Digital transformation and sustainable performance: the mediating role of triple-A supply chain capabilities

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Abstract

Purpose – Drawing on resource orchestration theory, this paper aims to empirically investigate the relationships between digital transformation (DT), triple-A supply chain capabilities (i.e. agility, adaptability and alignment) and sustainable performance. The research focuses on the pharmaceutical industry, which best represents a business environment characterized by volatility, uncertainty, complexity and ambiguity.

Design/methodology/approach – Data were collected at different echelons of a globally oriented pharmaceutical supply chain, with the focal company located in the Netherlands. Empirical data were analyzed with partial least squares – structural equation modelling.

Findings – The findings reveal that DT enhances the triple-A supply chain capabilities. Nevertheless, not all three capabilities are necessary to improve overall sustainable performance. The results highlight that, among the three, only supply chain agility and adaptability significantly mediate the relationship between DT and sustainable performance.

Originality/value – This research supports the literature affirming that not all the triple-A supply chain capabilities equally affect sustainable performance. Moreover, it deepens the understanding of how orchestrating the triple-A capabilities at a firm level fosters overall sustainable performance, facing resource scarcity and investments in DT.

Keywords Sustainability, Digital transformation, Triple-A supply chain, Resource orchestration theory, VUCA

Paper type Research paper

1. Introduction

Our contemporary business environment is marked by ongoing uncertainties, stemming from ever-changing customer requirements, intense market competition, rapid technological advancements and the pervasive influence of digitalization. Recently, the COVID-19 pandemic and international geopolitical tensions have injected even more uncertainty into the business environments, imposing unprecedented pressure on various industries within the international context (Khan *et al.*, 2022; Troise *et al.*, 2022; Zhang-Zhang *et al.*, 2022) and leading to the collapse of certain supply chains (Craighead *et al.*, 2020; Tunisini *et al.*, 2023). This challenging situation best represents the acronym "VUCA" for increasing volatility, uncertainty, complexity and ambiguity (VUCA) (Bennett and Lemoine, 2014).

Within the VUCA context, the pharmaceutical supply chain (PSC) is a prime example, as it also faces additional challenges (Viegas *et al.*, 2019). First, pharmaceutical products need to be tracked throughout the entire supply chain (Jaberidoost *et al.*, 2013). Second, the temperature-controlled drug storage (i.e. the cold chain for vaccines transportation) has to meet strict environmental and temperature standards (Lin *et al.*, 2020). Third, PSCs are facing the new challenge of balancing sustainability and efficiency in delivery, e.g. drugs are usually transported by air, which ensures service effectiveness but is highly pollutant (Li *et al.*, 2022).

Given these complexities, it becomes imperative to understand how firms can effectively orchestrate their resources and investments in supply chain capabilities. A review of the literature suggests that, in the VUCA era, firms striving to achieve competitive advantage must rapidly and effectively change their

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Journal of Business & Industrial Marketing
Emerald Publishing Limited [ISSN 0885-8624]
[DOI 10.1108/JBIM-02-2023-0098]

We acknowledge the financial support from the Verona Chamber of Commerce (Italy), with special recognition to the late Riccardo Borghero, former Secretary General, for his interest in digital transformations and business logistics. We also thank Suzanne Hoogendoorn for her help with data collection. Finally, we express our gratitude to the editor and the three anonymous reviewers for their insightful comments and suggestions.

Received 17 February 2023
Revised 3 November 2023
7 June 2024
Accepted 5 August 2024

modus operandi, becoming more agile, flexible and responsive (Erhun *et al.*, 2021; Mohaghegh *et al.*, 2023; Patrucco and Kähkönen, 2021; Richey *et al.*, 2023). Following Lee's (2004) proposal of triple-A supply chain capabilities, agility, adaptability and alignment are three key capabilities to be developed for business success. Agility refers to the ability to respond quickly and effectively to changes in the environment or customer demands (Gligor *et al.*, 2022b; Patel and Sambasivan, 2022). Adaptability entails the flexibility to adjust and successfully reconfigure processes in response to changing market needs (Gligor *et al.*, 2022b; Morgan *et al.*, 2023). Alignment involves the ability to fully reap the benefits of collaborations among supply chain actors to achieve maximum economic performance within the supply network (Narayanan and Ishfaq, 2022). Recent disruptions in global supply chains show that companies with well-orchestrated triple-A capabilities are more capable of adjusting their operations, gaining competitive advantage and achieving business success (Skipworth *et al.*, 2023).

However, due to the sustainability pressure imposed by stakeholders involved in supply chains (e.g. customers), business success is no longer solely determined by profitability and economic factors. Rather, it is also dependent on a company's commitment to environmental and social responsibilities (Mohaghegh *et al.*, 2023; Geyi *et al.*, 2020), referred to as sustainable performance across the triple bottom line or triple bottom line (TBL) (Elkington, 1997).

Existing literature proposes the digitalization of supply chain processes as a strategic investment to improve sustainable performance (Wang *et al.*, 2016). However, it is still underexplored how firms, considering the resource scarcity and their substantial investments in digital transformation (DT), can strategically orchestrate triple-A supply chain capabilities for sustainability purposes. Without critically discussing the role of DT, extant studies also suffer from too much emphasis on the aggregate (higher-order) triple-A supply chain capability (Li *et al.*, 2015; Whitten *et al.*, 2012), while neglecting to investigate the individual impacts of these capabilities on sustainable performance (Mohaghegh *et al.*, 2023; Geyi *et al.*, 2020; Eckstein *et al.*, 2015).

The lack of investigation in the literature on identifying the most optimal match between DT and triple-A supply chain capabilities for competitive advantage leads us to explore the mediating effects of (individual) triple-A supply chain capabilities for the DT – sustainable performance relationship. Building upon the notion that DT alone does not necessarily guarantee improved performance (Bai *et al.*, 2022), we propose that firms need to orchestrate the triple-A capabilities to fully realize the potential of DT and translate their investments in digital solutions into sustainable performance. While DT introduces new tools and processes, firms without the ability to agilely respond to changes, adapt to new conditions and align these changes with strategic objectives cannot fully capitalize on the potential benefits of DT for sustainability purposes. The strategic resource/capability orchestration, therefore, is required to ensure that digital tools are not merely implemented but are integrated in a way that supports the firm's goals and enhances overall performance.

Theoretically, the resource orchestration theory (ROT) can enhance our understanding by explaining why resource/capability orchestration matters and why mediation exists. This theory emphasizes the importance of effectively structuring, bundling and leveraging a firm's resources/capabilities to achieve competitive advantage (Sirmon *et al.*, 2011; Skipworth *et al.*, 2023). Therefore, it can shed light on which supply chain capabilities should be prioritized to maximize the effects of DT on sustainable performance, especially within the context of resource scarcity.

Using the ROT and in response to the identified gaps in the literature, our research question is as follows:

RQ1. How does the orchestration of triple-A supply chain capabilities mediate the relationship between digital transformation and sustainable performance across the TBL?

The rest of the paper is organized as follows. Section 2 presents the theoretical framework. Section 3 develops the research hypotheses. Section 4 lays out the research methodology, and Section 5 describes the analysis and results. Section 6 concludes the paper with a summary of the main findings, managerial implications, limitations and directions for future research.

2. Theoretical contextualization of the triple-A supply chain capabilities in a VUCA environment

The recent global disruptions highlight the necessity of enhancing supply chain capabilities to thrive in the VUCA context (Bals *et al.*, 2023; Ramos *et al.*, 2023; Tunisini *et al.*, 2023). Traditional strategies centered on delivering customer value at reduced costs no longer suffice to outperform competitors and sustain competitive advantage in rapidly changing and unpredictable environments (Christopher and Holweg, 2017). Furthermore, research suggests that to reap the benefits associated with the management of supply chains, firms must develop certain capabilities (Eckstein *et al.*, 2015; Erhun *et al.*, 2021). The strategic amalgamation of various resources and capabilities at the firm level holds the potential to significantly enhance overall business performance (Gligor *et al.*, 2020). Accordingly, this study builds on the ROT as a theoretical lens. ROT emphasizes the strategic deployment and rearrangement of a firm's scarce resources to effectively respond to evolving conditions and challenges (Chirico *et al.*, 2011). In detail, ROT posits that creating value for the firm is primarily influenced by how resources are cultivated and used by managers, rather than solely by their ownership (Sirmon *et al.*, 2011; Skipworth *et al.*, 2023). Moreover, the industrial marketing and purchasing (IMP) perspective, which highlights the significance of relationships, interactions and networks within industrial and market contexts (Håkansson *et al.*, 2009), offers an insightful complement to the ROT. While existing studies on resource interaction within IMP provide valuable insights (Baraldi *et al.*, 2012; Gadde and Lind, 2016), we share the viewpoint of Bocconcelli *et al.* (2020) that the IMP approach could benefit from further development in today's dynamic business environment. This development avenue might involve gaining a nuanced understanding of how firms collaborate and interact with various stakeholders, including suppliers, customers and partners, to optimize resource utilization in a VUCA environment. Furthermore, it underscores that addressing these challenges extends beyond individual firms and necessitates a holistic view at the supply chain level, emphasizing the interdependence and interactions among various actors within the supply network (Jarzabkowski *et al.*, 2021; Tunisini *et al.*, 2023).

Building upon these perspectives, we delve into the interplay of triple-A supply chain capabilities (i.e. agility, adaptability and alignment), sustainability and digitalization. Following Lee's (2004) triple-A supply chain capabilities, supply chain agility refers to the ability of a supply chain network to quickly and effectively respond to rapid changes in market conditions, customer demands or external disruptions (Gligor *et al.*, 2022b; Patel and Sambasivan, 2022). Supply chain adaptability represents a firm's capability to modify or reconfigure its supply chain to both short-term changes and long-term market shifts (Gligor *et al.*, 2022b; Morgan *et al.*, 2023). Supply chain alignment refers to the extent to which various components, partners and functions within a supply chain are synchronized and integrated to pursue shared goals and objectives (Narayanan and Ishfaq, 2022).

Together, these capabilities, optimize operations, enhance responsiveness and improve overall supply chain performance (Mak and Max Shen, 2021; Marin-Garcia *et al.*, 2023). However, a study conducted by Gligor *et al.* (2020) highlights that achieving high levels of agility, adaptability and alignment simultaneously is not mandatory for optimal performance. This prompts a crucial call for further research, particularly facing resource scarcity, where managers are required to establish which investments to prioritize. In this context, our empirical research endeavors to perform empirical analysis with the goal of obtaining a comprehensive understanding of how firms orchestrate triple-A capabilities in the face of resource deficiencies. In particular, this research aims to shed light on the activation of particular supply chain capabilities and investments, such as digitalization, in response to VUCA challenges, as advocated by Tunisini *et al.* (2023).

3. Hypotheses development

3.1 Digital transformation and triple-A supply chain capabilities

DT refers to the process by which firms reshape their business models and ecosystems through the integration of high-impact digital technologies and capabilities (Nayal *et al.*, 2022). This encompasses various technologies such as Big Data (analytics), Internet of Things (IoT), robotics, machine learning and business-to-business networks (Dean *et al.*, 2017), to name a few. Given that firms, to achieve competitive advantage, are required to integrate internal and external resources, striking a balance between technology and business practices, we conceptualize DT as a comprehensive process involving the integration of advanced digital technologies and capabilities into operations, with a focus on enhancing efficiency, data utilization and connectivity.

Despite being challenging due to the implementation cost of digital technologies, DT is capable of impacting business resources/capabilities, including the triple-A supply chain capabilities (Bai *et al.*, 2022; Mak and Max Shen, 2021). Ding (2018), for example, noted that the adoption of digital technologies helps firms establish more robust and agile processes, characterized by fewer interruptions and defects. Zhou *et al.* (2023), surveying 223 Chinese companies, empirically report a positive relationship between supply chain digitalization and supply chain agility. The authors also show that supply chain agility partially mediates the relationship between supply chain digitalization and supply chain performance. Al Humdan *et al.* (2020), in a systematic literature review, highlighted the importance of supportive information technology (IT) and promoted the use of IT tools as the enabler of supply chain agility. Ciampi *et al.* (2022) also emphasize that, in turbulent environments, firms need to process a vast amount of data to maintain agility. IT-based technologies play a crucial role in this process, enabling firms to sense and respond effectively to environmental changes.

In addition to agility, a synthesis of the literature reveals that in highly turbulent environments, firms must be flexible to adjust to environmental turbulence and to respond to rapid changes through reconfiguring their supply chain processes and transforming their resources/capabilities, i.e. supply chain adaptability (Aslam *et al.*, 2018; Mohaghegh and Größler, 2024). Prior research has emphasized the importance of DT and high-impact digital technologies in facilitating supply chain adaptability. For instance, Zhao *et al.* (2023) claim that digitalization empowers enterprises to readily reconfigure their internal and external resources/capabilities to adapt and recover more effectively in a dynamic environment. Pettit *et al.* (2019) argue that blockchain and cloud technology can improve supply chain adaptation capabilities. Also, Zouari *et al.* (2021) referred to adaptability as an important feature (or component) of supply chain resiliency and empirically indicated that digital tools adoption and digital maturity positively affect supply chain resiliency.

Furthermore, the adoption of digital technologies arguably improves supply chain transparency, efficiency and flexibility, which in turn further stimulates collaboration and communication among supply chain actors, i.e. supply chain alignment (Kamble *et al.*, 2020; Khan *et al.*, 2022; Nayal *et al.*, 2022). As an example, Kache and Seuring (2017) determine supply chain integration as the opportunity offered by Big Data (Analytics). The authors argue that integrated data exchange platforms are necessary for supply chain collaboration and information sharing. Also, Haddud *et al.* (2017) identified several advantages of IoT implementation in supply chains and highlight improved integration of inter-organizational business processes as a key benefit.

The significance of DT in enhancing supply chain capabilities can be viewed through the lens of ROT as well. While ROT's application in the realm of technology and digital adoption remains an uncharted territory, it presents a promising avenue for deepening our understanding of how firms strategically manage their resources/capabilities within the DT process (Xu and Pero, 2023). Consequently, we claim that the synergy of digitization and ROT is crucial for analyzing strategic changes and orchestrating resources effectively, thereby enabling distinctive supply chain capabilities that potentially lead to competitive advantage. Amid these research insights, however, it remains uncertain which triple-A supply chain capabilities can be strengthened by DT, particularly within resource-constrained environments. Adopting the ROT lens and acknowledging the resource-scare setting, we propose to examine the individual impact of DT on each supply chain capability separately. We therefore formulate the following hypotheses:

H1a. There is a positive relationship between DT and supply chain agility.

H1b. There is a positive relationship between DT and supply chain adaptability.

H1c. There is a positive relationship between DT and supply chain alignment.

3.2 Triple-A supply chain capabilities and sustainable performance

Several studies state that agility, adaptability and alignment are critical capabilities that allow supply chains to sustain competitive advantage and achieve higher performance (e.g. Feizabadi *et al.*, 2019; Whitten *et al.*, 2012). So far, existing literature in supply chain management, to the best of the authors' knowledge, mainly investigates the effect of the triple-A supply chain capability (as an integrated construct) on firm performance or supply chain performance (Feizabadi *et al.*, 2021; Li *et al.*, 2015; Whitten *et al.*, 2012) and sometimes focus only on one or two of the triple-A capabilities (e.g. Al Humdan *et al.*, 2020; Aslam *et al.*, 2018). What is less explored, in fact, in the literature is the direct relationship between individual triple-As at the firm level and overall sustainable business performance. Given that the focus on firm performance has evolved from a single economic perspective to a simultaneous and increasing emphasis on environmental and social sustainability dimensions (Zhang *et al.*, 2022), the present study aims to investigate the direct impact of the triple-As in isolation on sustainable performance, giving equal importance to economic, environmental and social dimensions.

In the context of relationships between individual triple-A capabilities and sustainable performance, for example, Gligor and Holcomb (2014) empirically demonstrate that agility positively impacts both operational and relational performance. Agility is not only directly linked to economic performance, as demonstrated by Gligor *et al.* (2015) and Inman *et al.* (2011), but appears to be influential for environmental performance. An agile supply chain can minimize inventory requirements, reducing waste and resource consumption (Geyi *et al.*, 2020). Furthermore, agility optimizes transportation and distribution, leading to lower emissions and energy usage, contributing to environmental sustainability (Geyi *et al.*, 2020; Raut *et al.*, 2021). From the TBL perspective, Mohaghegh *et al.* (2023), based on a sample of Italian manufacturing firms, discover empirical support for the positive relationships between agility and all triple dimensions of sustainable performance, i.e. economic, environmental and social performance.

With a focus on the relationship between supply chain adaptability and sustainable performance, Christopher and Holweg (2011) found profitability to be a direct outcome of supply chain adaptability. Adaptive supply chains are more resilient in the face of potential disruptions, reducing financial losses and environmental damage (Adobor, 2020; Zhao *et al.*, 2019). Furthermore, adaptability enables companies to move toward sustainable practices, which may involve sourcing eco-friendly materials, enhancing energy efficiency or creating more environmentally friendly packaging solutions (Negri *et al.*, 2021). Considering the social sustainability dimension, Mohaghegh and Größler (2024) claimed that easily reconfigured supply chains offer a flexible environment to implement social sustainability practices throughout the supply chain, including supplier evaluation measures aimed at ensuring compliance with social sustainability standards.

Similar to supply chain agility and adaptability, supply chain alignment appears also to be associated with financial performance (Liu *et al.*, 2016) and operational performance (Morgan *et al.*, 2016), both of which are critical to improving the economic dimension of sustainable performance. As discussed by Gligor *et al.* (2022a), alignment encourages ethical practices throughout the supply chain, such as fair labor practices, which can eventually improve the social dimension of sustainable performance. Using interpretive structural modeling, Mohaghegh and Größler (2024) also demonstrate that supply chain integration (i.e. to collaboratively removing all boundaries to ease the flow of material, resources and information between different actors involved in the supply chain) is a necessary step to enhance all three dimensions of sustainable performance.

Considering the expected benefits of supply chain agility, adaptability and alignment for equally important dimensions of sustainable performance (i.e. economic, environmental and social performance), the resulting hypotheses are as follows:

H2a. There is a positive relationship between supply chain agility and overall sustainable performance.

H2b. There is a positive relationship between supply chain adaptability and overall sustainable performance.

H2c. There is a positive relationship between supply chain alignment and overall sustainable performance.

3.3 The mediating role of triple-A supply chain capabilities

As described earlier, DT has become a strategic requirement for supply chains to gain a competitive advantage in the marketplace (Frederico *et al.*, 2021). The reason can relate to the potential of DT to enhance certain supply chain capabilities such as supply chain visibility, transparency and flexibility (Nayal *et al.*, 2022), supply chain resilience (Ivanov and Dolgui, 2021) and supply chain collaboration (Stank *et al.*, 2019), all of which are necessary to achieve competitive advantage and improve overall business performance (Wang *et al.*, 2016). Therefore, it is plausible to claim that supply chain capabilities can be seen as mechanisms through which DT contributes to firm-level performance (e.g. Nayal *et al.*, 2022; Troise *et al.*, 2022). This claim aligns with the perspectives shared by several studies such as Akhtar *et al.* (2018) and Bai *et al.* (2022) that DT affects performance only in association with certain capabilities. As an example, the results of a study conducted by Zhou *et al.* (2023) revealed that supply chain agility acts as the mediator for the relationship between supply chain digitalization and supply chain performance. The authors argue that technology alone may not ensure business success (Zhou *et al.*, 2023). Instead, the effects of technology on performance can be maximized when agile capabilities are present to partially transfer the effects of technology on performance. Also, with the focus on the role of alignment for the DT-sustainable performance relationship, Zhou *et al.* (2023) discovered empirical support for the mediating role of supply chain integration (or alignment), specifically in terms of customer collaboration, on the association between digitalization and financial performance.

Although, in this section and in line with previous studies, we hypothesize that DT in association with triple-A supply chain capabilities (i.e. agility, adaptability and alignment) can yield competitive advantage and enhance sustainable performance, it is of particular interest to investigate which triple-A supply chain capabilities can effectively transfer the effects of DT on sustainable performance. Marin-Garcia *et al.* (2023) emphasized the necessity of investigating triple-A capabilities individually. The authors argue focusing on individual capabilities, rather than addressing them as an aggregate (high order) capability, allows researchers to better understand their isolated effects on performance, thereby finding the most optimal capability match for competitive advancement and performance. This becomes even more critical within the context of resource scarcity and substantial investments of firms in DT, where managers need to strategically prioritize and orchestrate their resources to achieve competitive advantage. Our perspective resonates with Gligor *et al.* (2020) conclusion that achieving optimal performance does not necessarily demand high levels of agility, adaptability and alignment simultaneously.

According to the hypotheses developed earlier, where agility, adaptability and alignment are assumed to positively influence sustainable performance and being positively impacted by the DT, we suggest that the triple-A supply chain capabilities (separately) at the firm-level mediate the relationship between DT and overall sustainable performance. This leads to finding the most optimal capabilities match to mediate the relationship between DT and sustainable performance. Accordingly, the formulation of the next hypothesis is as follows:

H3. Supply chain agility, adaptability and alignment can serve as mediators for the relationship between DT and overall sustainable performance.

The conceptual model with expected relationships is depicted in Figure 1.

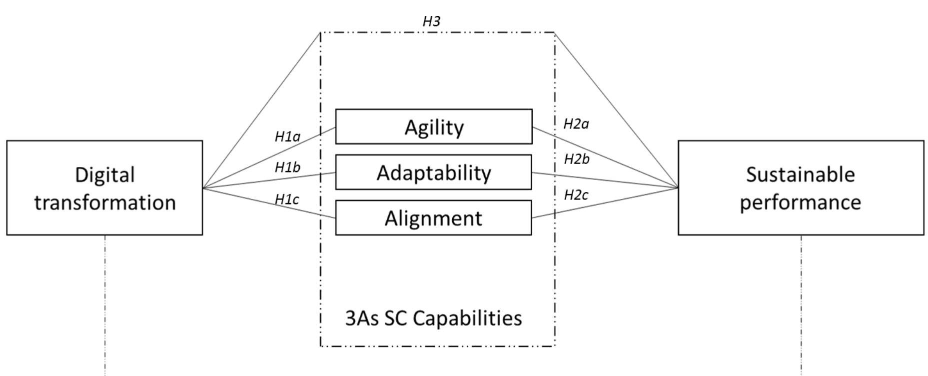
4. Methodology

4.1 Data collection and sample characteristics

This study follows a quantitative cross-sectional research design. To collect data, we developed a questionnaire-based survey using the online tool Qualtrics. The empirical context of this research is a globally oriented PSC, with the focal company located in the Netherlands. We targeted executives at various echelons within the PSC, with a specific focus on those working in supplier firms, pre-wholesale firms and wholesale firms involved in the international distribution of healthcare products. This is because the executives in such positions are required to deal with the strategic decisions related to DT and sustainability issues. The main language used in the questionnaire was English, due to the global orientation of the PSC. The survey was pre-tested and validated by three experts who were involved daily in the PSC process and by research group members. The questionnaire link was distributed to the executives by email. The respondent's names and emails were identified from companies' websites. Each mailing contained a cover letter explaining the purpose and intention of the survey. Initially, 360 executives were contacted to participate in the study. We received 84 valid and usable responses, representing a response rate of 24%. This seems to be an acceptable response rate as compared with similar research with a response rate of 19% (Ali and Khalid, 2017) or lower (Aljafari and Brown, 2020; Gligor *et al.*, 2015; Mohaghegh *et al.*, 2021).

Data collection from one single respondent through a self-reported questionnaire can be a source of concern regarding common method bias (CMB). We controlled for CMB through both procedural and statistical controls, as suggested by Podsakoff *et al.* (2003). For the procedural remedies, we used two strategies. First, we assured all respondents the anonymity and confidentiality of their answers, and we also assured them that there were no right or wrong answers. This procedure allowed us to also control for the social desirability bias. Second, we provided descriptions for potentially unfamiliar terms, i.e. the constructs of our study, and avoided complicated syntax to improve clarity and scale items (Podsakoff *et al.*, 2003). Regarding the statistical strategies, we conducted Harman's single-factor test to detect the presence of CMB in our data (Harman, 1967). A CMB is present if a single factor emerges from the factor analysis or one general factor accounts for most of the variance among the variables (Podsakoff *et al.*, 2012). We conducted a confirmatory factor analysis (CFA), which did not highlight the existence of a single factor accounting for most of the variability of the data. The test revealed the existence of eight distinctive factors with eigenvalues > 1.0. The first and

Figure 1 Proposed conceptual model



Source: Author's own work

largest factor accounted for only 26.5% of the total variance. Therefore, the CMB is not an issue in our analysis.

The sample characteristics are summarized in Table 1, which presents the respondents' profiles. The participants are mainly senior managers such as supply chain managers (22.6%) and members of the top management team (50.0%); they have a clear and in-depth understanding of the constructs studied in the current research. Work experience of more than 15 years for over half of the sample is further proof of respondents' detailed knowledge. Following a few questions about their positions within the PSC, respondents provided information about their respective firms. Table 2 summarizes the firm profiles. The sample demonstrates a good balance in terms of firm size, encompassing a diverse range of companies: 12 micro (14.3%), 30 small (35.7%), 15 medium (17.9%) and 27 large firms (32.1%).

Table 1 Respondents profile

	Total responses (84)	
Category	**Frequency**	**% Distribution**
Description of function		
Upstream supply chain management	7	8.3
Downstream supply chain management	16	19.0
Supply chain management	19	22.6
Top management	42	50.0
Gender		
Female	15	17.9
Male	69	82.1
Job experience		
Less than 10 years	7	8.3
Between 10 and 15 years	3	3.5
Between 15 and 20 years	15	17.9
Between 20 and 25 years	35	41.7
> 30 years	24	28.6

Source: Author's own work

Table 2 Firm profile

	Total responses (84)	
Category	**Frequency**	**% Distribution**
Firm size		
Micro < 10 employees or < €2m turnover	12	14.3
Small < 50 employees or < €10m turnover	30	35.7
Medium < 250 employees or < €50m turnover	15	17.9
Large > 250 employees or > €50m turnover	27	32.1
Age of firm		
<1 year	1	1.2
1–3 years old	1	1.2
3–5 years old	6	7.1
5–10 years old	7	8.3
10–15 yearls old	9	10.7
15–20 years old	9	10.7
> 20 years old	51	60.7

Source: Author's own work

4.2 Measures

Our items used to operationalize the constructs were based on validated scales in the extant literature (see Online supplementary material). Each construct was measured through multi-item scales. The survey questionnaire was divided into three main sections:

1 DT;
2 sustainable performance (i.e. economic, environmental and social sustainability dimensions); and
3 triple-A supply chain capabilities (i.e. agility, adaptability and alignment).

DT was assessed based on seven items proposed by Nayal *et al.* (2022). Supply chain capabilities were measured with the help of six items each, as suggested by Gligor *et al.* (2020). Sustainable performance was considered as a second-order construct consisting of economic, environmental and social sustainability performance, thus following the TBL perspective. The three sustainable performance measures were measured by five items each, as proposed by Mohaghegh *et al.* (2021). The economic dimension measured "the use of raw materials", "profitability" and "return on investment", for example. The environmental dimension focused on "emissions" and "waste". The social dimension gauged social considerations such as "health and safety of community and employees". Most survey items used a seven-point Likert-type scale to assess respondents' level of agreement, ranging from 1 ("strongly disagree") to 7 ("strongly agree"). However, for the social and environmental sustainability dimensions, the scale focused on perceived performance over the past two years. Here, the scale ranged from 1 ("much worse") to 7 ("much better").

5. Analysis and results

To evaluate the research model, partial least squares structural equation modeling (PLS-SEM) was used with SmartPLS 4. This method is appropriate when dealing with small sample sizes (Hair *et al.*, 2011). The minimum sample size acceptable for PLS-SEM is 10 times the largest number of structural paths directed at a particular construct in the structural model (Hair *et al.*, 2017). However, relying solely on this rule of thumb is not adequate (Wang *et al.*, 2023). As proposed by Hair *et al.* (2011), while determining the sample size, the characteristics of the reference population should be taken into consideration. We assert that our sample size can be satisfactory in a business-to-business context within a specific supply chain such as PSC. In addition, our sample size can be compared with similar studies using PLS-SEM. For example, Ali and Khalid (2017) use PLS-SEM to investigate predictive research models in the early stage of theory development, with a sample of 89. Likewise, Aljafari and Brown (2020) used PLS-SEM with a sample of 77 top managers to test their proposed hypotheses.

5.1 Measurement model assessment

As summarized in Table 3, we assessed the validity of the measurement model using established criteria for internal reliability, convergent and discriminant validity (Hair *et al.*, 2011;

Table 3 Construct measure assessment: reliability and convergent validity

Construct	Items	Standardized loading value	Cronbach's alpha (CA)	Composite reliability (CR)	Average variance extracted (AVE)
SC agility	SCAG1	0.85	0.91	0.92	0.67
	SCAG2	0.85			
	SCAG3	0.85			
	SCAG4	0.77			
	SCAG5	0.79			
	SCAG6	0.79			
SC adaptability	SCAD1	0.80	0.90	0.93	0.67
	SCAD2	0.85			
	SCAD3	0.79			
	SCAD4	0.82			
	SCAD5	0.85			
	SCAD6	0.82			
SC alignment	SCAL4	0.66	0.65	0.80	0.58
	SCAL5	0.87			
	SCAL6	0.73			
Digital transformation	DT1	0.83	0.80	0.86	0.61
	DT2	0.71			
	DT3	0.80			
	DT7	0.78			
Econ. perf.	Econ3	0.94	0.90	0.94	0.83
	Econ4	0.95			
	Econ5	0.85			
Env. perf.	Env1	0.89	0.92	0.94	0.77
	Env2	0.95			
	Env3	0.91			
	Env4	0.86			
	Env5	0.76			
Social perf.	Social1	0.78	0.91	0.94	0.76
	Social2	0.83			
	Social3	0.91			
	Social4	0.90			
	Social5	0.92			

Source: Author's own work

Wang *et al.*, 2023). Internal reliability of the constructs was measured using Cronbach's alpha (CA) and composite reliability (CR), being commonly reported values of scale reliability. CA and CR values exceeded 0.70 and hence considered satisfactory as recommended by Fornell and Larcker (1981). Convergent validity was assessed using both individual-item reliability and average variance extracted (AVE). Individual-item reliability was assessed through the standardized factor loading values between each item and its latent construct. Items with standardized loadings below the recommended 0.7 threshold were removed from the model, as recommended in the literature (Hair *et al.*, 2011). Also, all AVE scores were above the threshold of 0.5 suggested by the literature (Fornell and Larcker, 1981). These findings support the convergent validity of the model. Discriminant validity was examined using both the Fornell–Larcker criterion (see Table 4) and the Heterotrait-Monotrait ratio (see Table 5). Considering the former, the square roots of the AVEs of the latent variables were higher than the correlations among the latent variables (Fornell and Larcker, 1981). Based on the latter, the Heterotrait-Monotrait values were within the acceptable range, below the maximum threshold of 0.85 for nonrelated constructs and 0.90 for related constructs (Hair *et al.*, 2011). Therefore, the convergent validity of the model was assured. The results of the measurement model are depicted in Figure 2.

5.2 Structural model assessment

The structural model was checked using the evaluation criteria such as multi-collinearity assessment, significance of the path coefficients, R^2 measures, effect size (f^2) and predictive relevance (Q^2) (Hair *et al.*, 2011; Wang *et al.*, 2023). To check for multi-collinearity, variance inflation factor (VIF) was assessed for each predicting constructs. The VIF values were found to be below the threshold level (i.e. 5), indicating that there were no concerning effects of multicollinearity. Bootstrapping was used to assess the significance of path coefficients. Bootstrapping was performed using a 10,000 subsample following the updated guidelines by Sarstedt *et al.* (2023). Table 6 displays the results of the bootstrapping procedure for the structural model. Positive and significant relationships existed between DT and the triple-A supply chain capabilities. DT was positively associated with supply chain

Table 4 Construct correlations and discriminant validity: Fornell-Larcker criterion

	Digital transformation	Econ. perf.	Env. perf.	Social perf.	SCAG	SCAD	SCAL
Digital transformation	*0.78*	–	–	–	–	–	–
Econ. perf.	0.16	*0.91*	–	–	–	–	–
Env. perf.	0.34	0.32	*0.88*	–	–	–	–
Social perf.	0.31	0.16	0.30	*0.87*	–	–	–
SCAG	0.29	0.16	0.22	0.27	*0.82*	–	–
SCAD	0.31	−0.10	0.17	0.24	0.57	*0.82*	–
SCAL	0.18	−0.02	0.37	0.22	0.26	0.29	*0.76*

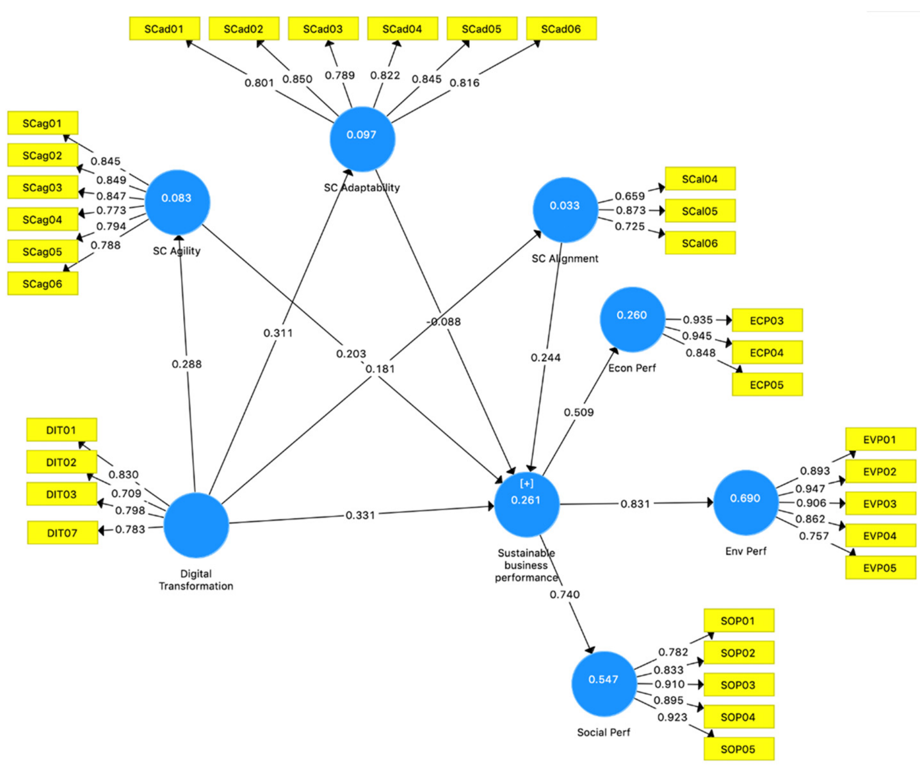
Source: Author's own work

Table 5 Discriminant validity: Heterotrait–Monotrait ratio

	Digital transformation	Econ. perf.	Env. Perf.	Social perf.	SCAG	SCAD	SCAL
Digital transformation	–						
Econ. perf.	0.24	–					
Env. Perf.	0.40	0.57	–				
Social perf.	0.36	0.13	0.32	–			
SCAG	0.28	0.19	0.20	0.27	–		
SCAD	0.34	0.25	0.19	0.26	0.65	–	
SCAL	0.25	0.43	0.45	0.27	0.34	0.35	–

Source: Author's own work

Figure 2 Measurement model



Source: Author's own work

Table 6 PLS-SEM analysis results

Hypothesized relationship	HPs	Standardized coefficient	T-statistics	*p*-value	HP supported or not?
DT → SC agility	*H1a*	0.32***	2.62	0.009	Supported
DT → SC adaptability	*H1b*	0.34**	2.46	0.01	Supported
DT → SC alignment	*H1c*	0.21*	1.76	0.07	Supported
SC agility → Sus. perf.	*H2a*	0.26**	1.99	0.04	Supported
SC adaptability → Sus. Perf.	*H2b*	−0.03 (n.s)	0.24	0.81	Not Supported
SC alignment → Sus. perf.	*H2c*	0.27***	2.97	0.003	Supported

Notes: ***p <0.01; **p <0.05; *p <0.1; and not significant (ns)
Source: Author's own work

agility ($\beta = 0.32$; $p < 0.001$), thus supporting *H1a*. DT positively and significantly influenced supply chain adaptability ($\beta = 0.34$; $p < 0.1$), confirming *H1b*. *H1c* is also supported as DT showed a positive and significant effect on supply chain alignment ($\beta = 0.21$; $p < 0.05$).

Empirical evidence was found for *H2a* as there was a positive relationship between supply chain agility and sustainable performance ($\beta = 0.26$; $p < 0.1$). However, no empirical support was found for *H2b*, as the correlation coefficient between supply chain adaptability and sustainable performance was not statistically significant. Finally, the positive and statistically significant relationship between supply chain alignment and sustainable performance ($\beta = 0.27$; $p < 0.001$) supported *H2c*.

To assess the explanatory power of the proposed model, R^2 values were evaluated for the endogenous constructs. The values considered satisfactory vary with the discipline (Hair *et al.*, 2017). The R^2 value for sustainable performance was 0.16, while supply chain agility, alignment and adaptability had values of 0.10, 0.04 and 0.11, respectively. Furthermore, we assessed the effect size (f^2) to measure the predictive power of the structural model. This measure evaluates whether the omission of an exogenous construct from the model substantively impacts an endogenous construct (Hair *et al.*, 2017). The highest f^2 for sustainable performance was supply chain alignment with a value of 0.077. Following the guidelines by Hair *et al.* (2017) values greater than 0.02 indicate a small effect of the exogenous construct on the endogenous one. Finally, we measured the Q^2 to assess the predictive relevance of the model. The recommended default of 10 folds and 10 repetitions was used. The Q^2 was 0.082, which is greater than 0, indicating that the exogenous constructs have a predictive relevance for sustainable performance as the endogenous construct.

To test the mediating role of the triple-A supply chain capabilities in the relationship between DT and sustainable performance, we began by examining the direct relationships. As Baron and Kenny (1986) emphasize, it is unnecessary to examine the mediation relationship if there is no direct link between the independent variable (IV) and the dependent variable (DV). Therefore, we first checked the direct relationship between our DV (sustainable performance) and IV (DT). Based on the positive and statistically significant relationship between these two variables ($\beta = 0.41$; $p < 0.001$), we then proceeded to investigate the type of mediation (partial or full), following the approach suggested by Nitzl *et al.* (2016). The mediation analysis results, summarized in Table 7, showed that supply chain agility and supply chain alignment partially mediated the relationships between DT and sustainable performance, thus supporting *H3a* and *H3c*. However, *H2b* was not supported, as no empirical evidence was found for the mediating role of supply chain adaptability.

6. Discussion and implications

This study aims to investigate whether orchestrating triple-A supply chain capabilities, namely, agility, adaptability and alignment, mediates the relationship between DT and sustainable performance. The results highlight that supply chain agility and supply chain alignment act as mediators for the DT-sustainable performance relationship. However, no empirical evidence is found for the mediating role of supply chain adaptability. Considering these findings, firms can allocate their resources more efficiently, investing in supply chain agility and supply chain alignment, where they are more likely to yield tangible benefits in terms of sustainable performance. Prioritizing these two capabilities fosters a long-term perspective on sustainability and equips firms to successfully cope with the VUCA nature of changing market conditions.

6.1 Theoretical implications

The results of this research lead to several theoretical implications. First, we contribute to the evolving body of literature on the triple-A supply chain capabilities. This research emphasizes that these capabilities are essential in navigating the complex and dynamic environment of VUCA within the PSC. The paper affirms a positive relationship between DT and each of the triple-A supply chain capabilities. This highlights how investments in DT enable adjustments to long-term structural shifts, facilitate agile responses to short-term fluctuations and enhance alignment among supply chain actors.

Second, our findings reveal that while supply chain agility and supply chain alignment significantly influence sustainable performance, supply chain adaptability does not have a significant impact. This result is coherent with the study conducted by Gligor *et al.* (2020), which states that it is not necessary to develop at the same time high levels of agility, adaptability and alignment to achieve better performance. Our paper provides further evidence and corroborates the idea that not all the triple-A supply chain capabilities equally affect sustainable performance. In detail, adaptability refers to the ability to gradually reconfigure supply chain resources to

Table 7 Mediation analysis

Hypothesized relationship	Direct beta without mediation (*p*-value)	Direct beta with mediation or c′ (p-value)	Indirect beta or a *b (*p*-value)	Mediation type	HP supported or not
DT → SC agility → Sus. perf. **DT → Sus. perf** **DT → SC agility** **SC agility → Sus. perf.**	0.41*** (0.000)	0.34*** (0.001)	0.06* (0.1)	Partial mediation	*H3a:* Supported
DT → SC adaptability → Sus. perf. **DT → Sus. perf** **DT → SC adaptability** **SC adaptability → Sus. Perf.**	0.41*** (0.000)	0.38*** (0.001)	0.02 (ns) (0.5)	No mediation	*H3b:* Not supported
DT → SC alignment → Sus. perf. **DT → Sus. perf** **DT → SC alignment** **SC alignment → Sus. perf.**	0.41*** (0.000)	0.36*** (0.000)	0.05* (0.1)	Partial mediation	*H3c:* Supported

Notes: ***p <0.01; **p <0.05; *p <0.1; and not significant (ns)
Source: Author's own work

respond to long-term, structural changes. In contrast, DT often involves rapid technological innovations and quick implementation of digital tools and processes. The mismatch in the time horizons might explain why adaptability does not mediate the relationship between DT and sustainable performance (Gligor *et al.*, 2020). Hence, with the current research, we go beyond the interaction approach to triple-A supply chain capabilities, by moving a step forward in the orchestration of the triple-A supply chain capabilities considered in isolation. By understanding the hierarchical view of those capabilities, organizations can navigate modern business complexities and maintain a sustainable competitive advantage. This perspective allows for more nuanced strategies that align with the varying impacts of capabilities (Marin-Garcia *et al.*, 2023). Furthermore, our research also explores underdeveloped or inconclusive areas such as blockchain and information sharing for supply chain adaptability (Phadnis, 2024). Re-examining these relationships can enhance the marketing and Supply Chain Management (SCM) scholars' understanding of these concepts.

Third, the research expands the conventional focus on economic performance by considering the broader TBL perspective. Traditionally, research in this domain primarily emphasized economic factors (Feizabadi *et al.*, 2019). However, this study broadens the horizon by incorporating the social and environmental dimensions, aligning with the contemporary understanding that sustainable performance should be evaluated holistically. By doing so, it enriches the body of knowledge related to sustainable performance which is a growing but still developing field. By studying supply chain agility and supply chain alignment as mediators in the relationship between DT and sustainable performance in the PSC, characterized by a complex and global nature, this paper adds valuable insights that can be applied to similarly complex supply chains.

Fourth, the paper leverages the ROT to deepen the theoretical underpinnings of the study. The ROT sheds light on the orchestration and integration of key resources/capabilities for gaining competitive advantage and achieving superior performance. Our study extends ROT by exploring the mechanisms behind isolated and distinctive capabilities, specifically identifying agility and alignment as crucial supply chain capabilities. When adeptly managed and orchestrated, these capabilities empower firms to achieve sustainable performance. Our empirical findings highlight DT as a significant driver that enables supply chain agility and alignment, both critical for sustainable performance. This investigation adds a layer of theoretical depth to the ROT, highlighting the intricate relationship between DT and sustainable performance with the mediating roles of agility and alignment, thereby accentuating their strategic significance in enhancing overall sustainability. In this sense, our research aims to address the underdeveloped aspects of capabilities orchestration, advancing the understanding of how managers' influence can impact the development of distinct capabilities (Fawcett *et al.*, 2022). However, it should be noted that our study does not extensively cover long-term capabilities such as supply chain adaptability in the context of sustainable performance. This absence is attributed to the immediate focus of ROT on short-term, dynamic capabilities, rather than on the long-range, adaptive strategies necessary for sustaining performance over time. Nevertheless, an intriguing contribution of this study is the inherent tension between short-term agility and long-term adaptation, which needs further research according to other studies (Feizabadi *et al.*, 2021; Phadnis, 2024).

6.2 Managerial implications

From the managerial perspective, this study offers valuable guidance to managers who grapple with the challenge of limited supply chain resources. Given the resource constraints, the recommendation is to strategically prioritize the development and implementation of agility and alignment. These two are identified as considerable capabilities in facilitating process reconfiguration, particularly driven by DT. This strategic prioritization ensures optimal utilization of scarce resources for the maximum impact. Furthermore, the findings of the current research provide actionable insights for managers operating in VUCA environments. By focusing on agility and alignment, supply chain managers can effectively navigate and respond to the dynamics of VUCA. Agility enables them to react swiftly and adjust to short-term changes, crucial in turbulent environments. Alignment, on the other hand, ensures that interests and responsibilities are shared effectively, fostering a collaborative and responsive approach. Therefore, our results emphasize a strategic differentiation between adaptability and agility/alignment. It highlights that in response to dynamic changes, agility and alignment are better suited for swift adjustments and short-term changes. Conversely, adaptability involves a gradual reconfiguration of resources to align with long-term structural changes. This understanding equips managers with a nuanced approach, enabling them to tailor their strategies according to the specific nature and time horizon of changes in their operational landscape. In VUCA environments, the amalgamation of these resources and capabilities could potentially serve as the linchpin for the survival and prosperity of companies.

Following ROT, our results also suggest that managers need to treat DT not as a one-off activity, but they should combine it with a implementation of supply chain capabilities for sustainable outcomes. More in detail, the integration of DT with supply chain capabilities is identified as a pathway to attain competitive advantage. This advantage emanates from the digitalization and automatization of operational activities and processes within the supply chain. By leveraging digital technologies and automating processes, operational efficiency and effectiveness are enhanced, contributing to a competitive edge in the market. Furthermore, DT, when combined with supply chain capabilities, enables firms to effectively manage and exploit big data. This efficient use of data can lead to data-driven insights and decision-making, further contributing to competitive advantage.

Finally, the literature has extensively highlighted sustainability issues concerning PSC. Various studies (Guercini *et al.*, 2020; Milanesi *et al.*, 2020) have shed light on the sustainability concerns, emphasizing their multifaceted implications for companies operating in this sector. Notably, the environmental impact of the pharmaceutical sector extends beyond production and encompasses transportation, distribution, usage (Nayal *et al.*, 2022) and the dispersion of drug residues into the environment (Milanesi *et al.*, 2020). The findings strongly advocate that DT represents a highly effective investment for enhancing sustainable performance within PSC. Digitalization can optimize processes, reduce waste and enhance energy efficiency, all of which contribute to a more sustainable supply chain. Allocating resources and effort into effectively integrating digital technologies and strategies is not only beneficial for competitiveness but also aligns with environmental goals and mandates. This insight serves as a clear message to managers, providing a viable response to the escalating governmental pressures and requirements, such as those outlined in the European Green Deal. The emphasis is on orchestrating DT and supply chain capabilities, positioning this integration as a crucial initial step toward the much-needed transition to decarbonization.

6.3 Limitation and future research

Several limitations can be identified, which can provide indications for future research. First, the concepts of DT and sustainability encompass a wide range of aspects, and hence, the constructs used in the current study cannot comprehensively address all the dimensions. Second, the geographical boundaries represent a limitation to our study; our findings could be generalized in future studies by considering geographical diversification, such as the PSC in the USA. Third, to investigate whether the observed impacts of triple-A supply chain capabilities, as mediators in the relationship between DT and sustainable performance, is industry-specific, future studies could conduct interviews with executives and employees at different supply chain echelons in sectors beyond pharmaceuticals. Moreover, as a prospective avenue for future research, it could be interesting to delve into the intricate ways in which specific managerial skills and organizational routines impact resource structuring, bundling and exploitation to steer supply chains toward success in the ever-evolving marketplace of tomorrow. Fourth, due to the nature of our data (cross-sectional), we could not address the problem of endogeneity (i.e. reverse causality between studied constructs). Therefore, we suggest that future studies address this problem using longitudinal data. Moreover, action research can uncover the nuanced interactions between DT initiatives and sustainable performance outcomes, providing actionable recommendations for both scholars and practitioners. Fifth, our study does not conclusively determine the role of supply chain adaptability. More research is needed to understand how short-term changes may influence long-term responses, where the need for supply chain adaptation is more critical (Phadnis, 2024). In this context, future research could use complexity adaptive system (CAS) theory as a valuable lens. CAS views supply chains as evolving systems driven by interactions among components and their environments. This perspective can help scholars explore how supply chains might self-organize, adapt to uncertainties and achieve long-term sustainability. Finally, exploring the role of artificial intelligence (AI) for DT and sustainable performance in VUCA environments presents a promising area for future research. Investigating AI's potential to optimize efficiency, foster sustainability in supply chain operations, and enhance supply chain capabilities will yield valuable insights (Richey *et al.*, 2023). We encourage researchers to use interdisciplinary approaches, drawing from fields such as computer science, business management, sustainability and ethics, to comprehensively explore the multifaceted integration between AI and DT in the new business contest. Exploring these areas can advance our understanding of the development of business strategies that harness the full potential of AI while promoting sustainability, efficiency and triple-A supply chain capabilities.

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Supplementary material

The supplementary material for this article can be found online.

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