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Unlocking Circular Supply Chains' potentials through technologies and sustainable practices

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ABSTRACT

This paper aims to demonstrate the effect that the introduction of sustainable practices and digital technologies have on the development of a Circular Supply Chain (CSC). Furthermore, it was also considered important to focus on the change that the introduction of this new business model has on companies' economic performance. To carry out this research we used the PLS-PM method from which derived a positive outcome for the scenario previously described.

To obtain a more complete analysis, we opted for the development of a multigroup analysis focused on digital technologies that allowed us to understand which technologies improve the positive result within the scenario, but also to understand the indirect effects between the different variables.

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INTRODUCTON

1.1 CSC definition and characteristics

Circular Supply Chain Management can be defined as "*the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholders in a product/service lifecycle including parts/product manufacturers, service providers, consumers, and users*" (Farooque et al.,2018).

From a theoretical point of view, the aim of a CSCM is to generate zero waste through the collaboration between the producer's supply chain and secondary chains thanks to which a company can restore and regenerate resources. This aim can be achieved only thanks a Cross-Sector Collaboration that is based on industrial symbiosis. Hofmann and Jaeger-Erben (2020) gives a definition of Cross-Sector collaboration that is when "independent actors from different sectors collaborate and negotiate to share their resources and develop their core capabilities"; usually it is a long-term relationship that is based on risks sharing and common goals. An example of this phenomena can be The Circle-House-Project that is a cross-sectoral collaborative project aimed at creating circular economy in the Danish construction sector; this sector is one of the most resource-intensive because consume a lot of raw materials, energy and water and it also include a multitude of suppliers. The aim of The Circle-House-Project is to implement the diffusion of sustainable practices within this sector and include the largest possible number of participants "right from the design phase, to ensure that the knowledge created stretches as far as possible" (Köhler et al., 2021).

Another example of Cross-Sector collaboration is the one between Volvo and Battery Loop that are working together to give a second life to the batteries, used by Volvo in their cars, to create a solar-powered energy storage system.

CSCM has its foundation on three elements: natural environment, society, and economic performance at a broader level that represents the three aspects of the organizational sustainability. By modifying the weight of these three factors, various concepts have been developed in literature:

-Sustainable Supply Chain Management→It is the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of the triple bottom line. (Seuring et al., 2008).

-Green Supply Chain Management (GSCM)→ It represents the integration of environmental thinking into supply chain management, including product design, material sourcing and selection,

manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life. The aim of GSCM is to mitigate the environmental impact of not only the supply chain but also the entire organization. (Srivastava, 2007).
-Environmental Supply Chain Management→It represents the set of objectives, plans and management systems that determine manufacturing's position and responsiveness to environmental issues and regulation (Zsidisin et al., 2000).
-Closed Loop Supply Chain→ focuses on product returns and essentially combines the traditional supply chain with the reverse logistic, after that the product reached its end-of-life or end-of-use lifecycle. (Daniel, 2006).
In summary, CSCM improve the concept of Sustainable Supply Chain Management and Green Supply Chain Management because apply the circular thinking in all supply chain phases and functions and moreover is applicable both to manufacturing product and to services.
Differently to Closed Loop Supply Chain, CSC includes a secondary supply chain that not only guarantee back flow but also create an added value form waste thanks to the collaboration with other organizations which may belong to a different sector.

During the last years, firms had embraced new business models based on the re-use and upcycling of raw materials with the implementation of sustainable practices, to face the climate changes (Genovese, 2017).
To achieve better results and develop a circular supply chain, firms should introduce more sustainable practices and collaborate with external stakeholders to guarantee the reverse flow and the creation of an added value for the products (Del Giudice et al., 2020). Consequently, the implementation of a greener supply chain can be translated, in most of the cases, into important financial and commercial benefits, in fact, in most of the cases, companies have a reduction of the operating costs, a stronger brand and a greater ease of access to resources (Gideon et al.,2020).
This interest in circularity is also shared with customers who are very concerned about the impact of their consumption experience and want to melt the economic and personal wellness with the environmental and social ones (Min et al., 2019). For this reason, companies are asked to develop greener production processes that reflect the high expectations that costumers have regarding environmental issues but also because they are driven by growing legislative restrictions (De Giovanni et al., 2019).
The introduction of the sustainability concept into the Supply Chain Management has been very discussed in literature and in practice. Organizations are driven by various factors in adopting

sustainable practices into their supply chain that can be classified in pressures, triggers, enablers, and drivers.
These factors are, first of all, pressures because push companies toward the application of specific sustainability measures (Caniato et al., 2012) but also drivers because motivate organizations in implementing CSC practices (Kösal et al., 2017). These elements are defined also triggers because push organizations to introduce new sustainable practices throughout the supply chain (Saeed, 2017).

Another important categorization in literature is the division in primary and secondary factors, depending on their contribution to introduce sustainable practices (Saeed, 2017). Primary factors are, for example, pressures from shareholders, suppliers, or employees so that have a direct influence on the supply chain and on the organization, in general. While the secondary drivers are pressures related to reputation, image, and NGOs so have an indirect pressure.

1.2 CSC's Drivers

The literature mainly distinguishes between internal and external drivers. Starting from the **external dimension**, we can identify three main pressures: regulatory, societal, and market.
Regulatory pressures are the one carried out from government agencies, certifications and trade associations that can "oblige" companies to implement some practices because any non-adherence to regulations may create production or trade barriers (Caniato, et al. 2012). Regarding this theme, the scientific literature highlights the important role of certifications like ISO 14001, that help companies to improve their operational performance and show their commitment toward environmental issues (Walker, 2008).
For example, government can impose laws regarding reusing and recycling of products and packaging that can be the starting point to create a Circular Supply Chain. Authorities can also stress the importance of environmental collaboration with suppliers that could be encouraged to adopt sustainable manufacturing practices or push organizations to choose sustainable supplier through the introduction of incentives (Moktadir et al., 2020).

Social pressures come from nonprofit organizations and communication channels that can inform people about the companies' efforts to improve the sustainability of their supply chain (Saeed, 2017). Additionally, NGOs can involve potential stakeholder to finance innovative project to achieve sustainable goals.
People are increasingly interested about the application of circularity to the production process as the examples of BMH and Fortum demonstrate: BMH' s clients ask for a more efficient and accurate waste separation technology while Fortum's customers demand for a better utilization of residual heat

(Tura et al., 2018). This type of pressure pushes companies to satisfy the wishes of customers in order to avoid losing the market share.

Sustainable practices are put in place also to face the market pressure and gain a competitive advantage towards competitors; examples of market pressures are competitors, suppliers, and financial institutions (Saeed, 2017). Competition can be considered one of the main drivers that push organizations to adopt sustainable procedures and obtain a competitive advantage (Meixell, et al. 2015) to differentiate themselves from their competitors. Indeed, creating a Circular Supply Chain can be an element of differentiation from other competitors that allows the development of new products that meet the needs of customers.

In addition to the external factors, it is also important to highlight the **internal dimensions** that are: corporate strategy, organizational resources, organizational culture, and organizational characteristics.

Sustainable practices can be implemented only if they suit the long-term strategy of a company; this category is composed of top management commitment, cost-related pressure, and operational performance (Saeed, 2017). Cost-related pressure is one of the main elements that push a company to introduce sustainable practices because, on a hand, enable to save money by conservation of energy, water, and materials and on the other hand increased efficiency and profit (Schrettle et al., 2014).

In a CSC, cost reduction combined with long-term strategies can lead to the development of new process and product innovations that lead to the creation of new green products that will increase the market share but also, the reputation of the company.

Organizational culture is represented by the corporate social responsibility (CSR) that nowadays is one of the most relevant aspects for the client. For this reason, usually organizations try to improve the current practices to reach new goals through the introduction of innovative environmental-friendly practices (Hsu et al., 2013). In order to implement these new procedures, organizations usually create a code of business thanks to which new initiatives are implemented in accordance with the international law and stakeholders' expectations.

In a CSC, the corporate social responsibility is a fundamental element thanks to which the organization can achieve consumer awareness and a positive reputation, that became a form of strategic investment to gain a competitive advantage.

Another main factor is represented by organizational resources because the shortage of raw materials imposes to companies to review their linear production system based on producing goods, sell them and then throw out into landfills and seas or send them to other countries (Tate et al., 2010).
To overcome this production system, companies start to change their business model around the concept of circularity that is based on the reuse and recycling of end-of-use or end-of-life products that also involve a transformation of the supply chain that became a circular supply chain.

LITERATURE REVIEW

2.1 Sustainable Practices

Since the possible sustainable practices that firms can use to implement CSCM has been specifically addressed by previous research, we aim at identifying the sustainable practices that can support firms and systems in the creation of CSCM.
Thanks to the increasing consciousness of people regarding the environmental and social issues, companies have to identify and implement new sustainable solutions, not only inside their organizations, but also across their supply chain network.
The Ellen MacArthur Foundation (2014) sustains that to implement a Circular Supply Chain, a company should focus on three main themes.
The first one is the **rethinking of the product design** to maximize the utilization of raw materials and the life of the product. Regarding this theme is important to talk about some design policies like product life extension or eco-design.
The Product-Life Extension is a type of design whose goal is to maximize both lifespan and utilization, by increasing the value extracted from products before they are discarded, in this way the company reduce the amount of raw materials and energy sources destined for the production process. An application of this design can be seen into the fashion industry, and it is called Service Shirt's 50-year use and exchange cycle described by Pedersen et al. (2019). This service starts with the original product that, after the personal use, is redesigned using digital printing techniques so that the life of the shirt can be extended, and then the owner can share the product with friends or sell it. After this first phase, the shirt can be used as lining material inside a polyester jacket, which goes through the same lifecycle stages of first private use. After that the jacket is shared with friends or sell, it becomes one-off jewelry products and such shift create a huge added value.
The Eco-Design or Design for the Environment is a type of layout that want to minimize the environmental impact of a product during is all lifecycle and for this reason is seen by the European

Commission as a key approach for the development of the sustainable practices (Mendoza et al., 2017).
This type of design is developing a lot withing the sector of packaging because this industry looks for new solutions that are strong, hygienic and especially sustainable. Thanks to eco-design, companies start to replace the use of virgin petrochemicals with mineral fillers and recycled materials. This change made possible to create packaging with less environmental emission but maintaining the same technical feasibility and reducing costs, indeed thanks to this change the environmental impact was reduced of an average of 12%.

The second practice to create a CSC is to set up a **reverse network**. The task of a circular economy is not only the recycling or up-cycling of materials because the majority of the value is enclosed into the reuse, maintenance, refurbishment, and remanufacturing of components and products, and for this reason is important to improve the reverse capabilities. Companies should evaluate the best path to follow to create the perfect reverse network, that has to consider the cost advantage for each alternative.
The central element to create a reverse network is the product return because this phase can generate a loss in revenues if the product is not correctly transported from clients to manufacturers, in consequence a company's profit and environmental efficiency can be achieved through a controlled returned cycle (Fernando et al., 2022). This paper, also, affirms that companies will increase their competitive advantage if they share resources among their supply chain network to handle product returns using partnership.
Therefore, another important element is to choose green suppliers because they have a high impact on the overall cost and are also responsible for most of the environmental damage related to the logistic process (Mirzaee et al., 2018). Consequently, choose the proper supplier can decrease both environmental damage and costs and lead to circularity of used materials. Kannan et al. (2020) proposed a framework to choose the right supplier based on social, economic, environmental, and circular criteria, however the model for the selection of supplier depends on a lot from the needs of the companies.
Also, Talluri et al. (2002) affirmed that suppliers should be screened technically on several variables that are: "*an emphasis on quality at the source, design competency, process capability, declining non-conformities, declining WIP, lead-time, space, flow distance, operators being cross-trained, doing preventive maintenance, operators able to present SPC and a quick set-up, operators able to chart problems and process issues, hours of operator training in TQC/JIT, concurrent design, equipment and labor flexibility, dedicated capacity, and production and process innovation*".

According to Sagar et al. (2012), the criteria to select suppliers change over time and are based on different elements such as: political, economic, social, and environmental characteristics of the business.
In order to create a long-term partnership, companies should always monitor suppliers' performances using different variables and also, provide feedback for enhancement.

The third sustainable practice to introduce is the **creation of a new business model** that follow the shift from a linear production system to a circular one and accelerate the adoption of sustainable practices.
In literature, during the last years, new sustainable business models and strategies has been introduced such as: Sharing Platform or Product as a Service.
The Sharing Platform is a business model that connect product owners with individuals or organizations that would like to use a product but rather than buy it, people are co-owning it; this type of model allows to customers to use the same resources and to reduce the demand for new manufacturing (Lacy et al., 2015).
The integration of the sharing principle into a supply chain can create great possibilities because for example, companies can collaborate sharing human resources or physical assets to satisfy customer demand in a timely manner. An important application of this principle during these years is the collaboration between Nestle and Pepsi; these companies are competitors into the market but decided to combined parts of its supply chain for fresh and chilled products in Belgium. They decided to coordinate warehousing, packing and synchronized deliveries to fill trucks. The result was a 44% reduction in transportation costs, 55% lower carbon emissions and higher customer satisfaction levels (Hunt, 2018).
The Product as a Service business model is when the manufacturers sell integrated products and services and its aim is to sell the same product to the maximum amount of people and examples of this business model are leasing, renting, or pay-for-use agreements (Reim et al., 2015).
This model has been designed not only to improve the financial performance of a product but also to minimize the environmental impact of consumption by creating a closing material cycles, reducing consumption through alternative scenarios of product use and increasing overall resource productivity and dematerialization.
From the literature review, a gap emerges on the identification of a portfolio of practices that firms can undertake when implementing CE. In fact, the previous research focuses on single practices and strategies, for example the implementation of reverse logistic or the introduction of new business models. Research needs to be carried out on the simultaneous adoption of more than one practice

and/or strategies for implementing CSC. With the purpose of identifying such portfolio and testing its impact on the CSC formation, we hypothesize that:

H1: The adoption of an ad hoc portfolio of sustainable practices has a positive impact on the creation and management of CSC

The Ellen Mcarthur Report, claims that sustainable practices have benefits both from an operational and strategic point of view that can be summarized as follow:

- Substantial net material savings→ In a medium-lived complex products industries, the application of sustainable practices can provide a net materials cost savings opportunity of US$ 340 to 380 billion. Those materials savings would represent about 20% of the materials input costs incurred by the consumer goods industry.
- Mitigation of price volatility and supply risks → The previous savings will decrease the cost curve for different raw materials. For example, if we take into consideration the steel industry, the global market can save up to 100 millions of tones if organizations apply practices to share the material flows. This modification will sterilize the steel industry from the rising costs of extracting and using virgin raw materials.
- Innovation→ The ambition to implement sustainable practices into an existing company and creating a reverse logistic system is a formidable way to stimulate people creativity, that will generate a development of innovation across the economy.
- Lasting benefits for a more resilient economy→ The circular supply chain aims to develop resilience across economies and reduce dependence from energy-intensive materials and primary extraction, creating a new paradigm based on reuse, remanufacturing, and recycling.

2.2 Digital Technologies

Along with the sustainable practices, the CSCM also requires the adoption of digital technologies to successfully pursue its targets. The application of digital technologies is a game-changer for the introduction of sustainable practices into the supply chain, indeed numerous scientific research has highlighted the positive effects of technology into a circular supply chain (Tseng et al., 2018).

Indeed, as empirically proved by De Giovanni (2021) digital technologies can ensure both environmental, social and economic benefits.

The circular supply chain approach is based on a technological process in which products and components are designed to be re-used and reduce waste (Rizos et al., 2017) and technology is also needed to analyze the supply chain footprints and measure some sustainability indicators of performance (Wu et al., 2017).

Aris Pagoropoulos et al. (2017) identify different types of technologies and show their possible application into a circular supply chain.

Obviously one of the most important is Blockchain that give to the supply chain automation, transparency, and reliability; it ensures the integration of information along all the value chain and a high cyber-security level to protect the organization' confidential data.
Thanks to blockchain, organizations can reduce supply chain management time, increase quality of goods, and meet demand avoiding waste of products (Yuan et al., 2020); it enables customers to be aware of the sustainable production and transportation of the products and permit to tracks the position of each item to optimize reverse logistic operations by making them faster and cheaper (De Giovanni, 2020).
By doing so, this technology creates digital chains, also thanks to the cooperation with other tokens and technologies, that solve issues in different fields like production, inventory, logistic and quality control (De Giovanni, 2022).
The integration of Blockchain with Radio Frequency Identification (RFID) can help organizations to reduce the difficulties of circular supply chain management. RFID can be used to track the material flows and implement a recovery strategy to guarantee the creation of an added value for products and this is possible thanks to electromagnetic fields that automatically identify, and track tags attached to object (Pagoropoulos et al., 2017). Thus, RFID is a noticeable emerging data-ensuring technology because using tags, can capture, analyze, and store data and for this reason, is commonly used in logistic processes and has several benefits such as cost reduction, process improvements and better quality of the service provided (Chanchaichujit et al., 2020).
Thanks to these technologies, companies can map the journey of goods and analyze pollution and energy consumptions to reduce greenhouse gas emissions and better organize logistic activities (Saberi et al., 2019).
While RFID collect data on the production and logistic process of a product, Blockchain can help with the integration and sharing of data across the different subjects across the supply chain. Moreover, Blockchain assure a high level of protection regarding the storing of data online and also, gives the possibility to all the members of the supply chain, to access to more detailed information such as the use of raw materials and the manufacturing process (Terrada et al., 2020). Furthermore, can supervise and rate product life cycles, allowing to the different stakeholders involved into the supply chain to achieve both resource efficiency and material supply resilience in the acquisition process.

It is necessary to highlight that RFID are technologies included into the IOT macro class, together, for example, with QR codes.
IoT is the acronym of Internet of Things that is another relevant technology to mention, especially if we are talking about the reverse logistic because can enhance process-oriented performance and reduce energy consumption (Garrido-Hidalgo et al., 2019).
Internet of Things (IoT) are sensors connected to a network that can manage the actions of objects or machines connected to the net and into a supply chain is important because can collect data and send information to the different stakeholders or suppliers across the value chain (Xu et al., 2011). Through simulations done thanks to the data collected, operators can visualize possible obstacles into the logistic process and monitor indistinct queues or delays into logistic in real-time (Abideen et al., 2020).
There are two critical issues related to the application of IoT that are trust and privacy.
Trust is related both to consumers and players include within the supply chain and, from a business perspective, trust is the base of information sharing.
Privacy because the utilization of IoT create huge data raising privacy worries and for this is important to create a security mechanism to protect data collected along the supply chain (Harwood et al., 2017).
Mastos et al. (2020) applied IoT to the scrap metal industry and demonstrate that the use of this technology improves the competitive advantage of both waste producers and waste management companies towards sustainable supply chain management. This benefit derived from the capability of organizations to better manage their processes and make efficient solutions. Moreover, applying the framework proposed in this research, that is based on the implementation of IoT solutions, companies can reduce the utilization of non-renewable energy resources and CO2 emissions.
Another important research is the one of Varriale et al. (2021) who developed two scenarios: the first is the traditional one without the use of digital technologies while the second scenario blend the use of blockchain, smart contracts, IoT and RFID. They propose this 5-year simulation to study the impact of technologies in the long term and, also, added disruption events to analyze the management of these problems in both the scenarios.
In the second scenario, the IoT infrastructure and RFID connect the real and the virtual warehouse in real time to better manage the inventory and due to the fact that the goods are tracked in all the stages of the supply chain, when a disruptive event happens, products are immediately withdrawn, and the inefficiencies are reduced by 3.2%. Thanks to blockchain and smart contracts, organizations can create more automated and efficient systems thanks to which there is an increase of operational efficiency.

Thanks to the introduction of these technologies, the number of orders raised, and the status of goods is checked in real time; moreover, the management of disruptive events is no longer a duty of the retailer because is managed by technology that manage the entire system (Varriale et al., 2021).

Another important technology is Machine Learning that is based on algorithm thanks to which a machine can learn from data and not from rules imposed by a technician. This technology together with Artificial Intelligence can support and optimize processes that analyze big amount of data, allowing organizations to react quickly to unpredictable situations (Wojtusiak et al., 2012).
The introduction of AI into a CSC can help with the design, control and management of the supply chain and also to establish solid relationship with green suppliers and partners to increase the logistical effectiveness (Kumar et al., 2021). Indeed, thanks to the introduction of this technology, organizations can easily exchange information among suppliers and use forecasting methods, based on reliable simulation, to reduce the production of waste that is one of the central issues in a CSC (Grimm et al., 2014).
The combination of AI and Machine Learning into a CSC can provide different benefits such as (Kumar et al., 2021):
-The sharing of shipment between various partners because the AI-based system enables companies to share issues with other organizations and speed up shipping, save money and minimize pollution;
-Development of independent vehicles to achieve better route planning since driverless cars can follow paths that are more efficient than those created for humans;
-Taking sustainable decision because thanks to Machine Learning, companies can train systems to take positive and green decision, for example choosing the perfect amount of goods to be shipped and the type of vehicle to use;
-Lower goods waste because the AI system recognize damaged products that are immediately substituted so the demand for returns, and refund is reduced;
-Optimization of reverse logistic because AI can help to define the number of products returned during the collection’s phase. Agarwal et al. (2012) described a particular application of AI thanks to which organizations can determine the optimal monetary incentive for consumers to return items to maximize the producer’s profit.
A great example of the use of AI is Pirelli, one of the leading manufacturers, that in its warehouses uses sensors and AI to track pneumatic locations and the exact numbers and amount of new goods to be put into production; in this way, Pirelli can decrease emissions of toxin and reduce waste through a tailored production

The creation of new processes and systems can reduce waste and have a great impact on sustainability. Moreover, the implementation of digital technologies facilitates the information and materials flow and also the optimization of logistic using software or geolocation systems (Uniyal et al., 2021).
As well as creating more sustainable packages, there are other enhancement solutions that companies can make into practice, for example: elimination of unnecessary travel and the optimization of container loading plans (Alharbi et al., 2015). The efficiency of the service is improved thanks to the scheduled loads that reduced the environmental impacts, decrease the wait for transporters during the pick-up and delivery phase. Additionally, it is important to reduce the number of deliveries combining orders from different customers to reduce costs and carbon emissions (Caracciolo et al., 2018).
From the literature review, emerges a gap on the recognition of different technologies that a company can implement to facilitate the creation of a CSC. In fact, most of the research tested the impact of new technologies in a specific sector, that usually is the manufacturing one. This work aims to identify the effect of technologies on supply chains that operates in heterogeneous sectors.
With the objective to identify the portfolio of possible technologies that can have an impact on diversified CSC, we hypnotize that:
H2: The adoption of an ad hoc portfolio of digital technologies has a positive impact on the creation and management of CSC.
To have a complete background, we can align the fundamental principles of Circular Supply Chain with the different technologies previously mentioned (Dev et al., 2020):
-Regenerate can associate with the implementation of a suitable process that use data coming from IoT.
-Share can be align with the use of cloud-based resources and blockchain because companies can share information related to the inventory or the demand with the other actors of the supply chain and moreover, thanks to these technologies, organizations can collect data about costumer behavior to optimize the use of resources and reduce the environmental impact.
-Optimize can be associate with IoT and Machine Learning through which companies can collect information from the different process and maximize the use of raw materials and avoid waste.
-Loop is compatible with RFID tags that allow to keep track of reverse logistic operations

2.3 Firm's Performance
The creation of a Circular Supply Chain, thanks to the introduction of sustainable practices and digital technologies, has also effects from the point of view of performance.
In general, firm's performance is tested based on its efficiency, profitability and financial ratio but recently, literature has started to study the impact of social and environmental-friendly practices on the company's performance (Govindan et al., 2020).

Organizations can measure sustainability performance based on three dimensions, directing to solve the economic, social, and environmental problems that derive from a sustainable supply chain management.

From the economic point of view, the improvement of sustainable performance should be connected to the control of profits, investments, and costs. For example, if we talk about a manufacturing industry, it means to reduce procurement-related expenditure and the costs related to energy or water consumption.

Regarding the social aspect, elements that highlight the sustainable development of companies are linked to costumers, stakeholders, and employee, indeed, a sustainable development is represented by the capability of an organization to focus on a durable economic performance. The indicators associated to social sustainability are focused on work conditions, societal commitment, customer issues, turnover rate and equal opportunities and diversity.

The last aspect is the environmental performance that is represented by the capability of companies to reduce air emissions, wastewater, solid waste, the consumption of harmful and toxic substances and recovery and reuse of used products. Acar et al., (2019) claim that organizations that don't give attention to environmental issues cannot enjoy long-term benefits.

Starting from the Natural Resource Based View (NRBV), authors like Golicic et al. (2013) affirm that there is a positive relationship between firm's performance and sustainable practices and for this reason, this feature can be used as a competitive advantage.

According to Zhu et al. (2004), the management of a circular supply chain can have both negative and positive features. In the short period, the implementation of a CSC can increase costs due to big initial investment such as new machineries or process modification while in the long term, aspects like lower energy costs, savings from using recycled/reused materials, and reduced fees for waste discharge can decrease costs.

On the other hand, King et al. (2001) claimed that even if are assured lower production costs, Circular Supply Chain is related to poor financial performance.

During the last years, people become more aware of environmental problems and, for this reason are willing to pay more to have a sustainable product that has behind a green supply chain, and this will cause an enhancement of performance.

The improvement in performance can be from an operational or cost point of view. There can be an increase of the operational performance due to a better and more efficient collaboration with suppliers and through the development of environmental specific capabilities or, on the other hand, the cost prospective that is more related to lower carbon tax, pollution penalties, and resource wastage (Dong et al., 2019).

The CSC can create different additional revenue flows. The first example is based on the idea that into a circular supply chain that is based on the Product as a Service business model, costumers don't own the product, but they rent it for a period. This type of contract generates a long-time relationship between the participant and enables the manufacturer to reduce costs and create a long-term revenue stream, based on product lifetime extension (Blokpoel, 2016).
This long-time deal is also an opportunity for the company to test their products and collect statistical data, thanks to new technologies, that will be analyzed to highlight the most common problems of a specific product.
In the current literature are recommended some indicators that are used in empirical studies to measure the relationship between the environmental performance and the financial performance of a company.
These indicators can be classified into two categories: the Accounting-based indicators and the Market-based indictors. The first ones are evidence of the past or short- term financial performance that reflect the internal decision-making and resource allocation and examples are ROE and ROA (Albertini, 2013).
The Market-based indicators are more related to the future or long-term financial performance and measure this performance from the shareholders' point of view. The advantages of these indicators are that: firstly, are connected with the external prospective so they are less vulnerable to the company manipulation and secondly, they represent the expectations of investors about the company profitability; some examples are Tobin's Q and the share price (Gentry et al., 2010).
Albertini (2013) affirms that the relationship between environmental and financial performance can be influenced by the category of indictors that the researcher uses to analyze the environmental and financial performance but, in general, he claimed that if we use Accounting-based indicators, usually the result is positive for environmental performance while if we want to study the financial performance, to have a positive result, we should use Market-based indicators.

From the previous literature review, it is important to highlight that there isn't scientific research that analyzed the effects on the performance caused by the implementation of a Circular Supply Chain into a company. The aim of my work is to study the consequences on the performance after the creation of a CSC and especially, the analysis of the financial performance indicators that were most influenced.
Using the information on the previous paragraph, we can affirm that in general, the development of a CSC has a positive impact on the company performance, so we can hypnotize that:
H3: The adoption of CSC has a positive effect on firm's performance.

METHODOLOGY

3.1 Survey Design and Sample Description

To test our research hypotheses, we designed a survey to collect information about the respondents (e.g., industry and company type), the investments in blockchain technology, the implemented omnichannel strategies, the logistics strategies, the last mile management, and the performance. The following step consisted of pre-testing the questionnaire on a pool of experts (e.g., professors, Ph.D. students, professionals, managers) from whom we asked for feedback about wording, readability, and completeness. Consequently, the survey was modified and improved accordingly.

The data collection process began by subjecting the survey to an initial sample of 120 firms' managers. Because our research focuses on supply chain management, we chose to interview professionals who are active in this domain. They were contacted via email. Within two weeks, we received the majority of the responses. In the meantime, we extended our investigation by contacting them by phone. Overall, we obtained a total of 157 usable observations, excluding those removed as invalid. This represents about 12% of the entire population of companies that we targeted (1200). The sample primarily constituted large enterprises, both in terms of sale turnover and employees. More than half of the organizations had an average sale turnover of more than 100 million (52%) and a workforce of more than 200 employees (53%).

The data collected was primarily from European and American companies, 73% and 16%, respectively. Most of the interviewees are supply chain managers (52%), working mainly for manufacturing companies (36%) and retailers (23%). The results reveal a heterogeneous industrial panorama with the Food and Beverage (22%) and the Fashion & Apparel (12%) sectors predominating. A more detailed representation of the distribution of the respondents and the composition of the sample characteristics are illustrated in Table 1.

Several approaches were used to assess the non-response bias. The first approach consisted of comparing early and late respondents (i.e., first and second to third surveys). A one-way analysis of variance (ANOVA) found no significant differences between the early and late responses for all items. These findings support the conclusion that non-response bias is not a significant concern. Moreover, we checked for non-response bias by using the demographic variables size, number of employees, and sales. Once again, we found no significant differences between the groups.

All items included in the questionnaire were measured using a 7-point Likert scale, indicating the level of agreement with a certain question (where 1=not at all in agreement and 7=full agreement). Therefore, because the difference between the items matters and can be directly compared, we conducted the analysis at the original items' scale.

3.2 Model Assessment

To pursue the objective of this research, we use a technique called PLS-PM (Partial Least Square Path Modelling) and the XL-Stat 2021.2.1 software. PLS-PM is a component-based estimation algorithm that aims to predict the relationships between constructs and provides their scores at the original scale (Agyabeng-Mensah et al., 2020). Furthermore, PLS-PM does not require any distributional assumption for the data (in contrast with a maximum likelihood covariance-based approach). Finally, PLS-PM provides less biased estimates than other approaches to structural equation modeling sample sizes lower than 200 observations, while achieving the same power above 200 observations (Chin, 2010). These motivations underlie the use of PLS-PM in several business contexts, such as operations management (Peng & Lai, 2012), supply chain management (Colicev et al., 2016), sustainable supply chain (Agyabeng-Mensah et al., 2020), and closed-loop supply chain (Bhatia and Kumar Srivastava, 2020).

The first step in our research is to identify the Latent Variables that are constructs indirectly described by a block of observable variables which are called Manifest Variables, that in our case are represented by the choices in the survey.

Our Latent Variables are: Sustainable Practices, Technology, Circular Supply Chain and Performance that we linked to some Manifest Variables, as shown in Figure 1.

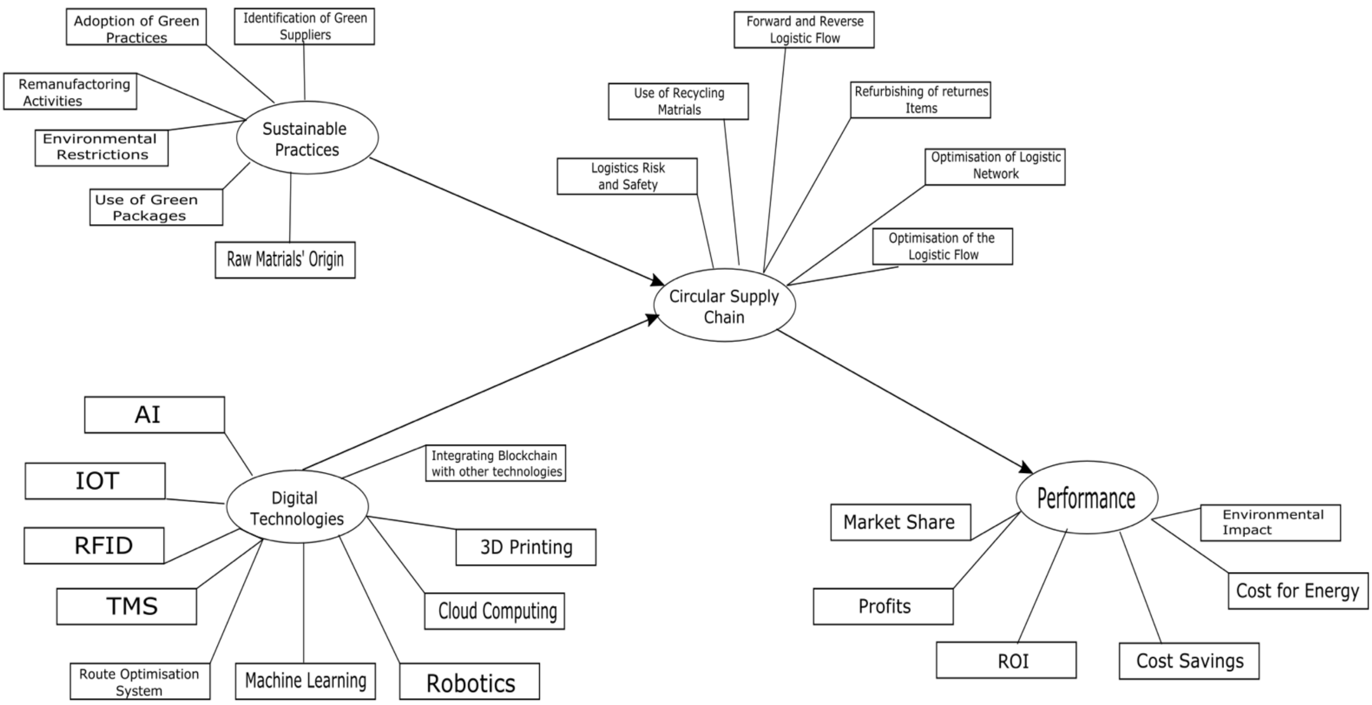

Figure 1-Initial Model

Sales	#	%	Employees	#	%	Country	#	%	Company type	#	%	Professionals	#	%	Industry	#	%
< 10	11	7.0%	< 50	14	8.9%	Europe	115	73.2%	Manufacturer	56	35.7%	SC Manager	82	52.2%	Food & Beverage	34	21.7%
10-50	38	24.2%	50-99	40	25.5%	USA	25	15.9%	Wholesaler	30	19.1%	Logistics Manager	12	7.6%	Fashion & Apparel	18	11.5%
50-100	26	16.6%	100-200	20	12.7%	Asia	4	2.5%	Distributor	14	8.9%	Operations Manager	13	8.3%	Medical & Healthcare	12	7.6%
> 100	82	52.2%	>200	83	52.9%	Other	13	8.3%	Supplier	21	13.4%	Sales Manager	3	1.9%	Automobile	11	7.0%
									Retailer	36	22.9%	Production Manager	9	5.7%	Mechanic	7	4.5%
												Purchasing Manager	2	1.3%	Energy	7	4.5%
												Procurement Manager	8	5.1%	Furniture	6	3.8%
												Distribution manager	2	1.3%	E-commerce	5	3.2%
												Other	26	16.6%	Aerospace	4	2.5%
															Sport	4	2.5%
															Entertainment	4	2.5%
															Glass	3	1.9%
															Cement	3	1.9%
															Telecommunications	2	1.3%
															Luxury	2	1.3%
															Beauty & Cosmetics	2	1.3%
															Electrical and electronics	2	1.3%
															Chemical	1	0.6%
															Other	30	19.1%
Total	157	1		157	1		157	1		157	1		157	1		157	1

Table 1 – Sample description

Figure 1 shows the Initial Scenario that we modify during the research to optimize our work, focusing only on the significant variables, and in the following parts we will base our results on the Final Scenario.

The final items' list allows for the detection of the cross-loadings associated with each construct, as displayed in Table 2.

	Sustainable practices	**Technology**	**Performance**	**Circular SC**
Identification of green suppliers	0,868			
Environmental restrictions	0,882			
Raw materials origin and provenance	0,826			
Artificial intelligence		0,768		
IOTsensors		0,691		
RFID		0,617		
Route optimization system		0,724		
TMS		0,726		
Mobile device monitoring of delivery people		0,681		
Machine learning		0,691		
Marketshare			0,779	
Profits			0,798	
ROI			0,820	
Cost savings			0,741	
Management of reverse logistics flows				0,678
Use of recycling material				0,558
Integration of forward and reverse logistics flows				0,650
Optimisation of the logistics network				0,797
Optimisation of the logistics loads				0,757
Logistics risks and safety				0,720

Table 2 – Summary of the cross-loadings

The first important elements to analyze are the Composite Reliability Indexes that allow to objectively evaluate how much a set of items can be grouped together in the same dimension. In fact, if a group of items aims to measure a certain concept, then the scores of these items are expected to be similar to each other.

In particular, we focus on the Cronbach's alpha and the Eigenvalue.

A high value of Cronbach's alpha, therefore close to 1, indicates that there is a high reliability within the dimension. This is because the more the alpha value increases, the more the percentage of error decreases. In our research, we consider acceptable a Cronbach's alpha higher than 0,8 and to obtain this result for all the Latent Variables we reduced the problematic dimensions. Herby, we can observe that Circular SC and Performance have a borderline Cronbach's alpha but is very close to 0,8 and for this reason we decide to accept them.

The Eigenvalue informs on how many dimensions we have in a certain concept and each value that is higher than 1 represent a dimension. As we can see in Table 3, all our Latent Variables achieve the one-dimensionality, therefore, we can proceed to evaluate the structural model.

Latent variable	Dimensions	Cronbach's alpha	Eigenvalues
Sustainable practices	3	0,821	2,213
Technology	7	0,828	3,476
Circular SC	6	0,786	2,927
Performance	4	0,792	2,467

Table 3 – Composite Reliability Indexes

ANALYSIS AND RESULTS

4.1 Hypothesis testing on the entire sample (Analysis 1)

This section provides the empirical results of the hypothesis testing by considering the entire sample; hence, no group is considered in this analysis. The general outcomes show a relative goodness-of-fit index of 0,940. All results are displayed in Table 4 in which we report the result "Supported" when a research hypothesis is empirically confirmed or "Not supported" otherwise.

H_1 is supported because we have a coefficient (which represent the direct effect) that is 0,457 and a p-value <0.01 therefore, this result confirms the literature thesis that the adoption of sustainable practices positively influences the creation of a CSC. In particular, the set of sustainable practices that led to support this first hypothesis are:

- Identification of green suppliers
- Environmental restrictions
- Raw Materials origin and provenance

H_2 is supported because the coefficient is 0,314 and the p-value < 0,01. This empirical result shows that also the adoption of digital technologies has a favorable impact on the development of a CSC, but in a lesser extent than the adoption of sustainable practices.

H_3 is supported because the coefficient is 0,606 and the p-value is < 0,01 hence, the creation of a Circular Supply Chain has a favorable impact on the performance especially if we consider indexes as: Marketshare, Profits, ROI and Cost Savings that are the one tested in our study.

Research hypotheses	Coefficients	Results
H1: The adoption of an ad hoc portfolio of sustainable practices has a positive impact on the creation and management of CSC	0.457***	Supported
H2: The adoption of an ad hoc portfolio of digital technologies has a positive impact on the creation and management of CSC	0.314***	Supported
H3: The adoption of CSC has a positive effect on firm's performance	0.606***	Supported

****p=value<0.01; **p=value<0.05; *p=value<0.1*

Table 4 – Results of the research hypotheses

4.2 Hypothesis testing on different groups (Analysis 2)

To improve our research and methodology, we decided to implement also a multigroup analysis, particularly focus on the digital technologies that we mentioned in the previous part.

The multigroup analysis allows to test if pre-defined data groups have significant differences in their group-specific parameter estimates and allows us to have information also about the indirect effects. Our multigroup analysis is comparing two groups: 1 and 0; 1 represent the group of companies that adopt a specific technology while in 0 there are all the firms that are not using that technology.

The objective of this analysis is to highlight whether the introduction of a specific technology leads to an improvement of the relationship between two Latent Variables.

To carry out the analysis, whose results are summarized in Table 5, we measure the difference between these two groups and then through standard deviation, we calculate the p-value and the level of significancy.

IoT

The first technology that we tested is IoT and using the data from our survey, we can count 81 firms in group 0 and 76 in group 1. Obviously, our empirical analysis, demonstrate that technology has a positive impact on CSC and if companies want to improve even more this relationship, they can invest in IoT to obtain better results (p-value 0.014). As we claim in the first part of this work, IoT can unlock the potentialities of a Circular Supply Chain because through sensors and electronic devices can monitor and support the lifecycle and the logistic behind the final product, to optimize the firm's business model.

It is also important to highlight the indirect effect that this technology has on performance because the development of IoT has a significant impact (p-value 0.039) also on this variable so thanks to IoT we can have improvement not only on the side of the environmental sustainability of the supply chain but also on the financial aspect. The positive effect on performance depends on the improvement of operational performance, that is a benefit of all the mentioned digital technologies, but with IoT companies can have real time information from each operating units about the inventory, the material flow and the customer demand; as a consequence, companies gain a more productive system that can face better the needs of clients and adjust their production based on the demand to reduce the waste of goods, raw material and money.

TMS (Transportation Management System)

The result of our survey shows that TMS is adopted by 88 firms while 69 companies are not implementing this technology. TMS is one of the best performing technologies among those analyzed in this section. A Transportation Management System is a logistic platform that apply different technologies to a supply chain with the objective to optimize the physical movement of products.

In addition to having a significant impact on the relationship between technology and CSC, it also improves the impact of sustainable practices on the supply chain because, thanks to a controlled shipment service, the environmental pollution caused by the means of transport necessary to move the goods is reduced since the space inside them is optimized and they are completely filled.

These systems also allow to improve warehouse efficiency and productivity because the incoming and outgoing goods are constantly tracked and in sectors where the warehouse is made up of products that deteriorate over time, the correct management of this asset is essential to avoid waste of goods that are reflected, from a point of economic view, by a loss of money.

Undoubtedly, these platforms lead to a significant improvement in performance, which is also demonstrated in our analysis by a p-value equal to 0.041, that represents the indirect effect of the adoption of sustainable practices on performance.

Machine Learning and Robotics

The multigroup analysis applied to Machine Learning and Robotics has shown similar results.

Obviously, both technologies improve the yet positive impact that technology has on the circular supply chain, in particular machine learning that has a p-value of 0.005, and this leads to an indirect improvement in the business performance shown by a p-value of 0.033 and 0.03.

The better results deriving from the introduction of these two technologies depends on their ability to improve quality, find concealed solutions, and reduce operative costs; machine learning can anticipate uncertain performance of the different production processes and detect flaws in circular systems while robotics can facilitate the exchange of goods within the production chain and carry out concurrent checks during the different phases of the production process.

3D Printing

3D Printing is the only technology studied that shows a significant indirect effect on Sustainable Practices that is demonstrated by a p-value equal to 0.030.

3D Printers improve the impact of technology on sustainable practices because they reduce waste. First, thanks to this technology it is possible to create spare parts necessary to fix machinery that otherwise could not be fixed. Secondly, 3D Printer has the advantage of close-to-demand, which can save ordering and delivery time but also reduce the inventory costs.

	Technology - CSC	Technology - Performance	Sustainable Practices - CSC	Sustainable Practices- Performance	Technology - Sustainable Practices
IoT	0,014 **	0,039 **			
TMS	0,004 ***		0,024 **	0,041 **	
Machine Learning	0,005 ***	0,033 **			
Robotics	0,037 **	0,031 **			
3D printing					0,030 **

****p=value<0.01; **p=value<0.05; *p=value<0.1*

Table 5 – Results of the Multigroup Analysis

DISCUSSION AND MANAGERIAL INSIGHTS

When considering the entire sample (Analysis 1), our finding demonstrates that the adoption of a portfolio of sustainable practices and technologies has a positive impact on the creation of a Circular Supply Chain.

As we mentioned previously, the analysis finds three practices that promote the creation of a Circular Supply Chain that are: Green Supplier, Environmental Restrictions and Raw Material Origin and Provenance.

As Mirzaee et al. (2018) affirm, a fundamental element for the creation of a CSC is the choice of suppliers since environmental pollution depends both on the production processes but also on the logistic necessary for assembly the final product and its subsequent transport to the consumer.

Consequently, choose a green supplier can reduce the environmental damage but also create a more sustainable supply chain that start from the procurement of raw materials up to the sale of the finished product.

Indeed, it is also important the choice of raw materials because Farooque et al. (2018) claim that a CSC is based on the restore and regeneration of materials so it is essential to choose the right elements that are the basis of the goods and that are characterized by durability and the possibility to restore; while, if companies choose raw materials only thinking about the economic convenience, without considering the possibility of re-using that materials, a CSC cannot be put in place because the fundamental element is missing: circularity.

The introduction of these two practices within companies would be much easier if the external context also encouraged the transition to circularity, sure enough that, as Moktadir et al. (2020) said, if authorities stress the importance of environmental collaboration through incentives, would be easier for companies to adopt sustainable manufacturing practices or choose sustainable supplier.
Clearly from a managerial point of view, these three sustainable practices are not the only one that ensure the creation of a Circular Supply Chain in fact they represent a possibility for companies to create a new business model, but it is important to highlight that there are many other options that a firm can implement, also based on its needs and problems. Surely, Green Supplier and the Choose of Raw Materials can be considered as the starting points for the development of a more sustainable supply chain that can subsequently be adapted or related to other elements to better fit the organization.

From the Analysis 1 result, as well, the positive impact that digital technologies have on the creation of a Circular Supply Chain, and this is in line with Rizos et al. (2017)'s idea that the creation of a CSC is based on the existence of a technology capable of reusing and regenerating a specific material and able to analyze the supply chain footprints.
Analyzing the previous outcome together with the results deriving from Analysis 2, first of all, we can identify which are the technologies that amplify the positive effect deriving from the Analysis 1, and subsequently, through the study of the indirect effects, it is also possible to understand which technologies optimize the effects on performance and sustainable practices.
From the combination of the two analyses, it emerged that the most performing technology is TMS.
Transportation Management System (TMS) is a platform that allows to better manage the transport of products from the producer to the final consumer, optimizing the efficiency. To do this, it is based on the combination of different technologies, and is for this reason that it is the most performing in our work and have effects on all three latent variables.
This platform is based on the use of IoT thanks to which companies can follow the movement of products and easily exchange information with the rest of the supply chain in a safe and fast way, also having the possibility to visualize possible obstacles into the logistic process and monitor indistinct queues. These logistic benefits are combined with the environmental one because as Mastos et al. (2020) argue, the application of IoT to a supply chain increase the advantages of both suppliers and companies that derive from the capability of organizations to better manage their processes and make efficient solutions and, moreover, firms can reduce the utilization of non-renewable energy resources and CO_2 emissions.

To maximize results, companies could combine TMS with technologies that have a greater impact on the production phase, such as Machine Learning and 3D printers in order to reduce the environmental impact even during the production process. Indeed, as we can see in Table 5, these two technologies act both by increasing the effect on CSC and performance but also on sustainable practices because on a hand, through Machine Learning, companies can train systems to take positive and green decision, for example choosing the perfect amount of raw materials to use or goods to be shipped, while 3D printers can extend the product life by repairing, replacing or customizing even single parts of machineries or products.

It is important to underline that both the analysis agree on one point: the development of a CSC has a positive effect on the company's economic performance. Our results are in contrast with King and Lenox (2001)'s idea that Circular Supply Chain is related to poor financial performance, and this is particularly evident in Table 5 in which all the technologies used, even if indirectly, cause a significant positive effect on performance which is added to the benefits deriving from the impact that the CSC has on this variable which emerge from Analysis 1.
In our study we took into consideration the following indices as economic performance indicators: Market share, Profits, ROI and Cost savings; these are the indices usually most used in business practice to understand the growth of the company and the quality of the investments made.
Concretely, these indices usually do not show a fully positive result in the short term as also claimed by Zhu and Sarkis (2004), due to the high cost of the initial investments but subsequently there will be a progressive improvement of these indicators thanks to the benefits deriving from the introduction of a circular business model.

CONCLUSION

This paper investigates the effects that the introduction of sustainable practices and digital technologies has on the creation of a Circular Supply Chain and subsequently understand if the introduction of this new concept leads to economic benefits for companies.
The positive impact that the two variables have on the CSC and on the performance emerged from the literature because the empiric tests carried out in other research, showed a reduction in logistic costs, consumption of raw materials but also mitigate the volatility of prices and supply risks.
The peculiarity of this work, with respect to other papers analyzed, is that usually technology and sustainable practices were analyzed separately so it was not possible to identify a work that studies the effects of these two variables on CSC at the same time. The same reasoning is valid on performance, in fact there are papers that treat the impact of CSC on performance but without touching the topic of technology and sustainable practices.
On the other hand, through my analysis, I wanted to create a more complete scenario which study the influence of these three variables on a sample made up of 157 companies active in different sectors and understand if the positive effects studied separately are valid even if we insert all these variables in a single analysis and using a single sample.
Our findings have confirmed the positive effects indicated by the literature; indeed, the choice of a specific portfolio of sustainable practices and digital technologies is fundamental for the development of a CSC.
Elements such as: the choice of supplier and sustainable raw materials or the introduction of certain digital technologies represent the starting point for the development of a sustainable supply chain since the scenario I presented does not include all the elements that can lead to the development of a CSC.
After carrying out this first general analysis, we concentrated on digital technologies identifying, through a multi-group analysis, which were the technologies that had the most significant effects on the various latent variables. Through this analysis, we were also able to study the indirect effects that individual technologies have on sustainable practices and performance, and it turned out that the technology that is able to have the greatest impact on all variables is TMS, probably because to achieve its goal use the coordination between different technologies.
This study is not free of limitations, which are listed hereafter to inspire future research. This paper focuses on a small group of sustainable practices and technologies so in the future other elements could be identified to understand their impact on the three latent variables. In future works it may be useful to reflect on the possibility of introducing incentives to encourage the introduction of

circularity within companies but also the possibility of exploiting the last mile to minimize the movement of goods and their economic, environmental and social consequences.

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LUISS

Dipartimento
di Economia e Management d'Impresa

Cattedra Management of Circular Economy

SUMMARY

Unlocking Circular Supply Chains' potentials through technologies and sustainable practices

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INTRODUCTION

CSC definition and characteristics

Nowadays, the idea of environmental sustainability and "zero-waste policy" are one of the main topics and companies become aware that the old conception of producing goods, sell them and then throw out into landfills and seas or send them to other countries, is overcome.

The linear production systems were increasing the risks and challenges for the economy related to the constrains on raw materials and an increasing volume of waste and pollution and, for this reason, companies decided to introduce the concept of circularity inside their business models but to do so, they should also develop new logistical practices that are related to the notion of Circular Supply Chain.

Circular Supply Chain Management can be defined as "*the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholders in a product/service lifecycle including parts/product manufacturers, service providers, consumers, and users*" (Farooque et al.,2018).

The aim of a CSCM is to generate zero waste through the collaboration between the producer's supply chain and secondary chains thanks to which a company can restore and regenerate resources.

LITERATURE REVIEW

Sustainable Practices

Thanks to the increasing consciousness of people regarding the environmental and social issues, companies have to identify and implement new sustainable solutions, not only inside their organizations, but also across their supply chain network.

The Ellen MacArthur Foundation (2014) sustains that to implement a Circular Supply Chain, a company should focus on three main themes.

The first one is the **rethinking of the product design** to maximize the utilization of raw materials and the life of the product. The two most common design polices are Product-Life Extension and Eco-Design.

The Product-Life Extension is a type of design whose goal is to maximize both lifespan and utilization, by increasing the value extracted from products before they are discarded, in this way the company reduce the amount of raw materials and energy sources destined for the production process.

The Eco-Design or Design for the Environment is a type of layout that want to minimize the environmental impact of a product during is all lifecycle and for this reason is seen by the European Commission as a key approach for the development of the sustainable practices (Mendoza et al., 2017).

The second practice to create a CSC is to set up a **reverse network**. The task of a circular economy is not only the recycling or up-cycling of materials because the majority of the value is enclosed into the reuse, maintenance, refurbishment, and remanufacturing of components and products, and for this reason is important to improve the reverse capabilities.
The central element to create a reverse network is the product return because this phase can generate a loss in revenues if the product is not correctly transported from clients to manufacturers, in consequence a company's profit and environmental efficiency can be achieved through a controlled returned cycle (Fernando et al., 2022).
Therefore, another important element is to choose green suppliers because they have a high impact on the overall cost and are also responsible for most of the environmental damage related to the logistic process (Mirzaee et al., 2018). Consequently, choose the proper supplier can decrease both environmental damage and costs and lead to circularity of used materials.

The third sustainable practice to introduce is the **creation of a new business model** that follow the shift from a linear production system to a circular one and accelerate the adoption of sustainable practices.
In literature, during the last years, new sustainable business models and strategies has been introduced such as: Sharing Platform or Product as a Service.
The Sharing Platform is a business model that connect product owners with individuals or organizations that would like to use a product but rather than buy it, people are co-owning it; The integration of the sharing principle into a supply chain can create great possibilities because for example, companies can collaborate sharing human resources or physical assets to satisfy customer demand in a timely manner.
The Product as a Service business model is when the manufacturers sell integrated products and services and its aim is to sell the same product to the maximum amount of people and examples of this business model are leasing, renting, or pay-for-use agreements (Reim et al., 2015).
This model has been designed not only to improve the financial performance of a product but also to minimize the environmental impact of consumption by creating a closing material cycles.

From the literature review, a gap emerges on the identification of a portfolio of practices that firms can undertake when implementing CE. In fact, the previous research focuses on single practices and strategies, for example the implementation of reverse logistic or the introduction of new business models. Research needs to be carried out on the simultaneous adoption of more than one practice and/or strategies for implementing CSC. With the purpose of identifying such portfolio and testing its impact on the CSC formation, we hypothesize that:

H1: The adoption of an ad hoc portfolio of sustainable practices has a positive impact on the creation and management of CSC

Digital Technologies

Along with the sustainable practices, the CSCM also requires the adoption of digital technologies to successfully pursue its targets; as empirically proved by De Giovanni (2021) digital technologies can ensure both environmental, social and economic benefits.

The circular supply chain approach is based on a technological process in which products and components are designed to be re-used and reduce waste (Rizos et al., 2017) and technology is also needed to analyze the supply chain footprints and measure some sustainability indicators of performance (Wu et al., 2017).

Obviously one of the most important is Blockchain that give to the supply chain automation, transparency, and reliability; it ensures the integration of information along all the value chain and a high cyber-security level to protect the organization' confidential data.

The integration of Blockchain with Radio Frequency Identification (RFID) can help organizations to reduce the difficulties of circular supply chain management. RFID can be used to track the material flows and implement a recovery strategy to guarantee the creation of an added value for products (Pagoropoulos et al., 2017). Thanks to these technologies, companies can map the journey of goods and analyze pollution and energy consumptions to reduce greenhouse gas emissions and better organize logistic activities (Saberi et al., 2019).

Another important technology is Machine Learning that is based on algorithm thanks to which a machine can learn from data and not from rules imposed by a technician. The introduction of this technology together with Artificial Intelligence into a CSC can help with the design, control and management of the supply chain and also to establish solid relationship with green suppliers and partners to increase the logistical effectiveness (Kumar et al., 2021).

The creation of new processes and systems can reduce waste and have a great impact on sustainability. Moreover, the implementation of digital technologies facilitates the information and materials flow and also the optimization of logistic using software or geolocation systems (Uniyal et al., 2021).

From this theoretical framework, emerges a gap on the recognition of different technologies that a company can implement to facilitate the creation of a CSC. In fact, most of the research tested the impact of new technologies in a specific sector, that usually is the manufacturing one. This work aims to identify the effect of technologies on supply chains that operates in heterogeneous sectors.

With the objective to identify the portfolio of possible technologies that can have an impact on diversified CSC, we hypnotize that:

H2: The adoption of an ad hoc portfolio of digital technologies has a positive impact on the creation and management of CSC.

Firm's Performance

The creation of a Circular Supply Chain, thanks to the introduction of sustainable practices and digital technologies, has also effects from the point of view of performance.

In general, firm's performance is tested based on its efficiency, profitability and financial ratio but recently, literature has started to study the impact of social and environmental-friendly practices on the company's performance (Govindan et al., 2020).

From the economic point of view, the improvement of sustainable performance should be connected to the control of profits, investments, and costs. For example, if we talk about a manufacturing industry, it means to reduce procurement-related expenditure and the costs related to energy or water consumption.

Regarding the social aspect, elements that highlight the sustainable development of companies are linked to costumers, stakeholders, and employee, indeed, a sustainable development is represented by the capability of an organization to focus on a durable economic performance.

The last aspect is the environmental performance that is represented by the capability of companies to reduce air emissions, wastewater, solid waste, the consumption of harmful and toxic substances and recovery and reuse of used products.

According to Zhu et al., (2004), the management of a circular supply chain can have both negative and positive features. In the short period, the implementation of a CSC can increase costs due to big initial investment such as new machineries or process modification while in the long term, aspects like lower energy costs, savings from using recycled/reused materials, and reduced fees for waste discharge can decrease costs.

The improvement in performance can be from an operational or cost point of view. There can be an increase of the operational performance due to a better and more efficient collaboration with suppliers and through the development of environmental specific capabilities or, on the other hand, the cost prospective that is more related to lower carbon tax, pollution penalties, and resource wastage (Dong et al., 2019).

It is important to highlight that there isn't scientific research that analyzed the effects on the performance caused by the implementation of a Circular Supply Chain into a company. The aim of my work is to study the consequences on the performance after the creation of a CSC and especially, the analysis of the financial performance indicators that were most influenced.

Using the information on the previous paragraph, we can affirm that in general, the development of a CSC has a positive impact on the company performance, so we can hypnotize that:

H3: The adoption of CSC has a positive effect on firm's performance.

METHODOLOGY

Survey Design and Model Assessment

To test our research hypotheses, we designed a survey to collect information about the respondents (e.g., industry and company type), the investments in blockchain technology, the implemented omnichannel strategies, the logistics strategies, the last mile management, and the performance. The data collection process began by subjecting the survey to an initial sample of 120 firms' managers, that later was extended to 1200 firms. Because our research focuses on supply chain management, we chose to interview professionals who are active in this domain.

To pursue the objective of this research, we use a technique called PLS-PM (Partial Least Square Path Modelling) and the XL-Stat 2021.2.1 software. PLS-PM is a component-based estimation algorithm that aims to predict the relationships between constructs and provides their scores at the original scale (Agyabeng-Mensah et al., 2020).

The first step in our research is to identify the Latent Variables that are constructs indirectly described by a block of observable variables which are called Manifest Variables, that in our case are represented by the choices in the survey.

Our Latent Variables are: Sustainable Practices, Technology, Circular Supply Chain and Performance that we linked to some Manifest Variables,

The first important elements to analyze are the Composite Reliability Indexes that allow to objectively evaluate how much a group of items can be grouped together in the same dimension.

In particular, we focus on the Cronbach's alpha and the Eigenvalue.

A high value of Cronbach's alpha, therefore close to 1, indicates that there is a high reliability within the dimension. This is because the more the alpha value increases, the more the percentage of error decreases; in our research, we consider acceptable a Cronbach's alpha higher than 0,8.

The Eigenvalue informs on how many dimensions we have in a certain concept and each value that is higher than 1 represent a dimension. As we can see in Table 1, all our Latent Variables achieve the one-dimensionality, therefore, we can proceed to evaluate the structural model.

Latent variable	Dimensions	Cronbach's alpha	Eigenvalues
Sustainable practices	3	0,821	2,213
Technology	7	0,828	3,476
Circular SC	6	0,786	2,927
Performance	4	0,792	2,467

Table 1 – Composite Reliability Indexes

ANALYSIS AND RESULTS

Analysis 1 and Analysis 2

This work can be divided into two analyses, the first one is carried out on the entire sample while the second one uses a multigroup analysis particularly focus on the digital technologies, that we mentioned in the previous part.

The general outcomes show a relative goodness-of-fit index of 0,940.

All the results from Analysis 1 are displayed in Table 2 in which we report the result "Supported" when a research hypothesis is empirically confirmed or "Not supported" otherwise.

Research hypotheses	Coefficients	Results
H_1: The adoption of an ad hoc portfolio of sustainable practices has a positive impact on the creation and management of CSC	0.457***	Supported
H_2: The adoption of an ad hoc portfolio of digital technologies has a positive impact on the creation and management of CSC	0.314***	Supported
H_3: The adoption of CSC has a positive effect on firm's performance	0.606***	Supported

****p=value<0.01; **p=value<0.05; *p=value<0.1*

Table 2 – Results of the research hypotheses

Moving on to Analysis 2, thanks to the multigroup analysis we can test if pre-defined data groups have significant differences in their group-specific parameter estimates and allows us to have information also about the indirect effects. The objective of this analysis is to highlight whether the introduction of a specific technology leads to an improvement of the relationship between two Latent Variables.

Our multigroup analysis is comparing two groups: 1 and 0; 1 represent the group of companies that adopt a specific technology while in 0 there are all the firms that are not using that technology.

To carry out the analysis, whose results are summarized in Table 3, we measure the difference between these two groups and then through standard deviation, we calculate the p-value and the level of significancy.

	Technology - CSC	**Technology - Performance**	**Sustainable Practices - CSC**	**Sustainable Practices- Performance**	**Technology - Sustainable Practices**
IoT	0,014 **	0,039 **			
TMS	0,004 ***		0,024 **	0,041 **	
Machine Learning	0,005 ***	0,033 **			
Robotics	0,037 **	0,031 **			
3D printing					0,030 **

****p=value<0.01; **p=value<0.05; *p=value<0.1*

Table 3 – Results of the Multigroup Analysis

DISCUSSION AND MANAGERIAL INSIGHTS

When considering the entire sample (Analysis 1), our finding demonstrates that the adoption of a portfolio of sustainable practices and technologies has a positive impact on the creation of a Circular Supply Chain.

The analysis finds three practices that promote the creation of a Circular Supply Chain that are: Green Supplier, Environmental Restrictions and Raw Material Origin and Provenance.

As Mirzaee et al. (2018) affirm, a fundamental element for the creation of a CSC is the choice of suppliers since environmental pollution depends both on the production processes but also on the logistic necessary for assembly the final product and its subsequent transport to the consumer.

Consequently, choose a green supplier can reduce the environmental damage but also create a more sustainable supply chain that start from the procurement of raw materials up to the sale of the finished product.

Indeed, it is also important the choice of raw materials because Farooque et al. (2018) claim that a CSC is based on the restore and regeneration of materials so it is essential to choose the right elements that are the basis of the goods and that are characterized by durability and the possibility to restore; while, if companies choose raw materials only thinking about the economic convenience, without considering the possibility of re-using that materials, a CSC cannot be put in place because the fundamental element is missing: circularity.

Clearly from a managerial point of view, these three sustainable practices are not the only one that ensure the creation of a Circular Supply Chain in fact they represent a possibility for companies to create a new business model, but it is important to highlight that there are many other options that a firm can implement, also based on its needs and problems.

From the Analysis 1 result, as well, the positive impact that digital technologies have on the creation of a Circular Supply Chain; analyzing the previous outcome together with the results deriving from Analysis 2, first of all, we can identify which are the technologies that amplify the positive effect deriving from the Analysis 1, and subsequently, through the study of the indirect effects, it is also possible to understand which technologies optimize the effects on performance and sustainable practices.

From the combination of the two analyses, it emerged that the most performing technology is TMS. Transportation Management System (TMS) is a platform that allows to better manage the transport of products from the producer to the final consumer, optimizing the efficiency. To do this, it is based on the combination of different technologies, and is for this reason that it is the most performing in our work and have effects on all three latent variables.

To maximize results, companies could combine TMS with technologies that have a greater impact on the production phase, such as Machine Learning and 3D printers in order to reduce the environmental impact even during the production process. Indeed, as we can see in Table 3, these two technologies act both by increasing the effect on CSC and performance but also on sustainable practices because on a hand, through Machine Learning, companies can train systems to take positive and green decision, for example choosing the perfect amount of raw materials to use or goods to be shipped, while 3D printers can extend the product life by repairing, replacing or customizing even single parts of machineries or products.

It is important to underline that both the analysis agree on one point: the development of a CSC has a positive effect on the company's economic performance. In our study we took into consideration the following indices as economic performance indicators: Market share, Profits, ROI and Cost savings; these are the indices usually most used in business practice to understand the growth of the company and the quality of the investments made.

Concretely, these indices usually do not show a fully positive result in the short term as also claimed by Zhu et al., (2004), due to the high cost of the initial investments but subsequently there will be a progressive improvement of these indicators thanks to the benefits deriving from the introduction of a circular business model.

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