthermore, recent research has also pointed at the lack of coordinated effort and the relatively weak institutional policies in developing countries as being barriers to the technological innovation that is needed to achieve SC4.0 maturity [8,12].

The International Monetary Fund (IMF) has positioned Indonesia as one of the newly industrialized countries (NICs), along with Brazil, China, India, Mexico, and Turkey [13]. Exacerbated by its social and geopolitical instability, particularly in the developing world including Indonesia, the growth of the nationwide SC4.0 has tended to be gradual, despite the fact that Indonesia is an inseparable part of the global supply chain. Achieving the maturity of SC4.0 in Indonesia is therefore critical to improving the country's ability to absorb and disseminate technologies at various stages of supply chains [14], taking into account the availability of large and relatively low-cost workforce [15].

Applying SC4.0 technologies requires high capital investment and thus a longer payback period. In the context of developing countries where the labor cost components are low, the maturity of SC4.0 implies not only being technologically ready, but also in being flexible, innovative, and efficient to meet the customers' demand via digital integration of business processes [16,17]. Inspired by this argument and combined with the scarcity of empirical studies discussing SC4.0, particularly in the context of developing countries, we formulated the following research questions:

RQ1. What are the key determinants of the maturity of SC4.0?
RQ2. How do these determinants interrelate with one another?

The benefits of SC4.0 are vast, but the extant literature discussing SC4.0 in developing countries is relatively scarce [18,19]. Our research offers insights on the operationalization of the SC4.0 key determinants and extends the extant literature by empirically elaborating antecedents of SC4.0 maturity and providing academic discourse on the relationships, impacts, and significance of SC4.0 maturity to supply chains, especially in the developing world. Our research also intends to facilitate the identification of future research directions as successful firms continue to compete through their supply chains and are inspired to make them smarter [20].

The remainder of this paper is organized as follows. First, the relevant literature on the focused areas of SC4.0 and in the context of developing countries will be reviewed. The research model will then be presented along with the research hypotheses developed based on the theoretical lens of SC4.0 maturity. The research method is discussed next, followed by the elaboration of the key findings and data analysis. The interpretation of the key findings is then discussed, taking into account the significance of these findings within the larger context of developing countries. The paper concludes with some lessons learnt, the academic contributions, implications for practice and policy making, and future work.

2. Literature Review

2.1. Industry 4.0 Readiness and Maturity Assessment

Industry 4.0 is a large-scale initiative, both on a national and firm level. Tripathi and Gupta [21] assessed the "Global readiness assessment model for Industry 4.0 (GRAMI4.0)" at the country level in 126 nations. They determined that 75% of countries have an Industry 4.0 readiness score of less than 0.5 on a scale of 0–1 (fully prepared), indicating that the vast majority of countries are unprepared for Industry 4.0. Several firm level assessment tools have been proposed [16,22–25] and the common maturity dimensions used are strategy, leadership, people, and technology. Using case studies in Sweden, it was found that the majority of manufacturing industries are in the initial maturity levels in their Industry 4.0 readiness [22]. Therefore, there is no empirical evidence of Industry 4.0 readiness.

2.2. Industry 4.0 in Developing Countries

Industry 4.0 has changed the way businesses are conducted from their design, production, culture, business models, etc., and this will transform supply chains to be more digitally connected and transparent [6,26]. Compared to developed countries, where the process of the formation of Industry 4.0 started earlier and was aimed at marketing and social results, developing countries including Indonesia face institutional (absence of state policy on the formation of Industry 4.0) and financial barriers and seek economic goals. At the same time, the initial approach to the formation of Industry 4.0 in developing countries, within which the initiators of this process are economic subjects (companies), envisages higher flexibility and effectiveness compared to the directive approach (state initiative), which is applied in developed countries [18]. Furthermore, Raj et al. [8] reported that the difficulties in the diffusion of technological innovation resulting from a lack of coordinated national policies in developing countries may prevent firms from fully reaping the benefits of Industry 4.0.

In Indonesia, as one of the developing countries, more than 73.7% of the total population (more than 200 million users) are Internet users and this number grew by 16% in 2021 [1], while e-commerce in Indonesia enjoyed a 37.4% growth in 2020 [2]. However, the problem is not in ordering the goods, but how to deliver them in a more responsive way and efficiently in a country with more than 17,000 islands. The Indonesian government is committed to increasing the adoption of Industry 4.0 technologies and is set to double the productivity to cost ratio, to increase exports to 10% of the gross domestic product (GDP), and to allocate 2% of GDP for technology research and development by 2030. A roadmap has been designed by the government to accelerate the adoption of Industry 4.0 by formulating the Making Indonesia 4.0 strategy [3], which is focused on selected industry sectors such as food and beverages, textiles and clothing, automotive, electronics, chemicals, pharmaceuticals, and medical devices. According to a report by AT Kearney [4], however, the level of preparedness of Making Indonesia 4.0 is considered to be 'nascent', and discussion on a system-based analysis of Industry 4.0 in Indonesia is close to absent. Therefore, Industry 4.0 is an opportunity for developing countries to be more efficient and innovative.

2.3. Supply Chain 4.0

The introduction of Industry 4.0 in today's factories, in fact, has created considerable impacts on the whole supply chain structure. The so-called Supply Chain 4.0 (SC4.0) [27–31] exploits new developments in digital technology including "advanced robotics and artificial intelligence, hi-tech sensors, cloud computing, the Internet of Things, data capture and analytics, digital fabrication, software-as-a-service and other new marketing models . . . " [32], providing supply chain actors with (almost) real-time information that improves visibility, transparency, and collaboration in supply chains. In this way, the potential disruption can be considerably mitigated while at the same time, the accuracy of demand forecast is increased and obsolete products lessened [29].

SC4.0 also allows the transformation of supply chains from a linear model in which instructions flow from the supplier to producer to distributor to consumer, to a more integrated model in which information flows in multiple directions [33]. McKinsey recently reported that digitization leads to SC4.0 becoming faster, more flexible, more granular, more accurate, and more efficient [34]. SC4.0 also makes the connections among supply chains become more flexible from upstream to downstream [6]. Furthermore, corporations with SC4.0 will improve their competitive advantage, product availability, and market share [35]. SC4.0 has therefore received considerable interest from scholars and practitioners working in various industry sectors [29,34,36].

Companies are investing heavily in developing their own SC4.0. In a recent PwC study on the advancement of Industry 4.0, a third of the respondents reported that their workplaces have embarked on digitizing their supply chains, while 72% are expected to do the same within five years [5]. LaBerge [37] found that the COVID-19 pandemic has fast-tracked the utilization and adoption of digital technologies, and is expected to do so

even when the crisis is over. In addition, McKinsey reported that the adoption of SC4.0 can reduce operational costs down to 30%, reduce lost sales by 75%, and produce a decrease in inventories of up to 75%. At the same time, the agility of the supply chains should increase significantly [34]. In summary, SC4.0 is an opportunity for developing countries because they are an integral part of the global supply chain.

2.4. Theoretical Lens: SC4.0 Maturity Model

Supply chain maturity is a measurable state of a supply chain, from its initial state to a more advanced state. The current state of supply chains is typically measured by using the total quality management indicators [38], the supply chain operations reference (SCOR) model [39,40], and the business process management approach [41]. Supply chain maturity cases are mostly reported by brick-and-mortar companies and demonstrate the positive impacts of being mature [39,40,42]. Recent empirical research has indicated a strong and positive relationship between supply chain maturity and performance in a developing country (e.g., [39,41]), in the context of small- and medium-sized enterprises (e.g., [43]). Understanding their maturity allows supply chains to be continuously improved [42].

A maturity model is a set of structured managerial capability levels that characterize organizational performance [44,45]. Maturity levels relate to identified managerial capability stages that can be executed in organizations [41,46]; each maturity level signifies gradational performance improvement. In practice, maturity models identify gaps in improvement and highlight weaknesses and strengths [42].

Frederico et al. [46] categorized SC4.0 maturity indicators into (1) managerial and capability support systems; (2) technological developments; (3) strategic outcomes; and (4) process performance requirements, which form the core or foundation of the proposed SC4.0 framework, along with their corresponding dimensions within four maturity levels: initial, intermediate, advanced, and cutting-edge. Managerial and capability supporters provide the organizational support, individual competency and skills, and collaboration with supply chain partners. Technological developments measure the ability of supply chains to take advantage of Industry 4.0 technologies to enhance supply chain processes, infrastructure, and information integration with suppliers and customers. Process performance requirements include process integration, collaboration, response rate, waste reduction, and man–machine–system interconnection. Finally, strategic outcomes signify the benefits the supply chains will accrue from the adoption of the above-mentioned technologies, which are typically indicated by cost reduction, positive customer experience, and strategic impacts. Therefore, we found a research gap on how to achieve SC4.0 maturity and its antecedents.

2.5. Agility, Ambidexterity, and Open Innovation

Digitalization has accelerated the adoption of Industry 4.0 technologies [47]. As they are required to be more agile, adaptive, and ambidextrous in order to boost innovation, many smart enterprises have embarked on digital innovation initiatives [48,49]. With these capabilities, they can respond quickly and be agile to market changes [50], and are able to share their knowledge, which in turn will drive an open innovation culture [51].

Puriwat and Tripopsakul's recent study [52] found that organizational agility has a positive correlation to open innovation adoption. This also implies that the configurations of open innovation and organizational agility may explain the reasons for highs or lows in the levels of business model innovation [53]. Furthermore, open innovation leads to organizational ambidexterity, company success, and sustainability [54,55]. The concept of open innovation in the supply chain contexts, however, appears to be under-researched [56].

Based on the literature review, the next section will therefore set out the development of our research hypotheses that will be tested and subsequently used to answer our research questions. The section describes the logic for the hypotheses and how we ground our theory-building in research related to the concepts of SC4.0 maturity, SC ambidexterity, and SC agility.

3. Hypotheses Development

We first describe the SC ambidexterity literature to demonstrate how exploitation and exploration may contribute to SC agility and SC4.0 maturity, then explore how corporate culture may impact on the interplays among them.

3.1. Positive Association between Supply Chain Ambidexterity and Agility

SC agility is defined as the ability of a supply chain to adjust its tactics and operations quickly [57]. SC agility enables firms to change routines and adapt to changing situations [58]. Within a supply chain, agility practices can be clustered into three levels [59,60]: (1) those that are developed upstream and are directly associated with firm-supplier interactions; (2) those that are employed in day-to-day internal operations; and (3) those that are cascaded downstream, which involve flows between firms and their partners in the process of delivery activities. These practices help organizations respond to environmental uncertainties accurately [61].

Structural ambidexterity [62] is expressed in empirical research models that characterize the interplay between exploration and exploitation research models [63–66]. Exploration looks for novel practices and employs searching, innovating, and risk-taking, whereas exploitation deals with improving and implementing efficient practices [67]. While exploration focuses on success in the long-term, exploitation emphasizes the achievement of short-term outcomes [68]. A simultaneous adoption of these practices will ensure that businesses succeed in ever-changing market situations [67,69].

Ambidextrous organizations can quickly adapt their strategies to address current market scenarios and environmental conditions to sustain them into the future [70]. Businesses are now increasingly adopting ambidextrous strategies to explore opportunities and exploit current resources for competitive advantages [71]. More recently, ambidexterity has been extended to supply chains [63–65,71–73].

The concepts of exploration and exploitation in the supply chain are likened to those in the strategy literature. On one hand, SC exploitation focuses on strengthening relationships with existing suppliers, sourcing solutions using available resources, and maximizing extant SC technologies. SC exploration searches for solutions that are anchored on new approaches and seeks to find novel ways of meeting customer needs [65,74].

An agile supply chain possesses internal capabilities to cope with market instability by adapting its operations quickly. This quick adaptation may be enabled by the ambidextrous supply chain that continuously exploits current resources and explores new opportunities or innovations to sustain firm performance. Based on this substantiation, in the context of the supply chain, we can formulate our first hypothesis:

Hypothesis 1 (H1). *SC ambidexterity positively affects SC agility.*

3.2. Positive Association between Supply Chain Agility and Maturity

We approach the association between supply chain agility and maturity by using four tenets of maturity proposed by Frederico et al. [46] that incorporate: (1) managerial and capability supporters; (2) technology; (3) process performance; and (4) strategic outcomes.

Managerial and capability supporters form the foundation of the SC4.0 strategy to support technology and include leadership support, HR and organizational skills, and coordination [46]. Leadership mediates supply chain and performance [75] and directly affects coordination through SC integration to gain competitive advantage, which is enabled by the agility of the supply chain [76]. SC integration positively affects SC agility and organizational flexibility [77].

Most of the literature has focused on implementing new and emerging technologies to enable agility [78]. Schönsleben [79] stated that agile companies that are enabled to optimize broad IT implementation systems compete within the framework of enhanced knowledge and competencies. In addition, IT integration has a positive impact on supply chain agility [60,80,81]. Christopher [82] further demonstrated that agility necessitates

the implementation of digitization processes and that agile supply chains are inherently digitally enabled SC strategies. Previous literature suggests that IT has transformed supply chains so that they reap a multitude of benefits, ranging from efficient coordination and responsiveness to competitiveness [83–89].

Agile supply chains can manage interdependencies and partnerships [78,82], and consequently, information sharing among partners supports agile supply chains [90]. Kim and Chai [91] showed that there was a positive relationship between information sharing, strategic sourcing, supplier innovation, and agile supply chains. Bovel and Martha [92] also stated that collaboration differentiates companies that adopt best practices in SC management. To adapt SC4.0, supply chains must be highly flexible to quickly reconfigure when there is a change in the business environment [93,94].

Strategic outcomes are the effects of customer and supplier focus, cost reduction, profitability, and strategies [46]. An important foundation of numerous supply chain initiatives has been the direct involvement of customers and suppliers in deciding on the management of resources through scheduling and vendor-managed inventory practices in order to improve agility [78]. Furthermore, effective inventory management and production planning are of paramount importance to companies that aim to be agile, while being a primary concern for aspiring agile companies to be cost-efficient [78]. Strategically, agile supply chains directly affect supply chain performance [90], and agility translates into multifarious strategic business objectives [95–99]. Based on the above arguments, we posit that:

Hypothesis 2 (H2). *SC agility positively affects SC4.0 maturity.*

3.3. Positive Association between Supply Chain Ambidexterity and Maturity

This aspect is the foundation of the SC4.0 strategy that supports technology and includes leadership support, HR and organizational skills, and coordination. Transformational leaders support building ambidextrous supply chains and organizational learning [100], and organizational ambidexterity is closely related to supply chain integration and organizational flexibility [77].

Technology adoption and IT infrastructure significantly contribute to the development of SC4.0 [46]. This technological development in SC4.0 requires innovation that is enabled by an ambidextrous inclination to penetrate new markets or improve current product lines [101,102]. For example, digital exploitation and integration influence business processes, products, and supply chains [103–105]. Ambidexterity has also enhanced digital technology applications in companies by employing big data to speed up some activities [106], or integrating social media data into the IT infrastructure to complement knowledge exploration and exploitation [107].

Several factors lead to supply chain improvements. Kristal et al. [65] found that ambidextrous supply chain strategies are consistent with competitive capabilities and increased supply chain performances, contradicting traditional beliefs that argue for exploration and exploitation trade-offs. Their investigation revealed that supply chain managers aspire to achieve efficient operations while simultaneously searching for opportunities to seize operational advantages. This is aligned with the complementarity view. Other studies have also shed light on the impacts of an ambidextrous supply chain on supply chain performance [73,74,108].

Blome et al. [63] pointed out the positive relationship between the ambidextrous administration of buyer–supplier transactions and highlighted the critical effect of organizational ambidexterity on innovation performance. Supply chain integration between suppliers and buyers has a significant positive effect on supplier performance [109]. Ambidextrous supply chains can manage alignment and adaptability simultaneously [71], leading to long-term competitive advantages [70,101,110,111]. Ambidextrous supply chains are positively associated with firm performance [72], which confirms that ambidextrous organizations promote firm performance [65,74,101,110], and therefore, we postulate that:

Hypothesis 3 (H3). *SC ambidexterity positively affects SC4.0 maturity.*

3.4. Moderating Roles of Organization Culture

The changes brought about by Industry 4.0 technologies have introduced new opportunities and challenges for most enterprises. Supply chain digitization offers many affordances to address these challenges and empowers firms to claim their stake in an ever-changing market environment. Enhanced customer service, integrated supplier–partner relationships, improved sales, and robust business development are often dependent on the values, ethos, and culture of organizations in embracing digital transformation [112].

Organizational culture is hereby defined by Detert et al. (p. 851) [113] as "the combination of artifacts, . . . values, and beliefs, and underlying assumptions that organizational members share about appropriate behavior". In facing the disruption from digital transformation, successful organizations need to innovate. Driven by their combination of value and beliefs in their organizations, they often innovate toward both externally-oriented focus and flexibility-oriented focus, indicated by the 'adhocracy' quadrant in Cameron and Quinn's work [114].

Exploration and exploitation are distinct modes of innovation characterized by contradictory features and are driven by different behaviors [67,115]. Although many models present exploration and exploitation innovation in a linear and sequential order, both occur extemporaneously and therefore cannot be easily separated; the organization culture has been found to be an important factor that determines whether a firm is more inclined to explore innovation or exploitation innovation [116,117].

Agility requires innovation. Organizations that implement traditional supply chain practices can transform themselves into agile, customer-focused, and demand-responsive organizations by applying emergent digital technologies [28], dispelling opaqueness in operations, decreasing costs and delivery times, and optimizing efficiency [28,118]. Recent research has demonstrated that organization culture has become a critical part of this digital transformation, which acts as a precursor of operational efficiency [119]. These organizations, supported by the right culture, were reported to have been able to utilize IoT and data analytics, in order to reduce slack resources and improve efficiency within an overall business process optimization standard [120,121]. Considering these facts, we therefore posit our final hypotheses:

Hypothesis 4 (H4). *Organization culture (flexibility-oriented focus) positively moderates the relationships between (a) SC ambidexterity and SC agility and (b) SC ambidexterity and SC4.0 maturity.*

Hypothesis 5 (H5). *Organization culture (externally-oriented focus) positively moderates the relationships between (a) SC ambidexterity and SC agility and (b) SC ambidexterity and SC4.0 maturity.*

Figure 1 depicts the theoretical model framework on the previous literature. This study tested this model using 154 company data and analyzed it using the structural equation model. The methodology for the testing is detailed in Section 4.

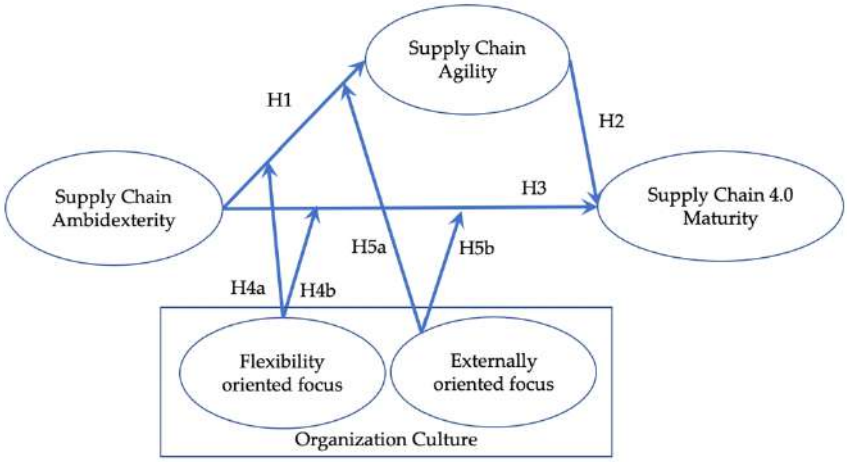

Figure 1. Theoretical model.

4. Methodology

Our intention was to examine the relationships between SC ambidexterity, SC agility, and SC4.0 maturity and investigate the effects of organization culture on these relationships. To achieve this objective, we designed the research as follows.

4.1. Sample and Data Collection

We conducted an online survey with manufacturing companies in Indonesia. As there is no specific directory of manufacturing companies in Indonesia, coupled with the difficulties in accessing respondents directly due to the pandemic, we employed a convenience sampling method by contacting colleagues who worked at manufacturing companies. Our respondents were business owners and staff at various levels including directors, managers, and supervisors, especially those in charge of the SC design and execution at the companies. The companies were selected due to the fact that they had implemented some Industry 4.0 technologies to manage their supply chain activities, although the depth of application and the breadth of technologies was not a critical determinant.

We carried out our investigation in the context of Indonesia because of its geographical position within the south east region. The country is considered a newly industrialized economy: an economy with a significant growth rate that exceeds those of developed countries [122], in terms of global value chains [13]. With the fourth largest population in the world, the manufacturing sector is important for the country's economic development. It consistently contributed 20–22% of the GDP in Indonesia from 2010 to 2020 [122], and this figure is on par with those of China (26% in 2020), South Korea (25%), Germany (18%), and Singapore (21%).

4.2. Profile of Respondents

We gathered 200 responses during the survey, of which 46 were incomplete, resulting in 154 valid responses. Most of our respondents were experienced, with the majority having working experience between three and 15 years. In terms of their position in their company, 22.7% were owners of the companies, 70.1% were directors or managers at various levels, and the rest were staff and supervisors. The majority of the companies were privately owned and joint ventures (74.1%), whilst the minority was foundations (3.2%). The sizes of the company were reasonably balanced. Table 1 summarizes the characteristics of the respondents and their companies.

Table 1. Profiles of the respondents and companies.

Profiles	Frequency	Percentage
Occupation		
Owner	35	22.7%
Director/equivalent	36	23.4%
Senior manager/general manager/equivalent	36	23.4%
Manager/equivalent	36	23.4%
Supervisor	7	4.5%
Staff	4	2.6%
Work experience		
<3 years	18	11.7%
3–5 years	35	22.7%
5–10 years	46	29.9%
10–15 years	26	16.9%
≥15 years	29	18.8%
Firm ownership		
State-owned enterprise	14	9.1%
Private company	54	35.1%
Joint venture	60	39.0%
Foreign investment	21	13.6%
Foundation	5	3.2%
Firm size		
10–49	33	21.4%
50–99	8	5.2%
100–249	17	11.0%
250–499	17	11.0%
500–999	21	13.6%
1000–4999	41	26.6%
>5000	17	11.0%

4.3. Measures

We used measures from previous studies to ensure reliable psychometric properties and tested the instrument using data gathered from the pre-test stage.

Four concepts were used to formulate the model: SC ambidexterity (SAM), SC agility (SAG), SC4.0 maturity (MAT), and organization culture (OC). The instruments to measure SAM were obtained from Kristal et al. [65], who assessed the capability of a firm to explore and exploit its current and potential resources and competencies. SAM consists of SC exploitation (four items) and SC exploration (four items). SAG measures were derived from Blome et al. [63], and there were five items used to measure the capability to respond to environmental changes. The measures of OC were adopted from Yunus and Tadisina [123], who measured the extent of flexibility-control (OC-A) and external–internal orientations (OC-B) of a firm using five items. All items were assessed using a five-point Likert scale. Following Frederico et al. [46], we phrased the indicators of MAT as four-level statements. During the pre-test, we gathered feedback from 37 participants as a face validity check and refined the instrument.

4.4. Data Analysis

The survey commenced with a pre-test to revise the instrument and proceeded with a full survey. The instrument was developed using a web-based questionnaire including the demographics of the firm and basic profiles of the respondents, and the items measuring all dimensions of each construct.

After two weeks, 37 data points were obtained from the instrument pre-test. We assessed the validity and reliability of the data as well as the feedback from the initial

participants regarding wording and meaning. As the inputs from the participants were minor (such as typos or missing words), the instruments were refined and used in the next step.

The full survey was conducted in July 2021 and lasted approximately one month, and 117 more data points were gathered. We pooled all the data because the 37 data points from the pre-test contained exactly the same information without any reduction. We further analyzed 154 data using structural equation modeling with the Lavaan R syntax on JASP 0.14.1 (Prof. Eric-Jan Wagenmakers, Amsterdam, The Netherlands).

5. Results

Following Anderson and Gerbing [124], we performed a two-step test to guarantee that the instrument had suitable psychometric properties in order to test the hypotheses. An interpretation of the results is provided below.

5.1. Instrument Evaluation

Before instrument evaluation, we checked the normality and multicollinearity assumptions. The skewness and kurtosis were below the threshold suggested by Kline [125] (i.e., the skewness for each variable was below 3.0 (range: −1.90 to 0.15), whereas the kurtosis was below 10.0 (range: −0.99 to 7.21)). The data closely followed the diagonal lines in the Q–Q plot, indicating a normal distribution. Tolerance and variance inflation factor (VIF) statistics were employed for multicollinearity. The data showed a tolerance of 0.307–0.663 and VIF of 1.509–2.699 for all variables. As the tolerance was above 0.20 and VIF was below 4.0 [126], we concluded that multicollinearity was not an issue.

In order to reduce common method bias, Harman's single factor test suggested by Podsakoff et al. [127] was conducted. Exploratory factor analysis (EFA) was used to check the extent of variance explained by the data. The EFA for all items resulted in seven underlying factors and could explain 66.23% of the variance in the data. Of the total, merely 14.26% of the variance was explained by the first factor after rotation. As the first factor was not a major factor, we could conclude that common method bias was not an issue in this study.

We employed confirmatory factor analysis (CFA) for the SAM, SAG, and OC. Table 2 presents the goodness-of-fit results (χ^2/df ratio, CFI, GFI, NFI, NNFI, and RMSEA). A few items were deleted due to their unidimensionality. The goodness-of-fit indices exceeded 0.90, and RMSEA was less than 0.08 [128]. All values exceeded the thresholds (i.e., 0.50 for loading to indicate validity and 0.70 for Cronbach's alpha to indicate reliability—see Appendix A, Tables A1–A4).

Table 2. Summary of goodness-of-fit for CFA.

	χ^2	df	χ^2/df	CFI	TLI	NFI	NNFI	RMSEA
SAM	25.14	13	1.9	0.981	0.970	0.963	0.970	0.0779
SAG	3.46	5	0.7	1.000	1.006	0.993	1.006	0.0000
OC	62.34	34	1.8	0.931	0.908	0.863	0.908	0.0736

Furthermore, we performed the EFA for MAT. The correlation analysis between MAT items showed that all items were significantly correlated (Pearson's r of 0.204–0.761), providing a sufficient basis for a subsequent adequacy test [126]. The Bartlett test revealed significance ($p < 0.000$), indicating that the data did not produce an identity matrix, whereas the Kaiser–Meyer–Olkin (KMO) statistic was 0.901, which is considered excellent [129]. The EFA suggested four factors; however, some items were loaded onto different factors from those predicted. To ensure adequate psychometric properties, we confirmed the results using CFA.

The CFA produced a good fit based on various measures (CFI = 0.981, TLI = 0.970, NFI = 0.953, NNFI = 0.969, and RMSEA = 0.065), and the item loadings were above

0.50, indicating unidimensionality [124]. Four items were deleted due to poor loading. The reliability for the overall SC4.0 maturity construct was excellent, with Cronbach's alpha = 0.930 [126]. The item loading and variable reliability are shown in Appendix A.

5.2. Hypotheses Testing

We conjectured that SAM would have significant and positive relationships with SAG and MAT and investigated the moderating role of OC in strengthening the positive relationships between SAM and SAG and between SAM and MAT.

The data were tested using path analysis with JASP 0.14.1. The full model showed a good fit, where $\chi^2(346) = 420.124$; $\chi^2/df = 1.214$; CFI = 0.970; TLI = 0.965; NNFI = 0.095; RMSEA = 0.037. Figure 2 presents the model and some results.

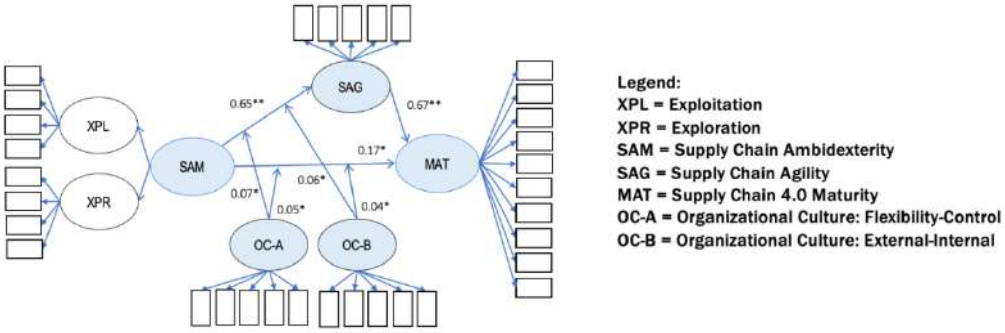

Figure 2. Results of hypothesis testing (* significant at $p < 0.05$, ** significant at $p < 0.01$).

As can be seen from Table 3, the first hypothesis predicted a positive influence of SAM on SAG. The relationship was positive and significant, supporting H1. The relationships between SAM and MAT, and between SAG and MAT, were also significant, supporting H2 and H3, respectively.

Table 3. Correlation analysis.

Path	β [+]	*p*-Value	Conclusion
SAM → SAG	0.6543	0.0000	H1 is supported
SAM → MAT	0.1645	0.0357	H2 is supported
SAG → MAT	0.6692	0.0000	H3 is supported
SAM → SAG → MAT	0.2695	0.0000	(Test of mediation)
OC-A x SAM → SAG	0.0672	0.0238	H4a is supported
OC-B x SAM → SAG	0.0587	0.0238	H4b is supported
OC-A x SAM → MAT	0.0422	0.0238	H5a is supported
OC-B x SAM → MAT	0.0368	0.0238	H5b is supported

[+] Standardized parameter estimates were reported.

We also tested the possibility that SAG fully mediates SAM and MAT. Both the direct and indirect paths between SAM and MAT were significant, indicating that SAG partially mediates this relationship. Finally, we tested the moderating effects of organization culture on the relationships between SAM and SAG and between SAM and MAT. Because the organization culture has two dimensions (OC-A and OC-B), and this study had distinct hypotheses for each one, we tested their moderating effects separately. The first moderating variable was flexibility (OC-A), measured by a continuum of 1 = controlled to 5 = flexible, and its effect on the path between SAM and SAG was significant. The second variable was external (OC-B) (a continuum of 1 = internal orientation to 5 = external orientation), and its effect on the same path was significant. A similar procedure was performed for the path from SAM to MAT, again revealing significance. These results fully support H4 and H5, as shown in Table 3.

6. Discussion

We were intrigued by the fact that our data fully supported our postulation that companies should continuously develop their SC ambidexterity, as this has a positive correlation with SC4.0 maturity. Nonetheless, SC agility mediates this correlation. In the following sections, we will discuss the implications of our findings on the performance of supply chains, the mediating roles of agility, and the moderating roles of organizational culture, on the maturity of SC4.0.

6.1. SC4.0 Maturity as the Driver for SC Performance

Current literature on SC4.0 maturity mostly discusses its conceptual framework [46,130,131]. This paper is pioneering the empirical study on SC4.0 and offers ways on how to achieve SC4.0 maturity through SC ambidexterity and SC agility, particularly in the context of developing countries whose financial and human resources are considerably limited compared to those of developing countries.

Since the term Industry 4.0 was coined in 2011, research related to this SC4.0 initiative has flourished significantly [7]. Although disruptive, Industry 4.0 initiatives have driven companies to be more competitive by producing more flexible, customized, and efficient products and services. One issue in this landscape is how companies manage and integrate their supply chains with their key partners. Frederico et al. [46] suggested using the SC4.0 maturity to measure the levels of integration of Industry 4.0 technologies in the supply chain context. By examining the SC ambidexterity and SC agility, we were able to determine one contingent factor that could enhance the relationship between those determinants and the level of company maturity.

The supply chains in which the Indonesian companies in our research operated did experience a high level of uncertainty [132] due to the geographical setting, which was exacerbated by infrastructures that were less developed. They were, however, mindful that the uncertainty may be reduced by increased agility, adaptability, and level of integration along the supply chain from the supplier, manufacturer, and retailer [77,133]. SC4.0 will help supply chains to mitigate the uncertainties [134] and enable seamless integration (e.g., for the purpose of ensuring any orders and designs for the manufacturer can be rapidly produced and delivered). This has demonstrated the strong influence Industry 4.0 has on supply chain integration. In line with Tseng et al. [135], the companies in our research, to a certain extent, have adopted these technologies to drive high-level integration in their supply chain, which in turn drives better and stronger supply chain performance.

6.2. SC4.0 Maturity and Growth

Indonesia has a large market but is still behind in the implementation of Industry 4.0 [136]; however, the government of Indonesia expects to leverage the impact of Industry 4.0. If Indonesia can accelerate the adoption of these technologies by the supply chains, then the country can reap the benefits from their implementation, which may include the ability to create higher efficiency, reduce production time and cost, minimize human errors, and improve product quality and accuracy. For instance, the optimization of supply chains, which involves many intermediaries, by using blockchain technology, offers significant benefits to agro-industry supply chains, thanks to its ability to store data and information, thus making transactions more transparent, reliable, and secure [137]. It is envisaged that Industry 4.0 technologies benefit both large corporations and small- and medium-sized enterprises, and in line with the work of Dossou [36], we found that those Indonesian companies who were able to adapt the digital technologies were able to continue the momentum to accelerate company growth.

6.3. The Importance of Culture to SC 4.0 Maturity for Indonesian Companies

Culture has been found to be an important factor for Indonesian companies as they are moving from an internal and rigid culture to a more external (outward facing) and flexible culture. Although Indonesians tend to emphasize collective well-being and show a

strong humane orientation within their society, our data demonstrated that the adoption of Industry 4.0 in the SC could be successful if the organizations possessed a culture that was assertive and paid attention to maintaining harmony [138,139].

An entrepreneurial-like culture (i.e., externally oriented, flexible, proactive—also referred to as an open culture) and one that is long-term oriented, had been exhibited by the successful Indonesian firms in our research. This seems to be unusual, as the majority of Indonesian firms tend to adopt a paternalistic and founder culture, which does not have a positive effect on the firms' innovation performance. An inward focusing culture usually impedes innovation, but an outward focusing or externally-oriented culture does have a positive effect on the firms' innovation performance [140].

Going forward, we postulated that companies continually need various mechanisms to encourage and foster an innovative culture in the organizations. These mechanisms are likely to facilitate the introduction, adoption, and diffusion of innovations, which, in turn, will result in the achievement of superior firm performance [141].

6.4. Agility, Ambidexterity, and Open Innovation

This study confirms that agile and ambidextrous capabilities are pertinent to maturing the digitalization of the supply chain. This finding is aligned with the studies by Puriwat and Tripopsakul [52] and Del Giudice et al. [48]. Del Giudice et al. [48] found that three organizational capabilities, namely "agility, adaptation, and ambidexterity", influenced digital innovation. In our study, adaptation capability is represented by dimensions of organizational culture: the company's flexibility orientation and external focus.

Interestingly, prior literature (e.g., [49,54,55]) found that open innovation practices significantly increased the company's ambidextrous capability. The finding proves that open innovation also serves as an enabler of company ambidexterity. Therefore, as companies are more open to collaborating with their supply chain partners, they might engage in joint innovation projects and build ambidexterity, further enhancing supply chain digitalization. Through our study, the relationship between ambidexterity in the supply chain and the maturity of supply chain digitalization was empirically tested. The current study also emphasizes the importance of having the right culture to foster open innovation dynamics (as argued by Yun et al. [142]), hence the SC4.0 maturity.

Furthermore, open innovation practices improve companies' capabilities in ambidexterity and agility. As the business environment demands, the current study confirmed the statement by Hizam-Hanafiah et al. [47] that companies further innovate by digitalizing their supply chain. As such, this study responds to Solaimani and van der Veen's [56] call for research on open innovation in the supply chain context.

7. Conclusions and Future Work

Our research demonstrated that SC4.0 implementation requires innovation that originates from SC ambidexterity and the ability to quickly adapt to market changes while a flexible and external looking culture will be an advantage. We investigated the effect of SC ambidexterity, SC agility, and organization culture moderation influencing SC4.0 maturity. SC agility and ambidexterity can be options for developing countries in response to SC4.0.

The Industry 4.0 technologies impacting supply chains have been listed by Tjahjono et al. [6]. Although, generally speaking, developing countries shall continue to catch up with technological advancements as they are part of the global supply chain, the technologies alone may not necessarily be applicable to developing countries due to their financial constraints. Developing countries, therefore, need to be selective in adopting the right technologies as Industry 4.0 technologies are not always feasible where human labor is not easy to replace. Task substitution is often challenging to perform, especially in developing countries [143].

We empirically showed that SC ambidexterity has a significant and positive effect on SC4.0 maturity and also has a significant and positive effect on SC agility, in agreement with previous studies by Aslam et al. [71] and Tuan [144]. Our research also confirmed that SC agility had a significant and positive effect on SC4.0 maturity and that SC agility positively

and significantly mediated the relationship between SC ambidexterity and SC4.0 maturity. Our research thus shows that SC ambidexterity and SC agility are positive antecedents of SC4.0 maturity.

We derived the SC4.0 maturity level introduced by Frederico et al. [46] using managerial and capability supporters, technological developments, process performance, and strategic outcomes; we introduced indicators based on those constructs, as shown in Appendix A and hypothesized the relationships between SC ambidexterity and these concepts.

7.1. Theoretical Implications

The current literature reports that the survival of organizational units is enhanced by simultaneous exploration and exploitation strategies [145]. Our research confirmed this conclusion by determining the effect that occurs in supply chains through the positive impacts of these practices on SC4.0 maturity and SC agility. This finding is especially important, and no prior studies have linked SC ambidexterity and SC agility to SC4.0 maturity. We empirically demonstrated that high levels of SC ambidexterity and SC agility also expedite the achievement of SC4.0 maturity to support the implementation of Industry 4.0 technologies.

This research further confirms that the flexibility-oriented and externally-focused organization culture positively moderates the relationship between SC ambidexterity and SC agility. Companies with flexible orientations are generally more responsive to change and are more willing to take risks to achieve their goals. These companies will better utilize their capabilities and resources to increase their agility and, in turn, competitive advantage. The extant literature, unfortunately, does not offer a clear indicator related to SC4.0 maturity. Even if they did, the majority of them explained the supply chain maturity solely from its technological ramifications. Our paper focused on operationalizing the indicators of SC4.0 maturity by Frederico et al. [46] and extended their work by empirically elaborating the indicators and antecedents of SC4.0 maturity, and 'joins in' the discourse with other research work such as that of Shao [146] and Büyüközkan and Göçer [28].

7.2. Practical Implications

Companies must also have an external focus on leveraging their capabilities to exploit and explore their resources. As SC ambidexterity positively influences SC agility, companies aiming to collaborate with external partners will perform better than those focusing on internal partners. As demonstrated by Büyüközkan and Göçer [28], our research also confirms that companies with outward-looking and various external networks do accelerate their capabilities toward SC4.0 maturity.

Regarding managerial implications, there are currently volatile circumstances regarding Industry 4.0 and digital technology. These have urged manufacturing firms to pay more attention to SC4.0 to remain competitive. Although firms must understand SC4.0 maturity and learn how to achieve it, it is also important for them to develop flexibility and external focus. Our research confirms that the stronger the organization culture, the greater the possibility of achieving high SC4.0 maturity. Managers can benefit from this research by developing the ability to work in an ambidextrous environment, becoming agile, and utilizing the final structural model as guidance.

Given the high costs of becoming a fully mature SC4.0 in developing countries, supply chain professionals should be able to continuously improve their ambidexterity and agility. In terms of ambidexterity, they should continuously leverage their existing supply chain technologies and focus on developing current competencies to remain efficient. In addition, supply chain professionals should also experiment to obtain new solutions that use relevant but economically justified SC4.0 technologies for developing countries. In terms of agility, supply chain professionals should be aware that SC4.0 is highly dependent on the readiness of their workforce [147] to shift toward an agile workforce, who is attuned with the SC4.0 processes implemented. This agile workforce must be able to quickly adapt their supply chain performance because of technological advancements that will impact their key supply

chain processes. In terms of SC4.0 maturity, SC professionals must make sure that SC4.0 is an integral part of their corporate strategic direction to extend the benefit from SC4.0 initiatives, from the supplier to customers, leadership, organization development, and employee competencies to support the implementation of SC4.0. It is also important for supply chain professionals to identify and prioritize relevant and the most cost–benefit technologies to support SC4.0, particularly in developing countries. Because the application of SC4.0 is costly, SC professionals must make sure that SC4.0 will be part of corporate strategic outcomes to enhance their competitive advantages.

7.3. Limitations and Future Research

Although our research is considered among the first to empirically examine the antecedents of SC4.0 maturity (i.e., SC ambidexterity and SC agility), surpassing all previous conceptual works in this field, we did not delve into the details of Industry 4.0 technologies being used by our sample companies. We presumed that the maturity of SC4.0 operations could be largely inferred by the parameters given by Frederico et al. [46]. Future studies should therefore include a larger sample size and a wider range of technologies within Industry 4.0 suites, investigated perhaps using case studies, in order to better elucidate how our findings will help supply chains make a more effective use of these technologies. Future research may also look into the interplay between exploration and exploitation practices.

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Appendix A

Table A1. SC ambidexterity—Item loading and variable reliability.

Dimension (Source)	Indicator	Estimate		Cronbach's Alpha
Exploitation (Kristal et al. [65])	AMBI2	In order to stay competitive, our supply chain managers focus on improving our existing technologies.	deleted	0.857
	AMBI3	Leveraging our current supply chain technologies is important to our firm's strategy.	0.6512	
	AMBI4	Our managers focus on developing strong competencies in our existing supply chain processes.	0.6816	
	AMBI6	We continually experiment to find new solutions that will improve our supply chain.	0.6258	
Exploration (Kristal et al. [65])	AMBI1	In order to stay competitive, our supply chain (distributor) managers focus on reducing operations.	0.5262	0.883
	AMBI5	We proactively pursue new supply chain solutions.	0.7125	
	AMBI7	To improve our supply chain, we continually explore new opportunities.	0.5240	
	AMBI8	We are constantly seeking novel approaches in order to solve supply chain problems.	0.5903	

Table A2. SC agility—Item loading and variable reliability.

Dimension (Source)	Indicator	Estimate		Cronbach's Alpha
Agility (Blome et al. [63])	AGI1	We are able to adapt our services and/or products sufficiently fast to new customer requirements.	0.6363	0.908
	AGI2	We are able to react sufficiently fast to new market developments.	0.7474	
	AGI3	We are able to react to significant increases and decreases in demand as fast as required by the market.	0.6614	
	AGI4	We are always able to adjust our product portfolio as fast as required by the market.	0.6713	
	AGI5	We are able to react adequately fast to supply-side changes, e.g., compensate for spontaneous supplier outages, delivery failures, market shortages.	0.7322	

Table A3. Organization culture—Item loading and variable reliability.

Dimension	Indicator	Estimate		Cronbach's Alpha
Flexibility-Control (Yunus and Tadisina [123])	OC1	(a) The glue that holds our organization together is formal rules and policies. Following rules is important.	0.5160	0.786
		(b) The glue that holds our organization together is commitment to innovation and development. There is an emphasis on being first with products and services.		
	OC2	(a) Our organization emphasizes permanence and stability. Efficiency is important.	0.5988	
		(b) Our organization is a very dynamic and entrepreneurial place. People are willing to stick their necks out and take risks.		
	OC3	(a) Our organization is a very controlled and structured place. Formal procedures generally govern what people do.	0.7307	
		(b) Our organization emphasizes growth through developing new ideas. Generating new products or services is important.		
	OC4	(a) The leadership in the organization is generally considered to exemplify coordinating, organizing, or smooth-running efficiency.	0.5917	
		(b) The leadership in the organization is generally considered to exemplify entrepreneurship, innovating, or risk taking.		
	OC5	(a) The management style in the organization is characterized by the security of employment, predictability, and stability in relationships.	0.7410	
		(b) The management style in the organization is characterized by risk-taking, innovation, freedom, and uniqueness.		

Table A3. *Cont.*

Dimension	Indicator	Estimate		Cronbach's Alpha
External-Internal (Yunus and Tadisina [123])	OC6	(a) The organization is very personal place. It is like an extended family. People seem to share a lot of themselves.		0.733
		(b) The organization is very results oriented. A major concern is getting the job done. People are very competitive and achievement oriented.	0.5956	
	OC7	(a) The organization defines success on the basis of the development of human resources, teamwork, employee commitment, and concern for people.		
		(b) The organization defines success on the basis of winning in the marketplace and outpacing the competition. Competitive market leadership is key.	0.6383	
	OC8	(a) The glue that holds the organization together is loyalty. Commitment to this organization runs high.		
		(b) The glue that holds the organization together is the emphasis on achievement and goal accomplishment. Aggressiveness and winning are common themes.	0.5744	
	OC9	(a) The leadership in the organization is generally considered to exemplify mentoring, facilitating, or nurturing.		
		(b) The leadership in the organization is generally considered to exemplify a no-nonsense, aggressive, results-oriented focus.	0.6724	
	OC10	(a) The management style in the organization is characterized by consensus.		
		(b) The management style in the organization is characterized by partnerships and achievement in the market.	0.4984	

Table A4. SC4.0 maturity—Item loading and variable reliability.

Dimension (Source)	Indicator	Estimate		Cronbach's Alpha
Strategic Outcomes (Frederico et al. [46])	MAT1	The extent of cost reduction because of more efficient suppliers.	deleted	0.930
	MAT2	The extent of benefit experienced by customers and suppliers from digital supply chain initiatives.	0.5897	
	MAT3	The extent of added value and competitive advantage of the company from digital supply chain initiatives.	0.6339	
Technological Advance-ments (Frederico et al. [46])	MAT4	How good is measurement, transparency, and process integration to prevent from disruption in production planning and process?	deleted	
	MAT9	The extent to which the application of technology provides benefits to the supply chain process.	0.5867	
	MAT10	The extent to which digital supply chain is a priority of the company's strategy.	0.6711	
	MAT11	The extent of information technology infrastructure support in digital supply chain initiative.	0.5924	

Table A4. *Cont.*

Dimension (Source)	Indicator	Estimate	Cronbach's Alpha
Processes Performance (Frederico et al. [46])	MAT5	How good is the collaboration with supply chain partners?	deleted
	MAT6	The extent of responsiveness and flexibility.	0.5924
	MAT7	The level of waste in the supply chain process.	deleted
	MAT8	The strength of the relationship between systems, machines, and people.	0.5544
Managerial Capability (Frederico et al. [46])	MAT12	The support of the company leadership in digital supply chain initiatives.	0.6297
	MAT13	The extent to which organizational development and employee competence can support the implementation of digital supply chain.	0.6880
	MAT14	The strength of the coordination between all supply chain partners.	0.5541

Notes

[1] Available online: https://datareportal.com/reports/digital-2021-indonesia (accessed on 20 March 2022).

[2] Available online: https://www.statista.com/statistics/1235476/indonesia-e-commerce-growth-rate/#statisticContainer (accessed on 20 March 2022).

[3] Available online: https://www.investindonesia.go.id/en/why-invest/indonesia-economic-update/making-indonesia-4.0-indonesias-strategy-to-enter-the-4th-generation-of-ind (accessed on 20 March 2022).

[4] Available online: https://www.kearney.com/operations-performance-transformation/indonesia-4.0-the-transformation-opportunity (accessed on 20 March 2022).

[5] Available online: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf (accessed on 20 March 2022).

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