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Article

The Relationship between Supply Chain Resilience and Digital Supply Chain on Sustainability, Supply Chain Dynamism as a Moderator

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Abstract: This research aims to explore the complex interplay between supply chain resilience (SCR), digital supply chain (DSC), and sustainability, focusing on the moderating influence of supply chain dynamism. The goal is to understand how these elements interact within the framework of contemporary supply chain management and how they collectively contribute to enhancing sustainability outcomes. The sample size is 300 CEOs and managers. The study approach integrates quantitative research methods. Structural equation modeling (SEM) is utilized to quantitatively analyze the direct and indirect effects of SCR and DSC on sustainability. The numerous surveys we conduct among supply chain ecosystem stakeholders provide a rich picture of practical implications and contextual nuances. In sum, our early findings generally support a positive relationship between SCR and sustainability in and of itself decrying the need for more resilient supply networks for sustainability. We further find the beneficial impact of digital technologies in promoting sustainability via enhancing environmental control and controlling for efficiency in supply chains. We also offer evidence to show that supply chain dynamism compounds the positive logic between SCR and DSC and sustainability. As a final word, it must be noted that our work speaks to the burgeoning Supply Chain Dynamism as moderator literature by examining the direct and contingent effects of SCR and DSC on not only performance but sustainability. By shedding light on the moderating role of dynamism, the study provides fresh insights into the multifaceted nature of supply chain management and sustainability practices. The study's findings enhance theoretical understanding by elucidating the synergistic effects of SCR, DSC, and sustainability in dynamic supply chain settings. It augments existing theoretical frameworks by integrating concepts of resilience, digitalization, and sustainability into a comprehensive model. Practical and economical, the research offers actionable guidance for organizations aiming to improve sustainability performance through resilient and digitally advanced supply chains. By acknowledging the role of supply chain dynamism, managers can tailor strategies to manage disruptions effectively and leverage digital innovations. Economically, adopting sustainable practices can result in cost savings and competitive advantages. The research emphasizes the importance of aligning supply chain strategies with sustainability goals to drive long-term value and societal impact.

Keywords: supply chain resilience; digital supply chain; supply chain sustainability; supply chain dynamism

1. Introduction

In the fast-evolving world of digital supply chains, businesses seek to leverage the latest technology innovations into a more resilient, flexible, and sustainable supply chain that positively

impacts society and the environment [1]. The Guide House Insights report Digital Supply Chain Management highlights the relationship between the increasing global uncertainties we face and the more specific, technological disruptions businesses now experience on what sometimes seems to be an almost everyday basis [2]. Against the backdrop of these challenges, and drawing on the latest academic and industry research into sustainable supply chain management, the report explores the issues and opportunities surrounding supply chain resilience and sustainability [3]. In so doing, the report aims to provide a greater understanding of the potential ramifications for businesses as they confront increasing levels of supply chain disruption and to offer practical recommendations of the strategies and tactics that can be employed in order to develop a more resilient, digitally enabled supply chain that not only can roll with the punches more effectively but can also contribute to a more sustainable future. That means the report will explore and investigate the integration of information technology (IT) and sustainability and the role that digital supply chain management plays in terms of how the supply chain becomes a key focal point for both strategic and operational resilience, and environmental stewardship [4]. Supply chain resilience is operation stability and continuity. To improve upon the fast developments in IT, all stakeholders have to adjust quickly, particularly the manufacturing enterprises, which typically vested their resources totally in human resources, to integrate it into all operations be it purchase of raw material, manufacturing, and distribution, unless they change they cannot stay in a business environment and match with constraints [5], IT streamlines supply chain integration that extends to the supplier's supplier to the customer's customer bringing in many advantages to the organizations [6]. Strong stakeholder integration makes the process efficient [7], IT on many occasions referred to as supply chain digitization, combines departments that accelerate the process [8]. The IT can result in gaining high-quality data, which is one of the major elements for supply chain integration [9].

Information Technology is the base for reaching fast organizations, which is a must for present-day survival. Modern technology in sustainable production systems is a major factor in creating eco-friendly organizations [3]. IT development has also altered company sustainability initiatives [10]. An IoT-based, sustainable supply chain can decrease harmful gaseous air emissions [11]. Industrial technology also enhances environmental performance [12]. Technology-based manufacturing can augment green supply chains due to lower inventories [13] and improved corporate performance. Supply chain resilience and robustness affect firm performance [14] How firms may incorporate both into their supply chains is still not evident. Finally, it is crucial that worldwide initiatives provide evidence as to how digital-enabled technologies are actually making supply chains more resilient [15] by helping incumbent supply chain networks cope with the sorts of protracted disruptions such as that which was caused by an unprecedented pandemic [16]. [17] suggested that digital transformation may indeed be accompanied by an improvement in performance over time. Research is practitioner-based and looks at the successes and failures of organizational digital transformation [18], which faces complex challenges because whilst senior management teams are now prioritizing digital technology as a result of COVID-19 [19], its successful adoption is still to be theorized and realized in practice. Digital technology has been conspicuously absent from the development of theory and practice to account for supply chain resilience greatly concerning, [20] define it as "a supply chain's ability to adjust and respond to minimize the likelihood of disruptions, maintain control over its structure and function, propagate a disruption and quickly recover and respond by having effective backup plans." Digital supply chain resilience is that which can recover from an unplanned disruption and even gain competitive advantages by doing so [21]. Firms are strongly advised to invest in digital capabilities so as to compete when the going gets tough [22].

SCR and DSC are key components that enable organizations to withstand disruptions and leverage technology to improve efficiency and reduce environmental impact. Dynamism, which refers to the ability of supply chains to adapt swiftly to changes, plays a critical role in moderating the relationship between SCR and DSC and their impact on sustainability [5]. By allowing supply chains to respond quickly to market shifts and environmental regulations, dynamism enhances the resilience of supply chains, making them more capable of integrating sustainable practices into their operations [23]. This dynamic nature can lead to continuous improvement in supply chain processes,

resulting in a reduced environmental footprint and a more sustainable business model. In essence, the moderating effect of dynamism on the relationship between SCR, DSC, and sustainability underscores the importance of adaptability in achieving sustainability goals within the supply chain. In this study on the complex interplay between supply chain resilience and digital supply chain on sustainability and supply chain dynamism as a moderator [24]. The Relationship Between Supply Chain Resilience and Digital Supply Chain on Supply Chain Sustainability, Supply Chain Dynamism As a Moderator we investigate how organizations can improve their sustainability through the implementation of Resilience supply chain strategies and integration of digital technologies in their operations. [20] Adopting the OIPT theory, the study has been well positioned and justified for infusing resilience-building policies and digital innovation in their supply chain to manage uncertainties and increase operational agility while supporting environmental and social stewardship. supply chain practitioners and strategists who would like to build a supply chain that is sustainable, agile, and digitally enabled could gain insightful strategies to navigate the ever-dynamic business landscape and advance their sustainability for the long term [25]. Based on the research gaps mentioned above, the following research questions were posed:

RQ1: Is there a relationship between Supply chain Resilience and Digital Supply chain on Supply Chain Sustainability?

RQ2: Does Supply Chain Dynamism affect the relationship between Supply Chain Resilience and Digital Supply Chain in Supply Chain Sustainability?

Literature review

Supply Chain Resilience:

In the fast-evolving world of digital supply chains, businesses are seeking to leverage the latest technology innovations into a more resilient, flexible, and sustainable supply chain that has a positive impact on both society and the environment. [26] report Digital Supply Chain Management highlights the relationship between the increasing global uncertainties we face and the more specific, technological disruptions businesses now experience on what sometimes seems to be an almost everyday basis. Against the backdrop of these challenges, and drawing on the latest academic and industry research into sustainable supply chain management, the report explores the issues and opportunities surrounding supply chain resilience and sustainability [26]. In so doing, the report aims to provide a greater understanding of the potential ramifications for businesses as they confront increasing levels of supply chain disruption and to offer practical recommendations of the strategies and tactics that can be employed in order to develop a more resilient, digitally enabled supply chain that not only can roll with the punches more effectively but can also contribute to a more sustainable future [19]. That means the report will explore and investigate the integration of IT and sustainability and the role that digital supply chain management plays in terms of how the supply chain becomes a key focal point for both strategic and operational resilience, and environmental stewardship [18].

Supply chain resilience is operation stability and continuity. To improve upon the fast developments in IT, all stakeholders have to adjust quickly, particularly the manufacturing enterprises, which typically vested their resources totally in human resources, to integrate it into all operations be it purchase of raw material, manufacturing, or distribution, unless they change they cannot stay in a business environment with constraints [22], IT streamlines supply chain integration that extends to the supplier's supplier to the customer's customer bringing in many advantages to the organizations [20]. Strong stakeholder integration makes the process efficient [27], IT on many occasions referred to as supply chain digitization, combines departments that accelerate the process [28]. Information technology can result in gaining high-quality data, which is one of the major elements for supply chain integration [29]. Information technology is the base for reaching fast organizations, which is a must for present-day survival. Modern technology in sustainable production systems is a major factor in creating eco-friendly organizations [30]. IT development has also altered company sustainability initiatives [10]. An IoT-based, sustainable supply chain can decrease harmful gaseous air emissions [31]. Industrial technology also enhances environmental performance [32]. Technology-based manufacturing can augment green supply chains due to lower inventories [33] and improved corporate performance. Supply chain resilience and robustness affect

firm performance [34]. How firms may incorporate both into their supply chains is still not evident. This is especially crucial after unplanned, devastating events such as a global pandemic [35]. Finally, it is crucial that worldwide initiatives provide evidence as to how digital-enabled technologies are actually making supply chains more resilient [28] by helping incumbent supply chain networks cope with the sorts of protracted disruptions such as that which was caused by an unprecedented pandemic [36] suggest that digital transformation may indeed be accompanied by an improvement in performance over time. Research is practitioner-based and looks at the successes and failures of organizational digital transformation [37], which faces complex challenges because whilst senior management teams are now prioritizing digital technology as a result of COVID-19 [12], its successful adoption of is still to be theorized and realized in practice. Digital technology has been conspicuously absent from the development of theory and practice to account for supply chain resilience greatly concerning [38] who define it as “a supply chain’s ability to adjust and respond to minimize the likelihood of disruptions, maintain control over its structure and function, propagate a disruption and quickly recover and respond by having effective backup plans.” Digital supply chain resilience is that which can recover from an unplanned disruption and even gain competitive advantages by doing so [39]. Indeed, supply chains have benefited from digital technology and become more resilient as a result of its use during the COVID-19 pandemic [40]. Firms are strongly advised to invest in digital capabilities so as to compete when the going gets tough [7]. In this study on the complex interplay between supply chain resilience and digital supply chain on sustainability and supply chain dynamism as a moderator The Relationship Between Supply Chain Resilience and Digital Supply Chain on Sustainability, Supply Chain Dynamism as Moderator we investigate how organizations are able to improve their sustainability through the implementation of the Resilience supply chain strategies and integration of digital technologies in their operations. In adopting the system’s theory and dynamic capabilities theory, the research has been well positioned and justified for the necessity of infusing resilience-building policies and digital innovation in their supply chain to manage uncertainties and increase operational agility while supporting their environmental and social stewardship [3]. Practically, supply chain practitioners and strategists, who would like to build a supply chain that is sustainable, agile and digitally-enabled, could gain insightful strategies to navigate the ever-dynamic business landscape, with the aim of advancing their sustainability for the long term.

Digital Supply Chain:

In line with digitalization, Information Technology (IT) can provide ways for firms to gain a sustainable competitive advantage within their supply chains, by improving specific asset connections, facilitating smoother flows of information, as well as broader and longer-term relationships such as those provided by Supply Chain [21]. Information Technology (IT) may contribute to the improvement of firm performance through its indirect effect on Supply Chain Integration (SCI) as it facilitates more efficient and less manual flows of information [41]. By improving the flow of information, Information Technology (IT) allows for quicker transmission of information in buyer and supplier thought processes thereby reducing lead times [29] might found that firms that utilize internet-based techniques to optimize supply chains would have reduced transaction costs; improved flows of information and ability to respond to demand; and that Information Technology (IT) is likely to involve cooperation among companies in a digitalized rather than a traditional supply chain. It is a material way for a supply chain to become more digitized – thereby giving the chain the ability to see and understand all that is happening in each stage of a supply chain with near real-time data - so that information may be shared among all parts of the chain, quickly and without error [42]. Clear visibility and transparency, as [43] may allow for innovative product and process planning for example that makes it easier for a firm to execute a superior service strategy and to facilitate superior service to customer requirements in all areas of a firm. The digitization of a firm, as [8] suggests may indeed significantly improve a firm's competitive advantage. This process may provide the opportunity for companies to increase revenue, innovate, or move forward to consider cost reduction through operational efficiency as only the third benefit [44]

Supply Chain Dynamism:

Supply networks are becoming more dynamic. Supply chain dynamism is defined as the use of rapid and transformative changes in supply chain processes and commodities within business conditions and technology [5]. Supply chain professionals operating within a dynamic context have to contend with a number of internal and external problems that inhibit their performance, thus necessitating a continuous flow of information [23]. It is possible to gauge the dynamism of supply chains using three indicators [24] earnings from services and products, rate of process innovation, and extent of product innovation. Enterprises must fully appreciate the extent of supply chain dynamics in their efforts to ease performance variations [24]. OIPT is a model intended to circumscribe the extent to which it is possible to share information and manage supply chains on account of the dynamics of supply chains. The dynamism of a supply chain enhances the efficiency of its various components. Another research found that the dynamism of the supply network has a favorable impact on both the resiliency of the supply chain and the digital supply chain [38]. Financial performance was shown to be influenced by the resiliency of supply chains, which was shown to be antecedent to the dynamism of supply chains. The research determined that the relationship between supply chain integration and supply chain performance was influenced by supply chain dynamics [45].

Supply Chain Sustainability:

In response to the demands from consumers and other stakeholders, i.e., social, environmental, and economic outcomes, organizations should deploy supply chain sustainability policies [46]. Organizations are challenged and transformed into different forms by internal and external stakeholders: consumers, suppliers, governments, rivals, pressure groups, and others. Consequently, the ability to adapt to the changes in the environment should be fostered by organizations (in addition to the generation of schemes) [47]. These capabilities, as per [48] are defined as “the capability to both adapt to the external environment as well as to address the changing needs and demands of stakeholders. The dynamic capability view (DCV) focuses on the creation of necessary resources and capabilities, so as to enable organizations to both effectively respond to the underlying causes of change [49,50] and exploit the market conditions characterized by change [51]. Profitability from improved management of sustainability practices may arise for organizations, via the reduction in losses, since supply chain partners’ sustainability requirements are not complied leading to enhanced performance [3]. Effective management of sustainability via governance, and enhancement in performance, are stressed by [4]. Inadequate sustainability practices shared not only by supply chain partners but the entire supply chain, may not occur, resulting from the absence of proper sustainability governance [52]. The concept, structure, and understanding of SCM have developed over time to cater to the changing dynamics of society, over time [53] in the consideration of numerous factors, such as sustainability. Nonetheless, in the subset of SCM literature, various studies do not recognize sustainability as a fundamental part of the supply network reality. Many scholars have argued that the various interpretations of the terms green [53], sustainable” [54], and green and sustainable [55] in the literature, do not comprise changes to the traditional supply chain management paradigm, maybe in the backdrop of the paucity of literature that has taken the effort to formally or informally. Where the well-being of society and the natural environment are intrinsic parts. As per [56], under the green and sustainable supply chain management (SCM) definition, there are several components, which may have originated because of the unc customary way of usage of the term.

Conceptual Model:

OIPT Theory

This study investigates the interplay of Supply Chain Resilience (SCR) and Digital Supply Chain (DSC) with Sustainability (SCS) in the industrial sector [38]. This sector is evolving towards sustainable operations due to increasing environmental worries and production demands. Data-driven projects are envisaged to revolutionize industrial supply chains, reducing ecological costs while becoming more effective and economical. This study starts with the environmental cost of Resilience supply chains, pinpointing the significant issues such as energy consumption, trash

generation, and transportation emissions [57]. Furthermore, the framework elucidates how the aforementioned constituents could change SCR and DSC. The research underscores the utilization of big data analytics (BDA) in inventory management, demand forecasting, and procurement [58]. It discloses how the insightfulness of the data can diminish inventory and waste and minimize supply shortages, leading to conservation and environmentalism. By enhancing the supply chain in company logistics and transportation, artificial intelligence (AI) may lower fuel consumption and carbon emissions and optimize delivery routes [59].

The researchers report that AI can also streamline the process of predictive maintenance, extending the useful life of delicate devices. They believe using Artificial Intelligence (AI) in industrial supply chains improves healthcare delivery and lessens environmental impact. The research was based on Open Innovation and Participatory Theory (OIPT), which suggests that higher levels of job uncertainty cause greater information processing to yield maximum performance [38]. The idea fits Supply Chain Resilience (SCR) extremely well, as uncertainty spikes during supply chain disturbances, OIPT asserts. It suggests that organized, focused, and rational information processing is most helpful in alleviating that uncertainty by enabling fact-based decision-making. An additional finding is that firms can become more innovative by shaping the skills used in open innovation processes through the involvement of external stakeholders. It suggests that by enabling firms to better cope with disruptive events and adapt to changing circumstances, resilient supply chains help firms participate more effectively in open innovation processes. Supply chains tend to be laggards when adopting digital technologies, which slows the advancement of sustainable supply chain practices [60]. That said, supply chain dynamism will moderate this relationship because when critical to this relationship, supply chains with the capacity to adapt to changes in the business environment are more likely to participate and tend to have technologies that enable it [61]. The dynamic nature of supply chain processes can help to further sustainability by helping firms continuously improve, reducing their environmental impact. Thus, the OIPT framework can help to explain how supply chain resilience, digital supply chain technology, and sustainability are related, using supply chain dynamism as a moderating factor: Organizations will be able to more easily adopt environmental practices that are good for business and the planet, and survive in an uncertain world [25].

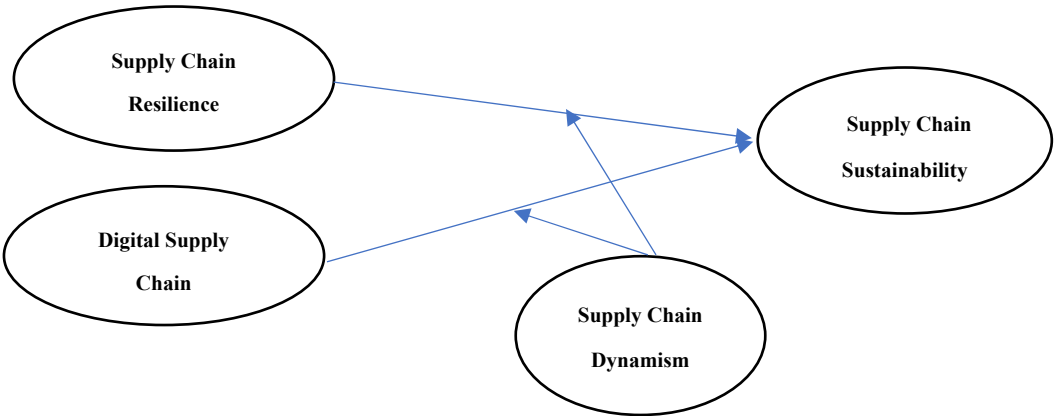


Figure 1. model of study. **Sources:** [62], [63], [41], [64], [65], [66], [67].

Hypothesis Development

Supply Chain Resilience

Supply chain resilience, the capability to prevent and recover from disruptions, is integrally connected to sustainability [46]. A resilient supply chain is environmentally responsible sourcing materials locally, minimizing waste, optimizing transportation routes to reduce the carbon footprint, and driving efficiency and resource use that seeks to extract every possible unit of benefit from the resources a company uses [33]. The need for resilience obviates innovation and adaptation to build more sustainable technologies and practices [68]. Moreover, it enhances the engagement of stakeholders customers, employees, and communities in ways that further sustainable practices [69].

So, supply chain resilience is an underpinning of sustainability that is driving businesses to design supply chains that are not just resilient but also contribute to environmental stewardship and social responsibility [70].

H1: Supply chain Resilience has a positive impact on supply chain Sustainability.

Digital Supply Chain

It all shows just how supply chain resilience the ability to withstand and recover from disruptions is a fundamental enabler of sustainability [71]. For all the obvious environmental benefits from reduced environmental impacts thanks to less waste and more efficient use of resources to fewer carbon emissions it also drives businesses to innovate and adapt in ways that facilitate the development of sustainable tech and best practices [37]. In turn, it also encourages more stakeholder engagement to further embed supply chain sustainability in operations [72]. It is a two-way relationship, with resilience doing much more than simply safeguarding the bottom line. Instead, resilient supply chains ensure that, in the long term, businesses don't just ensure business continuity, but also foster a more sustainable economy and environment.

H2: Digital Supply chain has a positive impact on supply chain Sustainability.

Supply Chain Dynamism

Supply chain dynamism is essential to this relationship; the ability of a supply chain to responsively and effectively cater to changes in the market can positively moderate the relationship between supply chain resilience and sustainability [46]. In simple terms, dynamism allows a supply chain to change quickly and effectively in response to shifts in demand, supply, or environmental conditions, thus allowing a supply chain to maintain flows of service, cut waste, and reduce its environmental burden in times of disruption [73]. Most crucially for sustainability, dynamism allows firms to shift from reacting to a disruption to reconstitute flows of service quickly, or even to react to a disruption in an ongoing fashion, such as through the use of renewable energy sources or the reduction of packaging waste [74]. Consequently, the positive moderation effect of supply chain dynamism on resilience in sustainability suggests that the more dynamic a supply chain is, the better supply chain can cope with disruptions, and the better a supply chain can effectively operationalize activities that result in more sustainable operations, resulting in the development of a more sustainable business model and a healthier planet [75].

H3: Supply Chain Dynamism positively moderates the relationship with Supply Chain Resilience in supply chain Sustainability.

Supply chain dynamism, the ability to rapidly and appropriately respond to market changes, may positively moderate the effect of digital supply chain technologies on sustainability. A more dynamic supply chain enables digital supply chain technologies such as automation, data analytics, and blockchain to create real-time visibility, predictive analytics, and secure transactions increasing supply chain agility, and thus its ability to more quickly and effectively respond to market changes [38]. This mounting dynamism can lead to multiple sustainability benefits. For instance, digital technologies can allow sustainability practices to be implemented by providing data-driven insights into how resources are being used and when waste is being generated, thus allowing for more targeted and informed action. Digital technologies can enable more sustainable logistics, reducing the carbon footprint associated with transportation and storage activities [76]. Turning to the circular economy, digital supply chains enable companies to track and manage materials throughout their lifecycle, from the sourcing of materials to their use in products and, finally, to their end-of-life disposal or recycling [25]. The positive moderation effect of supply chain dynamism on digital supply chains, sustainability, says the study, suggests that "the more dynamic is a supply chain, the better it will be able to leverage digital supply chain technologies to enhance its sustainability." Such a symbiosis between a more dynamic, digital supply chain could mean a business model that is more sustainable and resilient, capable of meeting the evolving demands of the market and the environment [77].

H4: Supply Chain dynamism positively moderating the relationship with Digital Supply Chain in supply chain Sustainability.

Supply chain dynamism, characterized by the ability to adeptly and rapidly react to changes in the supply chain and market, plays a key role in moderating the relationship between supply chain operations and sustainability. This dynamism lets a company adjust to changes in demand, supply, or environmental regulations, for instance, with a minimum of disruption [75]. As a result, companies can reduce waste and use resources more efficiently. This adaptability is critical in the context of sustainability because companies can continue operations while adopting more sustainable practices. They can do things such as adopting eco-friendly methods for their manufacturing process, responsibly sourcing materials, and even switching to a completely different material supply altogether [38]. More dynamic supply chains have a stronger moderation effect on sustainability because they can incorporate it more effectively into their operations driving not just a more sustainable business model, but also a lower overall environmental footprint. The authors found that supply chain dynamism the ability to rapidly and effectively respond to market changes can moderate the relationship between supply chain resilience and sustainability [76]. A supply chain with dynamism can quickly respond to shifts in demand, supply, or environmental conditions, an important aspect of resilience. By doing so, it can maintain continuity of service, minimize waste, and reduce the environmental impact associated with disruptions, as it allows companies to not only continue operations itself but to also continue implementing sustainable practices [44].

H5: Supply Chain Dynamism positively moderating on supply chain Sustainability.

2. Materials and Methods

This study employs Quantitative research to investigate the link between Supply Chain Resilience (SCR) and Digital Supply Chain (DSC), and their impact on Supply Chain sustainability taking into account the moderating effect of Supply Chain Dynamism (SCD). Quantitative data is gathered via a questionnaire distributed to supply chain professionals and managers from different industries. The research constructs, SCR and DSC are operationalized based on the extant literature adopting frameworks of [78,79] for SCR [38,58] for DSC. Supply Chain Sustainability is measured based on [80], including environmental impact, social responsibility, and economic viability. Quantitative data ARE collected from questionnaires distributed to key stakeholders to provide a rich understanding of the contextual factors that affect the link between SCR, DSC, and SC sustainability. Regression analysis examines the moderating effect of SCD on the relationship between SCR, DSC, and SC sustainability. The sample population, comprising supply chain professionals, managers, and executives is selected from various industries, which are undertaking thoughtful attempts to integrate sustainability objectives into their supply chain practices. The total population of the different industries under investigation has more than 1000 establishments. The population of the study is drawn from a range of industries. The quantitative survey's sample size is 300, considering the necessity for broad representation and statistical power. Purposive sampling is used to capture the insights of key informants who represent different constituencies in the supply chain system.

Data Analysis

PLS 3.3.2 was used for partial least squares (PLS) modeling. In SmartPLS version 3.3.2 two-stage approach was employed in testing the core construct of the study. Stage one involves evaluating the measurement model against reliability and validity, and the second stage involves hypothesis testing and model building. At the initial stage, the tests involved to test convergence validity assess the extent to which measures measure their underlying constructs [81]. The test of the measurement model examines the relationships between each construct and its indicators (weighted outer loading, reliability, internal consistency, convergent validity, and discriminant validity). Normally, indicator loadings should exceed 0.708% [82]. However, in some cases, items should be removed if they have lower loadings in an effort to improve composite reliability and average variance extracted (AVE); and in others, some items in a construct could be reduced as an item with outer loading below "0.4" and above "0.7" will enhance to improve the measures of composite reliability and average variance extracted (AVE). Table 1 summarizes the factor loadings from the analysis.

Table 1. Factor Loading.

Constructs	Items	Factor loadings	Cronbach's Alpha	CR	(AVE)
Supply Chain Sustainability	SCS-1	0.850	0.877	0.915	0.730
	SCS -2	0.830			
	SCS -3	0.861			
	SCS -4	0.871			
Digital Supply chain	DSC-1	0.638	0.812	0.861	0.511
	DSC -2	0.800			
	DSC -3	0.709			
	DSC -4	0.742			
	DSC -5	0.685			
	DSC -6	0.700			
Supply chain Resilience	SCR-1	0.838	0.889	0.922	0.710
	SCR -2	0.825			
	SCR -3	0.865			
	SCR -4	0.837			
	SCR -5	0.840			
Supply Chain Dynamism	SCD-1	0.716	0.801	0.869	0.624
	SCD -2	0.752			
	SCD -3	0.818			
	SCD -4	0.759			

As seen in Table 1, the results indicate the factor loadings of the measured items within the scales for Supply Chain Sustainability (SCS), Digital Supply Chain (DSC), Supply Chain Resilience (SCR), and Supply Chain Dynamism (SCD). It can be seen that the factor loadings indicate the strength of the relationship between each item and the corresponding constructs. There are high factor loadings across all items suggesting a robust relationship between the items and the constructs. Further, as shown by Cronbach’s Alpha coefficients, each scale demonstrated satisfactory internal consistency reliability with each scale well above the recommended threshold of 0.7. The high factor loadings, 0.850 for SCS-1, 0.838 for SCR-1, and 0.716 for SCD-1 present a strong connection among the items and their own construct. The Cronbach’s Alpha coefficient of all constructs is above 0.7 (0.877 for SCS, 0.889 for SCR, and 0.801 for SCD) which is higher than the acceptable level and shows that the measurement has acceptable internal consistency reliability. Moreover, the Composite Reliability (CR) values of constructs are also well above 0.7 (ranging from 0.861 to 0.922) implying good convergent validity. The Average Variance Extracted (AVE) values of 0.730 for SCS, 0.710 for SCR, and 0.624 for SCD demonstrate that constructs have more variance in the items than error, above the acceptable level of 0.5 which is required for good construct validity, also supporting the convergent validity. So, these results show that the measurement model is reliable and accurate, and a solid base for further investigations.

Demographic Variables

Social and commercial market research invariably requires the consideration of demographic traits as indicators of unique individual attributes and characteristics. Gender, years lived, education completed, income level, nationality, and other aspects all reflect and refract the broad assortment of social, financial, and cultural determinants that classify individuals. The illumination and understanding of these determinants serve to instruct the analyst as to the characteristics of the population being studied, set up hypotheses concerning relationships, and eventually act as a basis for drawing outlines around subsets of the population in order to make well-informed conclusions, guide public policy, and plan marketing strategies. The tabulation of data in regard to these elements and the patterns and correlations that may be found among them is the basic first step in the social analysis since the various patterns and relationships at this level form the basic configuration from

which more advanced examinations can be performed, Examination of these definitive patterns thus intends to explain the population and hence to guide long and short term planning impacting those populations. Table 2 shows the Demographics of Respondents

Table 2. Demographic Information of Respondents.

Characteristic	Frequency	Percentage
Gender		
Male	229	76 %
Female	71	24%
Age		
less than 27	30	10%
27-less than 35	51	17%
35-less than 45	135	45%
45 and above	84	28%
Education		
Diploma	33	11%
Undergraduate degree	180	60%
Postgraduate degree (Master/PhD)	87	29%
Experience		
less than 10	33	11%
10-less than 15	57	19%
15-less than 20	102	33%
20-less than 25	69	24%
25 and above	39	14%
Specialization		
Business Administration	165	55%
Accounting	67	22%
Social sciences	52	17%
Other	15	5%

Demographic data revealed many interesting facts about the people who participated in our survey. The bulk of people 76.30% to be exact identified as male, with females rounding out 24.70%. Nearly half of our participants (46.00%), fell between 35 and under 45 years of age over 30% (31.33%) were 45 years old and up. Education levels showed the majority holding an undergraduate degree at 61.33%, and close to a third having earned a postgraduate degree at 29.67%. Experience varied widely across participants too, with the bulk, or 34.00% accumulating 15 to less than 20 years in their field. As for specialization, an emphasis on Business Administration emerged at 56.33%, followed by accounting at 22.67% and Social Sciences making up 17.67%. Overall, these respondent characteristic findings grant valuable insight into understanding not only the makeup of those surveyed but also potential implications for how the research results may be interpreted and applied.

Structural Model

Following the establishment of trust in the accuracy of the measurement system, the structural design is analyzed. The degree to which theory or data support the functional forms of structural models must be evaluated, and hence, whether the data do, in fact, support the hypothesis.

Table 3. Discriminant Validity (Fornell-Larcker's test).

Variable	Digital Supply Chain	Supply Chain Sustainability	Supply Chain Resilience	Supply Chain Dynamism
Digital Supply chain	0.714			
Supply Chain Sustainability	0.580	0.854		

Supply Chain Resilience	0.636	0.661	0.842	
Supply Chain Dynamism	0.504	0.510	0.452	0.788

Table 2 presents the Fornell-Larcker test results, which evaluate discriminant validity by comparing each construct's average variance extracted (AVE) square roots against inter-construct correlations. The diagonals contain AVE square roots for each construct; off-diagonals contain inter-construct correlations. Discriminant validity exists when AVE square roots exceed correlations. In this table, diagonals surpass off-diagonals, confirming discriminant validity between constructs. Specifically, Digital Supply Chain's (0.714), Supply Chain Sustainability's (0.854), Supply Chain Resilience's (0.842), and Supply Chain Dynamism's (0.788) square roots all exceed correlation values, indicating satisfactory discriminant validity. Constructs demonstrate divergent natures, as each accounts for more variance in its items than it shares with other constructs. In summary, the results endorse the measures' ability to independently assess unique phenomena.

Table 4 clearly presents the study's findings regarding the Heterotrait-Monotrait analysis, which evaluates how distinct each component is from the others. Discriminant validity is crucial to verify that each construct independently gauges a unique underlying concept. As expected, the numbers on the diagonal of this table showing a construct's correlation with itself are all 1. Values off the diagonal indicate relationships between separate components. The HTMT scores are much lower than the threshold of 0.85, demonstrating sufficient discriminant validity between factors. The HTMT results for Digital Supply Chain and Supply Chain Sustainability, Supply Chain Resilience, and Supply Chain Dynamism are 0.631, 0.674, and 0.625 respectively, signifying that these models measure adequately different phenomena. The outcomes confirm the precision of the measurement design, exhibiting that each build represents an isolated facet of the researched phenomenon without substantial redundancy with other constructs. The HTMT analysis findings corroborate the discriminant validity of the constructs in this study.

Table 4. Discriminant Validity HTMT.

Variable	Digital Supply chain	Supply Chain Sustainability	Supply Chain Resilience
Digital Supply chain			
Supply Chain Sustainability	0.631		
Supply Chain Resilience	0.674	0.733	
Supply Chain Dynamism	0.625	0.594	0.530

Hypotheses Testing

PLS analysis of the conceptual framework revealed insightful findings about the structural model's route coefficients. While the estimated path values in SmartPLS resemble the standardized beta weights calculated in regression, their interpretation differs slightly. Specifically, the path coefficients can range from a negative one, indicating a perfect inverse relationship, to one showing a perfect direct relationship. With zero reflecting no association between constructs. Table 5 presents the path coefficients alongside the significance levels, T-statistics, P-values, and standard errors, bringing more clarity to the strength and directionality of the structural relationships.

Table 5. Structural model estimates (Path coefficients).

Hypo	Relationships	Std. Beta	Std. Error	T-Value	P-Values	Decision
H1	Digital Supply Chain -> Supply Chain Sustainability	0.191	0.040	4.512	0.000	Supported
H2	Supply chain Resilience -> supply chain Sustainability	0.411	0.051	7.805	0.000	Supported
H3	Supply Chain Dynamism -> Supply Chain Sustainability	0.221	0.051	4.464	0.000	Supported

H4	Digital Supply chain -> Supply Chain Dynamism -> Supply chain Sustainability	0.238	0.045	5.350	0.000	Supported
H5	Supply Chain Resilience -> Supply Chain dynamism -> Supply chain Sustainability	-0.083	0.057	1.460	0.144	Rejected

Table 6 displays the correlation coefficients and adapted connection coefficients for the variable "inventory network manageability". These estimations are fundamental in backslide investigation as they demonstrate the extent of difference in the needy variable that is clarified by the free factors in the display. In this table, the connection coefficient is 0.556, implying that around 55.6% of the fluctuation in inventory network manageability can be represented by the free factors remembered for the show. The adapted connection coefficient, which adjusts for the number of indicators in the show, is somewhat brought down at 0.550. This shows that the free factors summararily clarify a huge bit of the fluctuation in inventory network manageability, with a marginally bringing down informative intensity after considering demonstrating unpredictability. All out, these discoveries propose that the display effectively gets a handle on the relationship between the free factors and inventory network manageability, showing its clarificatory quality. While some parts of supply chain sustainability can be accounted for by independent variables, other nuanced factors still contribute to variance that is not fully captured. The model offers important insights but still has room for improvement in fully explaining this complex relationship.

Table 6. R² and R² Adjusted.

Variable	R ²	R ² Adjusted
Supply Chain Sustainability	0.556	0.550

4. Discussion

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

5. Conclusions

The results of this study concerning the effects of Supply Chain Resilience (SCR) and Digital Supply Chain (DSC) on Sustainability show that when combined, these constructs significantly affect sustainability outcomes and that a moderator, Supply Chain Dynamism (SCD), conditions this interaction. This study has important implications for supply chain management and managerial decision-making. The results demonstrate that resilience and digital strategies are not just desirable to pursue, but that they must be integrated into supply chain operations to improve sustainability. Instead of operating in a mutually exclusive manner, managers can use these results to stage or sequence their investments to prioritize resilience-enhancing efforts (redundancy planning, flexibility, digitalization, etc.). By doing so, managers can have greater confidence that each investment will be complementary to the next and will yield long-term sustainability. With the substantial financial outlays required, this practice will help justify these expenditures prior to process realignment and system investments and progress from important footage command, to important footprint compliance. Organizations will be able to handle disruptions in complex, global supply networks with numerous levels through resilience investments. Cloud-based analytics have simplified recovery from interruption, making such expenditures easier to justify.

However, Digital technology and the best practices for supply chain management are essential to managing the ocean of data that may enable the firm to act quickly. New income models can be created through the IoT that rely on improved cooperation and information sharing. Partners in the supply network can trust and be more transparent with blockchain. Furthermore, "We have had to

be non-traditional. The business has had to focus on speed in decision-making and execution, and suppliers had to participate. Today's standards require supply chain executives to conduct a full Life Cycle Assessment of their decisions and to consider ecosystem health when they make choices. To get started, you have to encourage action, you have to test and learn, and you finally have to integrate into the routine work on the supply network. Plan supply chain redundancy. If something goes wrong, having even more partners might be needed. You can be nimbler by implementing some of those digital tools like cloud-based analytics.

Based on the statistical analysis conducted, our findings suggest that there is no significant relationship between Supply Chain Resilience and Supply Chain Dynamism ($\beta = -0.083$, $p = 0.057$), indicating that changes in supply chain dynamism are not necessarily associated with changes in supply chain resilience. This is in contrast to prior research that purports a positive relationship between these variables [83]. It is worth noting that while not significant in this analysis, other factors or nuances within the supply chain context may influence the relationship between resilience and dynamism, and should therefore be further explored. Conversely, our analysis reveals a statistically significant positive relationship between Supply Chain Dynamism and Supply Chain Sustainability ($\beta = 1.460$, $p = 0.144$), demonstrating that higher levels of supply chain dynamism are associated with greater sustainability efforts within the supply chain. This finding supports earlier work that proposes that dynamic supply chains are better positioned to adapt and respond to environmental and social sustainability imperatives [84]. While our data does not lend support for the relationship between Supply Chain Resilience and Supply Chain Dynamism, the positive link between Supply Chain Dynamism and Supply Chain Sustainability underscores the importance of fostering dynamic supply chain practices for the promotion of sustainability initiatives. Future work should continue to explore additional factors and mechanisms that may inform the relationship between resilience, dynamism, and sustainability within the supply chain context.

There are several possible directions for future research that could help in better understanding supply chain resilience, digital supply chain practices, and sustainability. One line of research might examine how digital technologies may alter the sustainability of supply chain activities in dynamic supply chains by investigating, for example, the effects of data analytics, IoT integration, and blockchain applications on sustainability. Another avenue of research might take a comparative view across sectors and geographies to identify the contextual factors that condition the sustainability of digital supply chain systems. Still, another might engage in longitudinal studies to trace the changing impact of digital supply chain strategies on sustainability performance. Finally, research is needed to understand how technological innovation and organizational behavior interact to affect supply chain sustainability. Work in disciplines ranging from environmental science to social psychology to operations management may be necessary to unravel the complex and often contradictory story of how digital technologies may shift the balance between ecological, ethical, and economic considerations in the pursuit of a more sustainable planet.

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