The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/0960-0035.htm

What is next? The effect of reverse logistics adoption on digitalization and inter-organizational collaboration

Faisal Rasool
Department of Enterprise Engineering, University of Rome Tor Vergata, Roma, Italy
Marco Greco
Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Cassino, Italy, and
Gustavo Morales-Alonso and Ruth Carrasco-Gallego
Departamento de Ingeniería de Organización, ADE y Estadística, Universidad Politécnica de Madrid, Madrid, Spain

Received 9 June 2022
Revised 5 October 2022
6 March 2023
Accepted 14 April 2023

Abstract

Purpose – This study aims to examine and understand the impact of reverse logistics adoption on firms' digitalization and collaboration activities. Specifically, leveraging the knowledge-based view, this study examines how adopting sustainable logistic practices (reverse logistics) prepares firms to embrace digitalization and encourages them to collaborate with other organizations.

Design/methodology/approach – The study used longitudinal survey data from two waves (2017 and 2019) from the Mannheim Centre for European Economic Research. The authors used the negative binomial regression analyses to test the impact of reverse logistics adoption on the **digitalization and inter-organizational collaboration** dependent count variables.

Findings – The study's findings highlight the usefulness of reverse logistics in enabling digitalization and inter-organizational collaboration. The results show that the firms investing in sustainable supply chains will be better positioned to nurture digitalization and inter-organizational collaboration.

Practical implications – For resource-bound managers, this study provides an important insight into prioritizing activities by highlighting how reverse logistics can facilitate digitalization and collaboration. The study demonstrates that the knowledge generated by reverse logistics adoption can be an essential pillar and enabler toward achieving firms' digitalization and collaboration goals.

Originality/value – The study is among the first to examine the effect of reverse logistics adoption on firm activities that are not strictly associated with the circular economy (digitalization and collaboration). Utilizing the knowledge-based view, this study reports on the additional benefits of reverse logistics implementation previously not discussed in the literature.

Keywords Circular economy, Firm partnership, Sustainable logistics, Green supply chain, Closed-loop supply chain, Main machine interaction, Industry 4.0, Digital transformation, German innovation survey, Internet of thing (IoT)

Paper type Research paper

The authors wish to thank the data provider, the Leibniz-Zentrum für Europäische Wirtschaftsforschung, which granted access to the Mannheim Innovation Panel (MIP), ZEW, Mannheim, Germany.

International Journal of Physical Distribution & Logistics Management
Emerald Publishing Limited
0960-0035
DOI 10.1108/IJPDLM-06-2022-0173

1. Introduction

Logistics is the process of strategically managing the procurement, transport, and storage of materials, components, and finished goods within and outside the boundaries of an organization while maximizing current and future profitability through cost control and process optimization. In other words, logistics entails delivering goods to suppliers and customers in the best possible way (Min *et al.*, 2019). However, managing only forward logistics (traditional logistics) has become inadequate to compete and grow in an ever-changing global business environment (Baah and Jin, 2019). In addition, government regulations, stakeholder pressure and customer demands compel firms to take responsibility for their products at the end of life stage (Andiça *et al.*, 2012; Ni *et al.*, 2021). As a result, it has become essential for a firm to manage the forward and reverse flow of materials and goods. This reverse flow of goods is generally referred to as "reverse logistics". Reverse logistics activities focus not only on recycling the products but also on properly disposing of harmful components and repurposing the useful components in the returned products, for example, using old computer chips in toy manufacturing (Meade *et al.*, 2007). Studies have reported many benefits of successful reverse logistics activities, such as higher profits, increased customer satisfaction and loyalty, cost reduction and better environmental performance (Del *et al.*, 2019; Harold, 2011; Hazen *et al.*, 2012; Marić and Opazo-Basáez, 2019; Ni *et al.*, 2021; Sangwan, 2011; Sehnem *et al.*, 2019).

Though necessary, the process of implementing and managing reverse logistics is not easy and requires a significantly larger amount of resources and expertise compared to forward logistics to manage and implement it successfully (Gaur *et al.*, 2017; Giri *et al.*, 2017; Jayaraman *et al.*, 2008). Such a process includes building an appropriate infrastructure, IT capabilities and culture to share information with internal and external partners (Hudnurkar *et al.*, 2014; Marić and Opazo-Basáez, 2019; Moktadir *et al.*, 2020; Olorunniwo and Li, 2010; Zhang and Cao, 2018). As a result, companies invest in business operations and personnel to facilitate reverse logistics operations. Many studies have investigated how digitalization and collaboration activities can facilitate the reverse logistics adoption process and improve system efficiency (Aksin-Sivrikaya and Bhattacharya, 2017; Chen *et al.*, 2017). But surprisingly, no study has investigated the impact of reverse logistics adoption on firm digitalization and collaboration levels. First of its nature, by utilizing Knowledge-Based View (KBV), this study aims to empirically investigate the impact of reverse logistics adoption on firm digitalization and collaboration levels. Such investigation will be useful in advancing theory and managerial practices related to reverse logistics, digitalization and collaboration. The study aims to empirically investigate the impact of reverse logistics adoption on firm digitalization and inter-organizational collaboration by leveraging KBV and to demonstrate that newly created knowledge can serve as a competitive advantage for the firm. This study is the first of its nature to explore such relationships. Unlike the former flow of actions (implementation of digitalization and then reverse logistics), the law often imposes the adoption of reverse logistics on firms to achieve SDG 2030 goals. Therefore, in many cases, firms will not have the choice to delay or ignore the implementation of reverse logistics activities. Therefore, it is crucial to understand the impacts of reverse logistics adoption on firm activities and study the unintended consequences of reverse logistics on firm operations.

The outcome of this study confirms that adopting reverse logistics positively influences digitalization and collaboration in firms. As a result, the study presents several theoretical, managerial and policy implications. The manuscript is organized into seven sections. The following section, section two, presents the study's theoretical background. Section three focuses on developing and rationalizing the two hypotheses studied and tested in the study. Section four presents the methodology and data sets used to test the hypotheses. Section five is dedicated to reporting the results, while section six discusses the findings of the study. Finally, section seven concludes the study and discusses the theoretical, managerial and policy implications. This section also reports on the limitation of the study and presents possible future developments.

2. Theoretical background

2.1 Knowledge-based view

Barney (1991) argued that in the current information age, the Resource-Based View (RBV) proposed by Wernerfelt (1984) has evolved into KBV. According to KBV, knowledge is the most valuable resource created within the firm's boundaries by utilizing and enhancing employees' experience, skills and abilities (Curado and Bontis, 2006). Teece (2000) argued that a firm's competitive advantage is inextricably tied up with its ability to create, diffuse, maintain and use difficult-to-imitate knowledge. In other words, knowledge management enables firms to share information produced by different employees and sections to gain a competitive advantage (Nisar *et al.*, 2019). Ode and Ayavoo (2020) confirmed the positive relationship between knowledge creation, management activities and firm innovativeness. Knowledge is created when learning occurs at the individual level within an organization (Ganesh *et al.*, 2014). This individual learning is translated into organizational learning and eventually into organizational knowledge that has a positive impact on a firm's financial performance (Silvestre, 2016), purchasing performance (Schütz *et al.*, 2020), flexibility (Blome *et al.*, 2014), innovation and operations capabilities (Javaid *et al.*, 2021), and serves as a source of major competitive advantage (Teece, 2000). These advantages are accumulated by capturing and transferring implicit and explicit knowledge during the knowledge creation and transfer process. Therefore, it is vital for a firm to create and manage information to remain competitive.

2.2 Knowledge management

Knowledge management bridges the gap between information demand and supply by encouraging learning processes that improve organizational performance (Curado and Bontis, 2011). The studies have argued that even though a firm needs external knowledge and information, a lasting competitive advantage comes from creating and utilizing in-house knowledge (Azyabi, 2018; Chong *et al.*, 2014; Emden *et al.*, 2005). However, the firm can only enjoy these knowledge creation and sharing advantages when employees share information freely with their co-workers (Caputo *et al.*, 2021a). Bhatt (2019) defined knowledge as expertise gained through accumulation of experiences or study to understand facts, procedures and rules. For capitalization and value capture of knowledge, Loon (2019, p. 433) categorized knowledge management mechanisms into "a. Learning and knowledge creation culture; b. organizational knowledge architecture for adaptive and exaptive capacity; and 'c. business model'". Knowledge is created in cycles and transferred within the organization through different means and actions (Nonaka, 1994), making it vital to continuously produce new knowledge to maintain a competitive advantage by implementing new systems and processes. In other words, a valuable transferable knowledge is created whenever a firm performs a new activity that will shorten the learning curve in future projects (de Machado *et al.*, 2022).

2.3 Sustainability

Knowledge transfer and management activities can be important mediators in using sustainability tools in medium- and large-sized firms (Hörisch *et al.*, 2015), making them essential for achieving sustainability goals. In the last two decades, the concept of sustainability has gained significant interest from the popular press, policymakers and scientific journals in various technical fields (Lintona *et al.*, 2007). Sustainability can be defined as the extent to which current business actions affect the natural environment, society and firms' economic viability in the future (Krysiak, 2009). In other words, it requires a conscious decrease in the use of resources while still maintaining a steady flow of products to allow commercial entities to gain revenues from deliverables to market. The scarcity of resources and uninterrupted increase in pollution mainly caused by industrialized nations (Tahvonen, 2000) combined with ever-increasing economic, social and environmental uncertainties in recent years have encouraged researchers and practitioners to investigate and develop solutions from many points of view. In addition, the stakeholders (customers, shareholders, governments) are putting immense pressure on firms to change their habits of indiscriminately using and discarding natural resources. As a result, sustainability has become a major concern in decision making. Unlike in the past, where decisions were mainly economic (Ohnishi *et al.*, 2012), the decision-makers are being forced to consider the impact of their decisions on the triple bottom line of sustainability (economic, environmental, social). If implemented correctly, sustainable actions can offer firms several benefits and competitive advantages. These include, among others, decreased cost for materials, waste reduction, production/operations efficiency, increased firm reputation, brand value, better working conditions, and profits (Sangwan, 2011), innovation (Nidumolu *et al.*, 2009) and shared value creation (Porter and Kramer, 2011a). These benefits are often the result of introducing sustainable initiatives in the firms' value chain to make the supply chain green and lean. This new supply chain is not just about cost and efficiency: it also considers the triple bottom line of sustainability (Silvestre, 2016). Sustainable initiatives' success depends on using the right strategies and frameworks at both the implementation and operational stages (Preuss and Fearne, 2022) to increase the success of sustainable supply chain initiatives.

2.4 Supply chain and sustainability

In recent years, the pursuit of sustainability has been recognized as a viable strategy to resolve many of the contemporary challenges global supply chains face (Giannakis and Papadopoulos, 2016). Sustainable supply chains manage materials, information and capital flows and result in cooperation between different actors along the supply chain (Karaosman *et al.*, 2020). Sustainability in supply chain practices improves firms' financial performance and enhances competitiveness (Wang and Sarkis, 2013). Furthermore, it creates a moral capital that firms can utilize to mitigate the consequences of potential business risks (Jiang *et al.*, 2020) and create new opportunities. To this end, one powerful strategy used by the firms is to decrease the use of virgin materials by bringing back the material for reuse or repurposing at the end of life and creating a loop for the material. The process is generally termed as a "closed-loop supply chain". Min *et al.* (2006, p. 311) defined a closed-loop supply chain as the process associated with the "acquisition, distribution, and marketing activities involved in product returns/recoveries, source reduction/conservation, inspection, recycling, salvage, substitution, reuse, disposal, disassembly, refurbishment, repair, and remanufacturing". In other words, an ideal closed-loop supply chain is a supply chain with zero-waste where all the products at their end of life are recovered for reuse/repurpose or disposed of properly. However, the studies have argued that the closed-loop supply chain systems are often complex and unpredictable compared to the forward supply chain (Gaur *et al.*, 2017; Giri *et al.*, 2017) and, therefore, often require greater resources and commitments to manage (Morgan *et al.*, 2018). But firms are still willing to invest in these risky endeavors to reap the tangible and intangible benefits (Schenkel *et al.*, 2015) they offer.

2.5 Reverse logistics

Drivers such as legislation, stakeholder pressure, social accountability, economic interests and ethics compel a firm to adopt green activities in their supply chain (Andiça *et al.*, 2012), including the reuse of materials and end-of-life products. Reusing materials/products is generally referred to as "reverse logistics". Reverse logistics is a key element of green supply chain management since it helps decrease waste produced by processing and disposing returned and used goods by implementing a variety of disposition alternatives (Pokharel and Mutha, 2009). Many factors and points in the supply chain can lead to product returns, including production, distribution and returns connected to customers (Rogers and Tibben-Lembke, 2001), and reverse logistics aims to facilitate appropriate reuse, recycling and disposal of these returns. In the past, reverse logistics was viewed as the process of recycling used/malfunctioned products. However, in recent years, the definition and concept have expanded to include processes connected with product return and collection for recovery, repair, refurbishment, recycling, remanufacturing or disposal of used/end-of-life items (Rogers and Tibben-Lembke, 2001). The expansion in concept has increased the benefits obtained from reverse logistics, including increased profits (Marić and Opazo-Basáez, 2019; Toffel, 2004), cost reduction (Sangwan, 2011), customer loyalty (Jayaraman *et al.*, 2007), customer satisfaction (Hazen *et al.*, 2012) and environmental performance (Harold, 2011). Reverse logistics is a complex process and requires a significantly higher level of competencies and resources than forward logistics (Gaur *et al.*, 2017; Giri *et al.*, 2017). Therefore a greater level of investment and organizational commitment is needed to implement reverse logistics successfully (Morgan *et al.*, 2018).

2.6 Digital technologies and supply chain

By directly connecting suppliers and consumers and vice versa, digital technology can tackle some of the most pressing challenges in supply chain management by decreasing information delays, cost, and increasing volume and flexibility, leading to greater service levels (Agrawal and Narain, 2018). Although there have been academic contributions dealing with the repair, reuse and refurbishment of items for decades, the advent of digitalization in recent years has allowed a whole new set of tools to be implemented at the firm level (Hidalgo-Carvajal *et al.*, 2021). Unlike traditional supply chains, the Digital Supply Chain (DSC) depends primarily on technologies (such as software, hardware and communication networks) to enable operations such as buying, making, storing, moving and selling a product by globally dispersed partners (Bhargava *et al.*, 2013). Rasool *et al.* (2021, p. 1204) defined DSC as "a seamlessly interconnected transparent supply chain, that independently performs decision support activities to minimize human input needs". Studies have reported several benefits of DSC over the traditional supply chain, including improved transparency, speed, flexibility, productivity and profitability (Haoud and Hasnaoui, 2019; Oorschot *et al.*, 2022). The list of these benefits expands when applied to a closed-loop supply chain. Some studies have argued that without digital technologies, the activities associated with a closed-loop supply chain are impossible to manage and control (Jayaraman *et al.*, 2008; Pagoropoulos *et al.*, 2017; Wilson *et al.*, 2022). The ability of digital technologies to facilitate a closed-loop supply chain is well acknowledged and documented in the literature (Antikainena *et al.*, 2018; Awan *et al.*, 2021; Pagoropoulos *et al.*, 2017). Studies have reported that the technologies such as A.I, M.L, data mining and IoT enable firms to not only trace, monitor and make decisions on returned products/materials but also on the products still in circulation and their end-of-life destination (Pagoropoulos *et al.*, 2017; Rosa *et al.*, 2020).

2.7 Collaboration and supply chain

In the fast-moving globalized economy, firms have realized that they cannot provide high-quality products to their customers at competitive prices and with speed in silos. Therefore, they are forced to collaborate and leverage the knowledge and skills of the entities outside of their boundaries (Hudnurkar *et al.*, 2014). Gulati (1998, p. 293) defined collaboration as "*voluntary arrangements between firms involving exchange, sharing, or co-development of products, technologies, or services*". It can involve just two firms that have created a bilateral agreement or a complex system of multiple independent and interconnected entities working together to achieve the same goals by creating a shared value ecosystem (Grant and Baden-Fuller, 1995; Porter and Kramer, 2011b). The benefits of such collaborative activities often include expedited product development and launch processes at a reduced cost with significantly higher quality and technical specifications (Singh *et al.*, 2018; Walter, 2003). In addition, the collaborative activities help firms to share risk (Li and Nguyen, 2017) and reduce transaction costs (Kalwani and Narayandas, 1995) by accessing complementary resources (Park *et al.*, 2004) and knowledge (Grant and Baden-Fuller, 1995). As a result, firms improve their productivity (Kalwani and Narayandas, 1995), profits and competitive advantage (Mentzer *et al.*, 2000). Depending on the project's objective and need, the firms may seek both vertical (supplier and customers) and horizontal (competitors) collaboration together with private-private (among firms) or cross-sectoral collaboration (public-private-third sector collaboration). To identify which partners are best suited for collaboration in any given project, Barratt (2004) recommended asking why, where, what and whom before undertaking collaboration projects.

3. Hypotheses

3.1 Reverse logistics and digitalization

Adopting reverse logistics is a complex process and often requires firms to undergo substantial changes and overcome multiple internal and external barriers (González-Torre *et al.*, 2010). Some of these barriers include a lack of firm infrastructure readiness, employee skills, an appropriate support system to handle new activities, management commitment, strategic planning as well as market uncertainties and high initial cost (de Campos *et al.*, 2017; González-Torre *et al.*, 2010; Govindan and Bouzon, 2018; Prakash *et al.*, 2015; Prakash and Barua, 2017; Waqas *et al.*, 2018). To overcome these barriers, firms must unlearn and relearn several important competencies and develop new skills and knowledge. According to KBV, knowledge is created by individual actors within a firm and is transferred to other members and sections of organizations (Ganesh *et al.*, 2014). As a result, firm performance and maturity improve in different domains (Matos *et al.*, 2020). The case is no different for reverse logistics, whose adoption increases a firm's capabilities in different areas (Mihi Ramírez, 2012; Ramirez and Girdauskiene, 2013), including IT competencies (Daugherty *et al.*, 2005) that will help in increasing the firm's digitalization level. Azyabi (2018) reported that the management of internally developed knowledge is the only factor influencing the adoption of e-practices in Saudi SMEs. One of the most frequently reported barriers to adopt digitalization and reverse logistics is management commitment. The main reasons behind this attitude are the friction to change and the lack of understanding of the benefits of these changes (Agrawal *et al.*, 2020; Tham and Atan, 2021). Prior experience and knowledge can help in reducing such friction and encourage management to invest in new initiatives.

KBV dictates that valuable transferable knowledge is created whenever a firm performs a new activity that will shorten the learning curve in future projects. Following this view, we infer that the managers have already developed the knowledge and experience needed to manage and embrace change during their reverse logistics adoption activities. As a result, participating managers will be more open to changes in the system for future endeavors. Another big barrier to adopting digitalization is the initial cost of switching over (Agrawal *et al.*, 2020). This cost is mainly needed for employee training activities, building systems and updating firm infrastructure to handle this new way of doing business. To a firm's advantage, these are all activities performed by a firm before successfully implementing reverse logistics. Generally, a newer IT system is adopted to increase efficiency and enhance communication among stakeholders for reverse logistics, which often require employee training and system upgrades. KBV dictates that this knowledge and resources will be used in future firm activities (Marqués and Garrigós-Simón, 2006). Eller *et al.* (2020) confirmed this relation in their study of Australian SMEs, where employee skills and IT positively influence the level of digitalization. Similarly, SMEs in Malaysia were reported to have increased their digitalization level by managing internally and externally created knowledge (Chong *et al.*, 2014). Caputo *et al.* (2020) reported higher returns on big data investments for firms having skilled employees. Therefore, this study argues that the knowledge and competencies gained during the reverse logistics adoption process will help firms overcome digital transformation barriers and serve as antecedents for digital transformation. Hence, resulting in an increased level of digitalization. Therefore, we hypothesize that.

H1. The adoption of reverse logistics will lead to a higher level of digitalization.

3.2 Reverse logistics and collaboration

Strong collaboration has been reported as one of the most critical activities that a firm can perform to improve its performance (Mofokeng and Chinomona, 2019) and speed (Walter, 2003) to gain a competitive advantage (Mentzer *et al.*, 2000). The activity is complex and expensive, but the benefits outweigh the cost and efforts needed to implement it (Barratt, 2004). Studies have reported on both barriers hindering and antecedents enabling successful collaboration. The commonly reported barriers include commitment, firm culture, trust and market uncertainties (Enkel and Heil, 2014; Grant and Baden-Fuller, 1995; Hudnurkar *et al.*, 2014; Qazi and Appolloni, 2022; Zhang and Cao, 2018). Similarly, inter-organizational systems, information sharing, and technology adoption, regulatory pressure (Enkel and Heil, 2014; Hsu *et al.*, 2013; Hudnurkar *et al.*, 2014; Zhang and Cao, 2018) are important antecedents for successful collaboration. Several of these coincide with barriers and antecedents for adopting reverse logistics, such as market uncertainties (Bressanelli *et al.*, 2018), management commitment (Agrawal *et al.*, 2020; González-Torre *et al.*, 2010; Tham and Atan, 2021), complexity (Govindan and Bouzon, 2018; Waqas *et al.*, 2018), coordination and information sharing (Bressanelli *et al.*, 2018; Zhu *et al.*, 2018), and appropriate support systems (de Campos *et al.*, 2017; Govindan and Bouzon, 2018; Prakash *et al.*, 2015).

Leaning on KBV, we argue that the competencies developed to adopt reverse logistics will facilitate collaboration activities. A similar argument was also confirmed by Emden *et al.* (2005) when they reported the experience gained in performing internal functions is a valuable asset during collaboration activities. For example, an important competency required to implement reverse logistics is to embrace the collaborative culture and information sharing routines. These were also the prime antecedents that Hudnurkar *et al.* (2014) identified in their literature review to increase collaboration activities. Similarly, information-sharing practices, trust and appropriate infrastructure are needed for reverse logistics success (Bressanelli *et al.*, 2018; Govindan and Bouzon, 2018) and to kickstart and increase collaboration levels with external entities (Barratt, 2004; Enkel and Heil, 2014; Zhang and Cao, 2018). Additionally, Grant and Baden-Fuller (1995) argued that higher levels of uncertainty encourage firms to collaborate more with external entities, and the introduction of reverse logistics has been reported to introduce additional uncertainties in the firm value chain (Gaur *et al.*, 2017; Giri *et al.*, 2017; Wilson *et al.*, 2022). Therefore, the firms adopting reverse logistics will be motivated to increase collaboration activities, resulting in an increased level of collaboration.

H2. The adoption of reverse logistics will lead to a higher level of collaboration.

4. Methodology

4.1 Data

The data for this analysis comes from two waves (2017 and 2019) of the German Community Innovation Survey (CIS) performed by the Centre for European Economic Research (ZEW) in Mannheim. The binomial regression analysis of the panel data was conducted using STATA 16.0. Using secondary data from Germany to test the hypothesis is useful for several reasons.

First, Germany is at the forefront of legislation on reverse logistics. In 1991, Germany introduced the first-ever legislation on packaging materials and made manufacturers responsible for collecting, sorting and recycling packaging material for their products (Álvarez-Gil *et al.*, 2007). The 1994 European Union "Directive on Packaging and Packaging Waste" and subsequent updates further intensified German efforts on reverse logistics. The target is to recycle at least 65% of the product weight by 2025. Second, along with several drives that can be used to test and control hypotheses, the 2017 wave of the CIS survey specifically asked the participating firms about the adoption of reverse logistics in the past three years (2014–2016). Similarly, the 2019 CIS wave asked the firms about adopting AI techniques and collaboration activities in their day-to-day operations. Third, though the responses are anonymized, the changes in a firm over time can be tracked using the firm ID, and the impact of actions taken in the past can be estimated. Finally, by anonymizing the responses, CIS has reduced the chances of self-serving bias (i.e. respondents have no incentive to make their firm appear "better" than it is). Self-serving biases are a major concern for researchers when analyzing system traits using self-reported responses (Ketokivi, 2019).

4.2 Variables used in study

The study needed one independent (reverse logistics adoption) and two dependent (digitalization and collaboration) variables to test the proposed hypotheses. These three variables will be sufficient to measure the changes in digitalization and collaboration level in a given firm after adopting reverse logistics. Independent variables will be responsible for information regarding reverse logistics adoption, and the dependent variable will be responsible for information related to changes in digitalization and collaboration levels. The collaboration variable's development is consistent with similar studies (Cricelli *et al.*, 2021). At the same time, the available information from the survey instrument was used to develop the digitalization variable. Along with these three main variables, multiple control variables were also used in the study, discussed in detail in the following subsections.

4.2.1 Independent variable. We assess the impact of reverse logistics adoption on the digitalization and collaboration increase in the firm through the "logi5" question in CIS 2017. The independent variable "AdoptedRL17" (renamed logi5) is described with a Yes/No answer to the question, "*During the three years from 2014 to 2016 did your enterprise introduce any of the following innovations in logistics? Reverse logistics (reuse and return of products and materials, etc.)*".

4.2.2 Dependent variables. The two dependent variables, "DigitalizationCount" and "CollaborationCount", were generated by combining multiple variables from the CIS 2019 wave. The process and rationale for generating variables are given below.

4.2.2.1 DigitalizationCount. We defined the "DigitalizationCount" dependent variable by considering all the items in the survey that could describe the use of digital technologies by the focal firm. To this aim, we resorted to three sets of items.

The first describes the use of AI technologies in the firm activities. The CIS 2019 inquired about using five different types of AI technologies for five different activities, producing 25 binary variables. In addition, two different binary variables focusing on AI use were also available in the group. These 27 binary variables were merged into one binary variable digi_AI, having a value of 0 and 1. Where one represents a firm that has participated in any activities related to AI (regardless of intensity), and zero represents the firms that have not participated in any activity related to AI. The rationale for merging multiple variables from the AI group into one binary variable was rooted in the idea that all groups should have similar weightage and that one type of digitalization does not skew the results.

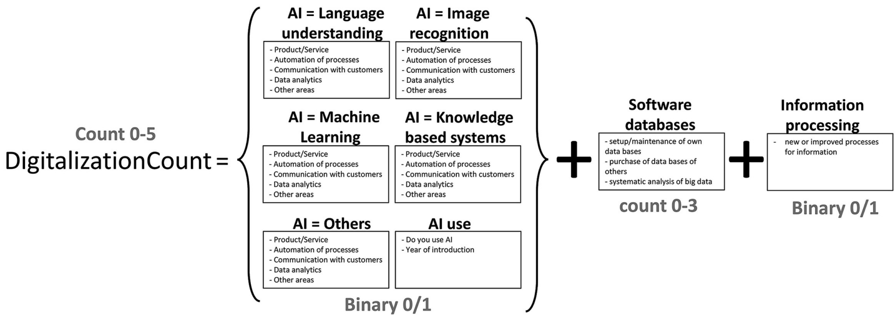
The second describes the use of software/big data for firm activities. Three binary variables inquiring about using big data/software for firm activities were merged into one count variable, digi_bd, having a value of 0–3.

The third describes the use of information processing techniques for firm activities. The one variable focusing on the use of digital information processing techniques for firm activities was renamed to digi_ip, having a value of 0–1.

The resulting three variables were merged into one "DigitalizationCount" dependent count variable for further analysis. The count variable is useful in identifying firms that have increased their level of digitalization and can help distinguish firms with a greater increase in digitalization. The resulting count variable can have a value of 0–5 for any focal firm. For example, a firm that has participated in both information processing and AI will have a value of two, and the firm that has only participated in AI will have a value of one. In addition, multiple other specifications have been attempted as a robustness check (see section 5.4). This new "DigitalizationCount" variable contains information from all variables that deliver information on the increase in digitalization levels between 2016 and 2018 in any given firm (Figure 1).

4.2.2.2 CollaborationCount:. Similar to the previous dependent variable, we defined the "CollaborationCount" by considering all the items in the survey that could describe the variety of inter-organizational collaborations pursued by the focal firm. To this aim, we resorted to four sets of items.

The first describes the location (domestic or foreign) of the collaborating partner. The CIS 2019 inquired about the location of the ten types of collaborating partners producing 20 binary variables. These 20 variables were merged into ten count variables, having one variable for each type of partner. For example, collaboration with domestic and foreign universities was merged into one count variable called collab_univer with a value of 0–2. Merging these variables into ten count variables provides a greater depth of information on inter-organization collaboration. It can distinguish firms with a higher level of collaboration from firms with a lower level of collaboration. To keep the variables in a manageable form, these ten variables were merged into one single count variable collab_location with a value of 0–20 (No information was lost).



Source(s): Figure by authors

Figure 1. DigitalizationCount generation

The second describes the collaboration for innovation. Five binary variables inquiring about the collaboration activities specifically focusing on innovation activities were merged into one count variable collab_innov, having a value of 0–5.

The third describes the collaboration for R&D. Three binary variables inquiring about the collaboration for activities associated with R&D were merged into one count variable, collab_rnd, having a value of 0–3.

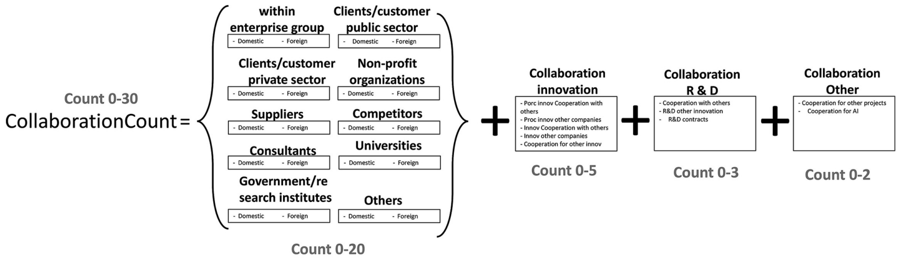
The fourth describes the collaboration for other activities. Two binary variables inquiring about the collaboration for other activities (AI and others) were merged into one count variable collab_oth with a 0–2.

The resulting 13 count variables were merged into one "CollaborationCount" dependent variable for further analysis. Similar to the previously developed variable, the "CollaborationCount" variable can have a value of 0–30. Where 0 means no involvement in collaboration activities and 30 means the involvement in all activities associated with collaboration (Figure 2). Multiple other specifications have been attempted as robustness checks (see section 5.4).

4.2.3 Control variables. For testing hypotheses H1 and H2, we introduced multiple control variables discussed in previous studies (Agrawal *et al.*, 2020; Agrawal and Narain, 2021; Becker *et al.*, 2018; Wrede *et al.*, 2020) that can facilitate the adoption of digitalization and collaboration practices (Table 1). Becker *et al.* (2018) reported several cases where a hiring Chief Technical Officer (CTO) expedited the digitalization process. Similarly, employee skills and training (Agrawal *et al.*, 2020) and the acquisition of newer technologies were major contributors to increased digitalization and collaboration (Agrawal and Narain, 2021; Usman Ahmad *et al.*, 2019). Furthermore, we controlled the impact of public funding and international competition by introducing variables "public_funding" and "export_perc" in the model, as studies have reported that the firms engaging in these activities demonstrate higher levels of engagement in both collaboration and digitalization activities (Caputo *et al.*, 2021b; Ito and Pucik, 1993; Matt *et al.*, 2011). For example, a higher percentage of export revenue is linked with higher foreign competition and higher R&D spending (Ito and Pucik, 1993), leading to greater digitalization investment. Similarly, public funding positively influences collaboration (Matt *et al.*, 2011) and digitalization activities (Nedilska and Oleniuk, 2020). Therefore, controlling these variables will eliminate any impact these two variables have on the study's dependent variables. The firm size, sector and sales volume were also introduced as the additional control variables.

4.3 Econometric approach

This study uses the binomial regression analysis method to test the proposed hypotheses. The binomial regression analysis of the panel data was conducted using STATA 16.0. Regression analysis is a reliable method of identifying which variables impact a topic of interest (independent variables). Several studies in the past have used regression analysis to



Source(s): Figure by authors

Figure 2.
CollaborationCount generation

Variables	Type	Description	Reference year
newemployee_knowl	Ordinal factor variable	Did the firm hire new employees who bring in know-how from other firms	2017
new_tech_acq	Binary Variable	Did the firm purchase new machines that are based on totally new technologies	2017
cost_employ_train17	Ordinal factor variable	How much did the firm spend on further education and training of current employees in 2015 and 2016	2017
graduate_employee17	Ordinal factor variable	Share of employees in percentage holding a university degree in 2015 and 2016	2017
Sector	Ordinal factor variable	Classification of participating firms in 21 economic sectors	2019
export_perc	Ordinal factor variable	Percentage of revenue coming from exports in 2016	2016–2018
public_funding	Binary Variable	Did the firm receive public funding between 2014 and 2016	2016–2018
firm_size	Ordinal factor variable	Firm size >50 50–249 ≤250	2019
Sales		Sales volume in millions	2018
AdoptedRL17	Binary Variable	If firms adopted reverse logistics between 2014 and 2016	2014–2016
DigitalizationCount	Count variable	Generated by merging multiple variables to report on all digitalization activities performed by the firm (see: Section 4)	2016–2018
CollaborationCount	Count variable	Generated by merging multiple variables to report on all collaboration activities performed by the firm (see: Section 4)	2016–2018

Source(s): Table by authors

Table 1. Description of variables used in the study

empirically test the impact of one variable over another while utilizing similar data sets (Czarnitzki *et al.*, 2020; Horbach and Rammer, 2020; Kobarg *et al.*, 2020). The process of performing a regression allows you to confidently determine which factors matter most, which factors can be ignored and how these factors influence each other (Myrtveit and Stensrud, 1999). The dependent variables used in the study are count variables. The data prediction based on count variables is supported perfectly by the Poisson-Gamma mixed distribution (Hilbe, 2011), which the negative binomial regression is based on. We employed the negative binomial regression method because the variance of dependent variables is greater than the mean and contains only non-negative integer values (Table 2). According to Joe and Zhu (2005), this dataset cannot support standard linear regression techniques pertaining to the dependent variable's abnormal, highly skewed and discontinuous nature. The independent and control variables were then subjected to a Variance Inflation Factor (VIF) test. VIF has an average value of 1.36 and a maximum value of 1.77. According to Baltagi (2005) and Peter (1998), the multicollinearity problem among the variables is not serious when the VIF value is below 10. Furthermore, to test the best fit for data AIC of the independent variable was calculated. The lower value of AIC indicates a better fit for the data. Hence, the model with the smallest AIC value was selected.

5. Results

5.1 Descriptive statistics

Table 2 presents descriptive statistics and a correlation matrix of the variables used. For example, the variable "AdoptedRL17" is a binary variable that represents the firm responses

Table 2. Summary of descriptive statistics and correlation matrix

Variable	Obs	Mean	Std. Dev	Min	Max	newemployee_ knowl	new_ tech_ acq	cost_ employ_ train17	graduate_ employee17	Sector	export_ perc	public_ funding	firm_ size	Sales
newemployee_ knowl	1,961	0.2193	0.4139	0	1	1								
new_tech_acq	1,830	0.1607	0.3673	0	1	0.19	1							
cost_employ_ train17	1,642	0.0082	0.0148	0	0.12	0.093	0.023	1						
graduate_ employee17	2,060	3.3966	2.6681	0	8	0.128	0.033	0.166	1					
Sector	2,161	11.6622	5.9670	1	21	0.015	−0.046	0.124	0.268	1				
export_perc	1,916	0.1296	0.2337	0	0.85	0.162	0.131	−0.0503	0.109	−0.237	1			
public_funding	2,161	0.2189	0.4136	0	1	0.147	0.210	0.0366	0.105	−0.096	0.201	1		
firm_size	1,889	1.4325	0.6451	1	3	0.249	0.174	−0.0571	−0.068	−0.085	0.24	0.104	1	
Sales	1,966	20.7927	73.8848	0	1373.45	0.177	0.061	−0.0178	0.02	−0.095	0.149	0.020	0.519	1
AdoptedRL17	4,491	0.0448	0.2068	0	1									
DigitalizationCount	4,491	0.3295	0.7625	0	5									
CollaborationCount	4,491	0.4438	0.9868	0	5									

Source(s): Table by authors

(Yes/NO) to the question of adopting reverse logistics between 2014 and 2016. These descriptive statistics indicate heterogeneity in the firms' reverse logistics adoption and offer validity as control variables.

5.2 Regression results

We used STATA 16.0 to perform negative binomial regression on panel data from the CIS 2017 and 2019 waves to test the proposed hypothesis. The regression results for both proposed hypotheses are reported in Tables 3 and 4. The first hypothesis investigating the increase in digitalization level is accepted at the 99% confidence level (p-value <0.01).

	Model 1: Base model			Model 2: H1 digitalization		
	Coef	Std. Err	$P > z$	Coef	Std. Err	$P > z$
AdoptedRL17				0.4217	0.1322	0.001
newemployee_knowl	0.5169	0.0769	0.000	0.5203	0.0761	0.000
new_tech_acq	0.4612	0.0816	0.000	0.4552	0.0810	0.000
cost_employ_train17	4.3537	2.0854	0.037	3.9750	2.0710	0.055
graduate_employee17						
$0 \leq \times < 5$	0.4871	0.1721	0.005	0.4894	0.1712	0.004
$5 \leq \times < 10$	0.3767	0.1645	0.022	0.3617	0.1638	0.027
$10 \leq \times < 15$	0.4359	0.1671	0.009	0.4262	0.1665	0.010
$15 \leq \times < 20$	0.4810	0.1835	0.009	0.4446	0.1835	0.015
$20 \leq \times < 30$	0.6474	0.1645	0.000	0.6615	0.1637	0.000
$30 \leq \times < 50$	0.4889	0.1676	0.004	0.4639	0.1673	0.006
$50 \leq \times < 75$	0.6556	0.1724	0.000	0.6490	0.1717	0.000
$75 \leq \times <= 100$	0.6898	0.1887	0.000	0.6764	0.1882	0.000
sector						
Food/Tobacco	0.0050	0.2958	0.987	−0.0404	0.2947	0.891
Textiles	0.4666	0.2701	0.084	0.4673	0.2681	0.081
Wood/Paper	0.0648	0.3312	0.845	0.0788	0.3293	0.811
Chemical	−0.0585	0.2856	0.838	−0.0600	0.2837	0.832
Plastics	0.4129	0.2814	0.142	0.3451	0.2806	0.219
Glass/Ceramics	0.2474	0.3208	0.441	0.1886	0.3206	0.556
Metals	0.2126	0.2462	0.388	0.2119	0.2446	0.386
Electrical equipment	0.4905	0.2318	0.034	0.4607	0.2303	0.045
Machinery	0.3584	0.2664	0.179	0.3588	0.2641	0.174
Retail/Automobile	0.4406	0.2886	0.127	0.4288	0.2868	0.135
Furniture/Toys/Medical tech.	0.0571	0.2685	0.831	0.0545	0.2666	0.838
Energy/Water	0.0293	0.2603	0.910	0.0538	0.2591	0.835
Wholesale	0.5950	0.2571	0.021	0.5397	0.2562	0.035
Transport equipment/Postal.	0.3649	0.2535	0.150	0.3823	0.2520	0.129
Media services	0.4939	0.2480	0.046	0.4933	0.2460	0.045
IT/Telecommunications	0.6066	0.2512	0.016	0.6111	0.2495	0.014
Banking/Insurance	0.9538	0.2497	0.000	0.9605	0.2480	0.000
Technical services/R&D serv.	0.5572	0.2397	0.020	0.5740	0.2385	0.016
Consulting/Advertisement	0.6978	0.2443	0.004	0.7175	0.2429	0.003
Firm-related services	0.6432	0.2595	0.013	0.6316	0.2577	0.014
firm_size						
50–249 employees	0.3377	0.0887	0.000	0.3231	0.0882	0.0000
>=250 employees	0.2750	0.1307	0.035	0.2694	0.1296	0.0380
export_perc	0.4120	0.1504	0.006	0.4072	0.1489	0.0060
public_funding	0.1773	0.0802	0.027	0.1672	0.0796	0.0360
sales	0.0012	0.0004	0.005	0.0012	0.0004	0.0040
_cons	−1.7453	0.2363	0.000	−1.7439	0.2349	0.0000

Source(s): Table by authors

Table 3. The results of the regression for the digitalization level

	Model1: Base model			Model 2: H2: Collaboration		
	Coef	Std. Err	$P > z$	Coef	Std. Err	$P > z$
AdoptedRL17				0.436	0.189	0.021
newemployee_knowl	0.4154	0.0989	0.000	0.410	0.099	0.000
new_tech_acq	0.5045	0.1084	0.000	0.514	0.108	0.000
cost_employ_train17	15.1095	2.6465	0.000	14.905	2.637	0.000
graduate_employee17						
$0 < \times < 5$	0.7133	0.1995	0.000	0.705	0.199	0.000
$5 \leq \times < 10$	0.5278	0.1913	0.006	0.516	0.191	0.007
$10 \leq \times < 15$	0.6626	0.1908	0.001	0.627	0.191	0.001
$15 \leq \times < 20$	0.8876	0.2124	0.000	0.863	0.212	0.000
$20 \leq \times < 30$	0.7498	0.1981	0.000	0.753	0.198	0.000
$30 \leq \times < 50$	0.6810	0.1947	0.000	0.649	0.195	0.001
$50 \leq \times < 75$	0.8769	0.2092	0.000	0.856	0.209	0.000
$75 \leq \times <= 100$	1.1072	0.2239	0.000	1.091	0.224	0.000
sector				0.705	0.199	0.000
Food/Tobacco	−0.1923	0.3431	0.575	−0.2439	0.3434	0.478
Textiles	0.5158	0.3102	0.096	0.5300	0.3094	0.087
Wood/Paper	0.1236	0.3585	0.730	0.1485	0.3579	0.678
Chemical	0.7921	0.3096	0.011	0.7738	0.3088	0.012
Plastics	0.4342	0.3311	0.190	0.4072	0.3313	0.219
Glass/Ceramics	0.5411	0.3657	0.139	0.5063	0.3666	0.167
Metals	0.4172	0.2789	0.135	0.4194	0.2784	0.132
Electrical equipment	0.4129	0.2817	0.143	0.3909	1.3900	0.165
Machinery	0.6945	0.3138	0.027	0.7127	0.3131	0.023
Retail/Automobile	0.5486	0.3623	0.130	0.5148	0.3619	0.155
Furniture/Toys/Medical tech.	0.4623	0.2906	0.112	0.4404	0.2898	0.129
Energy/Water	−0.1791	0.2953	0.544	−0.1479	0.2948	0.616
Wholesale	0.0510	0.3249	0.875	0.0294	0.3249	0.928
Transport equipment/Postal.	−0.2496	0.3108	0.422	−0.2273	−0.7300	0.464
Media services	0.5580	0.2962	0.060	0.5722	1.9400	0.053
IT/Telecommunications	0.4912	0.3140	0.118	0.5147	0.3135	0.101
Banking/Insurance	0.4703	0.3237	0.146	0.4994	0.3231	0.122
Technical services/R&D serv.	0.5916	0.2880	0.040	0.6196	2.1600	0.031
Consulting/Advertisement	0.6319	0.2897	0.029	0.6670	0.2894	0.021
Firm-related services	0.3549	1.130	0.257	0.3523	1.1300	0.260
firm_size						
50–249 employees	0.4057	0.1085	0.000	0.3996	3.6900	0.000
>=250 employees	0.3921	0.1783	0.028	0.3814	2.1500	0.032
export_perc	0.7455	0.1958	0.000	0.7557	0.1953	0.000
public_funding	0.7378	0.0996	0.000	0.7326	0.0995	0.000
sales	0.0021	0.0007	0.006	0.0021	0.0008	0.005
_cons	−1.6438	0.2658	0.000	−1.6531	0.2655	0.000

Source(s): Table by authors

Table 4.
The results of the regression analysis for the collaboration level

Similarly, the second hypothesis investigating the increase in firm collaboration level is also accepted at a 95% confidence level (p-value <0.05). As a result, it is confirmed that the firms adopting reverse logistics are more likely to have higher levels of digitalization and collaboration than those that do not adopt reverse logistics. All the control variables used in the study are also significant, hence confirming their impact and power in predicting digitalization and collaboration adoption. The control variables “newemployee_knowl”, “new_tech_acq”, “export_perc”, “public_funding”, and “sales” are strong predictors of both increased digitalization and collaboration levels in a firm. When combined, the control variable “sector” is significant. However, the analysis of individual sectors shows that the control is more significant for some industries than others. Furthermore, the percentage of graduate employees impacts both digitalization and collaboration levels, but it does not matter what percentage of employees possess a university degree. This finding contrasts with the earlier studies, such as those performed by Agrawal *et al.* (2020), where it was reported that employees with higher technical skills would be better able to guide firms in adopting digitalization and collaboration practices.

5.3 Robustness check

The robustness of the model was tested by changing the definitions of dependent variables. Multiple alternate “DigitalizationCount” and “CollaborationCount” variables were generated using different combinations of variables to see if the test results would vary. The list of these alternate variables and obtained regression results is presented in Table 5. The results in Table 5 confirm the robustness of the dependent variables as the varied definitions of the variables do not change the results significantly. Another measure adopted to check the robustness of the model was using the Logit and Probit models instead of negative binomial regression. The obtained results confirmed the robustness of the model as the results of these new tests did not produce values notably different from the original model.

6. Discussion

The existing literature has discussed the impact of digitalization and collaboration on reverse logistics and how these competencies facilitate a firm in moving toward sustainability

Impact of reverse logistics adoption on digitalization			Impact of reverse logistics adoption on collaboration		
Alternate definitions for DigitalizationCount variable	Coef	*p*-value	Alternate definitions for CollaborationCount variable	Coef	*p*-value
AI	0.7326	0.087	collab_dom + collab_inno + collab_rnd + collab_oth	0.4192	0.024
SDB	0.3563	0.049	collab_for + collab_inno + collab_rnd + collab_oth	0.3926	0.013
AI_lu + SDB + IP	0.4217	0.001	collab_inno + collab_rnd + collab_oth	0.3660	0.017
AI_ir + SDB + IP	0.4249	0.001	collab_dom + collab_for + collab_inno + collab_oth	0.4200	0.024
AI_ml + SDB + IP	0.4217	0.001	collab_dom + collab_for + collab_rnd + collab_oth	0.3356	0.183
AI_kbs + SDB + IP	0.4252	0.001	collab_dom + collab_for + collab_rnd + collab_inno	0.4970	0.016
AI_oth + SDB + IP	0.4217	0.001	collab_dom + collab_rnd + collab_oth	0.3133	0.203
AI + IP	0.4972	0.009	collab_dom + collab_for + collab_inno	0.4843	0.017
SDB + IP	0.4001	0.004	collab_for + collab_rnd + collab_inno	0.4390	0.009

Note(s): **AI** = Artificial Intelligence (Language understanding + Image recognition + Machine Learning + Knowledge based systems + Others)
AI_lu = **AI**–Language understanding **AI_ir** = **AI**- Image recognition **AI_ml** = **AI**–Machine Learning
AI_kbs = **AI**–Knowledge based systems **AI_oth** = **AI –** others **SDBs**= Software data bases
IP = information processing **collab_oth** = Other type of collaboration
collab_dom = Domestic collaboration **collab_for** = Domestic collaboration
collab_rnd = Collaboration for R&D **collab_inno** = Collaboration for innovation
Source(s): Table by authors

Table 5.
Robustness check

(Aksin-Sivrikaya and Bhattacharya, 2017; Chen *et al.*, 2017) and eventually toward the circular economy (Antikainen *et al.*, 2018; Mishra *et al.*, 2021; Pagoropoulos *et al.*, 2017). However, the literature has not investigated the impact of reverse logistics adoption on digitalization and firm collaboration. This study aimed to empirically test this reverse relation and highlighted the advantages firms can reap by implementing reverse logistics earlier in their system, including greater levels of collaboration and digitalization. Furthermore, KBV dictates that firms, while performing any activity, create new knowledge, and this process of creating new knowledge is multiplied when firms perform new activities or introduce new systems (Hörisch *et al.*, 2015; Yang, 2013). Therefore, the management and utilization of this internally generated knowledge play a vital role in the firm's future endeavors. This impact also emerges after the adoption of reverse logistics. It was argued earlier that while adopting reverse logistics, firms produce new implicit and explicit knowledge that will provide a competitive advantage and learning to the practicing firm. Proper knowledge management practices will help the firms effectively utilize these advantages and knowledge. It is important to note that these advantages can only be derived if the employees are willing to freely share this newly generated knowledge (Caputo *et al.*, 2021a). Therefore managers should focus on developing collaborative culture inside and outside the firm boundaries.

Relying on institutional theory, Fauzi and Sheng (2022) argued that all firms would eventually introduce digitalization into their system. But the introduction of digitalization will pose several challenges for implementing firms during the implementation process and before even starting the process. D'Este *et al.* (2012) divided barriers into two categories and argued that firms should focus on overcoming *deterring* (hindering firms from initiating new activities) barriers. The elimination of deterring barriers is an intricate process requiring top management commitment. Leaning on the KBV, the study results confirm that firms that implement reverse logistics are better positioned to overcome deterring barriers and engage in digitalization activities, including the initial cost that was reported as one of the biggest barriers toward digitalization (Agrawal *et al.*, 2020; Tham and Atan, 2021). In addition, additional gained employee skills and IT competencies will serve as enablers for the higher digitalization levels (Chong *et al.*, 2014; Eller *et al.*, 2020). This argument aligns with the previous studies that reported a positive impact on firm performance and capabilities after adopting reverse logistics activities (Matos *et al.*, 2020; Mihi Ramírez, 2012; Ramirez and Girdauskiene, 2013). Similarly, introducing reverse logistics will lead to higher IT capabilities for the practicing firm (Daugherty *et al.*, 2005) as the initial training required to implement digitalization will be already available to firm employees (Eller *et al.*, 2020; Marqués and Garrigós-Simón, 2006). Furthermore, the results obtained in this study are in line with Azyabi's (2018) findings. The author reported that knowledge acquisition activities (creation and transfer) are the most significant factors influencing the increase in the use of digital technologies in Saudi SMEs. Therefore, the study results confirm that adopting reverse logistics generates knowledge that not only encourages firms to participate in digitalization activities but is also helpful in overcoming barriers associated with adopting digitalization. This argument is in line with Chong *et al.* (2014), where authors reported that the knowledge creation process facilitates the firms in introducing newer technologies.

Similarly, it is no longer feasible for a firm to thrive in silos. Instead, firms need to collaborate with external entities to reduce risk and increase productivity and speed. Appropriate knowledge creation and management activities (implementing new processes) will enable the firm to share the newly created knowledge with both internal and external partners (Nisar *et al.*, 2019). The study's findings also confirm that reverse logistics adoption will help firms overcome collaboration barriers and make them open to utilizing external knowledge and techniques. Inter-firm collaboration was also reported by Hudnurkar *et al.* (2014) as an important activity to maximize success in reverse logistics activities.

Similarly, an appropriate infrastructure and knowledge sharing capabilities are created during reverse logistics adoption to serve as a base for inter-organization collaboration (Enkel and Heil, 2014; Zhang and Cao, 2018). These findings are in line with Yang (2013), where author confirmed that knowledge acquisition and dissemination activities significantly improve firms' collaborative relations. Furthermore, the findings also confirm the view of Olorunniwo and Li (2010), who argued that collaboration with partners and competitors is needed for any successful reverse logistics operation, which increases over time with the maturity of reverse logistics operations.

The adoption of reverse logistics offers many benefits and has become essential today. However, the adoption of reverse logistics is often involuntary. It is adopted to respond to policymakers and customers (Álvarez-Gil *et al.*, 2007; Hsu *et al.*, 2013) and, in general, is viewed as a money losing activity (Eltayeb and Zailani, 2011). The study's findings assert that though the activity is complex and expensive, it has lasting beneficial impacts on operational activities and has the potential to help in future changes.

7. Conclusion

The study **investigated** the impact of sustainability practices (reverse logisticsadoption) on firms' operational activities. In particular, it **explored whether** adopting reverse logistics **increased** firm**s'** digitalization and collaboration activities. To this end, an econometric analysis was conducted using Germany's Community Innovation Survey data from the 2017 and 2019 waves. The analysis of the results confirms a strong relationship between reverse logistics adoption and digitalization/collaboration increase. Furthermore, the study confirms a positive relationship between sustainability practices and digitalization/collaboration, confirming the proposed hypotheses. Therefore, the results highlight additional benefits offered by investments in sustainability practices. Furthermore, the study's findings advance the KBV theory by confirming the view that the knowledge created during the adoption of one activity is useful in performing different activities and can significantly shorten the learning curve for future activities. The findings have several implications for theory, practice and policymaking discussed below.

7.1 Theoretical implications

Previous studies have focused on the relationship between digitalization and reverse logistics and digitalization and collaboration. However, the reverse relation among these two pairs has never been explored. In particular, studies have not reported the knowledge-generating capabilities of reverse logistics and its potential to facilitate the process of digitalization and collaboration. This study is the first of its nature that explores this relationship. This is important as, unlike the former flow of actions, the adoption of reverse logistics is often involuntary and is adopted to comply with the law to achieve SDG 2030 goals. The outcome of this study confirms that adopting reverse logistics has significant power in explaining the increased digitalization and collaboration in German firms. This was confirmed by developing two hypotheses that focused on the impact of reverse logistics adoption on firm digitalization and collaboration levels. This experimental setting contributed to the growing literature on digitalization, collaboration and reverse logistics (sustainability). As a result, this study contributes to the literature to better understand these concepts and explain how they are connected. Respectively, the findings contribute to management literature. The study also contributes to the debate on the importance of KBV and provides empirical evidence to support the theory. A recent literature survey by Pereira and Bamel (2021) emphasized the need for further studies to demonstrate the usability and power of KBV. The authors argued that KBV could explain the performance variance among firms.

Furthermore, they highlighted that knowledge generating firms are better off in the long run and can easily transform their operations to respond to future technologies. The research results confirm these views of Pereira and Bamel (2021).

7.2 Managerial implications

Higher levels of collaboration and digitalization have been reported to bring a significant competitive advantage as they make the firm's value chain fast, innovative, responsive and cost effective. As a result, the firm becomes competitive and well-positioned to take advantage of future opportunities. From the managerial perspective, identifying a key enabler to increase firm collaboration and digitalization levels is important as firms are constantly searching for ways to improve business in the current disruptive environment. For example, when faced with the dilemma of investing in reverse logistics or digitalization/collaboration, managers can choose reverse logistics to respond to stakeholder demand (government, distributors, customers). This reverse logistics adoption will encourage firms to increase their digitalization and collaboration levels while enjoying the benefits of reverse logistics adoption. That includes customer loyalty, employee satisfaction, increased firm reputation and higher profits. Furthermore, the knowledge generated by reverse logistics adoption can be essential to achieving firms' digitalization and collaboration goals. This was demonstrated by Schlüter *et al.* (2021) in their pilot study of a manufacturing firm where machine learning triggered by reverse logistics (adopted to support reverse logistics) significantly improved the reverse logistics performance. Therefore, adopting reverse logistics can be an agent of change toward more digitalized operations. Wilson *et al.* (2022) reported several examples where firms already performing reverse logistics adopted AI technologies to improve their reverse logistics process. Similarly, Olorunniwo and Li (2010) reported that it is vital for a firm to collaborate and share information with its partners to manage reverse logistics operations successfully. Hence, reverse logistics strongly incentivizes information sharing and collaboration with other organizations. As a result, firms are more prepared to collaborate with their partners and competitors. SIGRAUTO in Spain can be cited as an example of different bodies and organizations collaborating to improve their reverse logistics operation. Where a single entity (SIGRAUTO) coordinates all elements of end-of-life returned auto parts from different automotive manufacturers in Spain. Hence, increasing collaboration and transparency among partners to enhance their reverse logistics operations.

7.3 Policymakers implication

Reverse logistics adoption promotes resource conservation, recycling and material reuse at the end-of-life stage. Europe in general and Germany, in particular, are working toward achieving a maximum of 10% of municipal waste in the landfill by 2035, which means a technical zero-waste. Numerous governmental regulations such as China's "Circular Economy" directive or European WEEE, the two EU Circular Economy Action Plans (2015 and 2020) push firms toward adopting reverse logistics, together with the impulse coming from the Next GenEU post-pandemic recovery program for a cleaner, circular and digital Europe. Policy directives are among the most important drivers in the western world for implementing reverse logistics. However, the adoption of reverse logistics is slow in countries where there are fewer regulations to bind firms to reduce their waste. Hence, strong regulations are essential for the speedy and early adoption of reverse logistics. This study provides important information to policymakers by demonstrating the usefulness and capability of reverse logistics in enabling firms to improve firm productivity and manage future changes. This information is vital for policymakers to persuade firms to implement reverse logistics earlier in their system. Though the study results come from the German industries, policy implications can be implemented in other European countries as they all have similar work ethics and are moving towards achieving 2030 SDG goals, particularly targets 12.1, 12.2, 12.3, 12.5 and 11.6.

7.4 Limitations

This study is not without limitations, which warrant future studies. Firstly, the article uses data from only German firms. Germany is at the forefront of environmental and reverse logistics regulations. Hence, some contextual results may not apply to other countries. Secondly, this study did not differentiate between the types of digitalization and collaboration activities. The study considered all types of activities related to digitalization and collaboration to be equal. This is not often the case, and some activities are more intense than others in practice. This may have undermined the importance and value of some activities performed by the firm. Future studies should consider the relative importance of these activities. Thirdly, the study only reported on a simple increase in digitalization and collaboration levels and did not go into details about the breadth of this increase. Future studies may consider the actual amount of increase in digitalization and collaboration levels. Lastly, the data was collected in a pre-covid era, and industry and society have changed drastically in the last three years. The adoption of digital technologies and collaboration has increased initially, but its long-term impact is yet to be determined. Further empirical and longitudinal studies are needed to answer these questions.

References

Agrawal, P. and Narain, R. (2018), "Digital supply chain management: an overview", *IOP Conference Series: Materials Science and Engineering*, doi: 10.1088/1757-899X/455/1/012074.

Agrawal, P. and Narain, R. (2021), "Analysis of enablers for the digitalization of supply chain using an interpretive structural modelling approach", Emerald Publishing, *International Journal of Productivity and Performance Management*, Vol. 72 No. 2, pp. 410-439.

Agrawal, P., Narain, R. and Ullah, I. (2020), "Analysis of barriers in implementation of digital transformation of supply chain using interpretive structural modelling approach", *Journal of Modelling in Management*, Emerald Group Holdings Limited, Vol. 15 No. 1, pp. 297-317.

Aksin-Sivrikaya, S. and Bhattacharya, C.B. (2017), "Where digitalization meets sustainability: opportunities and challenges", *CSR, Sustainability, Ethics and Governance Book Series (CSEG)*, Springer, Cham, pp. 37-49.

Álvarez-Gil, M.J., Berrone, P., Husillos, F.J. and Lado, N. (2007), "Reverse logistics, stakeholders' influence, organizational slack, and managers' posture", *Journal of Business Research*, Vol. 60 No. 5, pp. 463-473.

Andiça, E., Yurtb, Ö. and Baltacıoğlub, T. (2012), "Green supply chains: efforts and potential applications for the Turkish market", *Resources, Conservation and Recycling*, Vol. 58, pp. 50-68.

Antikainen, M., Uusitalo, T., Kivikytö-Reponen, P., Antikainena, M., Uusitaloa, T. and Kivikytö-Reponena., P. (2018), "Digitalisation as an enabler of circular economy", *Procedia CIRP*, Elsevier, Vol. 73, pp. 45-49.

Antikainena, M., Uusitaloa, T. and Kivikytö-Reponena, P. (2018), "Digitalisation as an enabler of circular economy", *Procedia CIRP*, Vol. 73, pp. 45-49.

Awan, U., Sroufe, R. and Shahbaz, M. (2021), "Industry 4.0 and the circular economy: a literature review and recommendations for future research", *Business Strategy and the Environment*, John Wiley & Sons, Limited, Vol. 30 No. 4, pp. 2038-2060.

Azyabi, G.N. (2018), "The influence of knowledge management on e-business adoption in Saudi SMEs", *International Journal of Information and Knowledge Management*, Vol. 8 No. 1, pp. 1-22.

Baah, C. and Jin, Z. (2019), "Sustainable supply chain management and organizational performance: the intermediary role of competitive advantage", *Journal of Management and Sustainability*, Vol. 9 No. 1, pp. 119-132.

Baltagi, B.H. (2005), *Econometric Analysis of Panel Data*, 3rd ed., John Wiley & Sons Limited, Chichester, doi: 10.1007/978-3-030-53953-5.

Barney, J. (1991), "Firm resources and sustained competitive advantage", *Journal of Management*, Sage Publications, Thousand Oaks, CA, Vol. 17 No. 1, pp. 99-120.

Barratt, M. (2004), "Understanding the meaning of collaboration in the supply chain", *Supply Chain Management: An International Journal*, Emerald Group Publishing Limited, Vol. 9 No. 1, pp. 30-42.

Becker, W., Schmid, O. and Botzkowski, T. (2018), "Role of CDOs in the digital transformation of SMEs and LSEs. An empirical analysis", *Proceedings of the Annual Hawaii International Conference on System Sciences*, Vols 2018, IEEE Computer Society, pp. 4534-4543.

Bhargava, B., Ranchal, R. and Ben Othmane, L. (2013), "Secure information sharing in digital supply chains", *Proceedings of the 2013 3rd IEEE International Advance Computing Conference, IACC 2013*, doi: 10.1109/IAdCC.2013.6514473.

Bhatt, S. (2019), "Knowledge portals", *Sustainable Resource Management through Innovative Management Practices*, pp. 106-118.

Blome, C., Schoenherr, T. and Eckstein, D. (2014), "The impact of knowledge transfer and complexity on supply chain flexibility: a knowledge-based view", *International Journal of Production Economics*, Elsevier, Vol. 147, pp. 307-316.

Bressanelli, G., Perona, M. and Saccani, N. (2018), "Towards the circular supply chain: a literature review of challenges", *XXIII Summer School "Francesco Turco" – Industrial Systems Engineering*, Palermo, pp. 171-178.

Caputo, F., Mazzoleni, A., Pellicelli, A.C. and Muller, J. (2020), "Over the mask of innovation management in the world of big data", *Journal of Business Research*, Vol. 119, pp. 330-338.

Caputo, F., Magni, D., Papac, A. and Corsid, C. (2021a), "Knowledge hiding in socioeconomic settings: matching organizational and environmental antecedents", *Journal of Business Research*, Vol. 135, pp. 19-27.

Caputo, F., Soto-Acosta, P., Chiacchierini, C., Mazzoleni, A. and Passaro, P. (2021b), "Smashing local boundaries for sustain companies' innovativeness: the role of international R&D teams", *Journal of Business Research*, Vol. 128, pp. 641-649.

Chen, L., Zhao, X., Tang, O., Price, L., Zhang, S. and Zhu, W. (2017), "Supply chain collaboration for sustainability: a literature review and future research agenda", *International Journal of Production Economics*, Elsevier, Vol. 194, pp. 73-87.

Chong, A.Y.-L., Ooi, K.-B., Lin, H.B. and B. (2014), "Can e-business adoption be influenced by knowledge management? An empirical analysis of Malaysian SMEs", *Journal of Knowledge Management*, Vol. 18 No. 1, pp. 121-136.

Cricelli, L., Greco, M. and Grimaldi, M. (2021), "An investigation on the effect of inter-organizational collaboration on reverse logistics", *International Journal of Production Economics*, Vol. 240, pp. 1-11.

Curado, C. and Bontis, N. (2006), "The knowledge-based view of the firm and its theoretical precursor", *International Journal of Learning and Intellectual Capital*, Inderscience Enterprises Limited, Vol. 3 No. 4, pp. 367-381.

Curado, C. and Bontis, N. (2011), "Parallels in knowledge cycles", *Computers in Human Behavior*, Vol. 27 No. 4, pp. 1438-1444.

Czarnitzki, D., Hünermund, P. and Moshgbar, N. (2020), "Public procurement of innovation: evidence from a German legislative reform", *International Journal of Industrial Organization*, North-Holland, Vol. 71, 102620.

Daugherty, P.J., Richey, R.G., Genchev, S.E. and Chena, H. (2005), "Reverse logistics: superior performance through focused resource commitments to information technology", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 41 No. 2, pp. 77-92.

Del, C., Pacheco, H., Mello, M., De Liberal, C. and Anderson Pires De Novais, M. (2019), "The benefits of reverse logistics in the health area", *International Journal of Development Research*, Vol. 9 No. 10, pp. 30962-30967.

de Campos, E.A.R., de Paula, I.C., Pagani, R.N. and Guarnieri, P. (2017), "Reverse logistics for the end-of-life and end-of-use products in the pharmaceutical industry: a systematic literature review", *Supply Chain Management: An International Journal*, Emerald Publishing Limited, Vol. 22 No. 4, pp. 375-392.

de Machado, A.B., Secinaro, S., Calandra, D. and Lanzalonga, F. (2022), "Knowledge management and digital transformation for industry 4.0: a structured literature review", *Knowledge Management Research and Practice*, Vol. 20 No. 2, pp. 320-338.

D'Este, P., Iammarino, S., Savona, M. and Von Tunzelmann, N. (2012), "What hampers innovation? Revealed barriers versus deterring barriers", *Research Policy*, North-Holland, Vol. 41 No. 2, pp. 482-488.

Eller, R., Alford, P., Kallmünzer, A. and Peters, M. (2020), "Antecedents, consequences, and challenges of small and medium-sized enterprise digitalization", *Journal of Business Research*, Elsevier, Vol. 112, pp. 119-127.

Eltayeb, T.K. and Zailani, S.H.M. (2011), "Drivers on the reverse logistics: evidence from Malaysian certified companies", *International Journal Logistics Systems and Management*, Vol. 10 No. 4, pp. 475-395.

Emden, Z., Yaprak, A. and Cavusgil, S.T. (2005), "Learning from experience in international alliances: antecedents and firm performance implications", *Journal of Business Research*, Elsevier, Vol. 58 No. 7, pp. 883-892.

Enkel, E. and Heil, S. (2014), "Preparing for distant collaboration: antecedents to potential absorptive capacity in cross-industry innovation, Technovation", *Elsevier*, Vol. 34 No. 4, pp. 242-260.

Fauzi, A.A. and Sheng, M.L. (2022), "The digitalization of micro, small, and medium-sized enterprises (MSMEs): an institutional theory perspective", *Journal of Small Business Management*, Vol. 60 No. 6, pp. 1288-1313.

Ganesh, K., Mohapatra, S. and Nagarajan, S. (2014), "Learning design for knowledge management solution implementation", *Design and Development of Knowledge Management for Manufacturing*, Springer, Cham, pp. 109-127.

Gaur, J., Amini, M. and Raoa, A.K. (2017), "Closed-loop supply chain configuration for new and reconditioned products: an integrated optimization model", *Omega*, Vol. 66, pp. 212-223.

Giannakis, M. and Papadopoulos, T. (2016), "Supply chain sustainability: a risk management approach", *International Journal of Production Economics*, Elsevier, Vol. 171, pp. 455-470.

Giri, B.C., Chakraborty, A. and Mait, T. (2017), "Pricing and return product collection decisions in a closed-loop supply chain with dual-channel in both forward and reverse logistics", *Journal of Manufacturing Systems*, Vol. 42, pp. 104-123.

González-Torre, P., Álvarez, M., Sarkis, J. and Adenso-Díaz, B. (2010), "Barriers to the implementation of environmentally oriented reverse logistics: evidence from the automotive industry sector", *British Journal of Management*, Vol. 21 No. 4, pp. 889-904.

Govindan, K. and Bouzon, M. (2018), "From a literature review to a multi-perspective framework for reverse logistics barriers and drivers", *Journal of Cleaner Production*, Elsevier, Vol. 187, pp. 318-337.

Grant, R.M. and Baden-Fuller, C. (1995), "A knowledge-based theory of inter-firm collaboration", *Academy of Management Proceedings*, Academy of Management Briarcliff Manor, NY, Vol. 1, pp. 17-21, 10510.

Gulati, R. (1998), "Alliances and network", *Strategic Management Journal*, Vol. 19, pp. 293-317.

Haoud, N. E. and Hasnaoui, M. E. (2019), "Supply chain and industry 4.0: impact and performance analysis: case of biomerieux", *International Colloquium on Logistics and Supply Chain Management, Logistiqua 2019*, Montreuil, Paris, pp. 1-6.

Harold, K. (2011), "Impact of closed-loop network configurations on carbon footprints: a case study in copiers", *Resources, Conservation and Recycling*, Vol. 55 No. 11, pp. 1196-1205.

Hazen, B.T., Wu, Y., Cegielski, C.G., Jones-Farmer, L.A. and Hall, D.J. (2012), "Consumer reactions to the adoption of green reverse logistics", *The International Review of Retail, Distribution and Consumer Research*, Vol. 22 No. 4, pp. 417-434.

Hidalgo-Carvajal, D., Carrasco-gallego, R. and Morales-alonso, G. (2021), "From goods to services and from linear to circular: the role of servitization's challenges and drivers in the shifting process", *Sustainability*, Multidisciplinary Digital Publishing Institute, Vol. 13, 4539.

Hilbe, J.M. (2011), *Negative Binomial Regression*, 2nd ed., Cambridge University Press, New York, doi: 10.1017/CBO9780511973420.

Hörisch, J., Johnson, M.P. and Schaltegger, S. (2015), "Implementation of sustainability management and company size: a knowledge-based view", *Business Strategy and the Environment*, John Wiley & Sons, Limited, Vol. 24 No. 8, pp. 765-779.

Horbach, J. and Rammer, C. (2020), "Circular economy innovations, growth and employment at the firm level: empirical evidence from Germany", *Journal of Industrial Ecology*, John Wiley & Sons, Limited, Vol. 24 No. 3, pp. 615-625.

Hsu, C.C., Tan, K.C., Zailani, S.H.M. and Jayaraman, V. (2013), "Supply chain drivers that foster the development of green initiatives in an emerging economy", *International Journal of Operations and Production Management*, Vol. 33 No. 6, pp. 656-688.

Hudnurkar, M., Jakhar, S. and Rathod, U. (2014), "Factors affecting collaboration in supply chain: a literature review", *Procedia–Social and Behavioral Sciences*, Elsevier, Vol. 133, pp. 189-202.

Ito, K. and Pucik, V. (1993), "R&D spending, domestic competition, and export performance of Japanese manufacturing firms", *Strategic Management Journal*, John Wiley & Sons, Limited, Vol. 14 No. 1, pp. 61-75.

Javaid, H.M., Ain, Q.U. and Renzi, A. (2021), "She-E-Os and innovation: do female CEOs influence firm innovation?", Emerald Group Holdings, Vol. ahead-of-print No. ahead-of-print, *European Journal of Innovation Management*, doi: 10.1108/EJIM-04-2021-0227/FULL/PDF.

Jayaraman, V., Yadong, L. and Findlay, E.M. (2007), "Creating competitive advantages through new value creation: a reverse logistics perspective", *Academy of Management Perspectives*, Vol. 21 No. 2, pp. 56-73.

Jayaraman, V., Ross, A.D. and Agarwal, A. (2008), "Role of information technology and collaboration in reverse logistics supply chains", *International Journal of Logistics Research and Applications*, Taylor & Francis, Vol. 11 No. 6, pp. 409-425.

Jiang, X., Qing, P. and Yang, Y. (2020), "Risk management of baijiu sustainable supply chain in China", *Financial Engineering and Risk Management*, Vol. 3 No. 1, pp. 31-44.

Joe, H. and Zhu, R. (2005), "Generalized Poisson distribution: the property of mixture of Poisson and comparison with negative binomial distribution", *Biometrical Journal*, Vol. 47 No. 2, pp. 219-229, doi: 10.1002/bimj.200410102.

Kalwani, M.U. and Narayandas, N. (1995), "Long-term manufacturer-supplier relationships: do they pay off for supplier firms?", *Journal of Marketing*, SAGE Publications, Los Angeles, CA, Vol. 59 No. 1, pp. 1-16.

Karaosman, H., Perry, P., Brun, A. and Morales-Alonso, G. (2020), "Behind the runway: extending sustainability in luxury fashion supply chains", *Journal of Business Research*, Elsevier, Vol. 117, pp. 652-663.

Ketokivi, M. (2019), "Avoiding bias and fallacy in survey research: a behavioral multilevel approach", *Journal of Operations Management*, Vol. 65 No. 4, pp. 380-402.

Kobarg, S., Stumpf-Wollersheim, J., Schlägel, C. and Welpe, I.M. (2020), "Green together? The effects of companies' innovation collaboration with different partner types on ecological process and product innovation", *Industry and Innovation*, Routledge, Vol. 27 No. 9, pp. 953-990.

Krysiak, F.C. (2009), "Risk management as a tool for sustainability", *Journal of Business Ethics*, Vol. 86, 483, doi: 10.1007/s10551-009-0217-7.

Li, M. and Nguyen, B. (2017), "When will firms share information and collaborate to achieve innovation? A review of collaboration strategies", *The Bottom Line*, Emerald Publishing Limited, Vol. 30 No. 1, pp. 65-86.

Lintona, J.D., Klassenb, R. and Jayaraman, V. (2007), "Sustainable supply chains: an introduction", *Journal of Operations Management*, Vol. 25 No. 6, pp. 1075-1082.

Loon, M. (2019), "Knowledge management practice system: theorising from an international meta-standard", *Journal of Business Research*, Vol. 94, pp. 432-441.

Marić, J. and Opazo-Basáez, M. (2019), "Green servitization for flexible and sustainable supply chain operations: a review of reverse logistics services in manufacturing", *Global Journal of Flexible Systems Management*, Vol. 20, pp. 65-80.

Marqués, D.P. and Garrigós-Simón, F.J. (2006), "The effect of knowledge management practices on firm performance", *Journal of Knowledge Management*, Emerald Group Publishing Limited, Vol. 10 No. 3, pp. 143-156.

Matos, S.V., Schleper, M.C., Gold, S. and Hall, J.K. (2020), "The hidden side of sustainable operations and supply chain management: unanticipated outcomes, trade-offs and tensions", *International Journal of Operations and Production Management*, Emerald Group Holdings Limited, Vol. 40 No. 12, pp. 1749-1770.

Matt, M., Robin, S. and Wolff, S. (2011), "The influence of public programs on inter-firm R&D collaboration strategies: project-level evidence from EU FP5 and FP6", *The Journal of Technology Transfer*, Springer, Vol. 37 No. 6, pp. 885-916.

Meade, L.M., Sarkis, J. and Presley, A. (2007), "The theory and practice to Reverse Logistics", *International Journal of Logistics Systems and Management*, Inderscience Publishers, Vol. 3 No. 1, pp. 56-84.

Mentzer, J.T., Foggin, J.H. and Golici, S.L. (2000), "Collaboration: the enablers, impediments, and benefits", *Supply Chain Management Review*, Vol. 4 No. 4, pp. 52-58.

Mihi Ramírez, A. (2012), "Product return and logistics knowledge: influence on performance of the firm", *Transportation Research Part E*, Logistics and Transportation Review, Elsevier Limited, Vol. 48 No. 6, pp. 1137-1151.

Min, H., Ko, H.S. and Ko, H.J. (2006), "The spatial and temporal consolidation of returned products in a closed-loop supply chain network", *Computers and Industrial Engineering*, Vol. 51, pp. 309-320.

Min, S., Zacharia, Z.G. and Smith, C.D. (2019), "Defining supply chain management: in the past, present, and future", *Journal of Business Logistics*, John Wiley & Sons, Limited, Vol. 40 No. 1, pp. 44-55.

Mishra, J.L., Chiwenga, K.D. and Ali, K. (2021), "Collaboration as an enabler for circular economy: a case study of a developing country", *Management Decision*, Emerald Group Holdings Limited, Vol. 59 No. 8, pp. 1784-1800.

Mofokeng, T.M. and Chinomona, R. (2019), "Supply chain partnership, supply chain collaboration and supply chain integration as the antecedents of supply chain performance", *South African Journal of Business Managemen*, Vol. 50 No. 1, pp. 1-10.

Moktadir, M.A., Rahman, T., Ali, S.M., Nahar, N. and Paul, S.K. (2020), "Examining barriers to reverse logistics practices in the leather footwear industry", *Annals of Operations Research*, Springer, Vol. 293 No. 2, pp. 715-746.

Morgan, T.R., Tokman, M., Richey, R.G. and Defee, C. (2018), "Resource commitment and sustainability: a reverse logistics performance process model", *International Journal of Physical Distribution and Logistics Management*, Vol. 48 No. 2, pp. 164-182.

Myrtveit, I. and Stensrud, E. (1999), "A controlled experiment to assess the benefits of estimating with analogy and regression models", *IEEE Transactions on Software Engineering*, Institute of Electrical and Electronics Engineers Incorporate, Vol. 25 No. 4, pp. 510-525.

Nedilska, L. and Oleniuk, D. (2020), "Agribusiness digitalization: trends and funding sources", *Scientific Horizons*, No. 91, pp. 26-32.

Ni, S., Lin, Y., Li, Y., Shao, H. and Wang, S. (2021), "Green and reverse logistics in conditions of sustainable development in enterprises in Slovakia", *Sustainability*, Multidisciplinary Digital Publishing Institute, Vol. 13 No. 2, 581.

Nidumolu, R., Prahalad, C.K. and Rangaswami, M.R. (2009), "Why sustainability is now the key driver of innovation", *Harvard Business Review*, Vol. 87, pp. 57-64.

Nisar, T.M., Prabhakar, G. and Strakova, L. (2019), "Social media information benefits, knowledge management and smart organizations", *Journal of Business Research*, Vol. 94, pp. 264-272.

Nonaka, I. (1994), "A dynamic theory of organizational knowledge creation", *Organization Science*, Vol. 5 No. 1, pp. 14-37, doi: 10.1287/orsc.5.1.14.

Ode, E. and Ayavoo, R. (2020), "The mediating role of knowledge application in the relationship between knowledge management practices and firm innovation", *Journal of Innovation and Knowledge*, Elsevier, Vol. 5 No. 3, pp. 210-218.

Ohnishi, S., Fujita, T., Chen, X. and Fujii, M. (2012), "Econometric analysis of the performance of recycling projects in Japanese Eco-Towns", *Journal of Cleaner Production*, Vol. 33, pp. 217-225.

Olorunniwo, F.O. and Li, X. (2010), "Information sharing and collaboration practices in reverse logistics", *Supply Chain Management*, Vol. 15 No. 6, pp. 454-462.

Oorschot, K.E., Akkermans, H.A., Van Wassenhove, L.N. and Wang, Y. (2022), "Organizing for permanent beta: performance measurement before vs performance monitoring after release of digital services", Emerald Group Holdings, *International Journal of Operations and Production Management*, Vol. 43 No. 3, pp. 520-542.

Pagoropoulos, A., Pigosso, D.C.A. and McAloone, T.C. (2017), "The emergent role of digital technologies in the circular economy: a review", *Procedia CIRP*, Vol. 64, pp. 19-24.

Park, N.K., Mezias, J.M. and Song, J. (2004), "A resource-based view of strategic alliances and firm value in the electronic marketplace", *Journal of Management*, Vol. 30 No. 1, pp. 7-27.

Pereira, V. and Bamel, U. (2021), "Extending the resource and knowledge based view: a critical analysis into its theoretical evolution and future research directions", *Journal of Business Research*, Vol. 132, pp. 557-570.

Peter, K. (1998), *A Guide to Econometrics*, 4th ed., MIT Press, Cambridge, MA, available at: https://books.google.it/books?hl=en&lr=&id=69MDEAAAQBAJ&oi=fnd&pg=PR10&dq=A+guide+to+econometrics&ots=VQJUCNVXmd&sig=qF45PBvwge2sE0VrnB4C2rhh1Sc&redir_esc=y#v=onepage&q=Aguide to econometrics&f=false (accessed 25 January 2022).

Pokharel, S. and Mutha, A. (2009), "Perspectives in reverse logistics: a review", *Resources, Conservation and Recyclin*, Vol. 53 No. 4, pp. 175-182.

Porter, M.E. and Kramer, M.R. (2011a), "Creating shared value", *Harvard Business Review*, Vol. 89, pp. 62-77.

Porter, M.E. and Kramer, M.R. (2011b), "The big idea : creating shared value moving beyond trade-offs-the roots of shared value", *Fortune*, pp. 1–12.

Prakash, C. and Barua, M.K. (2017), "Flexible modelling approach for evaluating reverse logistics adoption barriers using fuzzy AHP and IRP framework", *International Journal of Operational Research*, Inderscience Publishers, Vol. 30, pp. 151-171.

Prakash, C., Barua, M.K. and Pandya, K.V. (2015), "Barriers analysis for reverse logistics implementation in Indian electronics industry using fuzzy analytic hierarchy process", *Procedia–Social and Behavioral Sciences*, Elsevier BV, Vol. 189, pp. 91-102.

Preuss, L. and Fearne, A. (2022), "Cognitive frames held by supply chain managers: implications for the management of sustainability in supply chains", *Supply Chain Management*, Vol. 27 No. 6, pp. 681-695.

Qazi, A.A. and Appolloni, A. (2022), "A systematic review on barriers and enablers toward circular procurement management", *Sustainable Production and Consumption*, Elsevier, Vol. 33, pp. 343-359.

Ramirez, A.M. and Girdauskiene, L. (2013), "Creation of knowledge and reverse logistics. Empirical analysis from perspective of the resource based view theory", *Engineering Economics*, Kauno Technologijos Universitetas, Vol. 24 No. 5, pp. 478-487.

Rasool, F., Greco, M. and Strazzullo, S. (2021), "Is digital supply chain calling for new KPIs?", *IFKAD 2021 Managing Knowledge in Uncertain Times*, Rome, pp. 1196-1211.

Rogers, D.S. and Tibben-Lembke, R. (2001), "An examination of reverse logistics practices", *Journal of Business Logistics*, Vol. 22 No. 2, pp. 129-148.

Rosa, P., Sassanelli, C., Urbinati, A., Chiaroni, D. and Terzi, S. (2020), "Assessing relations between circular economy and industry 4.0: a systematic literature review", *International Journal of Production Research*, Vol. 58 No. 6, pp. 1162-1687.

Sangwan, K.S. (2011), "Quantitative and qualitative benefits of green manufacturing: an empirical study of Indian small and medium enterprises", in Hesselbach, J. and Herrmann, C. (Eds), *Glocalized Solutions for Sustainability in Manufacturing*, Springer, Berlin, Heidelberg, pp. 371-376.

Schenkel, M., Caniëls, M.C.J., Krikke, H. and Van Der Laan, E. (2015), "Understanding value creation in closed loop supply chains – past findings and future directions", *Journal of Manufacturing Systems*, Elsevier, Vol. 37, pp. 729-745.

Schlüter, M., Lickert, H., Schweitzerc, K., Bilgeb, P., Briesea, C., Dietrich, F. and JörgKrügera (2021), "AI-Enhanced identification, inspection and sorting for reverse logistics in remanufacturing", *Procedia CIRP*, Vol. 98, pp. 300-305.

Schütz, K., Kässer, M., Blome, C. and Foerstl, K. (2020), "How to achieve cost savings and strategic performance in purchasing simultaneously: a knowledge-based view", *Journal of Purchasing and Supply Management, Pergamon*, Vol. 26 No. 2, 100534.

Sehnem, S., Vazquez-Brust, D., Pereira, S.C.F. and Campos, L.M.S. (2019), "Circular economy: benefits, impacts and overlapping", *Supply Chain Management*, Emerald Group Holdings Limited, Vol. 24 No. 6, pp. 784-804.

Silvestre, B. (2016), "Sustainable supply chain management: current debate and future directions", *Gestão and Produção*, Vol. 23 No. 2, pp. 235-249.

Singh, H., Garg, R.K. and Sachdeva, A. (2018), "Supply chain collaboration: a state-of-the-art literature review", *Uncertain Supply Chain Management, Growing Science*, Vol. 6 No. 2, pp. 149-180.

Tahvonen, O. (2000), *Economic Sustainability and Scarcity of Natural Resources: A Brief Historical Review*, Resources for the Future, Washington, DC.

Teece, D.J. (2000), *Managing Intellectual Capital: Organizational, Strategic, and Policy Dimensions*, Oxford University Press, Oxford.

Tham, K.W. and Atan, S.A. (2021), "SME readiness towards digitalization in Malaysia", *Research in Management of Technology and Business*, Vol. 2 No. 1, pp. 361-375.

Toffel, M.W. (2004), "Strategic management of product recovery", *California Management Review*, Vol. 46 No. 2, pp. 120-141.

Usman Ahmad, M., Qaiser Danish, R., Fawad Ali, H., Shahid, R., Ahsan khan, M. and Nadeem, K. (2019), "Impact of training and supervisor support on organizational commitment with mediating role of job satisfaction", *European Online Journal of Natural and Social Sciences: Proceedings*, Vol. 8 No. 1, pp. 25-33.

Walter, A. (2003), "Relationship-specific factors influencing supplier involvement in customer new product development", *Journal of Business Research*, Elsevier, Vol. 56 No. 9, pp. 721-733.

Wang, Z. and Sarkis, J. (2013), "Investigating the relationship of sustainable supply chain management with corporate financial performance", *International Journal of Productivity and Performance Management*, Vol. 62 No. 8, pp. 871-888.

Waqas, M., Dong, Q.L., Ahmad, N., Zhu, Y. and Nadeem, M. (2018), "Critical barriers to implementation of reverse logistics in the manufacturing industry: a case study of a developing country", *Sustainability*, Vol. 10 No. 11, 4202.

Wernerfelt, B. (1984), "A resource-based view of the firm", *Strategic Management Journal*, John Wiley & Sons, Limited, Vol. 5 No. 2, pp. 171-180.

Wilson, M., Paschen, J. and Pitt, L. (2022), "The circular economy meets artificial intelligence (AI): understanding the opportunities of AI for reverse logistics", *Management of Environmental Quality*, Vol. 33 No. 1, pp. 9-25.

Wrede, M., Velamuri, V.K. and Dauth, T. (2020), "Top managers in the digital age: exploring the role and practices of top managers in firms' digital transformation", *Managerial and Decision Economics*, John Wiley & Sons, Limited, Vol. 41 No. 8, pp. 1549-1567.

Yang, J. (2013), "Harnessing value in knowledge management for performance in buyer–supplier collaboration", *International Journal of Production Research*, Taylor & Francis Group, Vol. 51 No. 7, pp. 1984-1991.

Zhang, Q. and Cao, M. (2018), "Exploring antecedents of supply chain collaboration: effects of culture and interorganizational system appropriation", *International Journal of Production Economics*, Elsevier, Vol. 195, pp. 146-157.

Zhu, Q., Krikke, H. and Caniëls, M.C.J. (2018), "Supply chain integration: value creation through managing inter-organizational learning", *International Journal of Operations and Production Management*, Emerald Group Publishing Limited, Vol. 38 No. 1, pp. 211-229.

About the authors

Faisal Rasool is currently a PhD student in the Department of Enterprise Engineering, University of Rome "Tor Vergata", Italy. He received his master's degree in Industrial and Manufacturing Engineering from the Asian Institute of Technology, Thailand. His research interests focus on sustainable and digital supply chains and their impact on firm performance. Faisal Rasool is the corresponding author and can be contacted at: faisal.rasool@uniroma2.it

Marco Greco is an Associate Professor of Industrial Marketing and Corporate Governance at the University of Cassino and Southern Lazio. He published articles in reputed journals such as *Technological Forecasting and Social Change, European Management Journal, Journal of Business Research, and International Journal of Project Management*. His main research interests include open innovation, intellectual capital, strategic management, negotiation and project management.

Gustavo Morales-Alonso is an Associate Professor in Economics, Entrepreneurship and Innovation at Universidad Politécnica de Madrid (UPM). With a sound interest in the drivers of economic development, the sharing economy and sustainability, he has published in SCI-indexed journals such as *Technological Forecasting and Social Change, Journal of Business Research and Sustainability*, among others. Belongs to the Editorial Advisory Board of the *European Journal of Innovation Management*.

Ruth Carrasco-Gallego is an Associate Professor of Regenerative Value Ecosystems at Universidad Politécnica de Madrid (UPM), where she is the Dean for SDGs at the Industrial Engineering School. Dr Carrasco-Gallego has published extensively in her areas of expertise and has participated in or led several research projects. Currently, she leads the CircularizatE initiative, an on-campus living lab of real circular economy, aiming to demonstrate that regenerative business models are technically viable, economically profitable and socially inclusive.