STUDY OF CO-ORDINATION MECHANISMS OF REVERSE SUPPLY CHAIN

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CANDIDATE'S DECLARATION

I Dharmendra Kumar certify that the work which is being presented in the thesis entitled Study of Co-ordination Mechanisms of Reverse Supply Chain in the partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy, submitted in the Department of Mechanical Engineering, Delhi Technological University is an authenticated record of my own work carried out during the period from July 2016 to April 2024 under the supervision of Dr Saurabh Agrawal, Associate Professor, Delhi School of Management and Dr. Raj Kumar Singh, Professor, Department of Mechanical engineering. The matter. discussed in the thesis has not been submitted by me for the award of any other degree of this or any other institute.

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This is to certify that the student has incorporated all the corrections suggested by the examiners in the thesis and the statement made by the candidate is correct to the best of our knowledge.

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Certified that Dharmendra Kumar (2K16/PhD/ME/49) has carried out their research work presented in this thesis entitled “Study of Co-ordination Mechanisms of Reverse Supply Chain” for the award of Doctor of Philosophy from Department of Mechanical Engineering, Delhi Technological University, Delhi, under our supervision. The thesis embodies results of original work, and studies are carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

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ABSTRACT

Reverse Supply Chain is one way to handle product returns efficiently. With zero waste, it is considered one of the best strategies of circular economy to manage product returns. A circular economy seeks to reduce waste by reusing, refurbishing, and recycling used products and increases the product/resource value of used goods. The effective execution of circular strategies necessitates coordination among all channel members participating in the activities, from acquisition to collection to disposal of returned items. Various difficulties from multiple angles must be addressed to carry out circular strategies. The pricing, quality, and warranty concerns of refurbished items must be investigated from the customer's standpoint. Supply chains are becoming increasingly data-driven and integrated due to digital technology. Supply chain participants are coordinating through digital platforms and real-time data. These technologies improve interaction and coordination, enabling organizations to coordinate tasks while keeping some decentralization or autonomy.

Considering the above challenges in the effective implementation of reverse supply chain coordination and for this thesis, it is deemed necessary to (i) study and analyze various coordination mechanisms for reverse supply chain, (ii) develop coordination models for the effective reverse supply chain, (iii) study the impact of various coordination issues on reverse supply chain performance, (iv) study & analyze the Indian consumer electronics industry concerning reverse supply chain performance, and (v) to explore the coordination issues through the case study.

A systematic literature review has been conducted to comprehend the above issues, and the Theory, Context, and Methodology framework have been used to identify the research gaps for future research directions. This literature review has identified the characteristics of reverse supply chain coordination. It consists of channel structures, coordination mechanisms, performance measuring parameters, the applied methodology, and industries that have been researched. The literature review adds value by examining reverse supply chain issues from strategic, governance, consumer behavior, and functionality decision-making perspectives. Surprisingly, few studies have been conducted on reverse supply chain coordination issues. Through the literature review, it is observed that contracts are considered the most crucial coordination

mechanism. The most widely used contract is the revenue-sharing contract. In the reviewed study, some studies have employed more than one type of coordination mechanism. Most studies used profit maximization as a yardstick to measure the effectiveness of the RSC to maximize performance.

The literature review analysis demonstrates that game-theoretical modeling in reverse supply chain coordination is the most prevalent approach for coordinating the channels. Accordingly, game theoretical modeling has been selected to develop coordination models for the effective reverse supply chain and to study the impact of various coordination issues on reverse supply chain performance. To study and analyze the consumer electronics industry concerning reverse supply chain performance and to investigate coordination issues, a game theory-based analytic study is conducted after gaining insights from interviews with industry stakeholders and a case study in the Indian context. Industry 4.0 technology facilitates the development of a coordinated supply chain to enhance channel performance. Accordingly, the present work has mainly used contract mechanisms. Information technology and information-sharing mechanisms of supply chain coordination have been integrated with contract mechanisms to expedite the exchange of products, information, and funds and optimize supply chain operations through collaborative methods.

A two-echelon circular supply chain is investigated using a game-theoretic approach to investigate the coordination problem. The centralized and decentralized model findings are compared, and observed that the decentralized model shows potential for improvement. It is found that the coordinated structure can improve the performance of the supply chain. The issue of channel conflicts, pricing of refurbished products, and sustainability has been addressed.

In continuation of the above, another model considering a two-echelon circular supply chain has been conducted to investigate the effects of extending product life and resource value of end-of-life/end-of-use products on channel performance using mobile technology in the era of Industry 4.0. The issue of channel conflicts, pricing of refurbished products, and the quality and guarantee of refurbished products have been addressed. A Stackelberg game model is built to optimize supply chain decisions. The study also created centralized, decentralized, revenue-sharing, and two-part tariff contract models and compared the outcomes to determine the optimal scenario. The findings revealed that a two-part tariff contract is the most successful contracting strategy for implementing expanded producer responsibility rules in the circular economy. It has also been found that mobile technology may be used for coordination purposes in the Industry 4.0 environment.

In addition, a mixed-method approach using analytical modeling, interviews with supply chain stakeholders, and a case study of the Indian consumer electronics industry is used to evaluate reverse supply chain performance and coordination concerns between stakeholders in implementing extended producer responsibility in India to streamline e-waste management and disposal of used consumer electronics products. The issue was examined using a consignment contract with revenue sharing for various channel structures. The decentralized channel is coordinated using a hybrid contract in a cooperative game paradigm. The findings demonstrate that the consignment contract cannot coordinate a decentralized firm. The recommerce platform achieves perfect coordination and a unique Pareto optimization through the hybrid contract. A system facilitated by the Internet of Things is proposed as a data collection and integration solution. It turns out that resources have not been lost, so businesses can use the circular economy idea to reach their sustainable objectives.

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LIST OF ABBREVIATIONS

CE	Circular Economy
CS	Cost Sharing
CSC	Circular supply chain
EoL	End-of-life
EoU	End-of-use
EPR	Extended Producer Responsibility
FSC	Forward Supply Chain
IoT	Internet of Things
IS	Information Sharing
IT	Information Technology
MABRC	Mobile application-based refurbishment company
MC	Minimize Cost
MM	Mathematical Model
MP	Maximize Profit
OEM	Original Equipment Manufacturer
ORP	Online recommerce platform
RFID	Radio Frequency Identification
RL	Reverse Logistics
RS	Revenue sharing
RSC	RSC
SC	Supply chain
SCM	Supply Chain Management
SG	Stackelberg game
TCM	Theory, Context, and Methodology
TPT	Two-part tariff
WEEE	Waste electrical and electronic equipment
WP	Wholesale price

CHAPTER 1: INTRODUCTION

1.1. Background

The government of India's initiatives like "Digital India" and "Smart City" programs have increased demand for electronics products. India has developed as one of the world's most significant marketplaces for electronic items, with a current market value of $ 140 billion (Invest India, n.d.). Indian consumer electronics industry deals with manufacturing, distributing, and selling electronic products and appliances for personal and home use. Technology revolutions such as the deployment of 5G networks and the Internet of Things (IoT) are further accelerating the uptake of electronic devices. These products include features/smartphones, personal computers/ laptops, televisions, tablets, etc., which usually have a short product life cycle. India is the world's third-largest producer of e-waste (Singh et al., 2023); however, only 10% of the waste is collected for recycling. India generates 146,000 tonnes of e-waste annually, which grows by 10% annually. In India, there is a shortage of interest in managing used/customer returned/end-of-use (EoU)/end-of-life (EoL) consumer electronic items. It indicates that India faces a challenge in managing consumer electronic waste, and electronic manufacturing companies must plan strategically for its appropriate disposition (Bali et al., 2022).

The government of India has implemented several measures to regulate the country's e-waste recycling industry. For instance, on November 2, 2022, the Ministry of Environment, Forests, and Climate Change of the Government of India announced the E-Waste (Management) Rules, 2022. These regulations usher in a new Extended Producer Responsibility (EPR) system for electronic waste recycling. Optimized management of consumer electronic wastes might be a viable alternative for achieving the economic, environmental, and social advantages predicted by implementing circular economy (CE) concepts. According to a draft policy paper on circular economy in the electrical and electronics industry published by the Ministry of Electronics and Information Technology, the extraction rate of abiotic resources for electrical and electronic equipment (EEE) manufacturing is significantly higher than the formation rate in nature. As a result, the CE strategy will be required to meet the country's resource demands (Ministry of Electronics and Information Technology, 2021).

Electronic commerce, lenient return policies, and cash-on-delivery also significantly contribute to the high product return rate (Al-Adwan et al., 2022). Accenture found that 11–20% of consumer electronic devices are returned. Accenture found that stakeholders spend a lot to receive, repair, re-box, and resell returned items. Since only 5% of returns are due to product faults, this data shows that the industry has a large chance of minimizing costs and reducing product returns (Kenney and Sedej, 2012, 2012). India's e-business markets are expected to grow considerably in the coming years, reaching $188 billion by 2025 and $350 billion by 2030 (Fatimah et al., 2023). Das and Chaudhari (2015) found that consumer electronic firms employ the RSC approach to deal with managing end-of-life (EOL)/end-of-use (EOU)/used/returned items.

1.2. RSC

The research on RSC has evolved over the years, and authors have defined RSC differently. The definition of RSC has widened its scope with the interest of researchers in this area. Rogers and Tibben-Lembke (1998) mentioned that the definition of Reverse logistics (RL) includes remanufacturing, refurbishing, reusing, recycling, obsolete equipment disposition, asset recovery, processing returned merchandise due to damage, seasonal inventory, restocking, salvage, recalls, and excess inventory. Guide and Wassenhove (2002) described RSC as the series of activities required to retrieve a used product from a customer and either dispose of it or reuse it. RSC refers to a series of activities necessary to retrieve a product from a customer and dispose of it to recover value (Kocabasoglu et al., 2007).

Some definitions of supply chain (SC) cover both forward and reverse SC. Baatz (1995) expands supply chain management (SCM) to include recycling or reuse. Unlike Forward SCs, design strategies for RSCs are relatively unexplored and underdeveloped. RL mainly deals with transportation, production planning, and inventory management, while RSC has a broader focus involving additional elements such as coordination and collaboration among channel partners. In other words, RL is one of the elements of an RSC (Prahinski and Kocabasoglu, 2006).

Based on the work carried out by different researchers, five key processes of RSC have been identified: product acquisition, collection, inspection and sorting, disposition, and re-distribution & sales. Product acquisition is acquiring used products from the end users for further processing (Agrawal et al., 2015). The acquired used /returned/unsold products would be returned from the customer/retailer to the collection center through the Collection process. Inspection and sorting activities result in splitting the flow of used products according to distinct reuse or disposal options (Krikke et al., 2003). Disposition is defined as making the most profitable decision for repair, reuse, remanufacturing, and recycling (Blackburn et al., 2004). Disposition is to determine an appropriate product recovery strategy for each product in the RSC. The following four common disposition alternatives have been discussed in the literature:

(a) Repair: Repair is to return the used products to the user in working condition. It repairs or replaces broken parts. Other parts are not affected. The quality of repaired products is generally inferior to the quality of new products. The warranty period of repaired products is generally less than that of newly manufactured equivalents. Also, the warranty may not cover the whole product but only the replaced component (Thierry et al., 1995; Jindal and Sangwan, 2016).

(b) Reuse: Reuse, that is, to immediately reuse or resell the product (Prahinski and Kocabasoglu, 2006). Reusable products require only minor inspection, cleaning, and minor maintenance. These products are generally returned to FSC and form a CLSC network (Agrawal et al., 2015).

(c) Remanufacturing or Refurbishment: Remanufacturing (or refurbishment) may be defined as returning the product to its original specifications (Blackburn et al., 2004). Remanufacturing improves old items to new standards. Remanufacturing can be combined with technological upgrading (Thierry et al., 1995). Refurbishing is slightly different from remanufacturing in terms of the quality of the product and the effort needed. The purpose of refurbishing is to bring used products up to specified quality. Refurbishing involves less effort than remanufacturing (Nußholz, 2017).

(d) Recycling: In recycling, the identity and functionality of products and components are lost. Recycling is reusing materials from used products and components (Thierry et al., 1995).

Re-distribution refers to directing reusable products to a potential market and physically moving them to future users (Krikke et al., 2003). By reselling the product, the product life may be extended. Blackburn et al. (2004) define marketing as creating secondary markets for the recovered product.

1.3. Zero waste approach in RSC context with integration of digital technology

The RSC is one of the strategies for attaining sustainability. RSCs encourage product take-back through relaxed take-back policies and provide subsidies to the organization, ultimately reaching consumers (Song et al., 2020b). The RSC may be either open-loop or closed-loop (Genovese et al., 2017). The open loop supply chain structure refers to the reprocessing of goods and materials by entities other than the OEM to cater to markets other than the primary market for a product (Gunasekara et al., 2023; Berlin et al., 2022b). Several terms, including reverse, closed-loop or open-loop, and green supply chain, have been used interchangeably in the literature to refer to CE framework implementations (Taddei et al., 2022; González-Sánchez et al., 2020; Batista et al., 2018). However, a circular supply chain (CSC) expands the RSC by focusing on stakeholder collaboration for circularity and zero waste (Amir et al., 2023; De Lima and Seuring, 2023). The present study considers the open structure of RSC taking zero waste. Accordingly, this study uses these terms, i.e., RSC or CSC interchangeably. Reusing waste as inputs in RSC processes is needed to minimize environmental and social impacts and achieve sustainability (Sellitto and de Almeida, 2019). RSC concentrates on managing and coordinating activities related to the return, reuse, refurbishment, and recycling of consumer electronics products. Coordination of the RSC involves efficient processing of product returns, managing product recovery processes, and recycling obsolete or defective electronic devices. Pricing, warranties, and product quality are the most common issues of any RSC operation. These issues are particularly severe in the electronics industry, characterized by a high rate of obsolescence, diminishing product lifecycles, and technological obsolescence (Das and Chaudhari, 2015).

Companies want to adopt such policies and materials to combat undesirable effects and reduce production costs by reusing recycled e-waste (Rezayat et al., 2020). Industry 4.0 technologies aim to improve operational excellence in companies (Mangla et al., 2020). Industry 4.0 technologies include IoTs, cloud computing, artificial intelligence, machine learning, and advanced robotics (Culot et al., 2020). IoT applications allow stakeholders of CE to work together more efficiently and exchange information more readily, improving decision-making. IoT comprises Radio Frequency Identification (RFID) technology and wireless sensor networks (Lei et al., 2022). There might be a lack of cooperation among RSC participants (Agrawal et al., 2014). Implementing industry 4.0 technology at the individual level may not improve SC coordination and results in inefficient resource usage (Singh et al., 2019). SCs should be carefully coordinated through the maximum use of these digital technologies (Ran et al., 2020). Decentralized industry 4.0 SC dominates the industry in sustainability when coordinated (Toktaş-Palut, 2022). Coordination will also assist in performing specialized activities such as refurbishment (Whalen et al., 2018).

1.4. SC coordination

Coordination is defined by Malone and Crowston (1994) as "Coordination is managing dependencies between activities." The lack of coordination may result in poor performance of SC. The terms like integration (combining to an integral whole), collaboration (working jointly), cooperation (joint operation), and coordination are complementary to each other and, when used in the context of SC, can easily be considered as a part of SC coordination (Arshinder et al., 2008). Organizations must coordinate with supply chain partners to adopt a CSC integrated with Industry 4.0 to improve sustainability (Kumar et al., 2023).

1.4.1. RSC coordination mechanisms

A coordination mechanism consists of adopting a specific practice, such as a contract, to meet the collective objectives of RSC (De Giovanni and Zaccour, 2019). Dissanayake and Sinha (2015) examined the remanufacturing process and revealed that coordination among key players is essential for business growth. Coordination among chain members is needed to maximize the profits in the RSC (Chakraborty et al., 2018). The coordination contract mechanism encourages supply chain members to act in a way that fulfills the goals of the entire supply chain, such as maximizing total supply chain profit (Agrawal et al., 2023b). Contracts are structured to enhance collaboration and realize a financially sustainable business model for stakeholders (Fischer and Pascucci, 2017). A key issue in SCM is to develop mechanisms that can align the objectives of independent SC members and coordinate their decisions and activities to optimize system performance (Li and Wang, 2007). According to Arshinder et al. (2008), SC coordination could be achieved by four different coordination mechanisms, namely, (i) coordination contracts, (ii) information technology, (iii) information sharing, and (iv) joint decision-making. Many techniques that have been found to coordinate the FSC may also be used to coordinate the RSC (Govindan and Popiuc, 2014). The discovery of appropriate methods for RSC coordination has much future potential for academics and business (Krapp and Kraus, 2017). In the next succeeding sub-sections, these four coordination mechanisms are discussed.

1.4.1.1. Contracts

Among these coordination mechanisms, contracts are valuable tools to facilitate interaction between disparate SC members to maximize total SC profit (Govindan and Popiuc, 2014). The analysis of RSC coordination contract implementation among channel members is worth it. However, with the increasing focus on recycling and RSC, the field of research remains far behind the progress made by the industry (Govindan et al., 2013). The two-part tariff and hybrid contracts are under-explored in reverse supply operations. Exploring these SC contracts is more complicated and challenging than the simpler SC contracts chain management (Guo et al., 2017).

1.4.1.2. Information Sharing

Information sharing can radically improve channel performance, especially in the wake of increasing globalization and outsourcing, which has and will continue to affect SC operations profoundly. Son et al. (2015) analyzed the effect of information sharing in an RSC and found that information sharing leads to a higher profit for the system.

1.4.1.3. Information Technology (IT)

Advances in IT, such as the internet, e-business, Radio Frequency Identification (RFID), Barcoding, and many more, enable firms to rapidly exchange products, information, and funds and utilize collaborative methods to optimize SC operations (Arshinder et al. 2008). The IT provides a tool to gather accurate information on time, analyze it, and execute it to increase performance and make the best RSC decision.

1.4.1.4. Joint Decision Making

Coherent decision-making helps resolve conflicts among SC members (Bazan et al., 2017).

1.5. Business models for consumer electronics about RSC

The Indian consumer electronics industry faces several challenges regarding RSC coordination. These challenges include the need for effective collaboration among stakeholders. Efficient RSC coordination in the Indian consumer electronics industry can lead to various benefits, including reduced environmental impact through proper disposal and recycling, increased resource efficiency through product recovery and reuse, cost savings through improved inventory management, and enhanced customer satisfaction through effective returns and warranty processes. Thus, there is a need to study RSC coordination issues considering the Indian consumer electronic industry. Recommerce is an online marketplace for trading and recycling pre-owned goods such as cell phones, tablets, and computers. For example, Gazelle, a recommerce company, operates in the consumer electronics market (Tang et al., 2022). The recommerce business model extends the lifespan of reusable products like electronic items to reduce waste (Caro et al., 2020). Many researchers have examined the recommerce business model in CE settings, which is gaining popularity (Tang et al., 2022). Accordingly, in subsequent sections, the term recommerce has been used in the context of RSC considering the consumer electronic industry. Any decision-making process involving multiple decision-makers dependent on each other can be effectively analyzed using the tools of game theory (Cachon & Netessine, 2004). Accordingly, the game-theoretic paradigm has been used to address CSC challenges in the CE (Choi et al., 2020; Cao & Zhang, 2020).

1.6. Motivation for the research

The RSC coordination study is in the growth phase, and there is a substantial opportunity for future work scope. Existing studies demonstrate that research is dispersed and diverse across industries and that some issues like, lack of industry-specific models (Mathiyazhagan et al., 2020), impact of supply chain coordination on different stakeholders (Paula et al., 2020), effective contract design and end-of-life product management (Corsini et al., 2020), and integration with emerging technologies (Hrouga et al., 2022) have received comparatively less attention in previous research. This research aims to identify and investigate these issues. The Indian consumer electronics market is expanding rapidly, propelled by factors such as rising disposable income and increased internet penetration (KPMG, 2022). This rapid expansion demands a strong and long-lasting RSC system. The vast volume of electronics produced and used in India need effective RSC practices to reduce environmental impact. The Indian government's ambitions to enforce stronger sustainable development laws demand immediate study of efficient RSC coordination strategies (NITI Aayog, 2023).

- Circular Economy for Consumer Electronics (CE): RSC coordination directly fosters a circular economy (CE) for consumer electronics by increasing resource use, reducing waste, and prolonging product lifespans (Paula et al., 2020). This study will create models and concepts for closing CE loops, promoting product reuse, refurbishing, and recycling, and investigating resource-saving business models.
- Environmental Sustainability: Effective coordination is essential for attaining environmental sustainability in the CE industry. It enables more efficient product and material management, reuse, recycling, and disposal, resulting in less waste and a smaller environmental footprint (Van Fan et al., 2021). This research will concentrate on establishing strategies and techniques to improve these RSC processes, reduce carbon footprints, and increase resource efficiency.
- Regulatory Compliance and Risk Mitigation: RSC management is governed by rules like as product return, waste management, and Extended Producer Responsibility (EPR) (Garg, 2021). Proper coordination enables firms to get a thorough understanding of these requirements, assure compliance, and prevent any fines or legal concerns. This research will delve into understanding and

complying with relevant legislation, as well as assisting in the development of effective circularity frameworks.

- Economic Gains: Improved RSC coordination can lead to huge economic gains for organizations. RSC coordination adds value to consumer-returned end-of-life or end-of-use items through refurbishment or recycling (Borenich et al., 2020). This can result in cost savings in areas such as product returns, inventory management, and disposal by optimizing RSC decisions and improving coordination. This research will create models that maximize economic value and improve RSC decision-making.

1.7. Research objectives

Based on the above discussions, the following research objectives are identified for this study:

- ❖ To study and analyze various coordination mechanisms for RSC/CSC.
- ❖ To develop coordination models for the effective RSC/CSC.
- ❖ To study the impact of various coordination issues on RSC/CSC performance.
- ❖ To study and analyze Indian consumer electronics industry in reference to RSC/CSC coordination.
- ❖ To explore the coordination issues through the case study.

To discover gaps and inefficiencies in the Indian consumer electronics business, one must understand RSC/CSC coordination mechanisms. Analyzing these mechanisms will provide a baseline for improvement models suited to market needs. First objective explores coordination methods to fill the research gap. The research can refine models and adapt them to India to promote a strong circular economy for consumer electronics.

To overcome dispersed research and operate well in the Indian RSC/CSC context, new or enhanced coordination mechanisms are needed. These models will help stakeholders adopt successful coordinating tactics. Second objective addresses the need for effective and sustainable RSC processes in the fast-growing Indian market. This will help achieve environmental sustainability, waste reduction, and resource use by creating new models. These models also assist firms comply with new rules and optimize CSC/RSC decisions for economic gain.

Determining how coordination issues affect RSC/CSC performance is crucial for identifying efficiency and effectiveness issues. Understanding these difficulties will enable solution development and coordination model adjustment. Third objective addresses unresolved Indian market challenges to address research dispersion. Better environmental and economic benefits will result.

Tailoring coordination models and solutions to the Indian consumer electronics industry requires analyzing its particular characteristics and problems. Understanding the industry will make models practical and implementable. Fourth goal directly addresses the need to bridge present research with Indian market demands. Studying the industry's current state, new rules, and growth trajectory will guarantee research findings and models are applicable and meaningful in India.

Case studies will illustrate RSC/CSC cooperation problems and opportunities in the Indian consumer electronics industry. This will verify present study and demonstrate models' practicality. Fifth objective supports research with empirical proof. A case study on coordination concerns might demonstrate how research addresses real-world issues experienced by Indian market stakeholders. This makes research credible and generalizable.

1.8. Findings of the Research

The study has identified key characteristics of RSC coordination mechanisms, such as channel structure, coordination mechanisms, performance measurement criteria, the methodology employed, and the industries involved. The study finds that the decentralized scenario yields a lower profit than the centralized option. The centralized scenario increases the profit of the whole SC but cannot guarantee that each member will earn an acceptable profit. Under the RS contract model, the overall profit is lower than the centralized approach. CSC's earnings under the TPT contract are equivalent to its profits under the centralized model. It is also observed that the decentralized channel under the WP contract has opportunities for improvement. The channel can reach a win-win situation but cannot coordinate perfectly with an RS contract. The TPT contract has resulted in perfect coordination. The TPT contract has improved the quality level and warranty period. The warranty period sensitivity coefficient positively impacts channel decisions (e.g., selling price, warranty period, and quality level of refurbished product) and the profit of channel players of CSC in various channel structures. The study reveals that the CSC is fully coordinated under the Nash bargaining model, and the Pareto improvement has been made. The recommerce platform achieves perfect coordination through the hybrid contract and obtains a unique Pareto optimization. It is found that IoT-enabled systems wherein resources are not wasted, thereby providing a way for businesses to use the CE concept to achieve sustainability goals.

The significant contributions of the study are as follows:

- Reduced Waste: By optimizing collection, reuse, refurbishment, and recycling processes, CLSC coordination can significantly decrease waste generation. This translates to less pressure on landfills and a smaller environmental footprint.

- Resource Conservation: Effective CLSC practices promote the recovery of valuable materials from end-of-life products. This conserves resources like metals, plastics, and rare earth elements, reducing dependence on virgin materials and their environmental impact.
- Lower Greenhouse Gas Emissions: Minimizing reliance on virgin material extraction and production through resource recovery leads to lower greenhouse gas emissions. This contributes to mitigating climate change and its associated environmental issues.
- Cost Savings: Improved coordination can lead to significant cost savings through: Optimized logistics for product returns and collection, Reduced waste disposal fees, and Potential revenue generation from recovered and recycled materials.
- Enhanced Profitability: Effective CSC management can create new business opportunities. Refurbished or remanufactured products can be sold at lower price points, attracting new customer segments. Development of innovative recycling technologies can lead to new revenue streams.
- Competitive Advantage: Companies demonstrating leadership in sustainable practices gain a competitive edge by attracting. Environmentally conscious consumers who value sustainability efforts. Investors seeking to support companies with strong ESG (Environmental, Social, and Governance) practices.
- Improved Supply Chain Efficiency: Streamlined communication and information sharing facilitated by coordination mechanisms can lead to:
    - ✓ Increased supply chain visibility, enabling better tracking of product movement and resource recovery processes.

- ✓ Optimized inventory management, reducing unnecessary stockpiling and potential stockouts.
- ✓ Improved responsiveness to market demands by adapting production and recovery processes based on real-time data.

- Enhanced Data-Driven Decision Making: Leveraging mobile and IoT technologies allows for real-time data collection and analysis on product location, condition, and resource recovery processes. This data can be used to:
  - ✓ Make informed decisions about logistics, pricing, and resource allocation.
  - ✓ Identify areas for improvement within the CLSC for ongoing optimization.
- Stronger Collaboration: Formalized contracts and collaborative planning can foster trust and stronger relationships between stakeholders (manufacturers, retailers, recyclers). This leads to smoother and more efficient operations throughout the CLSC.

1.9. Organization of the thesis in brief

The thesis is organized into seven chapters. The summary of each chapter is given as follows:

Chapter 1- "Introduction" – This chapter describes the research's background and context, as well as its objectives and significance. This chapter discusses the current scenario concerning RSC in India's consumer electronics industry. How coordination is required to manage end-of-use/end-of-life/customer-returned consumer electronics has been discussed. The coordination and mechanisms of the RSC have also been discussed. Various coordination issues related to contemporary study are discussed in this chapter.

This chapter illustrates how RSC with zero waste can be considered as CSC. Further, it is mentioned that the recommerce industry has been considered in the context of RSC with the consumer electronics industry. A summary of the remaining chapters of the thesis is then presented.

Chapter 2- “Literature review”- This chapter analyses a comprehensive literature review to construct a holistic view of recent, cutting-edge studies on coordination issues in RSC management. It also concentrates on a literature review of coordination issues relevant to the current study from the perspectives of strategy, functionality, government support, risk attitude, and customer attitude. Several RSC coordination concerns have been documented, including e-business, outsourcing, pricing, and sustainability. Key characteristics of RSC coordination mechanisms, such as channel structure, coordination mechanisms, performance measurement criteria, the methodology employed, and the industries involved, have been identified by reviewing the relevant literature. Based on the review of the relevant literature, research gaps were identified. A research gap analysis was used to establish the research objectives.

Chapter 3- “Research methodology”- This chapter of the thesis describes the methodology used for the research. The basis for method selection contributes to the accomplishment of research objectives. The implementation of research methodology based on the research 'onion' discussed by Saunders et al. (2007) is discussed. In addition, the research methods (Game theory, case study, and interview), numerical analysis, sensitivity analysis, and approach to the study's validity have been discussed.

Chapter 4- “Coordination strategy of a circular supply chain”- the CSC coordination problem in the re-commerce business using game theory is explored. The issue of channel conflicts, pricing of refurbished products, and sustainability has been addressed. The model focuses on refurbishing and recycling the used products with zero waste. The model uses CE strategies to extend product and resource value. The study reveals that the CSC is fully coordinated under the Nash bargaining model, and the Pareto improvement has been made. The channel participants have equitably distributed the additional profits generated by the TPT contract by implementing the Nash bargaining method.

Chapter 5- "Coordination of circular supply chain with mobile technology"- This chapter investigates the effects of extending product life and resource value of end-of-life/end-of-use products on channel performance in the era of Industry 4.0. The issues of channel conflicts, pricing of refurbished products, and improving the quality of refurbished items with a warranty have been addressed using mobile technology in the Industry 4.0 environment. The centralized, decentralized, and coordinating models (RS contract model and TPT Contract model) are built to examine equilibrium decisions using the game theoretical technique.

Chapter 6- "IoT-enabled coordination for recommerce circular supply chain"- This chapter investigates Internet-of-Thing (IoT)-enabled coordination for recommerce CSC in the industry 4.0 era. The study is analyzed using a mixed-method research strategy combining a case study with a game-theoretic model. This study aims to identify the coordinating decisions of IoT-enabled recommerce CSC in light of the Extended Producer Responsibility (EPR) regime for electronic-waste recycling in India under various decision-making structures. This study has developed a mathematical model to coordinate an IoT-enabled CSC to achieve the goal of CE through recovering value from EOL/EOU electronic products of the recommerce platform. The case study was undertaken in the Indian consumer electronics industry. The recommerce platform achieves perfect coordination through the hybrid contract and obtains a unique Pareto optimization. It is found that IoT-enabled systems wherein resources are not wasted, thereby providing a way for businesses to use the CE concept to achieve sustainability goals.

Chapter 7- “Conclusion”- This chapter overviews the important research results involving the study objectives. Furthermore, the implications of the research work for managers, researchers, and industrialists are discussed. Finally, the limitations and future scope of study on RSC coordination have been mentioned.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

The reserve supply chain (RSC) is one of the strategies for attaining sustainability. RSCs include collection, inspection, disposition, and redistribution (Mathiyazhagan et al., 2020). RSCs encourage product take-back through relaxed take-back policies and subsidies to the organization for consumer benefits (Song et al., 2020b). Reusing waste as inputs in RSC processes is needed to minimize environmental and social impacts and achieve sustainability (Sellitto and de Almeida, 2019). In recent years, all stakeholders of the RSC have paid growing attention to processing used goods due to potential cost savings, consumer environmental consciousness, and strict governmental legislation (Wei et al., 2019b). Companies want to adopt policies and materials to combat undesirable effects and reduce production costs by reusing recycled e-waste (Rezayat et al., 2020). A coordination mechanism consists of adopting a specific practice, such as a contract, to meet the collective objectives of RSC (De Giovanni and Zaccour, 2019). Dissanayake and Sinha (2015) examined the process of fashion remanufacturing and revealed that coordination among key players is essential for business growth. Coordination among chain members is needed to maximize the profits in the RSC (Chakraborty et al., 2018).

Some researchers have reviewed the literature on RSC coordination issues (Govindan et al., 2013; Guo et al., 2017). They reported that little work had been carried out regarding various contracts applied, information asymmetries and risk-allocation, variety of SC structures, and modeling of competition in RSC coordination. De Giovanni and Zaccour (2019) reviewed 73 papers between 2011 and 2018, considering two critical issues, including coordination mechanisms. They suggested that the competition issue would be a potential research avenue. In addition to the above, environmental considerations, social factors, and economic constraints all require a new approach to RSC planning and coordination at the strategic and functional levels (Bal and Satoglu, 2018). A conceptual decision framework is required to put an organization in a practical working environment (Govindan et al., 2015).

The literature review discovers that summarizing all the dimensions and issues related to RSC coordination is fragmented and not covered in a single study. Furthermore, throughout the literature search, it has also been found that no review compares factors such as strategic decisions, functional decisions, governmental interference, risk attitude of channel players, and consumer behavior. In the context of RSC coordination, the reviews on these issues are either missing or under-represented. Simultaneously, the relevance of research on coordination issues is expanding, particularly in the case of RSC. As a result of the increasing number of studies, many new issues and contexts, such as e-business and sustainability, that have not yet been summarized require investigation.

Decisions made by top management on cross-functional activity are made at the functional and strategic levels (Ramanathan et al., 2011). Under strategic decision-making, e-commerce, outsourcing, pricing, and sustainability are critical considerations when developing RSC strategies to achieve the sustainable development goal. Competition, effort, information asymmetry, and inventory are all critical functional issues that require investigation. The literature review aims to fill gaps through an in-depth review of the existing literature on RSC coordination. This study aims to enhance understanding of a primarily unexplored topic in RSC coordination by employing a problematization approach (Sandberg and Alvesson, 2011). This literature review answers the following questions:

RQ1. What are the coordination issues, core research areas, and trends in managing the RSC?

RQ2. What are theories that have been used to study coordination issues in RSC?

RQ3. What are the recent trends related to coordination issues and research opportunities for scholars in RSC coordination?

This chapter comprehensively studies all dimensions of managerial decisions for RSC, such as strategic considerations and functional interfaces. The literature review details all the undermined issues considering each dimension. A comparative analysis of six factors has been made: the context of the issue, the mechanisms for coordination, the channel structures, the methodologies employed, the performance measures, and the industries concerned. A variety of research issues based on the TCM framework have been determined.

2.2. Methodology for Literature Review

The study conducts a systematic literature review (Tranfield et al., 2003) to analyze and synthesize related studies on RSC coordination issues. It employs the TCM framework to find gaps and synergies (Paul et al., 2017). The literature review follows the three stages suggested by Tranfield et al. (2003): (1) planning the review, (2) conducting the review, and (3) reporting the review.

The review's planning phase includes determining the review's motives, defining the literature review objective, formulating research questions, and establishing a research protocol. Additionally, it determines the literature volume and delimits the subject area or topic. The previous section also discusses the literature review objective and questions. A protocol based on the literature review objectives has been established by following the strategy suggested by Yu et al. (2020), in which articles are read thoroughly, and the coordination issues under which the research has progressed are coded. Second, the articles are segregated into issues and assigned on a broader scale in accordance with the research aims of identifying management decision-making aspects. The articles were examined against the predefined categories to ascertain the issues' relevance and the results' interpretation. It is necessary to ascertain the research's quality (Dixon-Woods et al., 2004). Finally, the publications are summarized by categorizing them according to the dimensions of management decision-making. Krippendorff's alpha is used to verify the coding scheme, a versatile statistic (Agrawal et al. (2015). The study was conducted by the author and five trained independent coders. The inter-coder reliability as alpha values were obtained using SPSS 22.0 with the help of macros developed by Hayes and Krippendorff (2007). Five coders calculated alpha values larger than 0.8, validating the dependability of the selected articles.

Keywords drive the material collection. The related articles were found by searching Scopus and Web of Science. The keywords were selected from past literature reviews on similar subjects, such as Guo et al. (2017). Further, some keywords are selected based on research gaps found in the study of RSC, reverse logistics, closed-loop supply chain, remanufacturing, and recycling supply chain in a coordination context. Secondary keywords were chosen, where significant research gaps were found in the literature. The search strings are composed of primary and secondary keywords (Table 2-1), in which primary keywords are searched in the abstract, title, and author keywords fields, while secondary keywords are considered in all fields. After the initial search, the resultant articles were found to be 1602. Articles that were published between 2004 and 2021 were selected. The beginning of the period was set in 2004 because, in the same year, one of the most prominent articles on the scope of RSC coordination was published by Savaskan et al. (2004).

Table 2-1. Search keywords

Primary keywords strings	("Closed-loop supply chain" OR "product returns" OR "RSC" OR "Remanufacturing " OR "Recycling supply chain" OR "Reverse logistics" OR "product recovery" OR "waste product" OR "Waste management") AND ("coordination" OR "coordinate")
Secondary keywords string	"Competition" OR "Government support" OR "Reuse" OR "Returns" OR "Customer behavior" OR "Information asymmetry" OR "Takeback" OR "Risk" OR "E-business" OR "electronic-commerce" OR "Inventory" OR "Recycling" OR "Risk" OR "E-commerce" OR "Online channel" OR "Refurbishing" OR "Sustainability" OR "Efforts" OR "Outsourcing" OR "Remanufacture" OR "Third-party" OR "End of life" OR "End of use" OR "Pricing" OR "Remarketing" OR "inventory" OR "Recovery" OR "Resale" OR "uncertainty" OR "sustainable development"
Date source	February 2022

The shortlisted articles in the initial search were sorted out using the first filter, resulting in 1182 publications. In the next stage, duplicate publications between Scopus and Web of Science were removed, resulting in 598 publications. Further, the publications were scanned by studying the abstracts, resulting in 305 articles. Finally, the publications were screened by reading the complete paper for content related to issues. It resulted in 151 articles selected for the study from international journals listed in SCIE/SSCI and ABDC. A detailed selection process of 151 articles is shown in Figure 2-1. Literature review search process.

Category selection aims to build a framework of structural dimensions and analytical categories to help coordinate the literature review (Yu et al., 2020). Before the materials were reviewed, key factors, such as coordination mechanisms and methodologies, were selected through a deductive approach. After the literature search, a few factors and issues, such as sustainability, inventory, and e-business, were selected using an inductive approach (Yu et al., 2020). Six key factors that must be needed to model a problem were selected. During the categorization of literature, it was found that

151 articles fit appropriately into five categories. Structural dimensions, which form the major topics of analysis and framework of the study, are shown in Figure 2-2. It shows the categorization of the issues of RSC coordination. During the conducting of the review, a total of 11 major issues are extracted (see Figure 2-3), which are organized into five main categories: (1) issues about strategic decisions, (2) issues about functional decisions, (3) issues concerning government support, (4) issues considering risk attitude, and (5) issues considering consumer behavior.

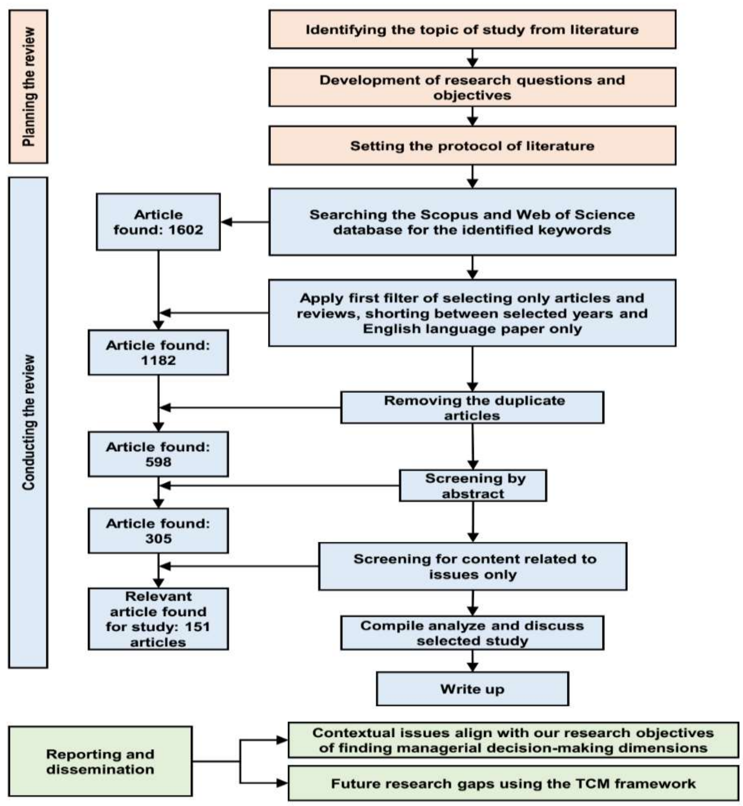


Figure 2-1. Literature review search process

During the coding stage, issues related to e-business, outsourcing, pricing, and sustainability are mapped as strategic considerations, and issues related to competition, efforts, information asymmetry, and inventory as functional interfaces. Similarly, the rest of the issues are mapped and presented in Figure 2-2. Figure 2.3 shows that the pricing issue has a maximum of 19 publications (approximately 13 %), followed by 18 publications for sustainability and so on.

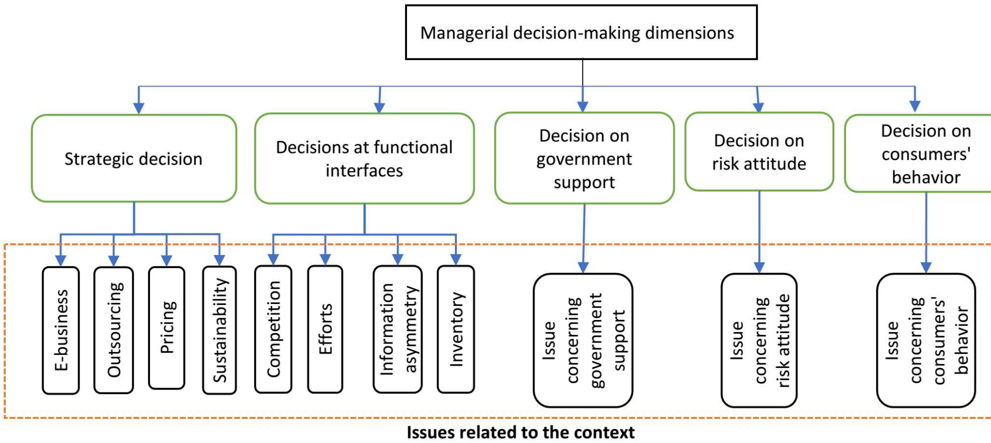


Figure 2-2. Managerial dimensions and issues of RSC coordination

2.3. Findings

Further, the selected articles of the literature review are discussed and analyzed based on the selected categories to construct a holistic view of the state-of-the-art studies on RSC coordination.

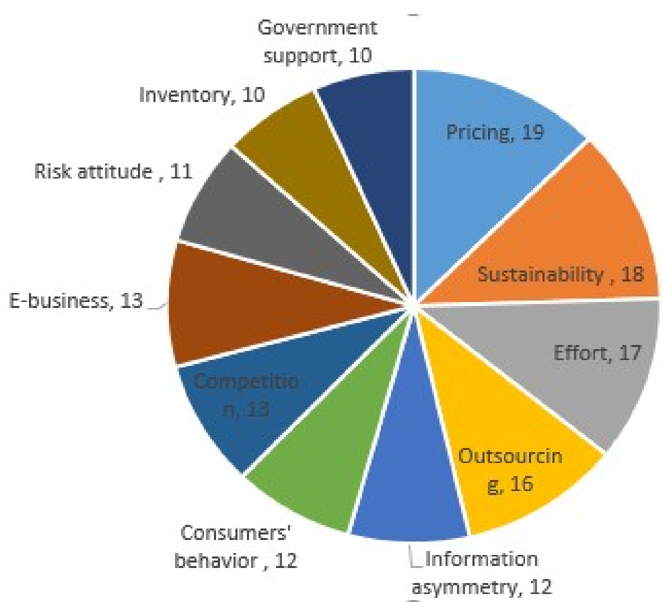


Figure 2-3. Issue-wise distribution of published articles on RSC coordination.

2.3.1. Issues under strategic considerations

Strategic decisions such as contracts and incentives, supply chain structure, pricing, and outsourcing have a long-term impact on the firm's operations (Santibanez-Gonzalez and Diabat, 2013). Strategic decisions drive the most profits and environmental impacts (Gupta and Palsule-Desai, 2011; Souza, 2012; Govindan et al., 2015). Kuiti et al. (2019) have also recommended outsourcing and sustainability as strategic decisions to achieve companies' long-term goals. Frei et al. (2020) investigated implementation issues of sustainability practices in RSC and outlined the implications on strategic management. Based on information revealed from the above literature, four issues, (i) E-business, (ii) Outsourcing, (iii) Pricing, and (iv) Sustainability, have been considered to analyze further under strategic decision and explained in the following sub-section.

2.3.1.1. E-business

Under the e-business model, manufacturers have extended their roles to online retailers and traditional manufacturers, turning the single-channel structure into a dual-channel structure. 80% of the United States America retailers have adopted a dual-channel retail strategy (Radhi and Zhang, 2018). The major impact of e-business on the return process consists of providing better information and knowledge to all the channel members about returns, points of return, product conditions, consumer reviews, and consumer instructions. Noticeable growth in the number of customer returns was observed during the operation of e-business because customers do not experience the products physically before purchasing (Yuan et al., 2020). Table 2-2 describes the work related to e-business regarding RSC coordination.

2.3.1.2. Outsourcing

Outsourcing enables businesses to concentrate on their core capabilities, decrease their asset base, and reallocate resources for productive purposes (Agrawal and Singh, 2020; Mathiyazhagan et al., 2020). Outsourcing in RSC can be utilized for various specialized tasks, including product collecting, recycling, and remanufacturing. Table 2-3 highlights the outsourcing work linked to RSC coordination.

2.3.1.3. Pricing

Used products have a relatively low rate of return. Economic incentives are necessary to persuade end-users to return their used products. The term "recycling price/buyback price" refers to these economic incentives (Shu et al., 2020). Simultaneously, the buyback price impacts both the wholesale and retail prices. The problem of pricing a used item becomes critical (Huang and Wang, 2018). The literature on new product pricing is extensive and covers a variety of strategies (Jena et al., 2019). The retail price/transfer price may be decided exogenously or by a single channel member with a dominant position (Huang et al., 2014; Dai et al., 2012). The work described in Table 2-4 pertains to the pricing issue associated with RSC coordination. In Table 2-4, pricing decisions are elaborated as items, their price, and the decision-maker of that price.

2.3.1.4. Sustainability

An RSC is a highly effective method of achieving sustainability for businesses. As part of their commitment to environmental stewardship and resource conservation for economic survival, several businesses have collected used products and recycled them into new ones (Li et al., 2017a).

Table 2-2. Analysis of E-business issues in the coordination of RSC studies

Author(s)	Role of e-business	Coordination mechanisms	Methodology	Channel Structure	Performance measure(s)	Industry
Jin et al. (2021)	Recycling	Acquisition price with two-part tariff contract, Information technology (IT)	Stackelberg game (SG)	Remanufacturer-collector	Maximize profit (MP)	General
Zheng et al. (2021a)	Recycling	Two-part tariff (TPT) contract, IT	SG	Remanufcaturer-recycler	MP	General
Wu et al. (2020a)	Recycling	Revenue sharing (RS) contract, IT	SG	Recycling center-recycler	MP	Waste electrical and electronic equipment (WEEE)
Yuan et al. (2020)	Recycling	Optimization analysis, IT	Mathematical model (MM)	Manufacturer-retailer-recycler	MP	General
Hosseini-Motlagh et al. (2019)	Retailing	TPT contract, IT	SG	Remanufacturer-collector-retailer	MP	Case study of a remanufacturing industry
Pei and Yan (2018)	Retailing and recycling	TPT contract, Cooperative wholesale price with profit-sharing mechanism, Information sharing (IS), IT	SG	Supplier-e-tailer	MP	General
Radhi and Zhang (2018)	Retailing and recycling	Integration, IT	SG and Nash game	Online store-physical store	MP	General
Taleizadeh et al. (2018)	Retailing	Cooperative advertising, TPT contract, IT	SG	Manufacturer-retailer- collector	MP	General
Xie et al. (2018)	Retailing	wholesale price (WP) contract, RS contract, Cost-sharing (CS) contract, IS, IT	SG	Manufacturer-retailer	MP	General
Feng et al. (2017)	Recycling	TPT contract, Profit sharing (PS) contract, IT	SG	Recyclable dealer-recycler	MP	WEEE
Kong et al. (2017)	Retailing	RS contract, IS, IT	SG	Manufacturer-retailer	MP	General
Maiti and Giri (2017)	Recycling	Bargaining, IT	SG and Nash game	Manufacturer-retailer	MP	General
Xie et al. (2017)	Retailing	RS contract, IT	MM	Manufacturer-retailer	MP	General

Table 2-3. Analysis of outsourcing issue in the coordination of RSC studies

Author(s)	Outsource Activity	Coordination mechanisms	Channel structure	Methodology	Performance measure(s)	Industry
Wang et al. (2021a)	Remanufacturing	Cost-sharing contract	Original equipment manufacturer - third-party remanufacturer	SG	MP	General
Zheng et al. (2021b)	Collection	Wholesale price contract, revenue sharing contract	Manufacturer-retailer- collector	SG	MP	General
Hosseini-Motlagh et al. (2020d)	Collection	TPT contract	Two collectors-remanufacturer	SG	MP	Phone
Hong et al. (2019)	Collection	Service cost-sharing contract, TPT contract	Manufacturer-retailer- collector	SG	MP	General
Xiang and Xu (2019)	Big Data services	CS contract	Manufacturer-retailer-Internet service platform	Differential game	MP	General
Zheng et al. (2019a)	Remanufacturing	Variable-weighted Shapley value	Manufacturer-retailer-remanufacturer	Cooperative game	MP	General
Chu et al. (2018)	Collection	TPT contract	Multi manufacturer-multi retailer- collector	SG	MP	Mobile phone industry
Zheng et al. (2017b)	Collection	TPT contract, Joint decision making	Manufacturer-retailer-collector	SG	MP	General
Dutta et al. (2016)	Collection	RS contract	Manufacturer-retailer- collector	MM	Minimize cost (MC)	General
Saha et al. (2016)	Collection	BB contract	Manufacturer-collector-retailer	SG	MP	General
Zu-Jun et al. (2016)	Collection	Joint decision making	Manufacturer-retailer-2 collector	Cooperative game	MP	General
Chen and Chang (2014)	Remanufacturing	RS contract, WP contract	Manufacturer-remanufacturer	Nash bargaining model	MP	General
De Giovanni and Zaccour (2014)	Collection	BB contract	Manufacturer-retailer- collector	Sub-game perfect Stackelberg equilibrium	MP	General
Yan and Sun (2012)	Collection	WP contract, Target rebate-punish contract, Joint decision making	Manufacturer-retailer- collector	SG	MP	Steel scrap
Kaya (2010)	Collection	Linear contract	Manufacturer-collector	NM	MP	General
Bhattacharya et al. (2006)	Remanufacturing	TPT contract	Manufacturer-retailer-remanufacturer	SG	MP	General

Consumers are willing to pay a premium for environmentally friendly products (Xu and Wang, 2018). Table 2-5 summarizes the work on sustainability problems in RSC coordination.

2.3.2. Decisions at the functional level

Functional issues involve medium and short-term decisions on the operations of an RSC. The issues considered include inventory management, competition, information asymmetry, and efforts. These issues are explained in the following sub-sections.

2.3.2.1. Competition

Competition plays an important role in creating demand and expanding market share for remanufactured products during their life cycle. Competition is the fundamental marketing issue in RSC systems. Table 2-6 summarizes the work related to the competition issue regarding RSC coordination.

2.3.2.2. Efforts for RSC activities

Collecting effort increases product return collection in RSC (Zhang et al., 2020a). Likewise, the Marketing effort is utilized to increase market demand through various strategies, including mass or social media advertising, displaying messages in prominent public locations via banners, developing attractive shelf spaces, and hiring intelligent sales employees to assist (Taleizadeh et al., 2016). Ferguson et al. (2006) and Huang et al. (2011) investigated how efforts can be made to prevent false failure returns by informing consumers about the product that meets their needs. Table 2-7 summarizes the activities relating to the topic of RSC coordination.

Table 2-4. Analysis of pricing issues in the coordination of RSC studies

Author(s)	Coordination mechanisms	Channel structure	Methodology	Pricing decision (Items – Price – decision maker)	Performance measure(s)	Industry
Song et al. (2021)	TPT contract	Manufacturer-retailer	SG	New product-direct price-manufacturer, New product-retail price-retailer, New product- wholesale price-manufacturer, waste product-transfer price- manufacturer	MP	General
Sarkar and Bhala (2021)	Wholesale price contract	Manufacturer-retailer	Subgame perfect Nash equilibrium	New/Remanufactured product-retail price-retailer, remanufactured/manufactured product-wholesale price-manufacturer	MP	General
Shu et al. (2020)	TPT contract	Manufacturer-retailer-2 collectors	SG	Used products-recycling price-Collectors, Used products-transfer price-manufacturer, New/remanufactured products-wholesale price-manufacturer, Remanufactured /new products-retail price- retailer	MP	General
Jena et al. (2019)	Integration	Two manufacturers-retailer	Cooperative game	New & remanufactured product-wholesale price–manufacturer, New product and remanufactured product-retail price–retailer, Used product–transfer price–manufacturer	MP	General
Huang and Wang (2018)	TPT contract	Manufacturer-retailer-remanufacturer	SG	New/remanufactured product-retail price -retailer; New/remanufactured product–wholesale price-manufacturer; Used product-acquisition price-remanufacturer	MP	General
Li et al. (2018)	PS contract	Manufacturer-retailer	SG	New product-retail price-retailer; New product-wholesale price-manufacturer	MP	General
Aydin et al. (2016)	Integration	Manufacturer-retailer-remanufacturer	SG	New & remanufactured product-wholesale price & retail price-manufacturer	Maximize market share & maximize profit	Tablet PCs
De Giovanni et al. (2016)	Incentive contract, Joint decision making	Manufacturer-retailer	cooperative game and SG	Remanufactured product-wholesale price-manufacturer; Remanufactured product-retail price-retailer	Minimize cost	WEEE
Ran et al. (2016)	RS contract: IS	Manufacturer-retailer	SG	New/manufactured product-wholesale price-manufacturer; New/remanufactured product–Retail price–retailer	MP	Waste glass bottle
Zhang and Ren (2016)	Revenue and expense sharing contract, TPT contract, Joint decision-making	Manufacturer-remanufacturer-retailer	SG	New product-wholesale price-manufacturer, Remanufactured product-wholesale price-remanufacturer, New product & Remanufactured product-retail price-retailer	MP	General
Yoo et al. (2015)	WP contract, BB contract, Quantity discount contract, Joint decision making	Supplier-retailer	Principal–agent game	New product-wholesale price-supplier, New product-retail price-retailer, Consumer returns-refund price-retailer	MP	General

Zou and Ye (2015)	RS contract	Manufacturer-retailer	SG	New/remanufactured product-wholesale price-manufacturer, New/remanufactured product-retail price-retailer	MP	General
Huang et al. (2014)	BB contract, Sales rebate contracts	Supplier–multi retailers	NM	New product – retail price-exogenous, New product-wholesale price-manufacturer, Returns & unsold product-discount price-retailer	MP	General
Ruiz-Benitez and Muriel (2014)	WP contract, BB contract	Manufacturer-retailer	NM	New product-retail price-exogenous, New product-wholesale price-manufacturer, Unsold product at retailer end-buyback price-manufacturer	MP	General
Dai et al. (2012)	BB contract	Manufacturer-retailer	SG & Nash game	New product-wholesale price-exogenous/manufacturer, New product-retail price-exogenous	MP	General
Li et al. (2012b)	BB contract, Joint decision making	Manufacturer-retailer	SG	New product-wholesale price-manufacturer, New product-retail price-retailer; Off-season product-buyback price-manufacturer, Off-seasonal product-discounted shelf-retailer	MP	Fashion products
Chen (2011b)	Returns-discount contract, WP contract	Manufacturer-retailer	SG	New product-retail price-exogenous, New product-wholesale price-manufacturer, Unsold products-buyback price-manufacturer	MP	Seasonal products having a short life cycle
Chiu et al. (2011)	WP contract, Rebate contract, BB contract	Manufacturer-retailer	SG	New product-wholesale price – manufacturer, New product-retail price-retailer, Unsold product-buy-back price-manufacturer	MP	Seasonal products having a short life cycle
Xiao et al. (2011)	RS contract, Joint decision making	Manufacturer-retailer	SG	New product-wholesale price-manufacturer, New product-retail price-retailer	MP	General

Table 2-5. Analysis of sustainability issues in the coordination of RSC studies

Author(s)	Coordination mechanism	Methodology	Channel Structure	Sustainability issue	Performance measure(s)	Industry
Hosseini-Motlagh et al. (2020a)	WP contract	SG	Two manufacturers-retailer	Economic, social welfare, and environment	MP	Dairy industry
Hosseini-Motlagh et al. (2020c)	PS contract	Nash-bargaining model	Manufacturer-2 retailers	Economic, social welfare, and environment	MP	Pharmaceutical sector
Wu et al. (2020b)	RS contract	SG and Nash bargaining model	Manufacturer-retailer	Economic and environment	Maximize profit and improve environmental performance	Faucet Industry
Modak et al. (2019)	TPT contract, Nash bargaining	SG	Manufacturer-retailer	Economic and social welfare	MP	General
Xu and Wang (2018)	PS contract	SG and Nash bargaining model	Manufacturer-retailer	Environment	Maximize degree of satisfaction	General

Bazan et al. (2017)	Vendor Managed Inventory with Consignment Stock	MM	Manufacturer-retailer	Environment	MC	General
Li et al. (2017a)	Joint decision-making (cooperative model)	Cooperative game model	Collector-remanufacturer – 2 retailers	Economic and social welfare	MP	General
Li et al. (2017b)	TPT, Joint decision making	SG	Formal collector–informal collector	Economic and environment	MP	WEEE
Li et al. (2017c)	Joint decision-making (cooperative model)	Cooperative game model	Collector-remanufacturer –2 retailers	Economic and social benefit	MP	WEEE
Panda et al. (2017)	RS contract	SG	Manufacturer-retailer	Social welfare and environment	MP	General
Weraikat et al. (2016a)	Negotiation based contract	MM	Producer-collector	Environment	Maximize the recovery of leftover medication	Pharmaceutical Industry
Weraikat et al. (2016b)	Negotiation based contract	MM	Retailer – multiple collectors	Environment	Maximize the recovery of leftover medication	Pharmaceutical Industry
De Giovanni (2014)	RS contract, WP contract	Nash game	Manufacturer-retailer	Environment	MP	General
Jaber et al. (2014)	Joint policy Decision (consignment stock policy)	MM	Vendor-retailer	Environment	MC	General
Mafakheri and Nasiri (2013)	RS contract	SG and System dynamics	Manufacturer-retailer	Environment	Maximize the number of cartridge units reclaimed, total carbon savings, and profit	Used ink cartridge
Jacobs and Subramanian (2012)	Menu of contracts consisting of appropriate combinations of the wholesale price and the level of responsibility-sharing	SG	Supplier-manufacturer	Social welfare	MP.	General
Nativi and Lee (2012)	Radio Frequency Identification (RFID); IS	Simulation-based analysis	Manufacturer-2 suppliers	Environment	MC	General
Walther et al. (2008)	Negotiation based contract	MM	Focal company-multiple recyclers	Environment	MP	WEEE

Table 2-6. Competition in the market

Author(s)	Types of competition	Coordination mechanism	Channel structure	Methodology	Performance measure(s)	Industry
Liu et al. (2021a)	Bertrand competition	Revenue-cost sharing contract	Manufacturer-2 retailers- recycler	SG	MP	General
Hosseini-Motlagh et al. (2022)	Bertrand competition	TPT contract	Remanufacturer-2 collectors	Bertrand; Collusion; Stackelberg game model	MP	Printer toner cartridges.
Wang et al. (2020c)	Cournot competition	PS contract	Manufacturer-2 retailers	Stackelberg-collusion model; Stackelberg-Nash model; Stackelberg-Stackelberg model.	MP, maximize environmental benefit; and maximize social benefit.	General
Johari and Hosseini-Motlagh (2019)	Cournot competition	Two-way TPT contract	Remanufacturer-2 retailers-2 collectors	SG	MP	Lead-acid battery industry
Liu et al. (2018)	Bertrand competition	Authorization cooperation	Manufacturer-reseller	SG	MP	Electrical and electronic industry
Roy et al. (2018)	Bertrand competition; Cournot–Bertrand competition	PS contract	Manufacturer-2 retailers	SG	MP	General
Wu and Kao (2018)	Cournot competition	Fixed-fee investment, licensing royalty, R&D joint venture cooperative scheme	Manufacturer-remanufacturer	Cournot game	MP	General
Hong et al. (2017)	Cournot competition	Fixed-fee licensing contract, Royalty licensing contract	Manufacturer-remanufacturer	SG	MP	General
Modak et al. (2016b)	Cournot competition	PS contract	Manufacturer-2 retailers	MM	MP	General
Hong et al. (2015)	Bertrand competition	Cooperative advertising, TPT contract	Manufacturer-retailer-collector	SG	MP	General
Xu et al. (2014)	Bertrand competition	Integration	Manufacturer-2 retailers	SG	MP	Durable product
Savaskan andWassenhove(2006)	Bertrand competition	TPT contract, BB contract	Manufacturer-2 retailers	SG	MP	General

2.3.2.3. Information asymmetry among supply chain members

Information asymmetry arises due to decentralized supply chain operations within the supply chain, and an information updating or sharing system is necessary to mitigate this situation (Zhao et al., 2017). In practice, the most critical information in the RSC is private, such as the cost of the collecting effort, which is the retailer's private information (Zhang et al., 2014). Optimum performance is possible if a system is developed to reveal private information to other channel participants. Otherwise, the result indicates that the asymmetric information structure may lose efficiency in the RSC (Zheng et al., 2017a). Contracts are frequently used to provide the essential incentive for information-sharing (Yan and Cao, 2017; Van Wassenhove & Guide, 2008). Thus, the problem of 'how to design contracts in RSC to encourage better information sharing' is interesting and challenging. Table 2-8 summarizes the research on information asymmetry in RSC coordination.

2.3.2.4. Inventory management

Inventory management of returned products is crucial in RSC (Kuvvetli and Erol, 2020). Inventory decisions are required in RSC to examine coordination issues at the operational level (Govindan et al., 2015). Table 2-9 summarizes the literature on inventory issues considered under RSC coordination.

2.3.3. Issues concerning government support

The government (policymaker) motivates RSC activities through regulations such as mandatory take-back laws, public awareness campaigns, and fiscal mechanisms such as subsidies and rewards (Cao et al., 2018). Government incentives are critical in encouraging consumers to buy remanufactured products (Wang et al., 2020b). Zhao and

Zhu (2017) used government subsidies to reduce new product consumption while boosting recycling and disposal of end-of-life (EOL) products. Without government interference, efficiency increases twofold when a government subsidy is provided (Manouchehrabadi and Yaghoubi, 2020). The government encourages channel coordination by giving tax concessions to channel participants (Heydari et al., 2017a). Table 2-10 summarizes the works related to various types of government support for RSC coordination.

2.3.4. Issues considering risk attitude

Different channel members may interpret the risk differently. The risk attitude of channel members will influence their perception of risk (Xing et al., 2020). In the context of a highly volatile market, the risk attitude of RSC companies plays a crucial role in their actions. Zhao and Zhu (2018) evaluated the impact of risk attitude on the quantity of remanufacturing, predicted profit, and coordination activities. The risk attitude is critical in deciding on a return policy and establishing channel contracts. Table 2-11 summarizes the work on risk attitude concerning RSC coordination. Table 2-11 additionally identifies risk parameters as 'Variable(s) under risk,' as well as risk-bearing stakeholders and risk attitude types as 'Player(s) - Risk attitude.'

2.3.5. Issues considering consumers' behavior

Consumer behavior is an important issue influencing key RSC decisions (Taleizadeh et al., 2016). To a large extent, product returns depend on consumer behavioral-related issues (Li et al., 2014). Heydari et al. (2018) stated that consumers' willingness to return products increases when an incentive is provided to consumers. Xu et al. (2015) observed that consumers face an uncertain product valuation before purchasing under the return policy. The importance of consumer behavior and supply chain returns policy is widely accepted. Huang et al. (2020) observed that environmental information about remanufactured products plays a significant role in the willingness to pay a consumer. Table 2-12 summarizes the work on consumers' behavior regarding RSC coordination.

2.4. Discussion

The results show increased interest in RSC coordination in the literature since 2004. The study discusses issues concerning different stakeholders of the RSC, including companies, customers, logistic firms, warehousing management, etc., have been discussed. For example, the outsourcing issue is concerned with companies and logistic firms. The inventory issue concerns logistics firms, companies, and warehouse management. The Pricing and sustainability issues are linked with customers and companies. All the issues discussed in the study would impact all channel members directly or indirectly connected with RSCs.

It is noted that e-business has been applied mostly for recycling, followed by retailing in the RSC coordination context. It reveals that e-business-based RSC improves the recycling rate and facilitates economic and environmentally friendly recycling scenarios. In line with the forward supply chain, retailing through e-business is also picking up. To fully exploit the e-business, some literature has used it for recycling and retailing simultaneously. Outsourcing in RSC can save money using economies of scale (Chu et al., 2018). Outsourcing has been applied mostly for collection/recycling purposes, followed by remanufacturing and so on, to coordinate the RSC. It will be better to outsource all the recovery activities.

Table 2-7. Analysis of effort issues in the coordination of RSC studies

Author(s)	Coordination mechanism	Methodology	Channel Structure	Types of efforts	Performance measure(s)	Industry
Asl-Najafi, and Yaghoubi (2021)	Hybrid contract	SG	Manufacturer-retailer	Collection effort	MP	General
Jian et al. (2021)	Profit-sharing contract	SG	Manufacturer-retailer	Marketing effort	MP	General
Li et al. (2021c)	Wholesale price contract	SG	Remanufacturer-collector	Collection effort	MP	General
Hosseini-Motlagh et al. (2020b)	TPT and energy-saving cost-sharing contract	Nash game	(Re-) manufacturer-2 retailers-2 collectors	Energy saving effort	MP	Home Appliances
Mondal and Giri (2020)	CS contract	SG	Manufacturer-retailer	Greening effort and marketing effort	MP	General
Song et al. (2020a)	Revenue and cost-sharing contract; Linear transfer payment-cost sharing contract	Differential game	Supplier-operator	Collection effort	MP	Bicycle sharing business
Zhang et al. (2020a)	RS contract	SG	Manufacturer- retailer	Collection effort	MP	Mobile phone
Zeng and Hou (2019)	Quantity discount contract	Quantitative model	Distributor-supplier	Quality improvement effort	Maximize profit and quality	Mobile phone
Alamdar et al. (2018)	RS contract	SG and Nash game	Retailer-collector-manufacturer	Marketing effort	MP	General
Modak et al. (2018)	Strategic bargaining	SG and Nash game	Manufacturer-retailer-collector	Collection efforts	MP	General
Gao et al. (2016)	TPT contract	SG and Nash game	Manufacturer-retailer	Collection effort and marketing effort	MP	General
Shi et al. (2016)	TPT contract, RS contract	SG	Manufacturer-retailer	Collection effort	MP	General
Taleizadeh et al. (2016)	TPT Contract	SG	Manufacturer-retailer	Marketing effort	MP	General

Choi et al. (2013)	TPT contract, spanning revenue-cost sharing contract	SG	Manufacturer-retailer-collector	Collection effort	MP	General
Huang et al. (2011)	Quantity discount contract	MM	Supplier-retailer	Effort to reduce false failure returns	MP	General
Ferguson et al. (2006)	Target rebate contract, BB contract, Quantity flexibility contract, Quantity discount contract	MM	Manufacturer-retailer	Effort to reduce false failure returns	MP	General
Savaskan et al. (2004)	TPT contract	SG	Manufacturer-retailer	Collection effort	MP	General

Table 2-8. Analysis of information asymmetry issues in the coordination of RSC studies

Author (s)	Private information & its holder	Coordination mechanism(s)	Channel Structure	Methodology	Performance Measure(s)	Industry
Zhang et al. (2020b)	Recovery cost – retailer	Information screening contract	Manufacturer-2 retailers	Dynamics game model and principal-agent model	MP	E-waste
Zhu and Yu (2019)	Recycling effort - third-party recycler	Information screening contract	Manufacturer-recycler	Principal-agent model	MP	Battery industry
Wang et al. (2018)	Recycling effort - third-party recycler	Information screening contract	Retailer-recycler	Principal-agent model	MP	E-waste
Yan and Cao (2017)	Customer returns –retailer	RS contract plus profit split mechanism, TPT contract, IS, IT	Manufacturer-retailer	SG	MP	General
Zhao et al. (2017)	Collection cost – retailer	Pull-contract, IS	Manufacturer-retailer	SG	MP	General
Zheng et al. (2017a)	Collection cost and supply of the used product – collector	TPT contract; IS	Remanufacturer-collector	SG	MP	General
Xiao and Shi (2016)	Demand & return – Retailer	A menu of wholesale price-order quantity contracts, IS	Manufacturer-multi retailer	SG	MC	General

Zhang et al. (2014)	Collection cost– Retailer	TPT contract, Collection effort requirement contract, IS	Manufacturer-retailer	MM	MP	General
Li et al. (2012a)	Customer returns – supplier	WP contract: IS	Supplier-retailer	SG and Nash game	MP	General
Chen (2011a)	Customer's expectation and taste information – retailer	BB contract: IS	Manufacturer-retailer	SG	MP	General
Chen and Bell (2011)	Customer returns - Retailer	BB contract: IS	Manufacturer-retailer	SG	MP	General
Yue and Raghunathan (2007)	Demand information – retailer	BB contract: IS	Manufacturer-retailer	SG	MP	General

Table 2-9. Analysis of inventory issues in the coordination of RSC studies

Author(s)	Coordination mechanism(s)	Methodology	Channel Structure	Coordination required for	Performance measure(s)	Industry
Kuvvetli and Erol (2020)	Simulated annealing-based decomposition heuristic	Mathematical model	Manufacturer-recycler	Production routing	MC	Oil supply chain
Fan et al. (2019)	CS contract	Nash bargaining model	Manufacturer-retailer	Returnable transport items loss	MC	General
Hasanov et al. (2019)	Joint decision making	MM	Multi-tier-2 suppliers – multi-tier-1 suppliers - vendor – multi buyers	Order quantity and number of shipments	MC	General
Habibi et al. (2017)	Joint decision making	MM	Collector-disassembler	Inventory level	MC	WEEE
Heydari et al. (2017b)	WP contract, BB contract, Dual-BB contract	NM	Manufacturer-retailer	Order quantity	MP	General
Zhang and Unnikrishnan (2016)	Joint decision making	MM	Multi distributors– multi retailers	Inventory cycle	MC	General

Devangan et al. (2013)	BB contract	Cooperative game	Supplier-retailer	Inventory level	MP	General
Jonrinaldi and Zhang (2013)	Semi-centralized decision-making process	MM	Multi suppliers-manufacturer-multi-distributors–multi retailers–collector	Inventory cycle	MC	General
Chen (2011c)	BB contract, PS contract	Non-cooperative games and cooperative games	Manufacturer-retailer	Order quantity	MP	Short-life cycle Commodity
Gurler and Yilmaz (2010)	BB contract	NM	Manufacturer-retailer	Inventory level	MP	Perishable product

Table 2-10. Analysis of governmental support issues in the coordination of RSC studies

Author(s)	Coordination mechanism(s)	Methodology	Channel Structure	Types of government support	Performance measure(s)	Industry
Wang et al. (2021b)	Government subsidy-sharing and cost-sharing contract	SG	Manufacturer-retailer	Subsidy	MP	General
Kim et al. (2020)	RS contract	SG	Manufacturer-retailer-recycler	Reward–penalty mechanism	MP	General
Song et al. (2020b)	CS contract	SG	Manufacturer-retailer	Subsidy	MP	General
Wang et al. (2020b)	Altruistic Preference Joint Commission contract	SG	Remanufacturer–E-platform	Subsidy	MP	General
Tat et al. (2020)	Buyback and shortage risk-sharing contract	MM	Supplier–retailer	Penalty	MP	Pharmaceutical Industry
Zand et al. (2019)	Asymmetrical Nash bargaining	SG	Manufacturer-retailer	Greening level threshold set by the government	Maximize social welfare	Light bulb companies
Heydari et al. (2017a)	Quantity discounts and increasing fee contracts	MM	Manufacturer-retailer	Subsidy/Tax exemption	MP	General
Wang et al. (2017)	Information screening contract, Information sharing	SG	Manufacturer-retailer	Reward/penalty	MP	WEEE
Zhao and Zhu (2017)	RS contract, WP contract	SG	Remanufacturer-retailer	Subsidy	MP	General

Table 2-11. Analysis of Risk attitude issues in the coordination of RSC studies

Author(s)	Variable(s) under risk	Player(s) -Risk attitude	Coordination mechanism(s)	Channel structure	Methodology	Performance measure(s)	Industry
Xing et al. (2020)	Demand and recycling volume	Manufacturer, retailer, third-party recyclers – risk-averse	RS contract, CS contract	Manufacturer-retailer-2 recyclers	SG	Maximize expected utility	General
Sun et al. (2019)	Customer returns	Manufacturer – risk-neutral; Dealers – risk-averse	Incentive contract	Manufacturer-2 dealers	Principal-agent model	Maximize expected utility	Electronics company
Zhao and Zhu (2018)	Shortage / lost sale	Remanufacturer - risk-averse; Retailer – risk-averse	RS contract	Remanufacturer-retailer	MM	Maximize profit; reduce risk	Truck engine
Ohmura and Matsuo (2016)	Demand	Manufacturer - risk-averse; Retailer – risk-averse	BB contract	Manufacturer-retailer	SG	Maximize mean-standard deviation value and profit	General
Li et al. (2014)	Demand	Manufacturer - risk-neutral; retailers - risk-neutral/averse	BB contract	Manufacturer-multi retailer	Mean-variance model	MP	Fast fashion product
Yoo (2014)	Product quality	Buyer - risk-neutral; Supplier - risk-averse/risk-neutral	Penalty contract, Joint decision making	Buyer-supplier	Principal-agent model	Maximize expected utility	General
Jeong (2012)	Demand	Manufacturer – risk free; Retailer - risk-neutral	BB contract; IS	Manufacturer-retailer	NM	MP	General
He and Zhang (2010)	Retailer's demand risk, supplier's production yield risk	Manufacturer – risk neutral; Recycler - risk-averse	RS contract	Supplier-retailer	SG	MP	General
Matsui (2010)	Demand	Manufacturer - risk-averse; Retailer – risk-averse	Outright sales contract, Returns policy contract	Manufacturer-retailer	SG	Maximize certainty equivalent	Perishable product
Choi et al. (2008)	Market demand and retailer's order quantity	Manufacturer - risk-averse; Retailer – risk-averse	BB contract	Manufacturer-retailer	Mean-variance model	MP	Seasonal product
He et al. (2006)	Demand	Supplier - risk-neutral /averse; Retailer – risk-neutral /averse	BB contract	Supplier-retailer	SG	MP	Short sale season product

Table 2-12. Analysis of consumers' behavior issues in the coordination of RSC studies

Authors	Coordination mechanism	Methodology	Channel Structure	Types of consumers' behavior	Performance measure	Industry
Huang et al. (2020)	TPT contract, WP contract	Nash bargaining model	Supplier-manufacturer	Purchasing behavior	MP	General
Wang et al. (2020a)	RS contract, TPT contract	SG	Manufacturer-retailer-collector	Choice behavior	MP	E-waste
He et al. (2019)	TPT contract, Authorization mechanism	SG	Manufacturer-retailer	Recycling behavior	MP	General
Heydari et al. (2018)	RS contract	MM	Manufacturer-retailer	Recycling behavior	MP	General
Xiao (2017)	Exchange-discount-sharing contract	NM	Manufacturer-retailer	Choice behavior	MP	Durable product
Hu et al. (2016)	WP contract, TPT contract, Subsidy contract, Cost-pooling contract, Indemnity contract	NM	Manufacturer-collector	Recycling behavior	MP	General
Ye et al. (2016)	WP contract	SG and Nash game	Multi remanufacturers-multi collectors	Recycling behavior	MP	General
Xu et al. (2015)	BB contract	MM	Manufacturer-retailer	Purchasing behavior, consumption behavior, and recycling behavior	MP	Electronic products
Govindan and Popiuc (2014)	RS contract	Cooperative Game model	Manufacturer-distributor-retailer	Recycling behavior	MP	Personal computers industry,
Zeng (2013)	RS contract, IS, Joint decision making	SG	Manufacturer-distributor-retailer	Recycling behavior	MP	Electronic products
Xiao et al. (2010)	BB contract, Markdown money contract	SG	Manufacturer-retailer	Purchasing behavior	MP	General
Su (2009)	BB contract, Sales rebate contract	Nash game	Manufacturer-retailer	Purchasing behavior	MP	General

Outsourcing is applied in RSC mostly from an economic perspective. Other perspectives of outsourcing, such as social and environmental, may be studied. The implementation of a subsidy scheme in outsourcing for RSC needs attention. Outsourcing may perform better in competitive conditions (Xing et al., 2020) and has not been studied much in RSC coordination.

It is found that most current literature considers both new and remanufactured products. The retailer mostly decides the retail price of new/remanufactured products. However, sometimes the retail price is decided exogenously. The wholesale price of new/remanufactured products is usually decided by the manufacturer/supplier. Aydin et al., 2016 described that the manufacturer decides both retail and wholesale prices when coordination is made through integration.

In most cases, the manufacturer decides the buyback price for the unsold product/off-seasoned products at the retailer's end. Unsold products or off-seasoned products that the manufacturer does not return are sold at a discounted price by retailers at their end. Only a few have discussed used product pricing, which needs attention. It is noted that most of the studies have focused on the environmental aspect to assess RSC's sustainability performance. Some of the studies have taken two dimensions of sustainability to measure the performance of RSC. Only a few have considered three dimensions of sustainability, i.e., economic, social welfare, and environment. Other sustainability aspects, such as political and technological, need attention. It is found that Bertrand competition and Cournot competition are preferred approaches in the RSC coordination context.

Further, different types of efforts have been considered in the literature to improve channel coordination and RSC performance. From the findings, most of the studies have focused on collection /recycling efforts. A few have also considered marketing/sales, energy-saving, and quality improvement efforts. Some of the literature has considered two different efforts simultaneously in their study, such as greening and marketing efforts and collection and sales efforts. Lesser-studied efforts need further attention. Information asymmetry affects coordination decisions within the RSC. It is well-established that information asymmetry has a detrimental effect on RSC performance. Across the literature on RSC coordination, various dimensions of asymmetric information based on the nature of the information were observed. According to our observations, most articles examined unilateral scenarios in which only one player possesses superior knowledge of a decision-making factor. According to the number of articles published in the RSC coordination literature, it is clear that cost information asymmetry (collection cost and recovery cost) and customer returns information asymmetry are the most extensively studied, followed by recycling effort information asymmetry and so on. From the findings, various inventory parameters have been used in RSC coordination. Inventory level is the most recurrent parameter in the examined research, followed by order quantity and inventory cycle. It demonstrates that inventory level is a critical issue affecting RSC coordination.

From the findings, the government supports RSC coordination by providing various incentives such as subsidies, rewards, and tax exemptions. In addition to incentives, governments can impose penalties, such as a carbon tax, to reduce manufacturing emissions, increasing the pace of remanufactured product collection. The subsidy is the most commonly used mechanism by the government to support RSC, followed by the reward/penalty mechanism. Other important governmental measures, like import and export policies, mandatory take-back laws, and public information campaigns, may be considered while modeling RSC coordination. The subsidy scheme determined through a survey may also be considered to coordinate the channel.

The diversity of customer behaviors, such as consumers 'purchasing behavior, recycling behavior, and choice behavior, has also been reported in the literature. It is found that recycling behavior is most studied in RSC coordination, followed by purchasing behavior and choice behavior. It reveals that consumer purchasing behavior is still not explored well. Research on other consumer behaviors, like take-back participation behavior and life extension behavior, needs attention.

Risk attitude is discussed for different parameters of RSC in the literature. From the findings, the most studied risk is customer demand. It is because customer demand is the most important principle in the RSC. Research on other risks, like the amount of customer returns and quality of returns, which affect most of the RSC, needs attention. Channel players sometimes face multiple risks (Xing et al., 2020). Out of 11 publications under risk attitude considered in this study, five publications have reported the same risk-averse behavior for all channel players. It reveals that RSC operation is highly risky, so players try to avoid it by showing risk-averse behavior. No one has studied the risk-reeking behavior of a channel player, and it needs attention.

2.4.1. Theoretical implications

The theoretical implications of this study are manifold. Firstly, the study contributes to the RSC coordination literature by addressing eleven critical issues, namely e-business, outsourcing, sustainability, pricing, inventory, competition, consumers' behavior, efforts, risk aversion, government support, and information asymmetry, which were unaddressed by previous similar work, such as Guo et al. (2017). Each issue can potentially impact RSC performance significantly and must be properly understood. As a result, from a scholarly standpoint, the work contributes to theory development while filling the research gap of a lack of comprehensive investigations on this subject. Future academics who want to publish review documents might look to this work for articles on RSC coordination. Second, most previous review studies concentrated solely on channel structures and coordination mechanisms. This research looked at the methodological features, performance measures, industrial uses of research, and channel structures and coordination mechanisms. The study provides better knowledge and an overall image of RSC coordination through a detailed evaluation. Third, earlier review studies on RSC coordination were undertaken over a shorter period. However, this study may fill a gap in the literature because it was conducted over a longer period, specifically between 2004 and 2021.

2.4.2. Practical implications

This study has business implications for managers of companies engaged in reverse logistics/remanufacturing/recycling/refurbishing business by considering strategic and functional perspectives in the implementation of coordination of RSC. The study has also addressed the issue of government support, the risk attitude of stakeholders, and consumer behavior, which are very relevant for the industries. The findings of this review can help channel players in the formulation and implementation of an effective RSC coordination strategy. Also, many studies are from particular countries such as China, the United States of America, India, and Iran, so channel players and academicians from other countries are encouraged to take an interest in the research of coordination of RSC in managing dependencies between activities. Apart from that, few studies have been done on recently developed mechanisms such as Internet-of-things (IoT) based coordination systems, smart contracts, and Blockchain-based coordination models. There are many potential areas in RSCs that practitioners may adopt to achieve the goal of coordination.

2.5. Research gaps and future research directions

After critical examination and due analysis of research opportunities, research gaps are identified using the Theory, Context, and Methodology (TCM) framework (Paul et al., 2017; Mishra et al., 2020). Paul et al. (2017) have considered 'theory' to develop an understanding of the small and medium-scale enterprises' strategic orientation towards exports, whereas 'context' pertains to firm-level antecedents such as ownership pattern, country of origin of research and concerned industry, and 'methodology' refers to the use of qualitative methods in international business. Similarly, Mishra et al. (2020) have considered 'theory' to encapsulate the principles and perspectives that guide Omni-channel retailing research, 'context' describes the analysis of various environmental factors that affect Omni-channel research outcomes, and 'methodology' refers to the identification of the limitations of existing research and to increase precision.

2.5.1. Theory

In the past 15 years, research on the coordination of RSC has focused on various theoretical frameworks such as game theory (Taleizadeh et al., 2018; Hosseini-Motlagh et al., 2020c), optimization analysis theory (Yuan et al., 2020), fuzzy theory (Alamdar et al., 2018), agency theory (Sun et al., 2019), and customer behavior theory (He et al., 2019). Among these theories, the most prominent is game theory. Under the game theoretical framework, several different theories have been studied in the RSC coordination, such as Stackelberg game theory (Aydin et al., 2016), Nash equilibrium theory (De Giovanni, 2014), Cooperative game theory (Zheng et al., 2019b), Nash bargaining theory (Xu and Wang, 2018), Principal-agent theory (Yoo et al., 2015). Some authors have used multiple theories in a single article, like Wang et al. (2020a), game theory, and consumer utility theory.

Several theories, like resource dependence theory, resource-based value, and transaction cost theory, may be applied in coordinating RSCs (Paras et al., 2019; Mahadevan, 2019). However, they are missing in the present context. Other theories, such as relational view, enterprise resource theory, queuing theory, graph theory, grounded theory, and behavioral theory, have been recommended in operations management and green supply chain management (Dubey et al., 2017; Walker et al., 2015). However, they are not used in the context of RSC coordination. Soosay and Hyland (2015) offered 12 potential theories for supply chain collaboration, which might be applied to the current situation in future research. Despite great gains in the theoretical application, several ideas relevant to RSC coordination were lacking in this review. Other theories, or a combination of two or more, can thus be investigated for RSC coordination. New theoretical perspectives could also be used to explain yet unexplored topics.

2.5.2. Context

There are multiple decision-makers in the RSC, which requires effective coordination and cooperation for success. Coordination is the core objective of the RSC system (De Giovanni and Zaccour, 2019). The distribution of articles across different industries on selected issues of RSC coordination is shown in Figure 2-4. The industries are divided into groups based on the information contained in the selected research papers. It implies that research on selected issues is not restricted to a few sectors but is very broad. WEEE industry (Feng et al., 2017; Wang et al., 2017; Wang et al., 2020a; Wu et al., 2020a) has been most (12 articles) exploited industry on selected issues, followed by eight articles on industry related to electronic products, including personal computer, tablets, printer cartridges (Sun et al., 2019; Aydin et al., 2016; Mafakheri and Nasiri, 2013) and four articles of the pharmaceutical industry. Some industries (11), like Steel scrap and waste glass bottles, have been considered a single paper. However, it is also observed that more than 67% of studies (100 papers) were conducted without considering any particular industry data (Kong et al., 2017; Radhi and Zhang, 2018; Xiang and Xu, 2019; Yuan et al., 2020). There is no doubt that these industries have a good future, but there are several areas to focus on, such as consumer goods, clothes, defense, railway, packaging, tire, paper, and plastics.

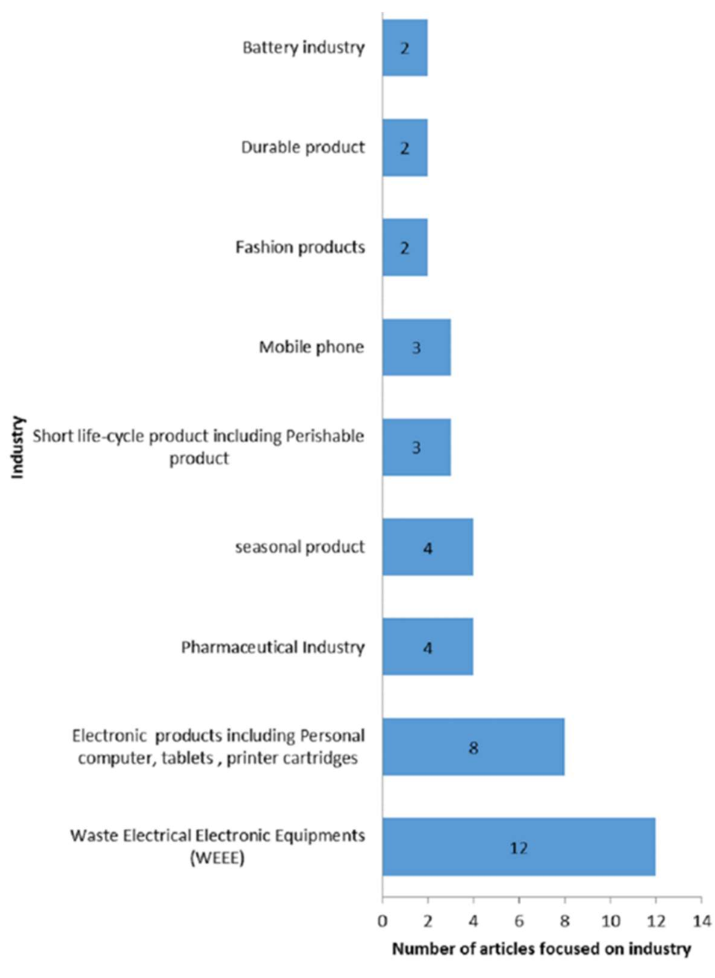


Figure 2-4. Distribution of articles (published between 2004 and 2021) on selected issues of RSC coordination across different industries (Show only if at least two articles)

The distribution of 151 articles across different countries on selected issues of RSC coordination is shown in Figure 2-5. A total of 21 countries have published different articles on the discussed issues. To identify the "country" characteristics in papers, the first author's country, as mentioned in the respective paper, has been considered. Because scholars from multiple nations co-author numerous publications, only the countries of the first author are given. From Figure 2-5, it is identified that most research in the field of coordination of RSC has been conducted in China with 73 Papers. The analysis revealed unexpected trends as developing economies like China, Iran, and India are in the top five and have published most articles. It indicates the increasing focus on these issues in developing countries. Interestingly, some developed countries like the United Kingdom and France have few papers. It also shows that there is an opportunity to research different countries.

Measuring the effectiveness of the RSC is an important task for companies to maximize performance (Mishra et al., 2018). Performance measurement criteria found in the literature that discuss the selected issues are summarized in Table 2-13. Most of the authors used profit maximization as a yardstick to measure the performance of RSC. These results are in line with the findings of Rizova et al. (2020). A little research has focused on measuring channel performance through life cycle analysis, eco-footprint analysis, Triple bottom line analysis, quality analysis, and social improvement analysis. It is an important research opportunity in this area.

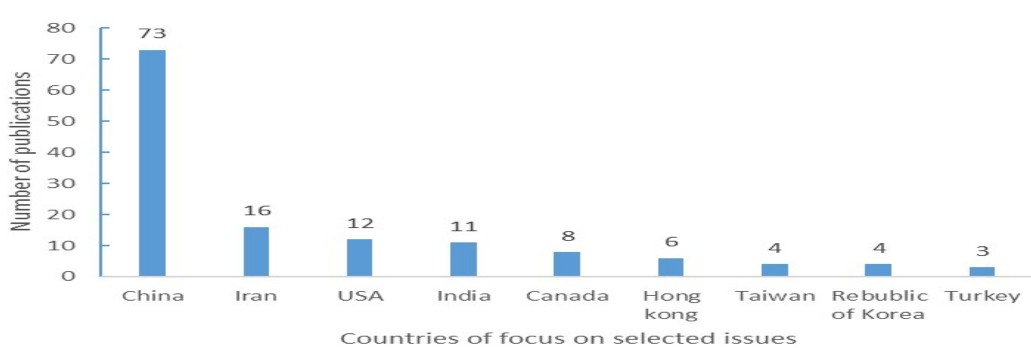


Figure 2-5. Distribution of articles (published between 2004 and 2021) on selected issues of RSC coordination across different countries (Show only at least three articles)

Table 2-13. Performance measurement criteria used in the literature

Performance measurement criteria	**Used by articles (in number)**
Maximize profit	127
Minimize cost	9
Maximize expected utilities	3
Maximize the recovery of leftover medication	2
Maximize profit, environmental benefit, and social benefit	1
Maximize market share & maximize profit	1
Maximize the number of cartridge units reclaimed, total carbon savings, and profit	1
Maximize degree of satisfaction	1
Maximize profit and improve environmental performance	1
Maximize profit and quality	1
Maximize certainty equivalent	1
Maximize mean-standard deviation value and profit	1
Maximize profit and reduce risk	1
Maximize social welfare	1

In RSCs, the number of channel players involved in the operation is important. Complexities arise as channel players grow, leading to more realistic scenarios. However, out of 151 reviewed papers, most (115) employed a two-echelon structure, and 34 used a three-echelon structure. Four and five echelon structures have been studied by one literature each. Accordingly, there is a need to study the structure of multiple echelons further. The same observation is also noted in earlier reviews. In the literature, contracts were considered the most important coordination mechanisms (92 papers), followed by joint decision-making (11 papers). The most widely used contract is the revenue sharing contract, followed by the buyback contract, wholesale price contract, etc. 36 articles have employed more than one type of coordination mechanism to maintain coordination within an RSC. For example, Yoo (2014) has employed joint decision-making and contract mechanisms. Kong et al. (2017) have used information sharing, information technology, and contracts to coordinate the channel. Some papers have also used negotiation-based contract mechanisms for coordination (Modak et al., 2019; Weraikat et al., 2016a). Kuvvetli and Erol (2020) have used a Simulated annealing-based decomposition heuristic to coordinate the channel. Aside from contracts, other mechanisms have received little attention and require further investigation.

2.5.3. Methodology

In earlier research, various methods such as Stackelberg game models (Cao et al., 2018; He et al., 2019; Mondal and Giri, 2020), mathematical models (Dutta et al., 2016; Hasanov et al., 2019), newsvendor models (Heydari et al., 2017b), cooperative game models (Jena et al., 2019), principal-agent game models (Yoo et al., 2015), Nash bargaining models (Fan et al., 2019) were widely used as shown above in various tables. The distribution of articles based on the methodology used for analyzing RSC coordination in the literature is shown in Figure 2-6. It is observed from Figure 2-6 that the most widely used methodology for modeling and analysis in RSC coordination was the Stackelberg game model (77 papers), followed by the mathematical model (22 papers), and so on. Some studies have also used Simulation-based analysis (Nativi and Lee, 2012), Differential game (Xiang and Xu, 2019), and the Mean-variance model (Li et al., 2014). These results align with the findings of Chauhan and Singh (2018) and Rizova et al. (2020). They have concluded that game theory is the most common modeling technique in the Supply chain coordination context.

Most reviewed papers have applied non-cooperative games using Stackelberg game modeling, and very few studies have used cooperative game modeling. A few researchers have used cooperative game modeling involving characteristic function forms such as the core, Shapley value, and nucleolus (Zheng et al., 2019a). A little application regarding mathematical modeling has been witnessed. A few researchers have applied the Nash bargaining technique. Other than the Nash bargaining solutions, such as Rubinstein Bargaining modeling and Kalai–Smorodinsky bargaining modeling have been used rarely. Very little study is observed in various other methodologies, such as differential game modeling and Simulation-based analysis. An evolutionary game theory that focuses more on strategy dynamics has not been used much for modeling. Therefore, it is suggested that future research consider under-studied methodologies in RSC coordination. Cloud computing and big data analytics can be serious challenges for organizations participating in RSC (Gupta et al., 2018). After synthesizing findings, the summary of research gaps is as follows.

- Various authors have studied coordination mechanisms; however, an appropriate coordination mechanism for RSC/CSC that would suit the current digital technologies era has not been discussed in the past.
- Designing and implementing effective contracts is a great challenge, and it is one factor that decides the success of any RSC/CSC. Studying the contract models necessary to coordinate RSC/CSC fully would be interesting. Determining which contract might fit best to the respective setting would be especially useful.
- Information sharing is one of the major coordination mechanisms, and channel members of RSC can benefit by sharing information. It is an unavoidable and prominent issue for RSC to achieve better performance.
- Despite the high importance of information technology (IT) in an RSC in supporting the coordination of SC, there is limited study found in the literature on IT as a coordination mechanism in RSC, so there is a need to explore this mechanism in the present context.
- A combination of coordination mechanisms (Contracts / Information sharing/ Information Technology/ Joint decision-making) may be considered to ensure strong coordination among RSC channel members and improve RSC performance.
- The research on RSC has not kept up with the modern trends and opportunities of Industry 4.0. RSC applications of Industry 4.0 technologies remain mainly unexplored.
- There has been little investigation into the open-loop supply chain structure.

- Some literature (e.g., Toktaş-Palut, 2022; Liu & De Giovanni, 2019) has discussed coordination issues utilizing game-theoretical settings in the context of Industry 4.0; however, they did not use CE strategies.
- It is evident from a literature review that the integration of digital technology and CE with RSC is in the evolving stage, and very few studies have been carried out in developing countries like India.

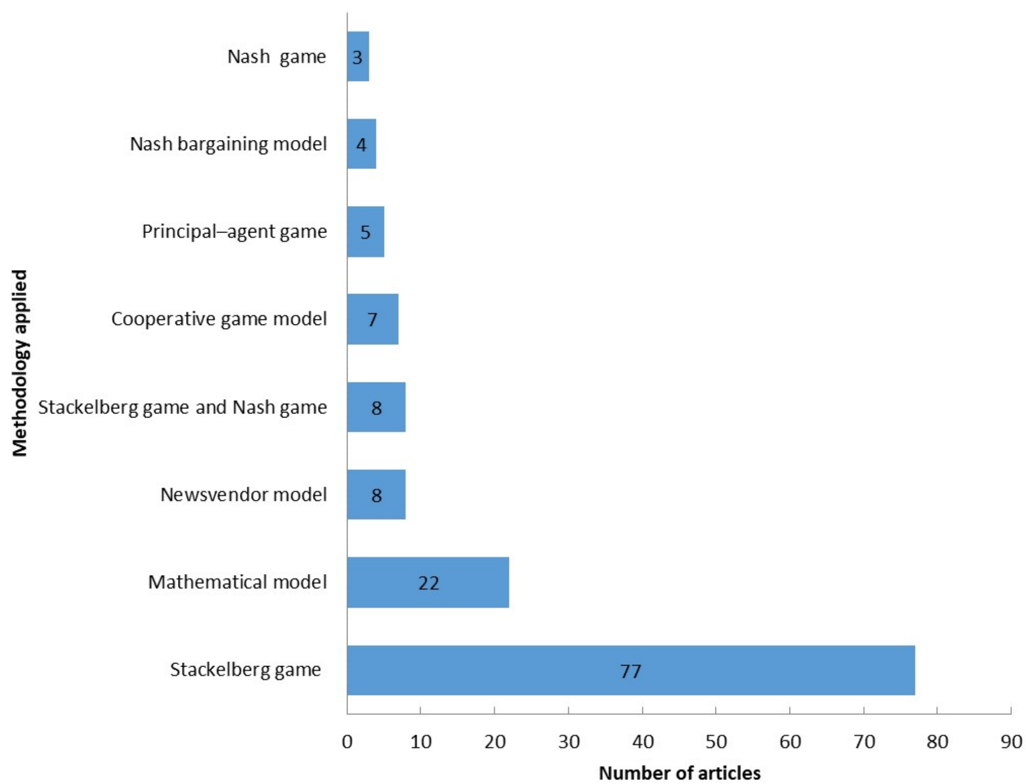


Figure 2-6. Distribution of articles based on the methodology used for analyzing RSC coordination (Shown only if at least three articles).

2.6. Conclusion of this chapter

The study has presented a systematic literature review of coordination in RSC. The review includes the articles published between 2004 and 2021. A total number of 151 articles are considered for this review. Online businesses have given many challenges and opportunities for researchers and practitioners to improve RSC coordination. The study extends the understanding of the coordination issues in RSC from different perspectives, such as an extensive bibliometric analysis of prior published articles. It addresses vital issues raised in respect of the strategic and functional perspective in the implementation of coordination of RSC. From a strategic perspective, four issues are analyzed. These are (i) E-business, (ii) Outsourcing, (iii) Pricing, and (iv) Sustainability. From a functional perspective, four issues are (i) Competition, (ii) Effort, (iii) Information asymmetry, and (iv) Inventory. These issues have been discussed in detail in the context of coordination mechanisms, methodologies, channel structure, parameters of a performance measure, and industrial settings considered by the researchers. RSC is welcomed in business circles to manage product returns by recovering residual economic value and improving sustainability. The study's findings will present a better understanding of coordination in RSC.

Furthermore, research gaps in the literature are identified from fragmented and disorganized literature. A theoretical, context, and methodological (TCM) framework addresses these research gaps and future directions. Findings will help academicians, researchers, and industry practitioners in their future work. Recent developments in coordination mechanisms such as the IoT-based coordination system, smart contracts, and Blockchain-enabled coordination model are the areas where practitioners may work to achieve the goal of coordination. Although this article followed an established research methodology, which many authors have used, it still has limitations. One of the limitations is the classification of the sample papers. Sometimes, original papers did not explicitly mention their major focus areas or some papers had more than one focus area. So, other researchers' interpretations of classification may differ from this article. In the future, researchers may also do a more comprehensive review considering other parameters of the CE.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

In Chapter 2, this study outlines the research gaps. This chapter illustrates which research methods can fill the study gaps and accomplish the objectives discussed in the first chapter. The research design followed in the study is shown in Figure 3-1.

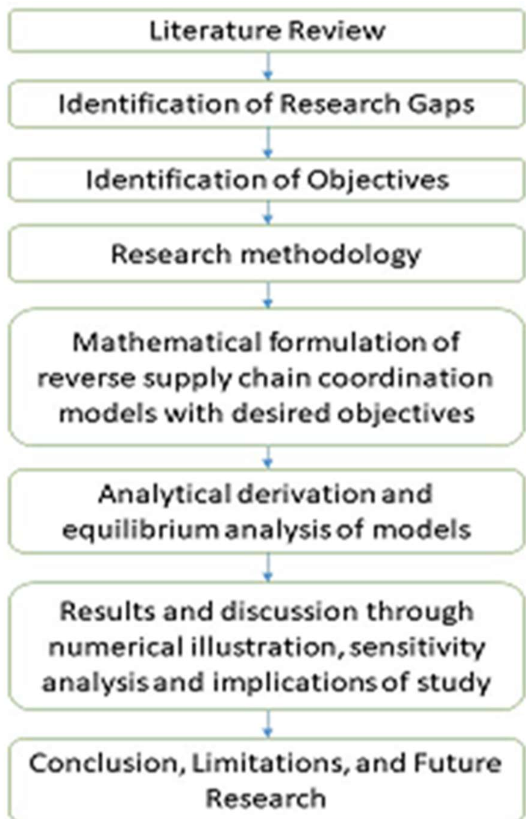


Figure 3-1 Phases of present research

Research methodology is the procedural framework in which research is to be conducted. Based on the concept of research discussed by Saunders et al. (2007), the research methodologies, including research philosophy, approach, methodological choice, strategy, time horizon, and data collection method used for the development of models, decision frameworks, and case studies are discussed in following sub-sections.

3.2. Research philosophy

The research philosophy framework guides research based on people's philosophies, their assumptions about the world, and the nature of knowledge (Rashid et al., 2019). Analytical modeling in game theory aims to develop mathematical models and derive theoretical insights that can be applied to various strategic interactions and decision-making scenarios. This approach aligns with the positivist philosophy as it emphasizes using objective and quantifiable data, logical deductions, and formal modeling techniques to analyze the behavior of rational actors and the outcomes of games. Interpretivism is a theoretical point of view that advocates the study of direct experience (Basias and Pollalis, 2018). It's important to note that while positivism is the dominant research philosophy in analytical modeling within the game's theoretical framework, there may be elements of interpretivism that come into play, particularly when considering the real-world context and qualitative data. The proposed research philosophy for this research is in between positivism and interpretivism. This research would be based on emphasizing objectivity; as a result, this research is closer to positivism.

3.3. Research approach

There are two main research approaches, i.e., deductive and inductive. Deductive reasoning starts with general theories and uses logical deductions to apply them to specific situations or cases (Onwuegbuzie and Leech, 2005). Analytical modeling within game theory typically involves developing mathematical equations and models that represent the game's strategic interactions and decision-making processes. These models are based on established game-theoretical principles, such as Nash equilibrium or subgame perfect equilibrium, which are deductively reasoned from general principles and assumptions. Researchers use deductive reasoning to analyze the logical implications of these models and derive specific results and equilibrium solutions. They apply mathematical and logical deductions to conclude the behavior of rational players, optimal strategies, or equilibrium outcomes. Using real-world observations, inductive reasoning may confirm or enhance game theory models, assumptions, and predictions (Gale et al., 2013). This research may employ deductive and inductive approaches; however, the proposed research is closer to the deductive approach.

3.4. Research strategies

The research strategy describes how the researcher intends to conduct the investigation. Numerous research strategies include Experiments, Surveys, Archival research, Case studies, Ethnography, Action research, and Grounded theory (Saunders et al., 2007). Strategies such as experiments, archival research, case studies, and surveys may be utilized in game-theoretic modeling of supply chain coordination. Supply chain coordination outcomes may be studied via experimental research. Experimental research can simulate various scenarios and modify variables to determine how they affect coordination and performance. Understanding strategic relationships between supply chain partners and establishing optimum coordination tactics may be helped by this. The archival study analyses supply chain coordination records, data, and documents. It may include examining historical coordination data or industry publications on coordination issues and methods. Case studies may examine supply chain coordinating activities. Understanding supply chain coordination methods, practices, and results requires an in-depth case study. Case studies give rich qualitative data and help comprehend the complexity of supply chain coordination. Surveys may collect supply chain members' coordination practices, perspectives, attitudes, and behaviors. Supply chain managers, workers, and other stakeholders might be surveyed to assess coordination issues, methods, and results.

3.5. Research methodological choice

Selecting a quantitative, qualitative, or mixed methodologies study design is a methodological choice. The mono approach uses one data-collecting method followed by qualitative or quantitative analysis (Soni and Kodali,2012). The multiple-method design uses numerous data collecting and analysis methods. A mixed-method approach collects and analyses qualitative and quantitative data (Tu, 2018). Analytical modeling in the game-theoretical framework relies heavily on mathematical and quantitative approaches to formulate, analyze, and derive strategic insights from mathematical equations and models. While analytical modeling is primarily quantitative, it is often complemented by qualitative reasoning to interpret the results, provide real-world context, and validate assumptions. A study that combines a case study with a game-theoretic model would fall under the mixed research design. This study will use both the quantitative and the mixed model research design.

3.6. Time horizons

According to Soni and Kodali (2012), a cross-sectional study concerns studying a particular phenomenon at a particular time, while a longitudinal study concerns change and development over a given period. This research is associated with a cross-sectional study because all required data will be collected through a survey and semi-structured interviews at one point (Vamsi and Kodali, 2014). That's the reason a cross-sectional study was chosen for this research.

3.7. Data collection

The data collection will consist of both primary and secondary data.

3.7.1. Primary data collection

Primary and secondary data collection methods may be used within the research methodology in a study that combines a case study with a game-theoretic model—conducting interviews with key stakeholders, experts, or participants involved in the case study (Choy, 2014). These interviews provide firsthand qualitative data and insights specific to the research context (Boyer and Swink, 2008). There is a case study to collect data directly related to the game-theoretic model. It involves gathering primary quantitative data on participants' preferences, decisions, or behavior within the game.

3.7.2. Secondary data collection

The secondary data will be collected mainly through academic journals and books for possible comparisons to the primary data (Kothari, 2004). The study collects and studies historical data related to the game. These data may include past decisions, outcomes, or relevant variables used as inputs for numerical analysis. The data collection methods would primarily rely on secondary data sources in a study with a game-theoretic model involving numerical analysis.

3.8. Research methods

Saunders et al. (2019) suggest a variety of research techniques. In addition to case study methods, the research employs several other methodologies for model development.

3.8.1. Case study method

Case study research is increasingly acknowledged as a valuable research technique (Yin, 2009). The case study method has been utilized in RSC (Agrawal et al., 2018). The data for the case study was collected from primary and secondary sources. The information and data collected from the companies and other secondary sources were used to analyze the issues in RSC coordination.

3.8.2. Game theoretical model

Any decision-making process involving multiple decision-makers dependent on each other can be effectively analyzed using the tools of game theory (Cachon & Netessine, 2004). Game theory is especially beneficial if a decision-making process involves multiple decision-makers, each with a possible action set. The game-theoretic paradigm has been used to address CSC challenges in the CE (Choi et al., 2020; Cao & Zhang, 2020).

In a CE approach, the game theory may facilitate agreement among stakeholders and the settlement of disputes (Palafox-Alcantar et al., 2020). The game theory models use different channel powers (Agrawal et al., 2023b). Game theoretical studies in supply chain coordination fall into two categories: (1) non-cooperative and (2) cooperative. The Stackelberg game model is widely used to investigate SC decision-making behaviors (Cheng et al., 2018).

Firstly, centralized and decentralized channel models are built. Equilibrium decisions obtained under the centralized model will be globally optimized. Various researchers have shown that a centralized supply chain outperforms a decentralized supply chain in benefit maximization and cost minimization. A centralized model is used as a reference case for the other models but does not address how total profit is distributed among channel members (Biswas et al., 2018). The players will not always function as a centralized system. Accordingly, the decentralized channel model has been analyzed. It defines the minimum acceptable profit for channel members engaging in the coordinating model. The decentralized channel will not match the centralized model's performance. As a result, effective frameworks for coordinating the decentralized channel structure must be established. The coordination framework seeks to induce channel participants to choose centralized decisions by giving incentives. Design it so that all players' profits increase compared to decentralized profits. So, decentralized and centralized results should be considered when designing coordination structures (Hosseini-Motlagh et al., 2020).

The cooperative game model, such as the Nash bargaining solution, has been utilized to handle the issue of surplus profit allocation (Shekarian, 2020; Zheng et al., 2019). Game theory helps decide whether to use a cooperative or non-cooperative strategy and which type of contract to use (Modak et al., 2019). Several researchers (e.g., Xu & Wang, 2018; Rezaei & Maihami, 2020) have adopted both the Stackelberg game and Nash bargaining game theories to get coordinated solutions for the supply chain. Alizadeh-Basban & Taleizadeh (2020) and Cao & Zhang (2020) used game theory to solve CSC challenges. Based on the above background, our study applies the Stackelberg game theory to analyze decision strategy and Nash bargaining to determine rational sharing of the additional profits.

3.8.3. Interview

Interviews are a qualitative research method that captures data through queries. Various interview varieties, including unstructured, semi-structured, and structured interviews, are distinguished by their level of structure (Susilawati et al., 2015). The study of the mixed-method approach includes interviews with all supply chain stakeholders, including a consumer, which have been considered.

3.9. Numerical analysis

Numerical analysis aims to design and analyze techniques that provide approximate but accurate solutions to various problems (Talaei et al., 20216). In the proposed research, the study investigates the impact of variations in parameter values on optimal decision-making using the proposed models (Seuring, 2013). Numerical analysis is conducted after the phases of model development and model solution. The proposed models are applicable in any supply chain coordination setting with suitable variables and parameter values. However, the numerical analysis section of chapters 4 and 5 of the study is created using secondary data in the context of recommerce.

3.10. Sensitivity analysis

Analytical modeling allows sensitivity analysis to examine how parameter changes impact the game's outcomes (Saltelli et al., 2019). Researchers can vary inputs and assess their effects on equilibrium solutions. The sensitivity analysis helps validate the model and offers insight into the SC's behavior (Kleijnen and Smits, 2003). In the study, sensitivity analysis is used to determine which information is crucial and which decisions should be coordinated by the SC.

3.11. Validity of the research

Sampling is finding and choosing a representative sample that appropriately reflects the population of interest. The chosen sample helps researchers draw significant findings and generalize the sample to the larger population. Sampling methods may differ, including probability sampling techniques and non-probability sampling approaches (Saunders et al., 2019). Given the limited number of experts in the recommerce industry and the fact that it is a relatively new industry, random sampling was not conceivable (Tieman, 2011). To attain representativeness, a non-probability purposive sampling strategy is adopted in this research. Purposive sampling entails selecting samples that are both conveniently available and willing to take part in the research. The research sample includes experts from the case study firms and the consumer (Yeo et al., 2021). The validity evaluation focused on the content rather than the number of respondents (Al-Atesh et al., 2023).

Limited interviews have been considered for only three samples for the initial phase and mathematical modeling purposes. As for taking the inputs from a larger sample, it is kept for a future study.

3.12. Conclusion

This chapter outlined the systematic procedure that was followed to analyze the study's predetermined objectives. In this chapter, the fundamental study procedures are discussed. Based on Saunders et al. (2007) discussion of the 'onion' concept of research, the study's research methodology has been illustrated. In addition, different research methods, such as game theory and case study, used to develop the model are briefly described. Detailed numerical analysis and sensitivity analysis are provided to validate the model. The mapping of the chosen research methodology for achieving the objectives has been discussed as the outcome.

CHAPTER 4: COORDINATION STRATEGY OF A CIRCULAR SUPPLY CHAIN

4.1. Introduction

The circular supply chain (CSC) is based on recovering value from returns and waste and is considered a combination of sustainable, green, open-loop, and closed-loop supply chains with the overall goal of zero waste (Batista et al., 2018; Farooque et al., 2019; Vegter et al., 2020). The idea is to recycle or reuse these materials after remanufacturing or refurbishing. Supply chains try to reduce waste and costs while preserving near-perfect sustainability for the welfare of society (Singh et al., 2022; Kumar et al., 2021a). For example, remanufacturing can save 20–70% of resources and minimize 35–50% waste. CSC partners with other businesses to profit from waste (Farooque et al., 2019). Practitioners and academicians worldwide are discussing CSC due to various factors such as economic and business opportunities, global resource concerns, and environmental issues (Tseng et al., 2022; Kayikci et al., 2022a; Kayikci et al., 2022b). To achieve the objectives of CSC, CE practices must be implemented. CE is a novel way to transform the traditional system into a circular one (Stahel, 2013).

Many global firms such as Bosch Power Tools, Apple, Patagonia, and Biopak implement CE practices in their supply chains using different strategies (Atasu et al., 2021). H&M Group has decided to become a completely circular company by 2030 (Group, 2018). The e-waste collection, segregation, and extraction ecosystem is lacking in developing economies like India. In India, 3% of the population is employed to manually scavenge e-waste and other waste. Most e-waste is stored in landfills, which leaches into the soil, water, and air, affecting human health and ecology (Goyal et al., 2018). Attero is an Indian company that recycles and refurbishes electronic waste and offers consumers online sales of refurbished items (Arya & Kumar, 2020). The core idea of the CE is to keep the value of resources (Uhrenholt et al., 2022) while avoiding the use of virgin materials and waste outputs (Joensuu et al., 2020). Product take-back systems are essential for the CE because they focus on recovering value by returning products to be recycled, remanufactured, or refurbished. However, product take-back systems face challenges in practice, posing a barrier to widespread CE adoption (Uhrenholt et al., 2022).

Re-commerce is the practice of purchasing/reselling used and refurbished goods online (Slaton & Pookulangara, 2022) and is considered a circular business model (Morrison et al., 2019). Product returns are rising in the e-commerce industry, posing a challenge to businesses and affecting their profitability (Frei et al., 2020). CE's sustainability and profitability objectives are met via the re-commerce business (Shrivastava et al., 2021). The re-commerce industry uses the gap exploiter business model to extend the product life of refurbish-able items and recycle non-refurbishable used items. The gap exploiter model of CE employs refurbishing to prolong product value and recycling to extend resource value, in line with slowing resource loops and closing loops (Suppipat & Hu, 2022). Reusing products extend their life span, paving the way for a CE (Dwivedi et al., 2022). Refurbishment is restoring end-of-life products to usable condition without destroying them. It is a viable alternative to remanufacturing and can help conserve raw resources and energy while lowering pollutants (Zacharaki et al., 2021). A new refrigerator, for example, requires 50 times the energy of a refurbishment (O'Connell et al., 2013a). Coordination will aid in executing specialized tasks such as refurbishment (Whalen et al., 2018). (Xu et al., 2020b) have emphasized time reduction through coordination in supply chains.

Coordination is essential for a successful CE because it aligns with the decisions of numerous players in the CSC (Liu et al., 2022). A CSC incorporates circular thinking into supply chain management. For example, better coordination among channel members might increase e-waste collection (Bressanelli et al., 2019). One of the biggest impediments to CSC development is the lack of member coordination (Kumar et al., 2019). The supply chain contract is the primary tool for managing circular material flows and making economic and environmental decisions (Raimondo et al., 2021). The contract type is determined by the business model of the agreement (Fischer & Pascucci, 2017). The wholesale pricing contract is commonly used in reality and literature (Cao & Zhang, 2020). The RS contract lowers the wholesale price and achieves channel coordination (Darbari et al., 2019). A TPT contract is a common coordinating mechanism in recent times (Yousaf et al., 2023). A TPT contract with bargaining may be used to deal with the issue of economic development and environmental conservation (Xu et al., 2020a).

Many studies have focused on supply chain coordination, circular business models, and refurbishment. However, only a few previous works have addressed the coordination issues of CSC, and the attention toward implementing a circular business model in industrial setup is quite limited. None has considered all research streams simultaneously. Alizadeh-Basban & Taleizadeh (2020) considered a game-theoretical approach to achieve the CE objectives of the supply chain and determine the equilibrium amounts through technology licensing using a hybrid remanufacturing process through a case study in the fashion apparel industry. They didn’t consider a contract mechanism to coordinate the channel. Li et al. (2021a) studied various contracts, including revenue sharing (RS) contract, to design a green product to achieve CE objectives and illustrated the model through a case study. Fang et al. (2021) explored a wholesale price (WP) contract to coordinate a supply chain that fulfills the CE objective by designing innovative products with a short life cycle and no environmental pollution. Li et al. (2021a) and Fang et al. (2021) did not consider extending product life or resource value strategies of CE.

The CE literature lacks studies on coordination, indicating a missed chance to embrace the CE (Velenturf & Purnell, 2021). A study on supply chain coordination contracts that maximize circular business models might be fruitful (Vegter et al., 2020). The multiple implications of a CSC, including economic value, make this research vital. A coordinated structure under different contracts resolves this. This study seeks to bridge the existing research gaps by answering the following research questions:

(i) How can the CE business model be implemented in an industrial setting to exploit the residual value of customer returns?

(ii) Is there a mechanism that coordinates decisions of a decentralized channel in the CSC so that they operate in unison and the supply chain achieves Pareto improvement?

An e-commerce company (hereafter, e-retailer) collects end-of-life products from customers and contracts with a re-commerce company for refurbishment. The debris from refurbishment is sent to a business that recycles precious metals and plastic from electronic components. The proposed study uses the gap exploiter circular business model, which combines product life extension and resource recovery. The main contributions of the current study are several-fold:

- CSC coordination: This study develops a coordination contract model to optimize CSC.

- Responsibility sharing: This study uses responsibility-sharing practices to refurbish EoU/EoL products. It is a prominent coordination strategy to ensure the circularity of the supply chain (Sudusinghe & Seuring, 2022).
- Circular business model: The gap exploiter business model of CE is proposed to be applied in the re-commerce industry. Both extending product and resource value strategies have been considered in this study.
- Extended producer responsibility (EPR): Few studies, such as Liu et al. (2022), have investigated the implementation of EPR guidelines integrated with CE. It is one of the best policy tools for accelerating CE (Arya & Kumar, 2020). However, they have not studied channel coordination.

4.2. Theoretical background

The study looks into CSC coordination using a circular business model to sell refurbished products and salvage non-refurbishable products. Our model combines three lines of research: circular business models, channel coordination, and game theoretical models. They are explained in more detail in the following subsections.

4.2.1. Circular business models

Many studies (e.g., Hina et al., 2022; Ferasso et al., 2020; Hansen & Revellio, 2020; Whalen, 2019) have investigated circular business models. As this work concerns the implementation of the gap exploiter model in an industrial setup, the research will concentrate on it. Closed-loop supply chains focus on product recovery and remarketing, but CSCs go beyond product recovery and remarketing to recover materials and minimize waste (Berlin et al., 2022b). The forward channel of a closed-loop supply chain has primary resource flows. The resources that flow in a circular channel are obtained through recycling, refurbishing, and other means (Farooque et al., 2019). Open-loop supply chains, which represent cascading material flows into other sectors, are included in the CSC (Batista et al., 2018).

The gap exploiter model employs extending product life and resource value strategy (Bauwens et al., 2020). Bocken et al. (2016) proposed three strategies for developing circular business models: narrowing, slowing, and closing resource loops. Most circular business model studies investigate the gap exploiter model to exploit leftover value in product systems. The gap exploiter paradigm has been used in many industries, including cell phones (Zufall et al., 2020) and information and communications technology (ICT) (Whalen et al., 2018). Whalen et al. (2018) recommend the gap exploiter approach requires collaboration and partnership. The gap exploiter model employs reuse and recovery.

In addition, several papers focus on implementing the gap exploiter model in the recommence industry to attain the CE goal. Notable studies include Alt (2020), Chu et al.(2021), and Chizaryfard et al. (2021). These papers detail how the recommence firm works as a gap exploiter and helps consumers save money while improving environmental sustainability. For example, consumer electronics are resold at a lower price on the secondary market after cleaning and repackaging (Krapp & Kraus, 2019). Some researchers have also conducted studies in activities related to the gap exploiter model in the context of the supply chain, for example, refurbishment (Singhal et al., 2019; Taleizadeh & Sadeghi, 2019) and Recycling (Schlosser et al., 2021). Santana et al. (2021) address the viability of refurbishing and recycling through a case study on the cell phone manufacturing business, where a cell phone manufacturer returns the phone to a refurbishment company for refurbishing. Also, the refurbishment debris is delivered to a recycling organization that recycles valuable metals and plastic from electronics components. This configuration is comparable to the proposed work. In the proposed model, EoL/EoU items, which are not primary resource materials, have been used. The study has focused on the refurbishing of these end-of-life/end-of-use items. However, the items not found to be refurbishable are moved through recycling operations by material recyclers, which come under an open-loop supply chain.

4.2.2. Channel coordination

The second stream addresses literature about Channel coordination. There is growing interest in studying supply chain coordination. The importance of coordination in the supply chain, including CE scenarios, has been discussed in many studies (Mangla et al., 2018; González-Sánchez et al., 2020; Tseng et al., 2021; Mahdiraji et al., 2023). These papers mentioned that coordination is vital in a CE because it aligns with stakeholders' decisions. Inefficient supply chains are a major challenge in rising economies. Coordination is essential because a company cannot handle all processing in-house, including recycling and remanufacturing. Several researchers have focused on coordination problems in the CE scenario to improve supply chain performance (Li et al., 2021a; Fang et al., 2021). Saha (2013) has analyzed supply chain coordination through rebate-induced contracts. Kumar et al. (2021a) have used a WP contract under various permutations to achieve supply chain coordination.

The contract is the most commonly used mechanism in supply chain literature for coordinating the channel (Agrawal et al., 2023b). RS or TPT contracts may be preferred to align the channel in sustainability literature (Guo et al., 2017; Chauhan & Singh, 2018). RS contract is also used for other than sustainability issues. For example, Yan et al. (2012) have applied the RS contract to coordinate the service supply chain. Sometimes, the RS contract cannot coordinate the channel; however, the TPT contract can (Rong & Xu, 2020). The TPT contract has recently been widely utilized in coordination literature (Sane-Zerang et al., 2020). Sometimes, the channel cannot be coordinated using the TPT contract alone. However, the TPT contract with bargaining can coordinate (Wang et al., 2019b; Zand et al., 2019). The study discusses three types of contracts: wholesale price (WP) contract, revenue sharing (RS) contract, and two-part tariff (TPT) contract with bargaining. First, the WP contract examined which fails to coordinate the supply chain. Following that, two other contracts, the RS contract and the TPT contract with bargaining, have been considered.

4.2.3. Game theoretical models

Game theoretical models have been employed in supply chain applications such as inventory management, pricing, and coordination (Agi et al., 2021; Agrawal et al., 2023b). When cooperation is lacking, game theory can be used to supplement decision-making tools. When capturing multiple values in compliance with CE principles, game theory may help facilitate conflict resolution and stakeholder consensus (Choi et al., 2020; Palafox-Alcantar et al., 2020). Game theoretical studies in supply chain coordination fall into two categories: (1) non-cooperative and (2) cooperative. Non-cooperative game models such as the Stackelberg game are frequently used to evaluate pricing strategies and their effect on profit (Zhang and Wang, 2021; Pathak et al., 2020). The cooperative game model, such as the Nash bargaining solution, has been utilized to handle the issue of surplus profit allocation (Shekarian, 2020; Zheng et al., 2019b). Game theory helps decide whether to use a cooperative or non-cooperative strategy and which type of contract to use (Modak et al., 2019).

A centralized model is used as a reference case for the other models but does not address how total profit is distributed among channel members (Biswas et al., 2018). In today's competitive market economy, each entity in a supply chain is concerned with maximizing its profit while ignoring the interests of others (Giri & Bardhan, 2012). In the decentralized model, each channel member optimizes its profit. Due to double marginalization, decentralized models have lower profits than centralized models. The decentralized model establishes the minimum acceptable profit level for SC members to participate in the coordination model (Hosseini-Motlagh et al., 2020e). The decentralized models have been examined using a Stackelberg game-theoretic approach. In the Stackelberg game, the leader gives a take-it-or-leave-it contract to followers (Ranjan & Jha, 2019).

The model based on wholesale price contracts is fundamental and serves as a second benchmark model for evaluating the anticipated results of any contract (Chakraborty et al., 2015). The coordination model offers SC members incentives to choose centralized decisions. It should be designed so all members' profits are higher than those of decentralized. The results of decentralized and centralized models should be used to design a coordination model (Hosseini-Motlagh et al., 2020e). In the actual world, agents have some bargaining power (Lippman et al., 2013). Several researchers (e.g., Modak et al., 2016a; Hua et al., 2017; Xu & Wang, 2018; Rezaei & Maihami, 2020) have adopted both the Stackelberg game and Nash bargaining game theories to get coordinated solutions for the supply chain. Alizadeh-Basban & Taleizadeh (2020) and Cao & Zhang (2020) used game theory to solve CSC challenges. Based on the above background, our study applies the Stackelberg game theory to analyze decision strategy and Nash bargaining to determine rational sharing of the additional profits.

4.3. Model development

An e-retailer as an upstream member and a re-commerce company as a downstream member is investigated in this study. The model uses CE strategies to extend product and resource value. This section discusses the model assumptions, parameters used in the study, description, model formulation, and analysis. The centralized and decentralized models are built. The optimal values of important decisions are compared in centralized and decentralized channels.

The game-theoretic models are developed under various channel power settings. Firstly, centralized and decentralized channel models are built. Equilibrium decisions obtained under the centralized model will be globally optimized. Various researchers have shown that a centralized supply chain outperforms a decentralized supply chain in benefit maximization and cost minimization. However, the players will not always function as a centralized system. Accordingly, the decentralized channel model has been analyzed. It defines the minimum acceptable profit for channel members engaging in the coordinating model. The decentralized channel will not match the centralized model's performance. As a result, effective frameworks for coordinating the decentralized channel structure must be established. The coordination framework seeks to induce channel participants to choose centralized decisions by giving incentives. Design it so that all players' profits increase compared to decentralized profits. So, decentralized and centralized results should be considered when designing coordination structures (Hosseini-Motlagh et al., 2020e).

This study develops the CSC models as centralized, decentralized, and coordinated decision-making structures. The decentralized model investigates the Stackelberg game led by the e-retailer. Two coordination contracts, i.e., 'RS contract' and 'TPT contract with bargaining'—have been modeled. The supply chain is not coordinated under the RS contract. Further, coordination based on a TPT contract with bargaining has been developed to resolve this issue. The Nash bargaining solution determines the best lump sum fee. This results in a well-coordinated CSC with Pareto improvement. Finally, the performance of the proposed model is investigated using numerical illustration and sensitivity analysis. In summary, Figure 4-1 depicts the major steps in the research methodology.

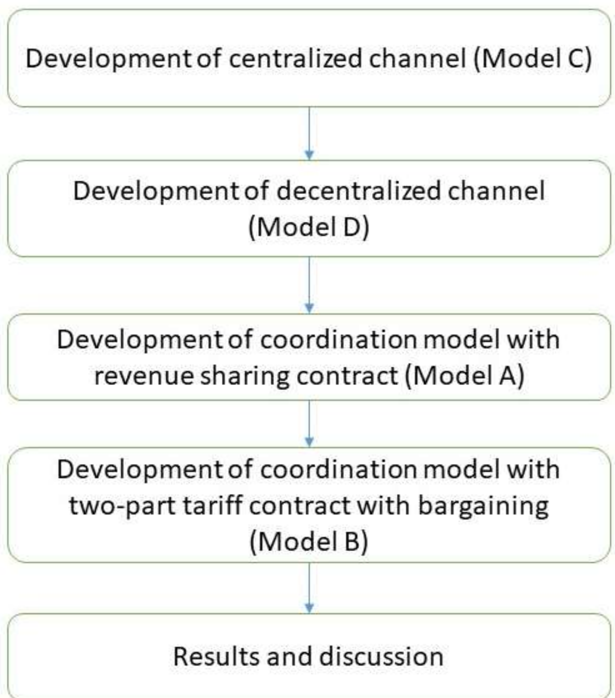


Figure 4-1. The major steps of the research methodology

4.3.1. Assumptions

Throughout the work, the most important assumptions are employed. When necessary, more assumptions are specified. The following assumptions are made:

1. A two-echelon CSC consists of an e-retailer (he) and a re-commerce company (she) that resells a single variety of refurbished products. The same information is accessed by both risk-neutral supply chain members (Rong & Xu, 2020).

2. The stylistic and linear price-dependent demand model is considered in the proposed study (Zhang et al., 2019a; Panda et al., 2017).
3. All collected used goods can be classified as refurbishable or non-refurbishable. After refurbishment, refurbished products are offered on the secondary market. Non-refurbishable items are sold as e-waste to a material recycler (Yoo & Kim, 2016).
4. All refurbished products have a constant unit cost of refurbishing, and all non-refurbishable products have a constant salvage value (Reimann, 2016). Transportation, cleaning, inspection, and other indirect charges are all included in the unit cost of refurbishing.
5. Shortages are not permitted (Mishra et al., 2020).

4.3.2. Model parameters

The most critical parameters are used throughout the project. More parameters are supplied if needed. The following variables, including decision variables, are used:

p : The selling price of a refurbished product (decision variable).

q : Wholesale price of a used product sold by the e-commerce company to the re-commerce company (decision variable).

v : Residual cost of a used product for an e-commerce company when considering all costs. Here: $v < q$.

t : Refurbishing cost of a used product.

z : Fraction of returns suitable for refurbishing [Probability of refurbishing a product].

d : Demand for the secondary market's refurbished products is a linear function of the unit selling price. Where d is always non-negative, deterministic, price-sensitive, and decreases with unit selling price p. The demand function is represented as:

a : Base demand for the market's total potential for refurbished products. Here $a > 0$.

b : Price sensitivity of demand function. Here $b > 0$.

g : Order placed by the re-commerce company to the e-commerce company:

s : Salvage value of a product (non-refurbishable units are salvaged by selling them as e-waste to a material recycler, who recovers the valuable recyclable material from the unit). Here: $s<v$.

j : Fraction of revenue the re-commerce company keeps for itself. $(1-j)$ fraction of revenue is shared with the e-commerce company. All the revenue received is assumed to be shared in the same proportion, so salvage revenue is also shared between members. Here: $0 < j < 1$.

h : Bargaining power of e-commerce company under TPT contract with bargaining.

F : Lump sum fee which is paid to the e-commerce company by the re-commerce company under a TPT contract with Nash bargaining.

e : Channel efficiency- a ratio of profits between the decentralized and centralized channels.

π : Profit function

Ω : Nash bargaining function

C : Centralized channel

D : Decentralized channel under WP contract setting

R : RS contract setting

B : TPT contract with bargaining

E : E-commerce company

M : Re-commerce company

S : Circular supply chain

* : Indicates optimal parameters in their respective models

Note: d is always non-negative, deterministic, and price-sensitive, decreasing with the unit selling price p.

The demand function (d) is represented as:

$$d = a - bp \tag{1}$$

Order placed by the re-commerce company to the e-commerce company is represented as:

$$g = \frac{d}{z} \tag{2}$$

Profit function of channel player of the process (o) of supply chain model (i) = π_o^i, where i = {R, B, C, D} and o = {E, M, S}

4.3.3. Model description

An e-retailer (he) and a re-commerce company (she) form a CSC. The e-retailer buys new products from the original equipment manufacturers through online retailing and sells them to consumers. An e-retailer collects end-of-life/end-of-use products under various collection schemes, such as an exchange/buyback program after implementing the e-waste (Management) Rules, 2016. The e-retailer gives these end-of-life/end-of-use items to the re-commerce company who refurbishes these used products. These items are evaluated and categorized into refurbishable and non-refurbishable (i.e., recyclable). Customers' data is protected via data sanitization of refurbishable products. After data sanitization, the items undergo thorough testing to determine if any repairs are required.

These items have been checked for quality. It is then cleaned to bring back the original look. After enclosing all accessories, they were re-wrapped with new material and sold as refurbished products. The non-refurbishable products are salvaged as e-waste to a material recycler, who recovers the valuable material from the products by recycling. Figure 4-2 depicts the schematic diagram of the flow of materials in the investigated circular supply chain model. The study focuses on the figure with a dash.

4.3.3.1. Model formulation and analysis

As the e-retailer dominates the supply chain, the event sequence under the Stackelberg game model is described as follows: firstly, the e-retailer chooses the wholesale price q, and the re-commerce company decides the order quantity g and unit selling price p.

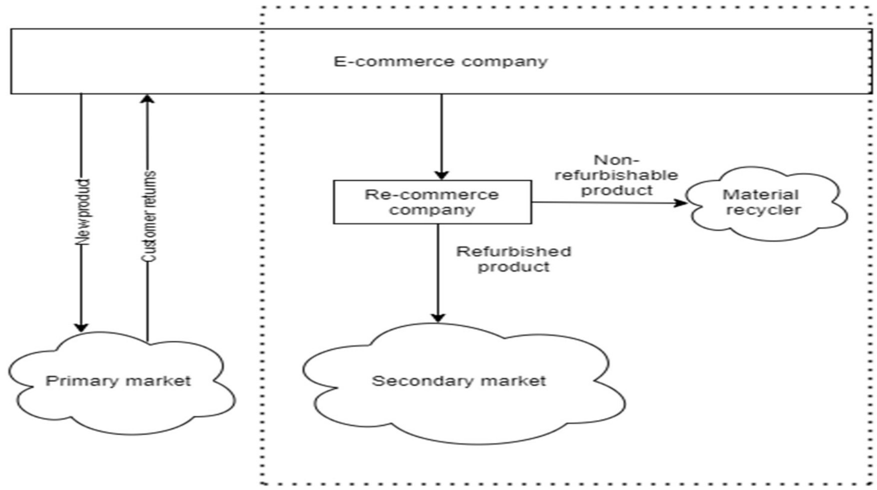


Figure 4-2. Investigated circular supply chain model

Based on the above assumption:

Quantity of refurbishable products available for sale to fulfill demand $d = gz$.

Quantity of non-refurbish products available for salvage as e-waste to a material recycler $= (1 - z)g$

The total cost of refurbishing for the re-commerce company $= z\,\mathrm{g}\,t$

Revenue received from salvaging the non-refurbish products as e-waste to a material recycler $= (1 - z)\,\mathrm{g}\,s$

The profit function Π for the e-retailer is:

$$\pi_E = g(q - v) \tag{3}$$

The profit function Π for the re-commerce company is:

$$\pi_M = zpg + (1 - z)gs - z\,\mathrm{g}\,t - gq \tag{4}$$

The profit function of the entire supply chain is:

$$\pi_S = zpg + (1-z)gs - zgt - gv \quad (5)$$

4.3.3.2. The centralized channel (Model C)

In the centralized channel (model C), the e-retailer and the re-commerce company are vertically integrated to maximize the channel's profit. The goal is to find the decision variables that maximize the channel's profit. The equilibrium results will guide future conversations (Biswas et al., 2018).

Total profit of the centralized channel,

$$\pi_S^C = zpg + (1-z)gs - zgt - gv \quad (6)$$

By substituting equations (1) and (2), the total profit function of the centralized model can be expressed as follows:

$$\pi_S^C = (zp + (1-z)s - tz - v)(\frac{(a-bp)}{z}) \quad (7)$$

Solving the first-order condition for equation (7), the expression obtained for the optimal value of *p* under a centralized channel is found as:

$$p^{C*} = \frac{((bz-b)s + tbz + bv + az)}{2bz} \quad (8)$$

The optimal demand for refurbished products in a centralized system is expressed as:

$$d^{C*} = a - bp^C * = \frac{(az - bsz - tbz + bs - bv)}{2z} \quad (9)$$

Taking the second-order derivative of the equation (7) for *p*, get the expression as:

$$\frac{\partial^2 \pi_S^C}{\partial p^2} = -2b < 0 \quad (10)$$

It indicates that unit selling price p for the centralized channel is a unique optimal solution.

The profit of the entire centralized channel π_S^C is calculated by taking the value of p from equation (8) in equation (7). The expression of total profit of the centralized model is found as:

$$\pi_S^{C*} = \frac{(az - bsz - tbz + bs - bv)^2}{4bz^2} \tag{11}$$

4.3.3.3. The decentralized channel (Model D)

In the decentralized channel (Model D), e-retailer and re-commerce company independently maximize revenues. Under the WP contract, the re-commerce company acquires customer returns from the e-retailer at wholesale price (Cao et al., 2013). In this game, the e-retailer leads, and the re-commerce company follows. The game order will be as follows: first, the e-retailer sets the wholesale price, and then the re-commerce company reacts to set the retail price for refurbished goods. This sequential move game is solved backward. The profit function for the re-commerce company is solved initially according to the backward induction method, using equation (4):

$$\pi_M^D = zgp + (1-z)gs - zgt - gq \tag{12}$$

By substituting equations (1) and (2), the profit function of the re-commerce company under the decentralized model can be expressed as follows:

$$\pi_M^D = (zp + (1-z)s - zt - q)(\frac{a - bp}{z}) \tag{13}$$

Solving the first-order condition of equation (13), the optimal value of p is

$$p^D = \frac{(bz - b)s + bzt + bq + az}{2bz} \tag{14}$$

Taking the second-order derivative of the equation (13) for p, get the expression as:

$$\frac{\partial^2 \pi_M^D}{\partial p^2} = -2bj < 0 \tag{15}$$

It indicates that the selling price p for model D is a unique optimal solution.

The profit function for the e-retailer is found using equations (1), (2), and (3) as follows:

$$\pi_E^D = g(w-v) = (\frac{a-bp}{z})(q-v) \tag{16}$$

After substituting the value of p from equation (14) in equation (16) and solving the first-order condition for a wholesale price, the expression obtained for the optimal value of q is found as:

$$q^D = \frac{bv + (b-bz)s - bzt + az}{2b} \tag{17}$$

By taking the second-order derivative of the equation (16) for a wholesale price, get the expression:

$$\frac{\partial^2 \pi_E^D}{\partial q^2} = -\frac{b}{z^2} < 0 \tag{18}$$

It indicates that the unit wholesale price for the decentralized model under the WP contract led by the e-retailer is a unique optimal solution.

Taking the value of w from equation (17) in equation (14) and find the optimal value of p under a decentralized channel:

$$P^{D*} = \frac{bv + sbz - sb + bzt + 3az}{4bz} \tag{19}$$

The optimal demand for refurbished products is

$$d^{D*} = a - bP^{D*} = \frac{az - bv - sbz + sb - bzt}{4z} \tag{20}$$

Substituting the optimal values of the wholesale price and selling price of the refurbished products from equations (17) and (19) into equations (13) and (16), respectively, obtains the total profit of the re-commerce company and total profit of the e-retailer, as follows:

Profit of the re-commerce company:

$$\pi_M^{D*} = \frac{(az - bv - sbz + sb - bzr)^2}{16bz^2} \tag{21}$$

Profit of the e-retailer:

$$\pi_E^{D*} = \frac{(az - bv - sbz + sb - bzr)^2}{8bz^2} \tag{22}$$

Further, the expression of profit of the entire supply chain under the decentralized model is found as follows:

$$\pi_S^{D*} = \frac{3(az - bv - sbz + sb - bzt)^2}{16bz^2} \tag{23}$$

Table 4-1. Optimal values in centralized channel case and decentralized channel case

Comparison measure	**Centralized Model**	**Decentralized Model**
Wholesale price q^*	-	$\frac{bv + (b - bz)s - bzt + az}{2b}$
Retail price p^*	$\frac{((bz - b)s + bzt + bv + az)}{2bz}$	$\frac{bv + sbz - sb + bzt + 3az}{4bz}$
Demand d^*	$\frac{(az - bsz - bzt + bs - bv)}{2z}$	$\frac{az - bv - sbz + sb - bzt}{4z}$
E-retailer's profit π_E^*	-	$\frac{(az - bv - sbz + sb - bzt)^2}{8bz^2}$

Re-commerce company's profit π_M^*	-	$\frac{(az - bv - sbz + sb - bzt)^2}{16bz^2}$
Total profit of supply chain π_S^*	$\frac{(az - bsz - bzt + bs - bv)^2}{4bz^2}$	$\frac{3(az - bv - sbz + sb - bzt)^2}{16bz^2}$

The obtained results under the centralized and decentralized channels are shown in Table 4-1**.** From Table 4-1, it is found that the total channel profit under the decentralized model π_S^{D*} is less than the channel profit under the centralized channel π_S^{C*} . Therefore, the loss in channel profit equals 25% due to the double marginalization problem of the decentralized model in the WP contract. Customer demand for refurbished products under the decentralized model is less than that in the centralized model. Channel demand must not be negative for a supply channel to function properly. From this, it is found that $(az - bsz - btz + bs - bv) > 0$. In this scenario, it is observed that the retail price of refurbished products under the decentralized model is higher than that in the centralized model. These results indicate the scope of improvement of the problem under the decentralized model.

4.4. Supply chain coordination using different contract mechanisms

This section will design a coordinated structure under two different coordination contracts, including an RS contract and a TPT contract with Nash bargaining, to improve the performance under a decentralized model.

4.4.1. Coordination using a revenue-sharing contract (Model R)

The RS contract model (model R) is designed to improve model D (Rong & Xu, 2020; Krishnan & Winter, 2011). The e-tailer leads a Stackelberg game model and offers an RS contract. The re-commerce company divides earnings received through reselling refurbished goods and salvaging non-refurbishable goods with the e-retailer. The re-commerce company keeps j % of sales and shares the rest with an e-retailer. The e-retailer sets the wholesale price, and then the re-commerce company sets the retail price and fraction of revenue. Based on the backward induction method, the profit function for the re-commerce company is solved initially.

Profit of the re-commerce company

$$\pi_M^R = jzpg + j(1-z)gs - zgt - gq \tag{24}$$

By substituting the equations (1) and (2), the profit function of the re-commerce company under Model A can be expressed as follows:

$$\pi_M^R = (jzg + j(1-z)s - zt - q)(\frac{a-bp}{z}) \tag{25}$$

Solving the first-order condition for equation (25), the expression obtained for optimal value p is found as:

$$p^R = \frac{bq + (z-1)sbj + bzt + ajz}{2bjz} \tag{26}$$

Second-order derivative of total profit π_M^R of the re-commerce company for p, expression is as:

$$\pi_E^R = \frac{(bv + sbz - sb + ztb - az)^2}{4(j+1)bz^2} \tag{27}$$

This indicates that a unique optimal value of p exists.

The profit function Π for the e-retailer in Model A is:

$$\pi_E^R = gq - gv + (1-j)(pzg + (1-z)gs) \tag{28}$$

By substituting the equations (1) and (2), the profit function for the e-retailer under Model A can be expressed as follows:

$$\pi_E^R = (q - v + (1-j)(pl + (1-z)s)(\frac{a-bp}{z}) \tag{29}$$

Substituting equation (26) in equation (29) and solving for the first-order, the expression obtained for the optimal value of q under an RS contract is found as:

$$q^{R*} = \frac{bjv + (1-z)bj^2 s - bzt + aj^2 z}{(1+j)b} \tag{30}$$

Second-order derivative of profit of the e-retailer for q, expression is as:

$$\frac{\partial^2 \pi_E^R}{\partial q^2} = -\frac{bj+b}{2j^2 z^2} < 0 \tag{31}$$

This indicates that a unique optimal value of q exists.

Taking the value of q from equation (30) in equation (26) of p and find the optimal value of p as:

$$p^{R*} = \frac{bv + 2ajz + sbz - sb + bzt + az}{2(j+1)bz} \tag{32}$$

Substituting equations (30) and (32) into equations (25), the optimal profit of the re-commerce company is obtained as follows:

Profit of the re-commerce company, $\pi_M^{R*} = \frac{j(bv + sbz - sb + ztb - az)^2}{4(j+1)^2 bz^2}$

(33)

Further, similar to the above, obtain the optimal profit of the e-retailer, as follows:

Profit of the e-retailer, $\pi_E^{R*} = \frac{(bv + sbz - sb + ztb - az)^2}{4(j+1)bz^2}$ (34)

Profit of the entire supply chain $\pi_S^{R*} = \frac{(bv+sbz-sb+ztb-az)^2(2j+1)}{4(j+1)^2bz^2}$ (35)

To make channel coordination under the RS contract, the optimal decision of model A is the same as those of model C. So that:

$$p^{R*} = p^{C*} \quad (36)$$

From this, get the result as;

$$j = 0 \quad (37)$$

It contradicts the assumption $0 < j < 1$. It indicates that channel coordination is not possible through an RS contract. This finding is consistent with the result of Giri et al. (2018).

4.4.2. Two-part tariff contract with bargaining (Model B)

In the TPT contract, the e-retailer authorized major decisions to the re-commerce company. In response, the re-commerce company pays the e-tailer a lump-sum fee (Chen et al., 2021b). The TPT contract is equivalent to vertical integration. Under the TPT contract, the optimal decisions of the decentralized and centralized channels are the same. To ensure both businesses sign the contract, their earnings must not be lower than those of Model D's business. A lower wholesale price and a lump sum fee are charged by the e-retailer (Wang et al., 2019b). The re-commerce company then executes the centralized system's selling decision.

In this case, the profit functions of re-commerce and e-commerce are as follows:

Profit of the re-commerce company:

$$\pi_M^B = gzp + (1-z)gs - tgz - gq - F \tag{38}$$

By substituting the equations (1) and (2), the profit function of the re-commerce company under model B can be expressed as follows:

$$\pi_M^B = (zp + (1-z)s - tz - q)(\frac{a-bp}{z}) - F \tag{39}$$

From first-order condition for optimality, optimal retail price:

$$p^B = \frac{bq + (z-1)sb + bzt + az}{2bz} \tag{40}$$

To make channel coordination under the TPT contract with bargaining, the optimal decision of model B is the same as those of Model C. So that:

$$p^{B*} = p^{C*} \tag{41}$$

From this, the optimal value of the wholesale price is as follows:

$$q^B = v \tag{42}$$

The profit function Π for the e-retailer is:

$$\pi_E^B = g(q-v) + F \tag{43}$$

By substituting the equations (1) and (2), the profit function for the e-retailer under Model B can be expressed as follows:

$$\pi_E^B = (q-v)(\frac{a-bp}{z}) + F \tag{44}$$

To coordinate the supply chain, the profits of channel members under model B should not be less than those obtained in Model D. So, using equations (22), (42), and (44), get the expressions as:

E-retailer's profit: $\pi_E^B = F \geq \frac{(za - sbz + sb - ztb - bv)^2}{8bz^2}$ (45)

Where $F_{Min} = \frac{(za - sbz + sb - ztb - bv)^2}{8bz^2}$ (46)

Similarly, from equations (21), (39), and (42), get the re-commerce company's profit;

$$\pi_M^B = (\pi_S^C - F) \geq \frac{(za - sbz + sb - bzt - bv)^2}{16bz^2} \quad (47)$$

Substituting equation (7) in equation (47), get the expression as:

$$\pi_M^B = (\pi_S^C - F) \geq \frac{(za - sbz + sb - bzt - bv)^2}{16bz^2} \quad (48)$$

Substituting the optimal value of π_S^C from equation (11) in equation (48), get the expression as;

$$F_{Max} = \frac{3(za - sbz + sb - ztb - bv)^2}{16bz^2} \quad (49)$$

Where $\frac{(za - sbz + sb - ztb - bv)^2}{8bz^2} \leq F \leq \frac{3(za - sbz + sb - ztb - bv)^2}{16bz^2}$ (50)

The optimal lump sum fee *F* is determined through negotiation between both channel players and agreed upon by them using the Nash bargaining solution. The difference between the negotiated profit and the profit under the decentralized channel is the excess profit of each player under the Nash bargaining solution (Modak et al., 2016a). Under the TPT contract with bargaining (Model B), the re-commerce company compensates the e-commerce company using a lump-sum payment. Let Model B create a Pareto improvement to the problem. According to the Nash bargaining solution under the asymmetric bargaining power, the Nash bargaining function (Ω) can be expressed as follows:

$$\text{Max } \Omega = (\pi_E^B - \pi_E^D)^h (\pi_M^B - \pi_M^D)^{(1-h)} \quad (51)$$

Where $\pi_E^B = F$ and $\pi_M^B = \pi_S^C - F$. Terms, h and (1-h) are the bargaining power of the e-retailer and re-commerce company, respectively.

Solving the first-order condition for equation (51), the expression obtained for the optimal value of lump-sum fee F is found as:

$$F^* = k(\pi_S^C - \pi_M^D) + (1-k)\pi_E^D) \quad (52)$$

The Nash bargaining function's second-order derivative $(\frac{\partial^2 \Omega}{\partial F^2})$ is negative, indicating an optimal value of F that maximizes the function may exist.

The optimal value of the re-commerce company's profit is expressed as;

$$\pi_M^{B*} = \pi_S^C - F^* \quad (53)$$

The optimal profit of the e-retailer is expressed as;

$$\pi_E^{B*} = F^* \quad (54)$$

4.5. Results and discussion

This section contains both numerical and sensitivity analyses. The established model's activities are analyzed numerically. The numerical representation also aids the managerial viewpoint. Finally, the results of the sensitivity analysis are shown. Later, we'll address the managerial consequences.

4.5.1. Numerical illustration

The following parameter values (in appropriate units) are used to compare the optimal results obtained for different models:

$a = 10000, b = 1, j = 0.5, k = 0.4, z = 0.9, t = 300, s = 100, v = 1000$.

After analyzing from demand equation (1), get the result as: $\frac{a}{b} \geq p$, since $d = a - bp \geq 0$. It is also analyzed to make a system viable $p \geq (v + t)$. Table 4-2 summarizes results under the centralized channel (Model C), a decentralized channel with a WP contract (Model D), an RS contract (Model R), and a TPT contract with bargaining (Model B). The optimal supply chain profit under Model C is more than that of Model D. The retail price is higher in Model D than in Model C. The demand for a refurbished product is less in Model D than in Model C. Thus, Model D fails to coordinate the channel. This finding is consistent with the result of Mondal & Giri (2021).

As reported in Table 4-2, the retail price of a refurbished product in model R is lower than that of model D but higher than that of model C. The optimal profit of the e-retailer and the entire supply chain under Model R is more than that of Model D. However, the re-commerce company's profit under Model R is less than that of Model D. This reveals that the channel is not coordinated under Model R. Channel efficiencies in Models D and R (at revenue sharing fraction, j = 0.5) are 75% and 88%, respectively. These results also indicate that there is still scope for improvement of the problem for model R. This finding is quite consistent with the result found by Panja & Mondal (2020).

In Model B, the profits received by channel members are higher than in Model D, and the total optimal profit is equal to that in Model C (Kumar et al., 2021b). The key highlights are as follows:

- It reveals that the CSC is fully coordinated under model B, and the Pareto improvement has been made.
- The Nash bargaining approach helps share additional profit rationally gained through the TPT contract between channel players. This finding is consistent with the result of Xu et al. (2020a). The results have several important interpretations.
- The findings show that CSC coordination is essential for improving all three dimensions of sustainability.
- The results indicate that with effective coordination, the economic performance of individual channel members and the entire supply chain has been improved substantially without investment in setting up recovery facilities.

The model also focuses on refurbishing and recycling used products with zero waste. These activities improve resource use, and so have a beneficial environmental impact. The model has also improved social performance by creating jobs in re-commerce companies to process pre-owned products. The proposed model operates following the model recommended by Lacy et al. (2014), which emphasizes that companies can use the product-life extension business model to keep return materials out of landfills, discover new sources of revenue, and improve their sustainability efforts by extending the product's lifespan.

Table 4-2. Results under the models C, D, R, and B

Comparison measure	**Model C**	**Model D**	**Model R**	**Model B**
Wholesale price q^*	-	4870	1655	1000
Retail price p^*	5700	7850	7133.33	5700
Demand d^*	4300	2150	2866.67	4300

Profit of e-retailer π_E^*	-	9245000	12326666.67	11094000
Profit of the re-commerce company π_M^*	-	4622500	4108888.89	7396000
Total profit of supply chain π_S^*	18490000	13867500	16435555.56	18490000
Lump-sum fee F^*	-	-	-	11094000
Channel efficiency e	-	75%	88%	100%

4.5.2. Sensitivity analysis

To access the effects of price sensitivity (*b*), refurbishing cost (*t*), revenue fraction (*j*), and bargaining power (*h*) on the supply chain performance parameters and profits of channel members under the different models D, R, and B, sensitivity analysis was performed.

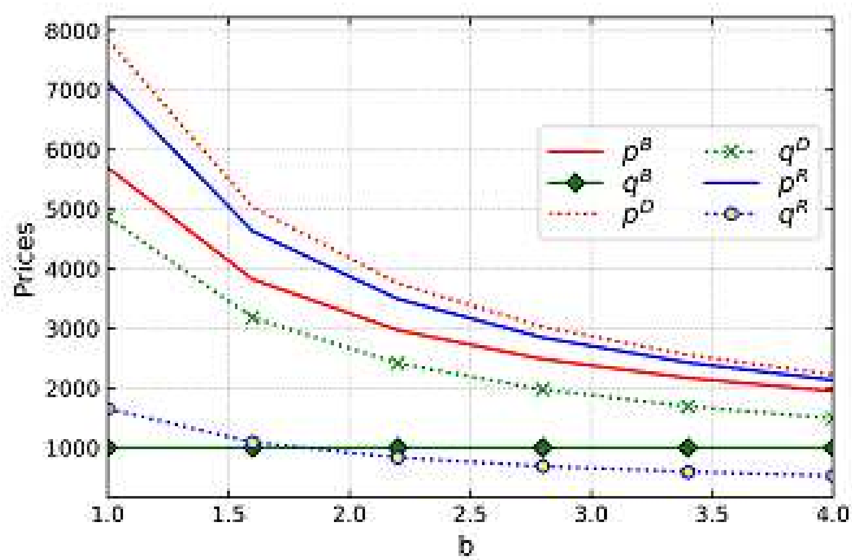
4.5.2.1. Effects of price sensitivity (*b*) of demand function on channel decisions and performances

First, the focus is on the effects of price sensitivity (*b*) on the supply chain performance parameters (i.e., *q* and *p*) and profit-sharing between channel members under the models D, R, and B. The following key parameter values are taken to discuss these issues in the subsequent illustration:

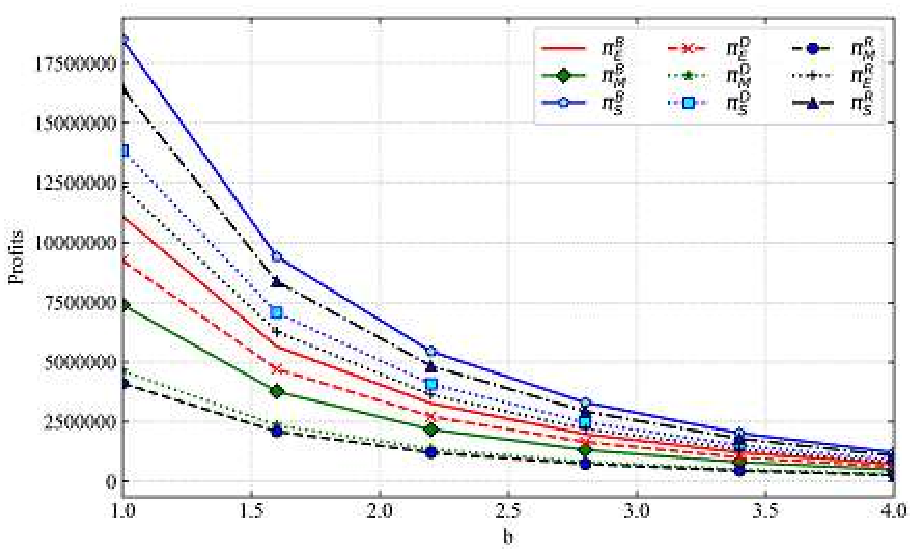
$a = 10000, b = 1, j = 0.5, h = 0.4, z = 0.9, t = 300, s = 100, v = 1000$. The value of *b* varies from 1 to 4; the effects are shown in Figure 4-3.

As depicted in Figure 4-3(a), the wholesale price in models R and D decreases with an increase in price sensitivity *b,* while the wholesale price in model B remains unchanged. An increase in the price sensitivity (*b*) reduces market demand directly. The selling price must be decreased to address rising price sensitivity while maintaining stable market demand.

According to Figure 4-3(b), the price sensitivity parameter (b) negatively affects the profits of all players and the entire supply chain. The parameter (b) similarly affects all models D, R, and B. The impact of price elasticity is also in line with the observation of Chen et al. (2021b). With the increase in b, profits decrease, resulting in a decrease in profit margin. It is consistent with real-world best practices. For example, Feng et al. (2017) and Wang et al. (2019a) mentioned that to realize the economic value of waste and keep the goal of sustainability, a two-part tariff contract succeeded in coordinating the channel.



(a)



(b)

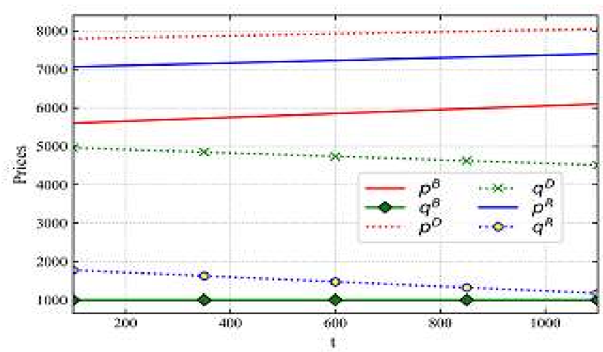
Figure 4-3. Impact of price sensitivity of demand function on (a) wholesale price and selling price, and (b) profits of the e-retailer, re-commerce company, and whole supply chain under models D, R, and B.

4.5.2.2. Effects of refurbishing cost (*t*) on channel decisions and performances

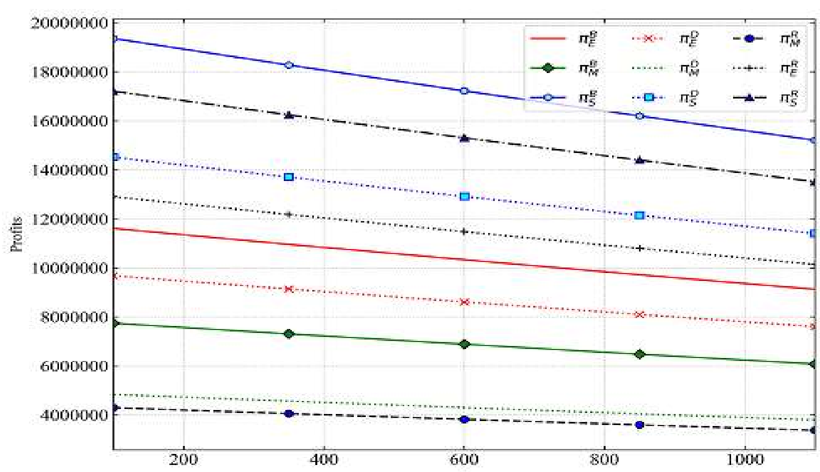
Next, on the line of earlier para 4.5.2.1, the focus is on the effects of refurbishing cost (*t*). The following key parameter values are taken to discuss these problems in the subsequent illustration: $a = 10000, b = 1, z = 0.9, s = 100, v = 1000, j = 0.5, h = 0.4$. The value of *t* varies from 100 to 1100, and the results achieved in the developed model are given in Figure 4-4.

From Figure 4-4(a), with an increase in *t*, the wholesale price under model B remains unchanged, but the wholesale prices under models D and A decrease. Comparison of wholesale price yields: $q^D > q^R > q^B$. The selling prices in each model increase with an increase in *t.* The relationship between all selling prices is as follows: $p^D > p^R > p^B$. This is because as *t* increases, the marginal cost of the re-commerce company increases. So, the re-commerce company increases its retail price to maintain marginal revenue. As a result, demands tend to decrease. Gan et al. (2019) also give a similar analogy regarding remanufacturing costs. The e-retailer has reduced its wholesale price to obtain more orders and expected profits.

According to Figure 4-4(b), profits of all players and the entire supply chain in all models D, R, and B decrease with an increase in refurbishing cost. A similar effect of remanufacturing cost is noticed by (Chen et al., 2021a). The reason for the decreased profits of the e-retailer is a decrease in demand and wholesale price for models D and R. Due to the decrease in wholesale price, marginal profit has been reduced. The profit of the e-retailer under model B decreases solely due to decreased demand. The reason for the decrease in the re-commerce company's profits is that with the increase in the value of *t*, marginal profit decreases as she will pay more to refurbish the product.



(a)



(b)

Figure 4-4. Impact of the refurbishing cost *t* on (a) wholesale and selling prices, and (b) profits of the e-retailer, re-commerce company, and whole supply chain under models D, R, and B.

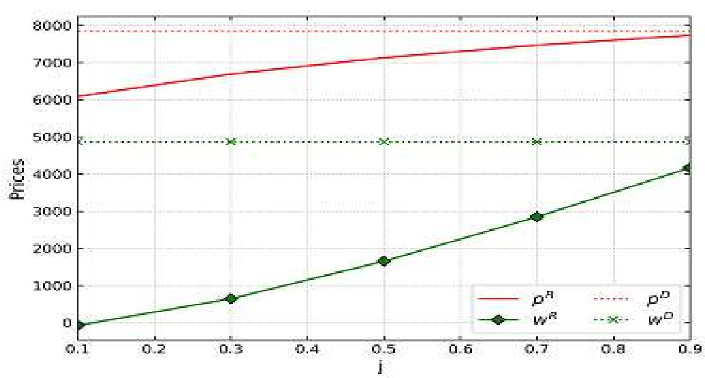
4.5.2.3. Effects of the revenue share (*j*) of the re-commerce company on channel decisions and performances

Next, on the line of earlier para 6.2.1, the re-commerce company's revenue fraction (j) effects on the supply chain performance parameters q and p and profits of channel members under the RS contract (Model R) are illustrated. Further, the values of these parameters obtained under Model A are compared with those obtained under Model D.

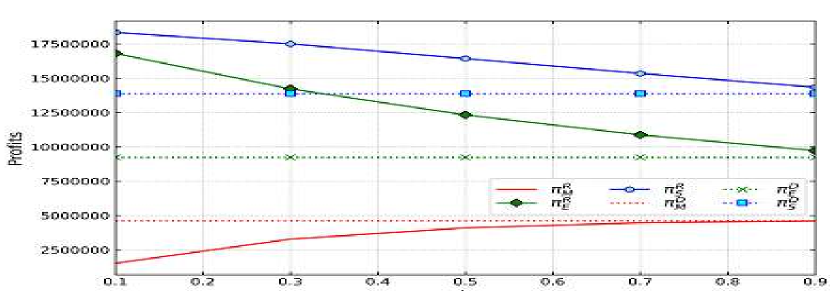
In the subsequent illustration, the following key parameter values are taken: $a = 10000, b = 1, z = 0.9, t = 300, s = 100, v = 1000$. The value of the revenue fraction j varies from 0.1 to 0.9. Results achieved in the developed model are given in Figure 4-5.

According to Figure 4-5(a), the wholesale and selling prices under Model R are lower than those under Model D. The wholesale and selling prices in Model R increase with the revenue share j. The demand for refurbished products under Model R decreases with the increase in the value of j. Still, it is always more than demand under Model D. This reveals that under the RS contract, the e-retailer shares a fraction of the revenue of the recommerce company and offers the re-commerce company a low wholesale price. Under these conditions, the re-commerce company's margin has improved; hence, the selling price has decreased, intending to increase demand. Customer sales are high, and both the e-retailer and re-commerce company benefit. However, as the revenue fraction of the re-commerce company increases, the e-retailer must raise its wholesale price to compensate for its losses. Accordingly, the re-commerce company also increases the selling price, and customers show less interest in purchasing the refurbished product.

Figure 4-5(b) shows a negative correlation between the profit of the e-retailer and revenue fraction *j* under model R. Still, the total revenue was higher than that of Model D. However, there was a positive correlation between the profit of the re-commerce company and revenue fraction *j* under Model R, but the total revenue was lower than that of Model D. The reason is that with the increase in *j*, wholesale price increases sharply which can compensate for the loss of demand for the e-retailer. But, the profit margin of the re-commerce company decreases along with demand. It reveals that although the total profit of the supply chain under model R is more than that of model D, the re-commerce couldn't accept this contract. The result shows that coordination is not possible through an RS contract. This result is consistent with the findings of (Wang et al., 2019a).



(a)



(b)

Figure 4-5. Impact of revenue fraction j on (a) wholesale and selling prices, and (b) profits of the e-retailer, re-commerce company, and entire supply chain under Model R and their comparison with Model D.

4.5.2.4. Effects of bargaining power (*h*) of the e-retailer on channel decisions and performances

Next, on the line of earlier para 4.5.2.1, the focus has been made on the bargaining power (h) of the e-retailer on the profits of channel members and the total profit of the supply chain under model B. These profits are compared with that in Model D. For illustration, the following key parameter values were taken:

$$a = 10000, b = 1, z = 0.9, t = 300, s = 100, v = 1000.$$

The value of h varies from 0 to 1, and the result is shown in Figure 4-6. Figure 4-6 shows that when h increases, the profit of the e-retailer increases while the re-commerce company's profit declines. Chen et al. (2021b) also observed a similar effect of bargaining power. If the bargaining power of the e-retailer is zero, his profit is equal to the decentralized model. It reveals that the e-retailer cannot profit from the bargaining in this scenario. When an e-retailer's bargaining power is equal to one, the e-retailer gains all the surplus profit generated, and the re-commerce company's profit is equal to the decentralized model, i.e., a re-commerce company gains no extra profit. Under Model B, the re-commerce company obtains a lower wholesale price, which motivates them to offer a lower selling price. Thus, the re-commerce company sets the selling price equal to that under a centralized channel, which is lower than their unit selling prices in the decentralized system. It will result in more consumers purchasing more products, and the re-commerce company gets more revenue. The e-retailer and re-commerce company negotiate a lump sum fee, ensuring that the channel players' revenues are not lower than in the decentralized situation.

This finding is consistent with the result (Chen et al., 2021b). Profits of the channel players and the entire supply chain under Model B are more than those achieved in Model D. Model B yields the same total supply chain profit as Model C. It reveals that the TPT contract with bargaining can effectively coordinate the supply chain. The Pareto optimal improvement can be achieved, and channel efficiency may reach 100%. When the e-retailer and the re-commerce company have equal bargaining power (i.e., h = 0.5), their profits are 11556250 and 6933750, respectively. This conclusion is consistent with Modak et al. (2019). As a result, it can be concluded that model B is more acceptable and leads to perfect coordination.

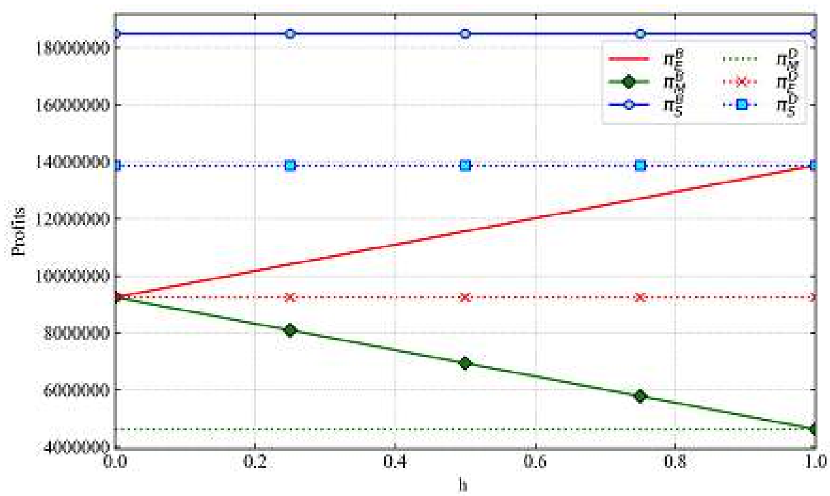


Figure 4-6. Impact of bargaining power (h) on profits of Channel players and the whole supply chain under Model B and their comparison with that obtained under Model D.

4.6. Managerial implications

The integration of CE principles in industrial sectors has received little attention. The present study explores circular business model implementation in re-commerce. Though the case of the re-commerce industry for the study has been considered, it can be applied to all industries wherever the CE approach is followed.

4.6.1. Theoretical contributions

The study makes several theoretical contributions. The study is the first to examine the issue of channel coordination of CSC. Second, the study integrated EPR guidelines with CE principles in the game theory framework. Third, it has been shown that the centralized channel outperforms the decentralized channel. Finally, it is revealed that a two-part tariff contract with Nash bargaining can generate the same profit as a centralized system contract, whereas a revenue-sharing contract cannot. According to the findings, the CSC is fully coordinated under the TPT contract with bargaining, and the Pareto improvement has been achieved.

Various theories (i.e., game theory, stakeholder theory, contract theory, prospect theory, etc.) have been used by researchers in CSC (Lahane et al., 2020). Game theory has received attention from researchers in resolving RSC coordination issues (Agrawal et al., 2023b) and is also a powerful tool for CE (Choi et al., 2020). Game theory can be used to optimize multi-player, decentralized supply chain organizations. Numerous academics use stakeholder theory to create value, leading to significant progress in dimensioning sustainability because its goal is to benefit all stakeholders (Kayikci et al., 2022b). The institutional theory and ecological modernization theory may also be relevant in the proposed study as channel members are integrated with implementation of EPC guidelines governed by government policies (Meherishi et al., 2019). Agency theory explains and resolves business leader-stakeholder issues (González-Sánchez et al., 2020). This study contributes to game theory, stakeholder theory, institutional theory, ecological modernization theory, and agency theory.

4.6.2. Managerial implications

Some meaningful implications can be derived from this study for supply chain managers, researchers, and academicians. Firstly, the study proves that two strategies, i.e., the 'extending product value' strategy and the 'extending resource value' strategy, can be used in the re-commerce business model of a CE. Practitioners would learn how to adopt these CE strategies in their setup. Secondly, this study explored implementation issues of the circular business model in industrial setup to exploit the residual value of the customer returns. So, the study's findings may be valuable for business practitioners and researchers who want to learn more about establishing a circular business to achieve nearly zero waste in the system.

Thirdly, the results indicate that the RS contract cannot coordinate in a two-echelon CSC. This has managerial significance for practitioners who wish to apply an RS contract in a similar situation. Fourthly, the TPT contract with the Nash bargaining model can determine the best profit-sharing system and ensure perfect coordination. CSC managers should focus on the cooperative game model. Fifth, our findings show that businesses should apply CE to different industries (such as clothing and e-waste) that are committed to promoting the circularity of products/materials by collaborating with CSC partners and forming a strong industrial symbiosis.

Finally, the study found that CSC coordination is critical for improving sustainability. Coordination improves the economic output of individual channel members and the entire supply chain. The e-tailer made much money through a two-part tariff contract with Nash bargaining without investing in recovery facilities. To achieve zero waste, the strategy also emphasizes refurbishment and recycling of used products. These actions are beneficial to the environment. The approach enhances social performance by establishing jobs in a re-commerce company.

4.7. Conclusion

This study examines the CSC coordination issue in the re-commerce industry through game theory. There is a scarcity of studies on implementing a circular business model to exploit residual value from consumer returns. The issue of optimal decisions and the performance of channel members is addressed using various coordination contracts. It is demonstrated how a TPT contract with Nash bargaining could help coordinate the CSC and resolve the disagreement by attaining Pareto improvement. In the suggested study, the re-commerce company acts as a gap exploiter to capitalize on the leftover value in product systems. The two new revenue streams are established by selling refurbished units and salvaging non-refurbished goods.

Channel decisions and profits for centralized and decentralized channels led by e-retailers under WP, RS, and TPT contracts with bargaining are derived. The actions of the models are analyzed through numerical illustrations. Our results show that the WP and RS contracts do not coordinate the channel. WP and RS contracts have 75% and 88% channel efficiencies. The supply chain is coordinated, and Pareto optimality is achieved under the TPT contract with Nash bargaining. Ultimately, major dimensions of sustainability, i.e., economic, environmental, and social sustainabilities, have been improved with zero-waste. The impact of price sensitivity, refurbishing cost, revenue fraction, and bargaining power on channel performance parameters and supply chain players' profits is examined using sensitivity analysis. In all models, the profits of all players and the supply chain decrease as price sensitivity and refurbishing cost increase. The e-retailer's profit and revenue fraction were negatively correlated, but the re-commerce company's profit and revenue fraction were positively correlated under the RS contract. With an increase in bargaining power under the TPT contract, the e-retailer's profit rises while the re-commerce company's falls.

Since it only covers e-retailers and re-commerce companys, the study can be expanded. In reality, a CSC is a multi-player network. Therefore, a case of multiple stakeholders can be an extension of the study for future research. In this model, information symmetry is assumed. In reality, information is rarely symmetrical, which impacts final decisions and the coordination strategy of the supply chain. It is exciting to analyze models with asymmetric information. During an inspection, a constant refurbishment rate is considered. In practice, however, randomness in the refurbishing rate is observed. Therefore, in future studies, it may be worthwhile to consider the variable refurbishment rate. Furthermore, the cost of refurbishment and the salvage value of non-refurbishable goods are thought to be predictable and consistent. To extend this work, refurbishing cost and the salvage value of non-refurbished goods may depend on industry problems like product quality and customer willingness.

CHAPTER 5: COORDINATION OF CIRCULAR SUPPLY CHAIN WITH MOBILE TECHNOLOGY

5.1. Introduction

CE models aided by industry 4.0 technologies turn end-of-life goods into new, distinct products (Mastos et al., 2021). CE maximizes the value of resources and things by extending their useful lives and extracting the greatest value from them by reusing and recovering them at the end of their useful lives (Mishra et al., 2022b; Bressanelli et al., 2019). CE shifts towards refurbished products with a warranty that may compete with new ones. Implementing a CE relies heavily on circular thinking in SC management, called a CSC (Maranesi & De Giovanni, 2020). The purpose of a CSC is to recycle EoL/EoU products and turn them into new ones or refurbish and resell them (Taghikhah et al., 2019).

Practitioners indicate that circularity fell from 9.1% in 2018 to 7.2% in 2023 due to rising material extraction. This indicates that over 90% of supplies are wasted, lost, or unusable (Economy, 2023). Due to this, the use of the CE approach may boost economic expansion and increase gross domestic product (Knäble et al., 2022). A CE growth route might deliver India yearly benefits of US$ 624 billion in 2050, which is equal to 30% of India's GDP (Foundation, 2016). Even the Government of India's E-waste Management Guidelines 2016 indicates the procedure for collecting, channelizing, and disposing of e-waste in an environmentally responsible manner. Under the E-waste (Management) Rules, 2016, manufacturers, e-retailers, and refurbishers have all been placed under the umbrella of extended producer responsibility (Arya & Kumar, 2020). Research in this field is critical because of the numerous benefits of a CSC, including economic value.

Utilizing the technological benefits of Industry 4.0, online platforms (also called recommerce) allow the buying and resale used/refurbished items, like mobile phones (Bag et al., 2023, Chen et al., 2022). An online recommerce platform (ORP) utilizes a "product value extension" approach via refurbishing and a "resource value extension" strategy through recycling (Zucchella, 2019). Implementing Industry 4.0 technology at the individual level makes the SC less coordinated and results in inefficient resource usage (Singh et al., 2019). SCs should be carefully coordinated to maximize the use of these digital technologies (Ran et al., 2020). Decentralized Industry 4.0 SC dominates the industry in sustainability when coordinated (Toktaş-Palut, 2022). Coordination will also assist in performing specialized activities such as refurbishment (Whalen et al., 2018). A CSC requires close coordination to achieve a formal alliance (Berlin et al., 2022a).

A major obstacle to implementing CSC is a lack of coordination among members (Ozkan-Ozen et al., 2020). For example, just 5% of the value of used plastic packaging gets captured (Agenda, 2016). Coordination has become a key element in achieving a successful CE because it involves the consistent decision-making of various participants in the CSC to achieve common goals (Sudusinghe & Seuring, 2022). Coordination is underrepresented in CE literature, implying a missed implementation opportunity (Velenturf & Purnell, 2021). The coordination issues of SCs in the context of the CE have become a new research paradigm (Fang et al., 2021; Li et al., 2021a). A contract is an agreement made to control circular material flows. The agreement's revenue model determines the contract type (Fischer & Pascucci, 2017). A relevant study topic could be designing coordination contracts to improve circular business models (Vegter et al., 2020). This study applies widely used coordination contracts, e.g., WP contract, RS contract, and TPT contract (Cao & Zhang, 2020; Darbari et al., 2019; Chen et al., 2021).

Refurbished products with quality and warranty service have relieved consumers from performance-related risks (Van Weelden et al., 2016). Although some papers (e.g., Chen et al., 2022; Sharifi & Shokouhyar, 2021) investigated the selling price, warranty period, and quality level in the SC context, they have not been discussed in the coordination context. Some researchers (e.g., Hosseini-Motlagh et al., 2018; Ma et al., 2013) have focused on channel management with selling price, quality improvement, and warranty period. However, they did not consider the circularity of resources. One of the major barriers to CE is a lack of funding for undertaking investments to implement the CE mandate (Scarpellini et al., 2019).

Therefore, to bridge existing research gaps, this research aims to find an effective method for coordinating decisions such as selling price, quality level, and warranty periods under various decision-making structures, as well as to investigate the consequences of these decisions on the performance of CSC in the industry 4.0 era. To achieve this objective, this study answers the following questions:

RQ1. Which contract structure most efficiently encourages the mobile application-based refurbishment company (MABRC) to focus on quality, motivates the ORP to provide warranty service, and optimizes SC profit?

RQ2. Is there a contract that can perfectly coordinate the CSC in the era of Industry 4.0?

RQ3. How do the warranty period sensitivity coefficient and warranty investments parameter affect the key decision variables (e.g., retail price, warranty period, quality level, and profitability of players and entire SC?

This study contributes to the literature on CSC coordination in the age of Industry 4.0, considering closing the resource loop by leveraging refurbishment and recycling processes. Initially, the simplest and most popular contract type, i.e., the WP contract, has been tried, though it results in an inefficient solution. It was found that the problem under the WP contract in the decentralized channel could be improved. Subsequently, an RS and a TPT contracts have been considered to achieve the system's optimal performance. The results show that the RS contract can achieve a win-win outcome but cannot perfectly coordinate the channel. However, the TPT contract achieves both channel coordination and a win-win situation. Further, the contributions of this study are as follows:

- The study implements industry 4.0 technology to coordinate the CSC.
- Our study used the recommerce business model of CE, which is rising rapidly at the current time (Tang et al., 2022).
- This study focused on coordinating mechanisms when refurbished products' selling price, quality level, and warranty duration influence demand.
- Studies on CSCs (e.g., Farooque et al., 2019; Lahane et al., 2020) have recommended that coordination contracts be developed to optimize the CSC in the era of Industry 4.0. Our research is focused on selecting the most appropriate contract for effectively coordinating the CSC.
- The impacts of the warranty period sensitivity coefficient and warranty investment parameter on channel decisions and the profitability of channel players have been investigated.

5.2. Theoretical background

This study investigates CSC coordination by implementing CE business model strategies in the era of Industry 4.0 using a game-theoretic framework wherein demand is a function of the selling price, warranty time, and refurbished product quality. The details of the background are summarized in the following subsections:

5.2.1. Implementation of circular models for ORP in the Industry 4.0 age

Circularity, digitization, and industry 4.0 promote sustainability (Prajapati et al., 2022a; Dwivedi & Paul, 2022; Mishra et al., 2022a). Adopting a CE is difficult since most organizations depend on a linear growth model (Husain et al., 2021). The role of industry 4.0 technologies in improving sustainability has been explained by various researchers (e.g., Patidar et al., 2022; Jamwal et al., 2021b; Jamwal et al., 2021a). Some researchers (Hettiarachchi et al., 2022; Khan et al., 2022; Bhattacharya, 2021; Dev et al., 2020) have suggested using Industry 4.0 and CE concepts together to achieve sustainability. Bocken et al. (2016) proposed three business development strategies: limiting resource flows by utilizing fewer resources per product, slowing resource loops by prolonging product life or designing long-life products, and completing the loop by recycling. Previous studies (e.g., den Hollander & Bakker, 2016; Whalen, 2019; Han et al., 2020) suggested various CE business models, including the recommerce model, to capture product system value. Many industries have used the recommerce business model of CE, including consumer electronics, digital devices, and fashion (Tang et al., 2022; Tang & Chen, 2022; Slaton & Pookulangara, 2022). Companies like Gazelle, Yerdle, Thredup, rebuy, and Loopster utilize ORPs (Matsui, 2022; Chu et al., 2021; Caro et al., 2020).

Some studies have considered recommerce business (e.g., Chu et al., 2021; Yrjölä et al., 2021). ORPs facilitate extending the usable life of an end-of-life/end-of-use/customer-returned product (Ertz et al., 2019). Exploiting leftover value is done by extending the useful life of goods through designing for refurbishment in the recommerce business (Nußholz, 2017). Refurbished consumer electronics items are sold in the secondary market at a lower price after minor cleanup and repackaging operations (Pan & Huynh, 2023; Jauhari et al., 2020). Ripanti et al. (2016) deliberated the application of CE concepts for designing product refurbishment operations. Giri et al. (2018) have considered refurbishing pre-owned products after their useful life for the smooth functioning of the channel and making appropriate decisions. Schlosser et al. (2021) have mentioned that recycling is also a key activity on the CE platform. Santana et al. (2021) discussed the refurbishment and recycling of cell phones to achieve sustainability goals. Accordingly, recommerce business model of CE has been used for the present study.

5.2.2. Application of Industry 4.0 technologies in SC coordination

According to industry, digital technology may improve SC performance and encourage sustainable initiatives (Akbari & Hopkins, 2022; Mukherjee et al., 2022). Numerous researchers have investigated SC coordination in the context of various technologies considered under Industry 4.0 (e.g., Big data (Hu et al., 2022), Blockchain (Ding & Bai, 2022; De Giovanni, 2020), and the IoT (Yadav et al., 2022)). Coordination contracts are typical coordination strategies. Blockchain, Big data, and IoT are the most debated technologies allowing such strategies. Digital technologies, particularly mobile phones, help in the effective implementation of Industry 4.0 (Gallego-García et al., 2022; Agnusdei et al., 2022; Shahin et al., 2020). Some literature (e.g., Bai et al., 2020; Zhou et al., 2021; Nascimento et al., 2019; Wang & Wang, 2019) emphasized that mobile technology may be useful for recycling purposes to achieve sustainability goals. Accordingly, mobile technology has been considered in this study. Industry 4.0 technology helps construct a coordinated CSC (Gebhardt et al., 2021; Kumar & Singh, 2021; Tiwari, 2021). Accordingly, CSC coordination with industry 4.0 technology is considered in the present study; however, it has not been studied earlier.

5.2.3. Application of Game theory for channel coordination in CSC

The players' strategies must be coordinated to achieve different objectives related to the CE (such as economic growth, environmental sustainability and social responsibility) (Maranesi & De Giovanni, 2020). Coordination is critical because a business entity cannot have all in-house processing arrangements. Some of the literature (e.g., Mangla et al., 2018; Ozkan-Ozen et al., 2020) found that one of the major barriers to successful CSC management is a lack of coordination among SC participants. Leal Filho et al. (2019) also marked the same reason for poor textile recycling. The game-theoretic paradigm has been used to address CSC challenges in the CE (Choi et al., 2020; Cao & Zhang, 2020). In a CE approach, the game theory may facilitate agreement among stakeholders and the settlement of disputes (Palafox-Alcantar et al., 2020). The optimum SC decisions are obtained using a Stackelberg game model. It is widely used to investigate SC decision-making behaviors (Cheng et al., 2018).

Some literature has also used smart contracts based on Blockchain technology (e.g., De Giovanni, 2020). However, some literature has demonstrated that an RS contract could not coordinate the sustainable SC (Xu et al.. 2016), but the TPT contract can perfectly coordinate the same (Kuiti et al., 2019; Chen et al., 2017). The Stackelberg model was used in the majority of previous literature. According to the analysis, the RS and TPT contracts will be employed in the Stackelberg game model to coordinate the current investigation.

5.2.4. Pricing, warranty, and quality strategies for refurbished products

Many recent studies have recommended that selling price, warranty period, and quality level are important factors for a refurbished product from a customer perspective (e.g., Chen et al., 2022; Sharifi & Shokouhyar, 2021; Nasiri & Shokouhyar, 2021). Several studies (e.g., Ovchinnikov, 2011; Yoo & Kim, 2016; Zhang et al., 2019b) have investigated the optimal prices for new and refurbished products. Sadeghi et al. (2019) and Li et al. (2010) investigated the pricing decision of refurbished products in different channel structures. Zhang et al. (2019b) looked at the quality and pricing decisions of new and refurbished products. Niu & Xie (2020) investigated the impact of quality uncertainty of refurbished products on Green SC. Pinçe et al. (2016) considered an allocation problem in choosing whether refurbished consumer returns would be used to fulfill warranty claims or remarketed as refurbished products to extract maximum value over the product's lifecycle.

Consumers who buy used/refurbished goods are concerned about product quality and warranty service (Esmaeilian et al., 2021; Liu et al., 2018; Oraiopoulos et al., 2012). Van Weelden et al. (2016) described that refurbished products with quality and warranty service would relieve consumers from performance-related risk. Nasiri & Shokouhyar (2021) explored two perceived consumer values, i.e., incentive and quality, including product warranty of refurbished smartphones. Sharifi & Shokouhyar (2021) identified four influential factors: (i) price, (ii) warranty, (iii) quality, and (iv) retailer reputation for promoting the refurbished mobile phone. Based on the above discussion, pricing, warranty, and quality strategies for refurbished products have been considered in this proposal.

5.2.5. Comparison of studies on channel coordination considering Industry 4.0

The emphasis of the studies mentioned above was on the price of new and refurbished items. Some papers have highlighted the importance of quality and warranty issues on consumer purchase behavior. Some literature has discussed coordination issues utilizing game-theoretical settings in Industry 4.0. However, they did not use CE strategies (e.g., Toktaş-Palut, 2022; B. Liu & De Giovanni, 2019). Some literature has discussed coordination issues utilizing game theoretical settings and CE strategies. However, they did not use Industry 4.0 technologies or consider EoU/EoL/customer-returned products for their study (e.g., Li et al., 2021a; Fang et al., 2021). CSC coordination in the era of Industry 4.0 technology has not been considered in the earlier study; however, it has a major obstacle to implementing CSC (Ran et al., 2020; Ozkan-Ozen et al., 2020). The above discussions demonstrate that our research challenges are significant yet unexplored. The discrepancy between our study and the most relevant research is shown in Table 5-1.

Table 5-1. The comparison between this study and the most related studies.

Literature	**Coordination mechanism**	**Types of SC**	**Modeling technique**	**Types of industry 4.0 technology**
Hu et al. (2022)	Zero WP-side-payment contract and greedy WP-side-payment contract	Forward supply chain (FSC)	Stackelberg game model (SGM)	Big data (BD)
Ding & Bai (2022)	Hybrid contract based on benefit-sharing and cost-sharing (CS)	FSC	SGM	Blockchain technology (BT)
De Giovanni (2020)	Smart WP contract and Smart RS contract	FSC	SGM	BT
Yadav et al. (2022)	IoTs-oriented coordinating mechanism	FSC	Interpretive Structural model and Fuzzy DEMATEL model	Internet of things
Li et al. (2021)	WP contract, CS contract and RS contract	FSC	SGM	-
Fang et al. (2021)	WP contract	Closed loop SC	Newsboy model and Stackelberg model	-
Toktaş-Palut (2022)	RS contract	FSC	Stackelberg model and	Industry 4.0 technology

			Nash bargaining	(in general but not specific)
Liu & De Giovanni (2019)	WP contract and RS contract	FSC	Differential game model	Industry 4.0 technology (in general but not specific)
This study	WP contract, RS contract and TPT contract	CSC	Stackelberg game	Mobile technology

5.3. Model development

This section describes the model's assumptions, notations, description, formulation, and analysis. The study investigates a two-echelon CSC consisting of a mobile application-based refurbishment company (MABRC) and an online recommerce platform (ORP) in the era of Industry 4.0. The decision variables are wholesale price and quality level for the MABRC, the warranty period, and the selling price for ORP, respectively.

The game theory models use different channel powers (Agrawal et al., 2023b). The centralized, decentralized, and coordinating models are built to examine equilibrium decisions. Firstly, the decentralized channel under the Stackelberg model has been analyzed (Zhang et al., 2019c). In a decentralized channel scenario, the MABRC and ORP make their own decisions under wholesale price contracts to increase revenues. To compare the performance of this model, a benchmark model in a centralized channel setting is to be built. In the centralized channel, the MABRC and the ORP are vertically integrated, aiming to optimize the whole channel's profit. Therefore, the goal is to evaluate the optimum values of the decision variables that maximize the total profit of the whole channel. Studies have demonstrated that a centralized approach works better than a decentralized one (Raj et al., 2018). But the players won't always be able to work as a unified unit. Therefore, decentralized models need effective coordination structures.

To that, a coordination contract is designed from the perspective of the MABRC, the game's leader, and offers a contract to the ORP. The MABRC has offered an RS contract to the ORP to decide the best choices for maximizing the entire supply chain's revenues. The ORP has agreed to share the revenue to be received from sell of refurbished goods under this contract. Under the RS contract, the MABRC will use a lower wholesale price to induce the ORP to share sales revenue. It will increase overall channel efficiency compared to the decentralized model; however, SC couldn't be perfectly coordinated.

Further, to coordinate perfectly, a TPT contract is designed. Finally, numerical demonstration and sensitivity analysis are used to test the proposed model.

5.3.1. Assumptions:

The study uses the following assumptions to ensure analytical consistency and agreement with previous work: -

1. A two-echelon CSC has a mobile application-based refurbishment company (MABRC) and an online recommerce platform (ORP) (Liu et al., 2022) that sells a single type of refurbished product on the secondary market through online retailing in the era of Industry 4.0 technology.
2. The same information is accessed by both the members of the SC who are risk-neutral (Rong & Xu, 2020).

3. The linear deterministic market demand, dependent on the selling price, warranty period, and quality level of the refurbished product, is considered for channel decisions (Panda et al., 2017; Zhang et al., 2019a).
4. All used products collected can be categorized into refurbishable and non-refurbishable products. Refurbishable products are sold in the secondary market after refurbishment (Oraiopoulos et al., 2012). Non-refurbishable products are sold to a recycler as e-waste (Yoo & Kim, 2016).
5. The unit cost of refurbishment and salvage value is assumed to be constant for all refurbishable and non-refurbishable products, respectively (Reimann, 2016). The unit refurbishment cost includes transportation, cleaning, inspection, and other indirect costs.
6. There will be no shortages (Mishra et al., 2020).

5.3.2. Notations

The parameters used in this study are explained as follows:

p : Unit retail price for a refurbished product to the end-user in the secondary market

v : Unit acquisition cost of the end-of-life/end-of-use products

q : Wholesale price of recycler

t : Refurbishing cost of the MABRC

d : Secondary market demand for refurbished goods, where $d \geq 0$. The demand function is illustrated as:

$$d = a - bp + kw + ly \tag{1}$$

a : Demand potential for a refurbished item. Note: $a > 0$.

b : Price sensitivity of demand. Note: $b > 0$

w : Warranty period.

k : Warranty period sensitivity coefficient. Note: $k > 0$.

y : Quality level of refurbished products

l : Quality level sensitivity coefficient. Note: $l > 0$.

z : Recovery rate of end-of-use/end-of-life item that can be refurbished

g : Items procured by the recycler. The expression of g is expressed as:

$$g = d / z \tag{2}$$

s : Salvage price of a non-refurbishable item. Note: $s < c$.

j : Fraction of unit retail price retained by the ORP; remainder $(1-j)$ offered to the MABRC. Note: $0 < j < 1$.

π_O^I : Profitability function of a participant O in the SC model I

I : Superscript, $I = D, C, R, T$ Where D: decentralized channel, C: centralized channel, R: RS contract model, T: TPT contract model

O : Subscript, $O = \mathrm{Re}f$ (MABRC), $\mathrm{Re}c$ (ORP), Csc (CSC)

* : Indicates optimal model parameter values

F : Lump sum fee under the TPT contract model

u : Warranty investment parameter

x : Quality investment parameter

The warranty cost is assumed to be a strictly convex function, which is represented as uw^2. Note: $u > 0; w > 0$.

It is also believed that the quality improvement cost is a strictly convex function, which is written as xy^2. Note: $x > 0; y > 0$.

5.3.3. Problem description

A CSC consisting of a mobile application-based refurbishment company (MABRC) and an online recommerce platform (ORP) is considered in the Industry 4.0 era. The MABRC collects used items through the mobile-based application from end-users or retailers/OEMs that have collected used items through various schemes such as an exchange program/buyback program to fulfill the direction laid down under extended producer responsibility in the implementation of e-waste (Management) Rules, 2016. These collected products are inspected and sorted into two categories: refurbishable and non-refurbishable (Prajapati et al., 2022b; Resmi & Fasila, 2017). Products categorized as refurbishable are processed for data sanitization to clean the hard drives. After inspection and data cleansing, the item is subjected to extensive testing to see if repairs are necessary.

To ensure adequate quality, the product has been transported for quality control. If it passes the quality check, they are cleaned to restore the original look as much as possible. MABRC makes efforts to improve the quality of refurbished quality. Accordingly, the MABRC makes decisions towards investment for the quality level of refurbished items. Finally, they are repackaged with new wrapping material enclosing all accessories. Products that fail during the inspection process are categorized as non-refurbishable. They are sent as electronic waste to a material recycler, who then uses the recycling process to recover the valuable recyclable material.

The MABRC works with the ORP operating in the secondary market. The MABRC sells the refurbished product at the wholesale price to the ORP, which then sells this product along with a warranty to the final customers in the secondary market at the retail price through online retailing. Customers will be provided free after-sales warranty services by the ORP and decide on warranty investment accordingly. The material flow in

CSC is shown pictorially in Figure 5-1. The area inside the dotted line is the focus of the analysis.

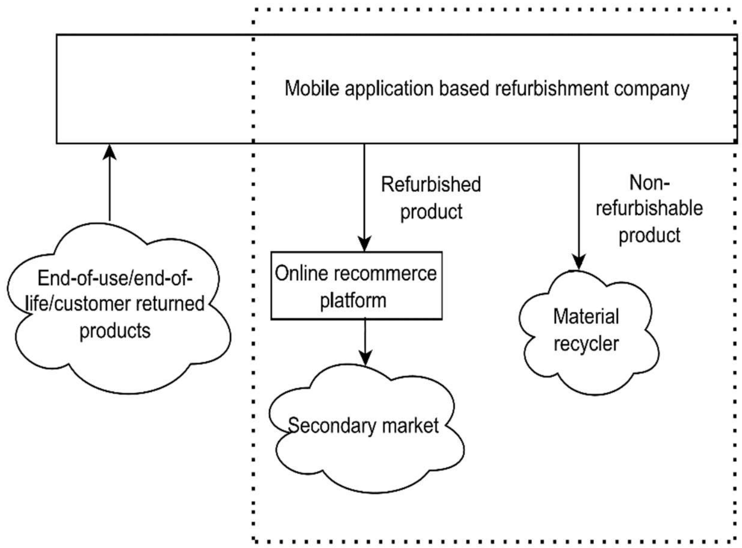


Figure 5-1 Investigated model of circular supply chain

5.3.4. Model development

As the refurbishment firm leads the SC, the Stackelberg game approach predicts the following series of events. First, the MABRC determines the wholesale price q and quality level y. Then ORP places an order of quantity g with the actual output of refurbished products is $d = gz$ and decides the warranty period w and unit retail price p of the refurbished product.

Considering the scenario mentioned above:

Total refurbished goods for sale $= gz$

Quantity of items that cannot be refurbished $= (1 - z)g$

Total expenditures for refurbishment $= zgt$

Revenue generated from the sale of non-refurbishable items $= (1-z)gs$

The expression of profit for the MABRC is given as follows: $gzq - gv + g(1-z)s - gzt - xy^2$

The expression of profit for the ORP is given as follows: $gzp - gzq - uw^2$

The overall profit function of the SC is stated as: $gzp + (1-z)gs - gzt - gv - uw^2 - xy^2$

5.3.5. Decentralized channel model (Model D)

In a decentralized channel scenario, the MABRC and ORP make their own decisions to increase their profits. In this setting, the MABRC sells the refurbished products to the ORP at wholesale price. A Stackelberg game model led by the MABRC is developed, and the solution is obtained through a WP contract. First, the MABRC offers a contract to the ORP. ORP determines whether to accept or reject a contract offer. The dynamic game order is as follows: firstly, the refurbishing company determines the unit wholesale price q and quality level y, and then the ORP reacts to determine the retail price p and warranty period w. Using the inverse induction method, first solve the profit function of the ORP.

The profit function for the ORP is expressed as:

$$\pi_{\mathrm{Rec}}^{D} = gzp - gzq - uw^2 \tag{3}$$

After substituting the result of equation (2) into equation (3), the expression for π_{Rec}^{D} is obtained as:

$$\pi_{\mathrm{Rec}}^{D} = (p-q)(a-bp+kw+ly)-uw^2 \tag{4}$$

Solving the first-order condition of equation (4) for p and w, the following expressions obtained:

$$\frac{\partial \pi_{\text{Rec}}^{D}}{\partial p} = -b(2p-q) + ly + kw + a = 0 \tag{5}$$

$$\frac{\partial \pi_{\text{Rec}}^{D}}{\partial w} = k(p-q) - 2uw = 0 \tag{6}$$

Solving the second-order conditions of equation (4) for p , w and y the following expressions obtained:

$$\frac{\partial^2 \pi_{\text{Rec}}^{D}}{\partial p^2} = -2b \tag{7}$$

$$\frac{\partial^2 \pi_{\text{Rec}}^{D}}{\partial p \partial w} = k \tag{8}$$

$$\frac{\partial^2 \pi_{\text{Rec}}^{D}}{\partial w \partial p} = k \tag{9}$$

$$\frac{\partial^2 \pi_{\text{Rec}}^{D}}{\partial w^2} = -2u \tag{10}$$

The expression of the Hessian matrix corresponding to the profit function for the ORP under the decentralized channel is

$$H(p,w) = \begin{pmatrix} -2b & k \\ k & -2u \end{pmatrix}$$

Thus, the ORP's profit function is jointly concave in *p* and *w* if the Hessian *H*(*p*, *w*) is negative. This results in the following conditions:

$$H_{11} = -2b < 0$$

$$H_{22} = 4bu - k^2 > 0$$

Solving equations (5) and (6), get the value of p and w as:

$$p = \frac{2luy + q(2bu - k^2) + 2au}{4bu - k^2} \quad (11)$$

$$w = \frac{kly - bkq + ak}{4bu - k^2} \quad (12)$$

The profit function for the MABRC is expressed as:

$$\pi_{\mathrm{Re}f}^{D} = gzq + g(1-z)s - gv - gzt - xy^2 \quad (13)$$

Substituting the value of 'g' from equation (2) into equation (13), get the equation for $\pi_{\mathrm{Re}f}^{D}$ as:

$$\pi_{\mathrm{Re}f}^{D} = (zq + (1-z)s - v - zt)(\frac{a - bp + kw + ly}{z}) - xy^2 \quad (14)$$

First, taking the value of p and w from equations (11) and (12) in equation (14), and then solving the first-order condition of equation (14) for q and y, the expressions obtained as follows:

$$\frac{\partial \pi_{\mathrm{Re}f}^{D}}{\partial q} = -\frac{2bu(z(b(2q-t-s)-ly-a)+b(s-v))}{(4bu-k^2)z} = 0 \quad (15)$$

$$\frac{\partial \pi_{\mathrm{Re}f}^{D}}{\partial y} = -\frac{((8bu-2k^2)xy+(2blt+2bls-2blq)u)z+(2bvl-2bls)u}{(4bu-k^2)z} = 0 \quad (16)$$

Equations (15) and (16) have been solved, and optimal values of q and y have been found; then, taking this optimal value in equations (11) and (12), get the following proposition.

Proposition 1. The optimal solution that maximizes the decentralized channel profit is achieved at

$$q^{D*} = \frac{(((4b^2t+4b^2s+4ab)u-bk^2t-bk^2s-ak^2)x+(-bl^2t-bl^2s)u)z + ((4b^2v-4b^2s)u+bk^2s-bvk^2)x+(bl^2s-bvl^2)u}{((8b^2u-2bk^2)x-bl^2u)z} \quad (17)$$

$$y^{D*} = -\frac{(blt + bls - al)uz + (bvl - bls)u}{((8bu - 2k^2)x - l^2u)z} \tag{18}$$

$$p^{D*} = \frac{((2b(b(t+s)+3a)u - bk^2t - bk^2s - ak^2)x - bl^2(t+s)u)z - b(s-v)(2bu-k^2)x + bl^2(s-v)u}{b(2(4bu-k^2)x - l^2u)z} \tag{19}$$

$$w^{D*} = -\frac{(kx((b(t+s)-a)z - b(s-v)))}{(2(4bu-k^2)x - l^2u)z} \tag{20}$$

$$\pi_{\text{Rec}}^{D*} = \frac{u(4bu-k^2)x^2((b(t+s)-a)z-b(s-v))^2}{(2(4bu-k^2)x-l^2u)^2z^2} \tag{21}$$

$$\pi_{\text{Ref}}^{D*} = \frac{ux((b(t+s)-a)z-b(s-v))^2}{(2(4bu-k^2)x-l^2u)z^2} \tag{22}$$

$$\pi_{\text{Csc}}^{D*} = \frac{(ux(3(4bu-k^2)x-l^2u)((b(t+s)-a)z-b(s-v))^2)}{((2(4bu-k^2)x-l^2u)^2z^2)} \tag{23}$$

Optimal demand under decentralized channel:

$$d^{D*} = -\frac{(2bux((b(t+s)-a)z-b(s-v)))}{((2(4bu-k^2)x-l^2u)z)} \tag{24}$$

Proposition 1 gives the optimal wholesale price, retail price, warranty period, quality level, and profits of the MABRC and ORP in the decentralized setting under the WP contract. It is also observed that the expected profit under the centralized channel is higher than the decentralized channel because the double marginal behavior reduces total profit under the decentralized channel (Raj et al., 2018). Accordingly, to compare the performance of the decentralized channel, a benchmark model has been developed in a centralized channel setting in the following section.

5.3.6. Centralized channel model (Model C)

This section investigates where a decision-maker may choose the optimal retail price, quality level, and warranty duration to build the study's benchmark. To optimize the expected profit of the whole SC, the centralized channel's decision-maker is a viable approach. In this case, the equilibrium decisions will be optimized globally. The equilibrium results will be a reference point for subsequent discussion (Biswas et al., 2018).

The profit function for the whole SC is expressed as

$$\pi_{\mathrm{Csc}}^{C} = gzp + g(1-z)s - gv - gzt - uw^2 - xy^2 \tag{25}$$

After taking the value of g from equation (2) into equation (25), the expression for Π_{Csc}^{c} is given as:

$$\pi_{\mathrm{Csc}}^{C} = (zp + (1-z)s - v - zt)(\frac{(a - bp + kw + ly)}{z}) - uw^2 - xy^2 \tag{26}$$

After solving the first-order condition of equation (26) for p , w and y, get the following expressions:

$$\frac{\partial \pi_{\mathrm{Csc}}^{C}}{\partial p} = (-b(2p - t - s) - \frac{b(s-v)}{z} + ly + kw + a) = 0 \tag{27}$$

$$\frac{\partial \pi_{\mathrm{Csc}}^{C}}{\partial w} = (\frac{k(-tz + pz + s(1-z) - v)}{z} - 2uw) = 0 \tag{28}$$

$$\frac{\partial \pi_{\mathrm{Csc}}^{C}}{\partial y} = (\frac{l(-tz + pz + s(1-z) - v)}{z} - 2xy) = 0 \tag{29}$$

After solving the second-order conditions of equation (26) for p , w and y , get the following expressions:

$$\frac{\partial^2 \pi_{\mathrm{Csc}}^{C}}{\partial p^2} = -2b \tag{30}$$

$$\frac{\partial^2 \pi_{\text{Csc}}^{C}}{\partial p \partial w} = k \tag{31}$$

$$\frac{\partial^2 \pi_{\text{Csc}}^{C}}{\partial p \partial y} = l \tag{32}$$

$$\frac{\partial^2 \pi_{\text{Csc}}^{C}}{\partial w \partial p} = k \tag{33}$$

$$\frac{\partial^2 \pi_{\text{Csc}}^{C}}{\partial w^2} = -2u \tag{34}$$

$$\frac{\partial^2 \pi_{\text{Csc}}^{C}}{\partial w \partial y} = 0 \tag{35}$$

$$\frac{\partial^2 \pi_{\text{Csc}}^{C}}{\partial y \partial p} = l \tag{36}$$

$$\frac{\partial^2 \pi_{\text{Csc}}^{C}}{\partial y \partial w} = 0 \tag{37}$$

$$\frac{\partial^2 \pi_{\text{Csc}}^{C}}{\partial y^2} = -2x \tag{38}$$

The following Hession matrix is obtained to prove the concavity of the profit function of the centralized channel for p, w, and y:

$$\begin{pmatrix} -2b & k & l \\ k & -2u & 0 \\ l & 0 & -2x \end{pmatrix}$$

The function will be concave if the Hessian Matrix's principal minors are alternately negative and positive (Modak et al., 2019). Accordingly, the following conditions are obtained:

$$H_{11} = -2b < 0$$

$$H_{22} = 4bu - k^2 > 0$$

$$H_{33} = -8bux + 2k^2x + l^2u < 0$$

Solving equations (27) to (29), get proposition 2.

Proposition 2. The optimal solution that maximizes the centralized channel profit is achieved at

$$p^{C*} = \frac{(((t(2bu-k^2)+s(2bu-k^2)+2au)x - l^2tu - l^2su)z + (v(2bu-k^2)+s(k^2-2bu))x + l^2su - vl^2u)}{((4bu-k^2)x - l^2u)z} \tag{39}$$

$$w^{C*} = -\frac{((bkt+bks-ak)xz + (bvk-bks)x)}{((4bu-k^2)x - l^2u)z} \tag{40}$$

$$y^{C*} = -\frac{((bltu+blsu-alu)z - blsu + bvlu)}{((4bu-k^2)x - l^2u)z} \tag{41}$$

The optimal profit under the centralized channel is achieved as follows:

$$\pi^{C*}_{Csc} = \frac{(ux((b(t+s)-a)z - b(s-v))^2)}{(((4bu-k^2)x - l^2u)z^2)} \tag{42}$$

Optimal demand under centralized channel:

$$d^{C*} = -\frac{(2bux((b(t+s)-a)z - b(s-v)))}{((4bu-k^2)x - l^2u)z} \tag{43}$$

Proposition 2 gives the optimal retail price, warranty period, quality level, and SC profit in the centralized setting. The centralized scenario merely raises the profit of the entire SC and cannot ensure that each member will make a satisfactory profit (Heydari & Rafiei, 2020). A coordination model using the RS contract is presented in the next subsection to address the disadvantages of the centralized and decentralized channels under the WP contract.

5.3.7. RS contract model (Model R)

The RS contract is formulated to improve the effectiveness of the decentralized model (Sharma et al., 2022; Rong & Xu, 2020). The MABRC has offered an RS contract under which the ORP shares its revenue received through remarketing of refurbished items with the MABRC. It is considered that the ORP retains a portion j of the selling price and shares the remaining $(1-j)$ with the MABRC. A Stackelberg game model led by the MABRC is developed. The MABRC first determines the wholesale price q and quality level y, and then, on this basis, the ORP determines the retail price p and warranty period w. Finally, the online recommerce platform determines the revenue fraction j. Initially, the profit function for the online recommerce platform is solved using the reverse induction approach.

The profit function for the online recommerce platform is expressed as:

$$\pi_{\text{Rec}}^{R} = jgzp - gzq - uw^2 \tag{44}$$

After substituting the value of g using equation (2) into equation (44), the expression for π_{Rec}^{R} is:

$$\pi_{\text{Rec}}^{R} = (jp-q)(a-bp+kw+ly) - uw^2 \tag{45}$$

Solving the first-order condition of equation (45) for p and w, the following expressions obtained:

$$\frac{\partial \pi_{\text{Rec}}^{D}}{\partial p} = j(ly+kw+a) - b(2jp-q) = 0 \tag{46}$$

$$\frac{\partial \pi_{\text{Rec}}^{D}}{\partial w} = k(jp-q) - 2uw = 0 \tag{47}$$

Solving equations (46) and (47), get the value of p and w, as:

$$p = \frac{(u(j(2ly+2a)+2bq)-jk^2q)}{j(4bu-jk^2)} \tag{48}$$

$$w = -\frac{(bkq - jk(ly+a))}{(4bu - jk^2)} \tag{49}$$

The profit function for the MABRC is expressed as:

$$\pi^R_{\mathrm{Re}f} = (1-j)p(a-bp+kw+ly)+gzq+g(1-z)s-gc-gzt-xy^2 \tag{50}$$

After substituting g from equation (2) into equation (50), the expression for $\pi^R_{\mathrm{Re}f}$ is given as:

$$\pi^R_{\mathrm{Re}f} = ((1-j)pz+(zq+(1-z)s-v-zt))(\frac{(a-bp+kw+ly)}{z})-xy^2 \tag{51}$$

First, taking the value of p and w from equations (48) and (49) in equation (51) and then solving the first-order condition of equation (51) for q and y, the following expressions are obtained:

$$\frac{\partial \pi^R_{Ref}}{\partial q} = -\frac{\begin{array}{l}(2bu(2b(2b(j+1)u-jk^2)zq-j(4bjluy-jk^2ly+4b^2tu+4b^2su+4abju-bjk^2t-bjk^2s-ajk^2)z+\\ 4b^2j(s-v)u-bj^2k^2s+bvj^2k^2))\end{array}}{(j^2(4bu-jk^2)^2z)} = 0 \tag{52}$$

$$\frac{\partial \pi^R_{\mathrm{Re}f}}{\partial y} = -\frac{\begin{array}{l}(2(((4bu-jk^2)^2x+4b(j-1)l^2u^2)zy+blu(4(b(t+s-q)+a(j-1))u-\\ k^2(j(t+s)-q))z-4b^2l(s-v)u^2+bjk^2l(s-v)u))\end{array}}{((4bu-jk^2)^2z)} = 0 \tag{53}$$

Equations (52) and (53) have been solved, and optimal values of q and y have been found; then, taking this optimal value in equations (48) and (49), get the following expressions for q, y, p and w:

$$q = \frac{\begin{array}{l}((((u(t(bjl^2-4b^2jx)+s(bjl^2-4b^2jx)-4abj^2x)+bj^2k^2tx+bj^2k^2sx+aj^2k^2x)z+\\ u(s(4b^2jx-bjl^2)-4b^2vjx+bvjl^2)-bj^2k^2sx+bvj^2k^2x))\end{array}}{((b((u(-4bjx-4bx+l^2)+2jk^2x)z))))} \tag{54}$$

$$y = \frac{((blt + bls - al)uz + (bvl - bls)u)}{((u(-4bjx - 4bx + l^2) + 2jk^2x)z)} \tag{55}$$

$$p = \frac{((2b(b(t+s) + a(2j+1))u - bjk^2t - bjk^2s - ajk^2)x - bl^2(t+s)u)z - b(s-v)(2bu - jk^2)x + bl^2(s-v)u}{b(2(2b(j+1)u - jk^2)x - l^2u)z} \tag{56}$$

$$w = -\frac{(jkx((b(t+s) - a)z - b(s-v)))}{(2(2b(j+1)u - jk^2)x - l^2u)z} \tag{57}$$

Put equations (54)-(57) into equation (45) and then obtain the first derivative of j:

$$\frac{\partial \pi^R_{\text{Rec}}}{\partial j} = -\frac{(2u^2x^2((b(t+s) - a)z - bs + bv)^2((8b^2ux - k^2l^2)j - 8b^2ux + 2bl^2u))}{(z^2(2(2bu - k^2)xj + 4bux - l^2u)^3)} \tag{58}$$

Set the first derivative equal to zero, and the optimal value of j is obtained as follows:

$$j^{R*} = \frac{(8b^2ux - 2bl^2u)}{(8b^2ux - k^2l^2)} \tag{59}$$

After substituting the optimal value of j, get the following proposition.

Proposition 3. The optimal solution that maximizes the decentralized channel profit after applying the coordination model mechanism, namely the RS contract, is achieved as

$$p^{R*} = \frac{((8b(2b^2tu + 2b^2su + 6abu - bk^2t - bk^2s - ak^2)x^2 - 8bl^2(b(t+s) + a)ux + k^2l^4t + k^2l^4s)z - 8b^2(s-v)(2bu - k^2)x^2 + 8b^2l^2(s-v)ux - k^2l^4s + vk^2l^4)}{(4bx - l^2)(16b^2ux - 4bk^2x - k^2l^2)z} \tag{60}$$

$$w^{R*} = -\frac{(2bkx((b(t+s) - a)z - b(s-v)))}{(16b^2ux - 4bk^2x - k^2l^2)z} \tag{61}$$

$$q^{R*} = \frac{(2bu(4bx - l^2)((2(b(t+s) + a)(4bu - k^2)x - k^2l^2t - k^2l^2s)z - 2b(s-v)(4bu - k^2)x + k^2l^2s - vk^2l^2))}{(8b^2ux - k^2l^2)(4b(4bu - k^2)x - k^2l^2)z} \tag{62}$$

$$y^{R*} = -\frac{(l(8b^2ux - k^2l^2)((b(t+s) - a)z - b(s-v)))}{(4bx - l^2)(16b^2ux - 4bk^2x - k^2l^2)z} \tag{63}$$

$$\pi_{\mathrm{Re}f}^{R*} = \frac{(x(8b^2ux - k^2l^2)((b(t+s)-a)z - b(s-v))^2)}{((4bx-l^2)(16b^2ux - 4bk^2x - k^2l^2)z^2)} \tag{64}$$

$$\pi_{\mathrm{Re}c}^{R*} = \frac{(4b^2ux^2((b(t+s)-a)z - b(s-v))^2)}{((4bx-l^2)(16b^2ux - 4bk^2x - k^2l^2)z^2)} \tag{65}$$

Proposition 3 gives the optimal wholesale price, retail price, warranty period, quality level, and profits for MABRC and ORP in the decentralized setting under the RS contract. The next section uses the TPT contract to coordinate the CSC perfectly.

5.3.8. TPT contract model (Model T)

A TPT contract is a simple and effective mechanism widely used to coordinate SC systems (Mahdiraji et al., 2022). To ensure both firms participate in the contract, their profits should not be less than those in the decentralized model. In this contract, the MABRC will charge a lower wholesale price to the ORP to motivate them to decrease their retail price to equal one under the centralized setting (Kuiti et al., 2019). This procedure increases market demand and raises the ORP's profit. Then, the ORP (benefited player) pays a lump sum fee F to the MABRC (losing player) to compensate for the loss of the MABRC (Chen et al., 2021). The TPT contract can coordinate the channel, and the optimal decisions regarding the retail price p, quality level y, and warranty period w are the same as the centralized scenario (Wang et al., 2019b).

The Profit function of the ORP is:

$$\pi_{\mathrm{Re}c}^{T} = gzp - gzq - uw^2 - F \tag{66}$$

After taking the value g from equation (2) into equation (66), the expression for $\pi_{\mathrm{Re}c}^{T}$ is as:

$$\pi^{T}_{\mathrm{Re}c} = (p-q)(a-bp+kw+ly) - uw^2 - F \tag{67}$$

The profit function of the MABRC is as follows:

$$\pi^{T}_{\mathrm{Re}f} = gzq + g(1-z)s - gv - gzt - xy^2 + F \tag{68}$$

After taking the value g from equation (2) into equation (68), the expression for $\pi^{T}_{\mathrm{Re}f}$ is as:

$$\pi^{T}_{\mathrm{Re}f} = (zq + (1-z)s - v - zt)(\frac{(a-bp+kw+ly)}{z}) - xy^2 + F \tag{69}$$

Differentiating equation (66) for p and equated with zero, get the optimal value of p as

$$p = \frac{ly + kw + bq + a}{z} \tag{70}$$

Now substitute the value of p, w and y as p^{C*}, w^{C*} and y^{C*} respectively into equation (70) and simplify them for q. Now get Proposition 4 as:

Proposition 4. To ensure the implementation of the contract, wholesale price q under the TPT contract and a feasible range of lump-sum fee F is achieved as:

$$q = \frac{(t+s)z - s + v}{z} \tag{71}$$

Now, substituting the above values of p, w and y as p^{C*}, w^{C*} and y^{C*} respectively and equation (71) and simplifying equation (67), get the expression for π^{T}_{Rec} as:

$$\pi^{T}_{\mathrm{Rec}} = \frac{(u(4bu-k^2)x^2((b(t+s)-a)z - b(s-v))^2)}{(((4bu-k^2)x - l^2u)^2 z^2)} - F \tag{72}$$

Along similar lines as above, get the expression for $\pi^{T}_{\mathrm{Re}f}$ as given below:

$$\pi^{T}_{\mathrm{Re}f} = -\frac{(l^2u^2x((b(t+s)-a)z - b(s-v))^2)}{(((4bu-k^2)x - l^2u)^2 z^2)} + F \tag{73}$$

To ensure proper SC coordination, the profits earned by participants of the channel using the TPT contract model mustn't be lower than those acquired using the WP contract in the decentralized approach. Thus, the profit of the MABRC follows: $\pi^{T}_{\mathrm{Re}f} \geq \pi^{D*}_{\mathrm{Re}f}$.

From equations (22) and (73), get the expression as,

$$\pi^{T}_{\mathrm{Re}f} = \left(-\frac{(l^2u^2x((b(t+s)-a)z-b(s-v))^2)}{(((4bu-k^2)x-l^2u)^2z^2)}+F\right) \geq \frac{(u(4bu-k^2)x^2((b(t+s)-a)z-b(s-v))^2)}{((2(4bu-k^2)x-l^2u)^2z^2)} \quad (74)$$

From equation (74), get the minimum value of the lump-sum fee F_{Min} as:

$$F_{Min} = \frac{(u(4bu-k^2)^2x^3((b(t+s)-a)z-b(s-v))^2)}{(((4bu-k^2)x-l^2u)^2(2(4bu-k^2)x-l^2u)z^2)} \quad (75)$$

On similar lines, get the result as, $\pi^{T}_{\mathrm{Re}c} \geq \pi^{D*}_{\leq \mathrm{Re}c}$

From equations (21) and (72), get the expression as:

$$\pi^{T}_{\mathrm{Re}c} = \left(\frac{(u(4bu-k^2)x^2((b(t+s)-a)z-b(s-v))^2)}{(((4bu-k^2)x-l^2u)^2z^2)}-F\right) \geq \frac{(u(4bu-k^2)x^2((b(t+s)-a)z-b(s-v))^2)}{((2(4bu-k^2)x-l^2u)^2z^2)} \quad (76)$$

From equation (76), get the maximum value of the lump sum fee F_{Max} as:

$$F_{Max} = \frac{(u(4bu-k^2)^2x^3(3(4bu-k^2)x-2l^2u)((b(t+s)-a)z-b(s-v))^2)}{(((4bu-k^2)x-l^2u)^2(2(4bu-k^2)x-l^2u)^2z^2)} \quad (77)$$

A specific lump sum fee determines the split of the surplus earnings between the MABRC and ORP. The maximum amount of the lump sum fee (F_{Max}) guarantees that the ORP will engage in the contract. Furthermore, the minimum value of the lump sum charge (F_{Min}) prohibits the TPT contract from being negative. Now, the concern is how the MABRC and ORP may decide the value of the lump sum fee. In reality, the channel members used to bargain to obtain a resolution. The TPT contract is the result of SC members' negotiation. When the ORP and MABRC agree to split the SC's overall profit, they negotiate the value of the contract parameter F , which is transferred from the ORP to the MABRC. The lump-sum charge F can be easily determined by members' relative channel bargaining power using the Nash bargaining model, which is not considered in this model. The following section presents a numerical illustration wherein the symmetric Nash bargaining concept has been followed for sharing the surplus profit as a lump sum fee, considering the equal negotiation power of the channel players.

5.4. Result & discussions

This section analyzes the study's optimal results using numerical demonstration and sensitivity analysis.

5.4.1. Numerical illustration

In this sub-section, a numerical illustration is used to analyze the performance of the established model. It facilitates achieving a managerial perspective. Table 5-2 shows the data (in appropriate units) for the parameters to analyze the performance. The optimal values of decision variables, demand, and profit functions of CSC and its channel members under the different scenarios, viz. centralized model (model C), decentralized model (model D), RS contract model (model R), and TPT contract model (model T), are shown in Table 5-3.

Table 5-2. Data of parameters

Parameter	a	b	v	k	l	s	t	u	x	z
Value	120000	20	800	50	30	100	400	100	80	0.6

Table 5-3. Optimal values under different scenarios

Comparison measure	Model D	Model C	Model R	Model T
p	5835.44	5628.57	5767.94	5628.57
q	4080.17	-	3751.1	1666.67
w	438.82	990.476	420.84	990.476
y	329.12	742.857	335	742.857
d	35105.5	79328	35733.2	79328
π_{Csc}	118425466	171682539.7	119862785.7	171682539.7
π_{Ref}	76061884.67		77421744	102690421.5
π_{Rec}	42363581.33		42441041.7	68992118.2
j			0.942	
F_{Min}				120208823.44
F_{Max}				173465897
F_{Avg} [=($F_{Min}+F_{Max}$)/2]				146837360.2

From Table 5-3, optimal decision variables, demand, and profit functions of decentralized and centralized channels can be compared and summarized in the following proposition: 5.

Proposition 5. The quality level, warranty period, retail price, and market demand for refurbished products, as well as channel profit for the centralized channel and the decentralized channel, are related as follows:

The channel profit for the centralized channel is greater than the total profit for the decentralized channel, i.e., $\pi_{\text{Csc}}^{C*} > \pi_{\text{Csc}}^{D*}$. Compared to the centralized channel, the retail price in the decentralized channel will be higher, i.e., $p^{C*} < p^{D*}$. In the decentralized channel, quality level, warranty period, and market demand for refurbished products are lower than in the centralized channel (i.e., $y^{C*} > y^{D*}$, $w^{C*} > w^{D*}$ and $d^{C*} > d^{D*}$). Thus, the channel cannot be coordinated using a decentralized model. This result aligns with the findings of Agrawal et al. (2023a). According to these findings, there is potential for the issue to be solved more effectively.

From Table 5-3, the impact of implementing the RS contract for coordinating the decentralized channel considering decisions for quality level, warranty period, and retail price of refurbished products has been observed, summarized in the following proposition 6.

Proposition 6. The RS contract can achieve a win-win outcome but cannot perfectly coordinate the channel.

The retail price under the RS contract model is more than that under a centralized channel setting and less than that under a decentralized channel, i.e., $p^{C*} < p^{R*} < p^{D*}$. The quality level under the RS contract model is lower than that in the centralized channel and higher than that in the decentralized channel setting, i.e., $y^{C*} > y^{R*} > y^{D*}$. The order of warranty period under different models is as follows: $w^{C*} > w^{D*} > w^{R*}$. The total channel profit under the RS contract is greater than that under the decentralized channel but lesser than that under the centralized channel, i.e., $\pi_{\text{Csc}}^{C*} > \pi_{\text{Csc}}^{R*} > \pi_{\text{Csc}}^{D*}$. The profits of individual players, i.e., ORP and MABRC under the RS contract model, are more than that in the decentralized channel setting (i.e., $\pi_{\text{Re}c}^{R*} > \pi_{\text{Re}c}^{D*}$ and $\pi_{\text{Re}f}^{R*} > \pi_{\text{Re}f}^{D*}$). These findings suggest that the RS contract model can create a win-win situation. This result agrees with the findings of Giri et al. (2018). However, since the total profit under Model R is less than that in Model C, Model R cannot lead to perfect coordination. As a result, there is still an opportunity for improvement regarding the issue, i.e., a more attractive contract mechanism should be developed.

From Table 5-3, the impact of the TPT contract on optimal decisions, market demand, and channel profits in CSC coordination has been observed and summarized in the following proposition: 7.

Proposition 7. The TPT contract achieves both channel coordination as well as a win-win situation.

The retail price, quality level, warranty period, and market demand under Model T are the same as in Model C. The profits of individual players, i.e., the ORP and MABRC under Model T, are more than that found in Model D, i.e., $\pi_{\mathrm{Re}c}^{T*} > \pi_{\mathrm{Re}c}^{D*}$ and $\pi_{\mathrm{Re}f}^{T*} > \pi_{\mathrm{Re}f}^{D*}$. The Sum of profits of the ORP and MABRC under Model T is equal to the profit under Model C (i.e., $\pi_{\mathrm{Re}c}^{T*} + \pi_{\mathrm{Re}f}^{T*} = \pi_{\mathrm{Csc}}^{C*}$). These findings suggest that the TPT contract can create a win-win situation and lead to perfect coordination. Thus, the TPT contract is an effective mechanism for coordinating the CSC. This result agrees with the one obtained by Hosseini-Motlagh et al. (2022) and Xu et al. (2016).

This model has used the concept of refurbishment and recycling used items and ultimately achieved zero waste. These actions positively influence the environment by reducing the use of fresh raw materials. The strategy also enhances social performance by providing jobs in the ORP.

5.4.2. Sensitivity analysis

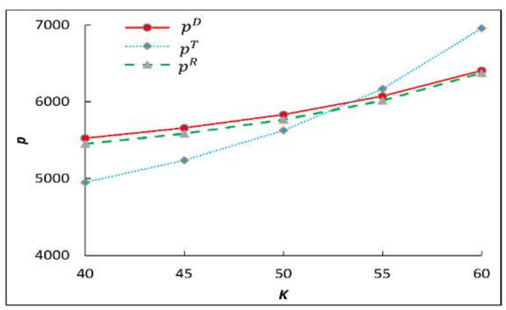
In this section, a sensitivity analysis is presented to study the effect of key parameters on the optimal decisions and profits of the proposed model. It is performed by keeping all key parameters constant except one parameter whose effects are to be observed. The sensitivity of the parameters k and u are shown in Figures 5-2 to 5-5. In the following subsections, the effects of warranty period sensitivity coefficient k and warranty investment parameter u on the channel parameters like retail price, wholesale price, warranty period, quality level, and profits of SC players under the various channel structures, i.e., centralized model (Model C), decentralized model (Model D), RS contract model (Model R) and TPT contract model (Model T), are examined. To illustrate the effects of key parameters, the average value of the lump sum fee under a two-part tariff contract has been taken.

5.4.2.1. Effects of warranty period sensitivity coefficient

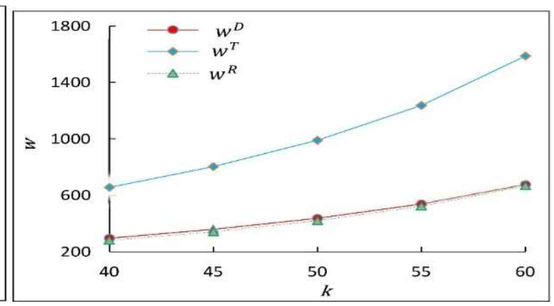
To illustrate the effects of the warranty period sensitivity coefficient k, the values of key parameters are taken as discussed in Table 5-2. To study the effects of k, its value varied from 40 to 60, and the effects are shown in Figure 5-2 and Figure 5-3.

Figure 5-2(a) shows that the retail price increases with an increase in the warranty period sensitivity coefficient k for all scenarios. However, it is observed that the retail price in Model T/Model C may be lower or higher than in Model D and Model R. When the warranty period sensitivity coefficient is large, the optimal retail price in Model T/model C is higher than in the Model D and Model R, while the optimal retail price in Model T/Model C is lower than that in the Model D and Model R when the warranty investment parameter is low. Figure 5-2(b) also shows that the warranty period increases with the sensitivity coefficient k for all scenarios. That is, the increase in warranty period sensitivity coefficient positively impacts customers. Figure 5-2(b) validates the conclusion of proposition 6 (i.e., $w^{C*} > w^{D*} > w^{R*}$). This is because with an increase in warranty period sensitivity coefficient, consumer preference towards refurbished products with increared warranty period. This motivates the ORP to improve the warranty period.

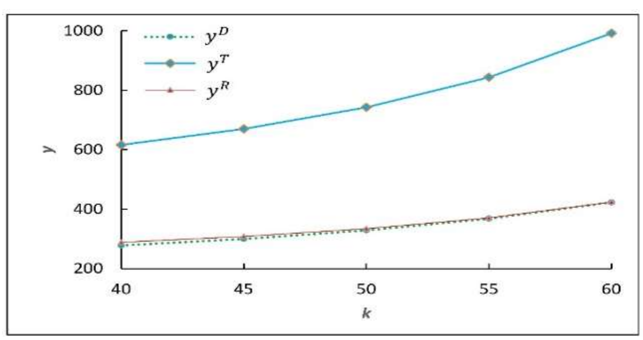
Meanwhile, the warranty period rankings are in descending order: Model T/Model C, Model D, and Model R, demonstrating that Model T may provide a longer warranty period. Figure 5-2(c) compares optimal quality levels against the warranty period sensitivity coefficient for various channel structures. Like an optimal warranty period, the quality level increases with an increase in the warranty period sensitivity coefficient k. The quality level is the highest for Model T, equal to Model C, and the lowest for Model D. Comparison of quality levels yields: $y^{C*} > y^{R*} > y^{D*}$. The result is consistent with Proposition 5.



(a)



(b)



(c)

Figure 5-2. Impact of the warranty period sensitivity coefficient k on (a) retail price, (b) warranty period, and (c) quality level

According to Figure 5-3(a), the MABRC's profit increases with the warranty period sensitivity coefficient k in all settings. The MABRC's profit is highest under Model T and lowest under Model D. A comparison of the MABRC's profit in different channel structures yields as: $\pi_{\mathrm{Re}f}^{T*} > \pi_{\mathrm{Re}f}^{R*} > \pi_{\mathrm{Re}f}^{D*}$. The result is consistent with Propositions 6 and 7. In Figure 5-3(b), the ORP's profit is compared under different models and has a similar trend to the MABRC's profit. In Figure 5-3(c), the CSC's profit is compared under different models and has a similar trend to the MABRC's profit. The warranty period sensitivity coefficient favors total SC profitability and channel performance, as shown in the numerical study scenario above. The increased warranty time encourages buyers to purchase more items, increasing market demand.

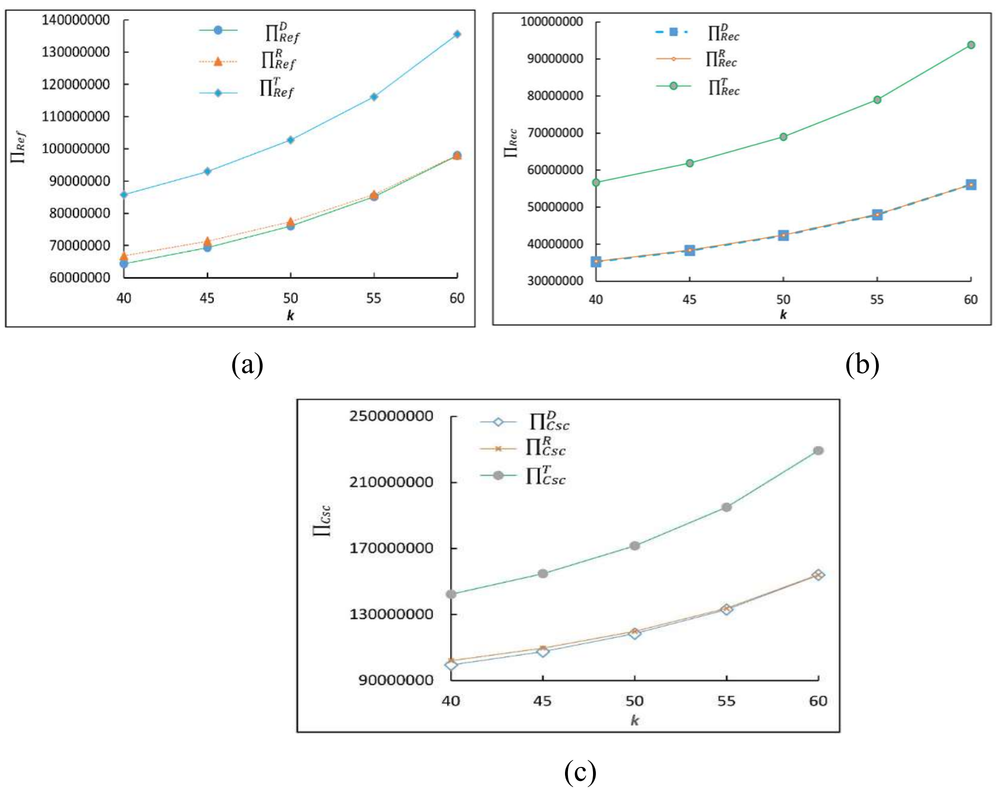


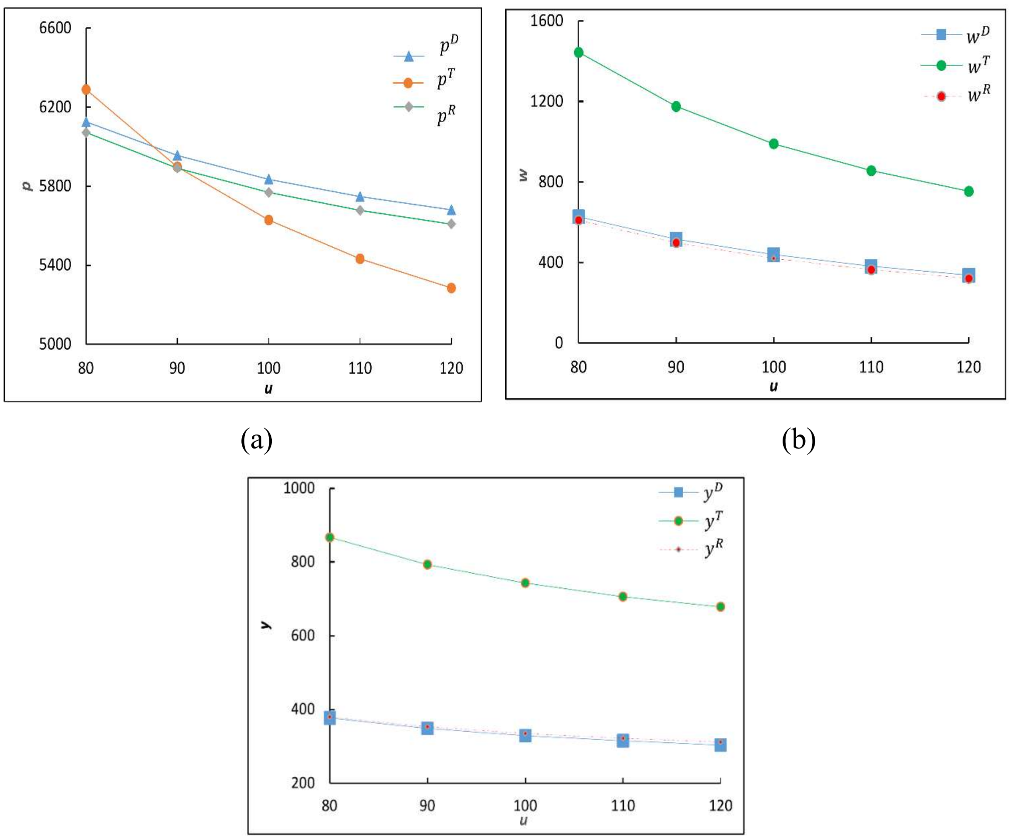
Figure 5-3. Impact of the warranty period sensitivity coefficient k on (a) the profit of MABRC, (b) the profit of ORP, and (c) the profit of CSC

As a consequence, the channel players' earnings increase. The numerical study also reveals that the RSC model may enhance the product quality level but not the warranty period compared to the decentralized model; therefore, the SC cannot be coordinated. TPT contracts have the potential to boost channel performance through optimizing channel decisions as well as improve channel player profitability. This fact demonstrates that the warranty and quality preferred consumer market offers chances for CSC participants to deliver warranty and quality level products. This will bring more advantages to SC members if the coordination system is designed appropriately. Similar results were found by Nouri-Harzvili et al. (2022), Ji et al. (2021), and Qu et al. (2021).

5.4.2.2. Effects of warranty investment parameter

To illustrate the effects of the warranty investment parameter u, the values of key parameters are taken as discussed in Table 5-2. To study the effects of u, its value varied from 80 to 120, and the effects are shown in Figure 5-4 and Figure 5-5. Figure 5-4(a) shows that the retail price decreases with an increase in the warranty investment parameter u for all scenarios. This is because the more expensive warranty investment becomes less desirable to the ORP, resulting in reduced customer demand. To attract more customers, the ORP lowers the pricing. However, an interesting observation is that retail prices in a centralized channel may be lower or higher than in a decentralized and RSC model. When the warranty investment parameter is large, the optimal retail price in a centralized channel is lower than in the decentralized and RSC models. In comparison, the optimal retail price in a centralized channel is higher than in the decentralized and RSC models when the warranty investment parameter is low.

Figure 5-4(b) also shows that the warranty period decreases with an increase in the warranty investment parameter u for all scenarios. That is, the warranty investment parameter has a negative impact on customers. This is because with an increase in warranty investment parameter, the cost of warranty increases, so, to compensate for the profit by ORP, the warranty period decreases. The warranty period is highest in Model T and equal to that of Model C, followed by Model D and Model R. The comparison of warranty level for all scenarios is as: $\omega^{C*} > \omega^{D*} > \omega^{R*}$. In Figure 5-4(c), optimal quality levels were compared against the warranty investment parameter for various channel structures. Like the optimal warranty period, the quality level also decreases with an increase in the warranty investment parameter u. The quality level is highest for Model T, equal to that of Model C, and lowest for Model D.

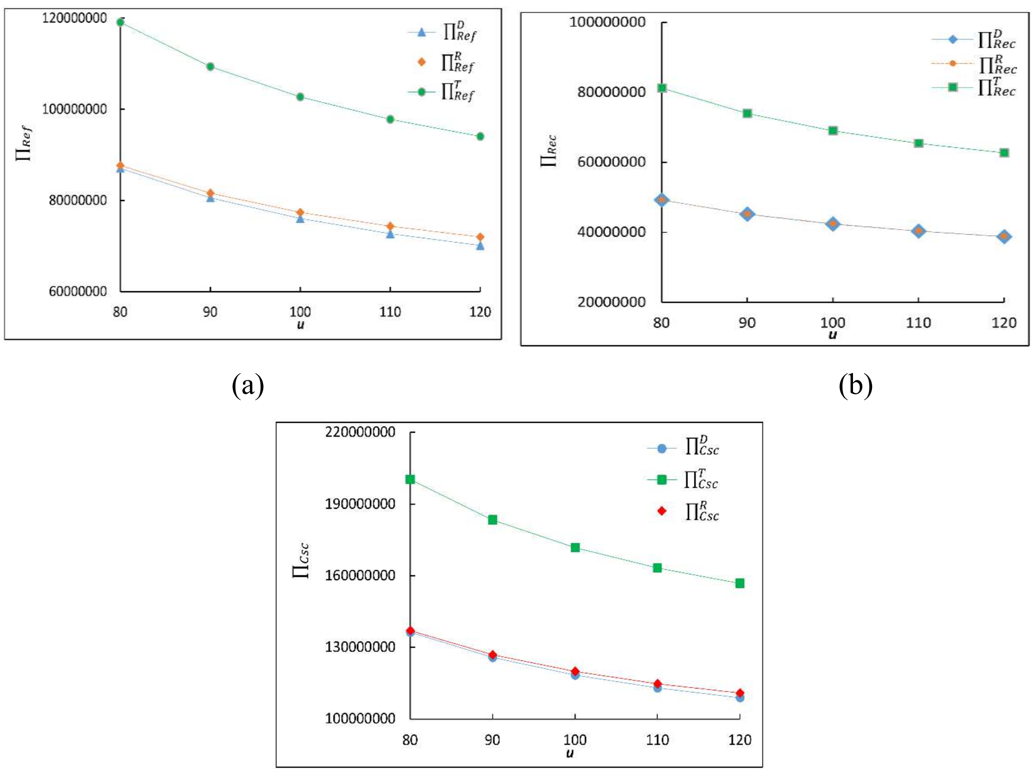


(a) (b)

(c)

Figure 5-4. Impact of the warranty investment parameter u on (a) retail price, (b) warranty period, and (c) quality level.

Comparison of quality levels yields: $y^{C*} > y^{R*} > y^{D*}$. The result is consistent with Proposition 5. According to Figure 5-5(a), the MABRC's profit decreases with the warranty investment parameter in all settings. As mentioned in the above para, the demand reduces with an increase in warranty investment parameter, so the profits of channel players decrease. The MABRC's profit is highest under model T and lowest under model D. Comparison of the MABRC's profit in different channel structures yields: $\pi_{\mathrm{Re}f}^{T*} > \pi_{\mathrm{Re}f}^{R*} > \pi_{\mathrm{Re}f}^{D*}$. In Figure 5-5(b), the ORP's profit is compared under different models, and a similar trend is found, as in the MABRC's profit. In Figure 5-5(c), the CSC's profit is compared under different models, and a similar trend is found, as in the MABRC's profit. Similar results were found by Qu et al. (2021). The result is consistent with Propositions 6 and 7.



(a) (b)

(c)

Figure 5-5. Impact of the warranty investment parameter u on (a) profit of MABRC (b) profit of ORP, and (c) profit of CSC

5.5. Managerial implications

Our research has immediate practical implications for businesses under extended producer responsibility. The findings have several implications for SC managers and policymakers operating within a CE framework in the era of Industry 4.0. First, managers must find a solution to process end-of-use products due to potential cost savings, technology innovation, global environmental consciousness, and stringent regulatory restrictions. Firms may wish to consider our findings while addressing these concerns. Second, the study finds that the mobile technology of Industry 4.0 may be used for coordination purposes. So, SC managers engaged in recommerce business may use this technology in collection work wherein CE strategies are considered. Third, refurbishment and recycling strategies may use SC managers, wherein sustainability is the goal of stakeholders. Fourth, the study also finds that key parameters (e.g., pricing, warranty period, and quality of refurbished goods) critically impact the CSC's performance. To increase SC surplus, policymakers should address the interplay between these parameters to promote commercially viable product reuse and environmentally acceptable e-waste disposal. Fifth, our results imply that all channel members can coordinate to maximize the profitability of the CSC by applying particular coordination contracts (Zheng et al., 2021b). Generally, organizations will profit from adopting a CSC approach. This allows businesses to save money and take advantage of new business opportunities while being environmentally and socially responsible.

5.5.1. Managerial insights

The results give key management insights for the two-echelon CSC to meet circularity objectives when the refurbishing firm leads and carries expanded producer responsibility. Firstly, the results prompt businesses to rethink their refurbished product price. The retail price rises with the warranty term sensitivity coefficient. When the warranty investment parameter is low, the optimum retail price in the TPT contract model is lower than in the decentralized model and RS contract model, but when the warranty period sensitivity coefficient is high, it is higher (see Figure 5-2(a)). Second, our study assists refurbishment companies in comprehending the function of refurbished product quality in regulating demand. Thirdly, this study assists recommerce companies in maintaining the product warranty of refurbished products to influence demand and retail pricing. A high-quality standard and lengthy guarantee duration might raise the demand for refurbished products. Profit levels are significantly influenced by circularity. Thus, examining realistic pricing-quality-guarantee recommerce CSC strategies is worthwhile. Finally, our analysis (see Figures 5-3 and 5-5) reveals that using a TPT contract may make the whole supply chain more profitable and place each CSC member in a win-win scenario instead of a WP contract.

5.6. Conclusion

This study uses a game-theoretic method to address the coordination issue in a CSC in the era of Industry 4.0, where market demand is a function of the retail price, warranty period, and quality of refurbished items. The TPT contract structure has been most effective in encouraging refurbishment companies to focus on quality, motivating ORPs to offer warranty services, and maximizing SC profits. It is also found that the TPT structure can perfectly coordinate the CSC with zero waste in Industry 4.0 era. Other findings show that the warranty period sensitivity coefficient and warranty investments parameter affect key decision parameters.

Four scenarios have been developed: centralized, decentralized, RS contract, and TPT contract models. Comparing the outcomes of four scenarios, the study finds that the decentralized scenario yields a lower profit than the centralized option. The centralized scenario increases the profit of the whole SC but cannot guarantee that each member will earn an acceptable profit. Under the RS contract model, the overall profit is lower than the centralized approach. CSC's earnings under the TPT contract are equivalent to its profits under the centralized model. A numerical illustration and sensitivity analysis is conducted to determine the effect of important parameters on the decisions. It is observed that the decentralized channel under the WP contract has opportunities for improvement. The channel can reach a win-win situation but cannot coordinate perfectly with an RS contract. The quality level has been improved; however, the RS contract has decreased the warranty period. The TPT contract has resulted in perfect coordination. The TPT contract has improved the quality level and warranty period. The warranty period sensitivity coefficient positively impacts channel decisions (e.g., selling price, warranty period, and quality level of refurbished product) and the profit of channel players of CSC in various channel structures. In contrast, the warranty investment parameter has a negative impact.

This study may be expanded in several ways. First, the scope of the investigation is restricted to the MABRC and the ORP. In reality, a CSC is a multi-player network. Therefore, a scenario involving several stakeholders might be a future research extension of the study. Second, information symmetry is assumed in this model. In practice, information is seldom symmetrical, influencing final decisions and the SC coordination approach. Analyzing models with asymmetric information is exciting. Third, during an examination, a constant refurbishment rate is accounted for. In actuality, the pace of refurbishment is seen to be random. Therefore, it may be advantageous for future research to examine the variable refurbishing rate. Fourth, the cost of refurbishing and the salvage value of non-refurbishable commodities are believed to be stable and predictable. To expand on this concept, the cost of refurbishing and the salvage value of non-refurbished items may rely on industry issues such as product quality and consumer willingness.

Though IoT has a huge potential to monitor the return management of goods (Mo et al., 2009), it has not been used in this model. Developing an IoT-based coordination paradigm should be the focus of future study.

CHAPTER 6: IOT-ENABLED COORDINATION FOR RECOMMERCE CIRCULAR SUPPLY CHAIN

6.1. Introduction

Industry 4.0 technologies help companies become more circular by recycling and reuse. Technological improvements aim to reduce material, energy, waste, and emissions (Laskurain-Iturbe et al., 2021). Models of the CE supported by industry 4.0 technologies enable the reusability of items at the end of their life cycle (Mastos et al., 2021). Industry 4.0 technologies include the IoT, cloud computing, artificial intelligence, machine learning, and advanced robotics (Culot et al., 2020). Technologies underlying Industry 4.0 play a crucial role in advancing CE objectives by extending the product life of End-of-Life (EoL)/End-of-Use (EoU) products (Wang and Wang, 2019; Ertz et al., 2022). The present data collection of EoL/EoU items is hampered by a broken information chain caused by customer dispersion after sales. To address these issues, IoT provides a data collection and integration solution (Pourrahmani et al., 2022). IoTs is an emerging technology developed to manage the issues of the CE idea.

The connection between CE and IoTs facilitates value creation (Ghiaci and Ghoushchi, 2023). By repurposing materials and products, the CE and IoTs can create value by improving resource efficiency, reducing waste, and creating new revenue streams (Rejeb et al., 2022a). IoT applications allow stakeholders of CE to work together more efficiently and exchange information more readily, improving decision-making. IoT comprises of Radio Frequency Identification (RFID) technology and wireless sensor networks (Lei et al., 2022). RFID and IoT sensors can increase recommerce operations and the total recovered value for Original Equipment Manufacturers (OEMs) to successfully manage returned or damaged items in the supply chain (Rejeb et al., 2020). Annual global production of electrical and electronic trash is around 50 million tonnes, of which only

20% is recycled (Ertz et al., 2022). Only 10 to 20% of sold cell phones are returned and properly disposed of, with the remainder ending up in landfills (Ullah and Sarkar, 2020). In light of the above, IoTs can potentially accelerate CE targets that have not been completely realized. Further research is required to appreciate IoTs-enabled circular strategies.

To help humanity move towards sustainable development, CE is a new business model that substitutes the "end-of-life idea" with reuse and reduces waste organization using improved product innovation (Okorie et al., 2018). The CE is described as an economic system that substitutes the idea of 'end-of-life' with reducing, reusing, recycling, and recovering resources in production and consumption processes (Kirchherr et al., 2017). CE provides businesses with novel methods to reduce resource demand, control waste with recycling and disposal, and promote sustainable production and consumption (Dantas et al., 2021). A circular perspective on energy and materials offers advantages to the economy, the environment, and society (Geissdoerfer et al., 2018). IoT generates real-time data on some processes, assisting production decisions and leading to sustainable processes, i.e., decreasing resource wastages and boosting the earth's ability for resource regeneration.

Recommerce is an online marketplace for trading and recycling pre-owned goods such as cell phones, tablets, and computers. For example, Gazelle, a recommerce company, operates in the consumer electronics market (Tang et al., 2022). The CE has emerged as a viable approach to electronic product reuse (Wang et al., 2022b). Refurbishment of electronic items is an appropriate activity that helps businesses keep their goods' value in the CE context (Chu et al., 2021). RFID is used by recycling and refurbishment businesses to boost recycling rates and identify the best EoL/EoU solution (O'Connell et al., 2013b). Despite this positive outlook, integrating circular business models in industry and society remains challenging (Fehrer and Wieland, 2021). A key part of a successful CE is coordinating the decisions of all the players in a CSC (Agrawal et al., 2023a).

The coordination contract mechanism encourages supply chain members to act in a way that fulfills the goals of the entire supply chain, such as maximizing total supply chain profit (Agrawal et al., 2023b). Contracts are structured to enhance collaboration and realize a financially sustainable business model for stakeholders (Fischer and Pascucci, 2017). Practitioners and scholars are paying more attention to the consignment contract (Tao et al., 2022). However, a single coordination contract cannot coordinate a supply chain when demand becomes price-dependent. In such a situation, a hybrid contract can coordinate the supply chain (Chiu et al., 2011; Zhang et al., 2021). Exploring a hybrid supply chain contract is complicated and challenging (Guo et al., 2017). Very few studies have been conducted on hybrid supply chain contracts.

One of the most effective policy measures for promoting CE is Extended Producer Responsibility (EPR) (Arya and Kumar, 2020). Under the EPR policy, the OEM is responsible for the whole life of a product, including collection, recycling, and reuse at the end-of-life stage (Wu et al., 2019). To fulfill the promise made to the environmental regulator under EPR, OEM utilizes IoT technologies for any device with embedded sensors and RFID tags, such as mobile phones and personal computers, to gather life cycle data to instantly identify all returned EoL/EoU goods and assess their remaining life (Ondemir and Gupta, 2014). However, the integration of the EPR with CE to recover the value from EoL/EoU items has not been explored. The hitherto unstudied coordination contract problem between the channel members of a recommerce CSC considering EPR policy must be investigated.

To close existing research gaps, this study aims to identify the coordinating decisions of IoTs-enabled recommerce CSCs in light of EPR policy under various decision-making structures. Additionally, the study explores the effects of price sensitivity on CSC performance in the age of Industry 4.0. So, to accomplish the goal, this research addresses the following questions:

Q1. Does CE's product-life extension business model fit into an IoT-based industrial setting to fulfill EPR regulations?

Q2. Which coordination mechanism would incentivize decentralized supply chain participants to operate in harmony and obtain a Pareto-equilibrium solution?

To fulfill the above objectives, in this study, a mathematical model has been developed to coordinate an IoT-enabled CSC to achieve the goal of CE through recovering value from EOL/EOU electronic products of the recommerce platform. The study investigates how a side-payment contract and a revenue-sharing consignment contract (hereinafter referred to as "consignment contract") can formulate a hybrid contract to coordinate the recommerce CSC. The decentralized channel achieves perfect coordination through the hybrid contract under a cooperative model and obtains a unique Pareto optimality. The side payment provides a solution for distributing the additional profits earned during a cooperative game model. The amount of side payment, termed as slotting fees, is paid by the IoT-enabled original equipment manufacturer (hereinafter referred to as "OEM") to the Web-based recommerce company (hereinafter referred to as "e-reseller") and determined through a bargaining process. According to the findings, a consignment contract cannot coordinate a decentralized channel. The decentralized structure achieves complete coordination and a unique Pareto optimum using the hybrid contract. The main contributions of the current study are given below:

- IoT-enabled CSC coordination: The study implements IoT technology to coordinate the CSC. Based on past studies (such as Farooque et al., 2019 and Lahane et al., 2021) done on CSC, this study creates a contract model for channel coordination to optimize a circular business. The IoT-enabled channel was used only in the forward supply chain (FSC). This study has used IoTs-enabled recommerce CSC coordination.

- Responsibility sharing: This research employs responsibility-sharing practices for the responsible disposal (recovery) of EOL/EOU electronic products under EPR (Sudusinghe and Seuring, 2021). Implementing EPR principles combined with CE has only been studied in limited studies (e.g., Liu et al., 2022). They also haven't looked at the supply chain coordination problem.
- Circular business model: The preceding study on circular business models was generic, not considering the industrial case. The present study is based on a real-world instance from the recommerce business of electronic products like smartphones.
- Hybrid contract: A novel hybrid contract, combining a side-payment contract and a consignment contract, is considered for channel coordination.

6.2. Theoretical background

This study uses a circular business model to handle the CSC coordination challenge. The study integrates three fields: application of IoT in recommerce circular business via digitalization of SC, refurbishment in the context of the recommerce business model of CE, and supply chain coordination integrating Industry 4.0 technologies. This is detailed in the next sub-sections. After that, the research gaps in the previous studies for the proposed study are placed.

6.2.1. Application of IoT in recommerce circular business via digitalization of SC

Artificial intelligence, the IoT, big data, blockchain technology, machine learning, and other sophisticated emerging technologies are being leveraged to execute Industry 4.0 to achieve long-term industry growth (Javaid et al., 2022). Digitalization may enable waste collectors to identify waste kinds, quantities, and owners without face-to-face contact by scanning barcodes on mobile phones (Kurniawan et al., 2022). The three stages of an organization's digital transformation are digitization, digitalization, and digital transformation (Verhoef et al., 2021).

Digitization is converting a firm's analog information into a digital version and transferring it (Loebbecke and Picot, 2015). Digitalization is applying technology to change company procedures (Li et al., 2016). SC digitization is not only the automation of one operation but a complete overhaul. It investigates the integration of many enterprises in the SC utilizing digital technology and modeling it leveraging digital twins. Hence, digital transformation refers to organizational-wide innovative thoughts that culminate in new business models. The amount to which an organization is digitally changed determines its readiness to execute Industry 4.0. Therefore, IoT and cloud computing were the RSC's most appropriate Industry 4.0 technologies (Krstić et al., 2022). The academic community recognizes the significance of merging CE practices and Industry 4.0 technology (Pham et al., 2019; Dantas et al., 2021). For example, de Sousa Jabbour et al. (2018) used the "Re SOLVE" framework to combine Industry 4.0 and CE concepts.

There are, however, distinctions in the possible implications of each technology (Laskurain-Iturbe et al., 2021). Various Industry 4.0 technologies have been used for different reasons within the framework of the recommerce industry. For instance, the IoT has increased the recycling efficiency of old items; artificial intelligence and industrial robots have simplified recycling operations; and blockchain technology has decreased customer worries about data loss (Wang et al., 2022b) substantially. By providing a decentralized structure for monitoring and authenticating products and resources, Blockchain technology can aid in developing more efficient and sustainable systems that benefit the environment and economy (De Giovanni, 2022; Rejeb et al., 2022b).

IoT allows data gathering across whole product life cycles to decide the best treatments to apply following product recovery, depending on their anticipated state (Delpla et al., 2022). RFID technology's primary role is to identify things that have been tagged with an RFID tag. RFID in WEEE management helps society attain the social optimum by achieving environmental objectives (Fernando and Jorge. 2015). Integrating RFID with the internet creates a system that provides real-time data on the global location and status of things (Ullah and Sarkar, 2020). IoT technology on CE activities (i.e., reuse, remanufacture, and recycle) have been considered in a variety of sectors, including the Electronic-waste industry (De Araujo et al., 2015) and the textile and clothing industry (Alves et al., 2022). The study aims to utilize IoTs technology in the recommerce business to achieve the research goals.

6.2.2. Refurbishment in the context of the recommerce business model

The CE can optimize resources, reduce raw material consumption, and recover waste by refurbishment or reusing it (Farooque et al., 2019). The aims of CSC can be achieved by reusing, refurbishing, and recycling used products (Mhatre et al., 2021). The benefits of a CE have been realized by developing and adopting various circular business models (de Kwant et al., 2021).

The recommerce business model extends the lifespan of reusable products like electronic items to reduce waste (Caro et al., 2020). Many researchers have examined the recommerce business model in CE settings, which is gaining popularity (Chu et al., 2021; Tang et al., 2022). The circular business prevents value loss of the used product by refurbishing, keeping the product in use for a longer period, and making ways for sales

(Whalen et al., 2018). The low prices of refurbished mobile phones attracted new buyers, which boosted the total demand for mobile phones. So, refurbished mobile phones don't affect the primary market for new mobile phones (Siderius and Poldner, 2021). Our goal is to optimize the parameters of the recommerce industry while adopting a refurbishment activity to meet the extended producer responsibility. The same is so far unreported in the extant literature.

6.2.3. Supply chain coordination integrating Industry 4.0 technologies

Coordination is integral to CSC management (Geissdoerfer et al., 2018). Internet use in the e-commerce industry will increase coordination efficiency by increasing the speed of decision-making (Gallaud et al., 2016). Contracts are the most effective tools among various coordination mechanisms (Agrawal et al., 2023b). The supply chain under a non-cooperative game setup cannot be coordinated perfectly through the consignment contract (Wang et al., 2004). The supply chain under a cooperative game model is coordinated perfectly by integrating the consignment contract with Nash bargaining (Li et al., 2009). The market price is higher for the non-cooperative decentralized channel than for the cooperative decentralized channel (Chen, 2013). Various researchers have investigated that a single coordination contract cannot coordinate a supply chain when demand becomes price-dependent; however, hybrid contracts provide complete coordination in this situation (Chiu et., 2011; Heydari et al., 2021; Liu et al., 2021b).

Numerous researchers have investigated SC coordination in the context of various technologies considered under Industry 4.0 (e.g., Big data (Wang et al., 2022a), Blockchain (Ding and Bai, 2022), and IoTs (Yan et al., 2017; Zheng et al., 2022). IoTs, Blockchain, and Big Data are the most debated technologies in channel coordination. Yadav et al. (2022) have identified key enablers of IoTs-enabled coordination systems.

Industry 4.0 technology helps construct a coordinated CSC (Gebhardt et al., 2022). Accordingly, IoT-enabled CSC coordination with industry 4.0 technology has been considered in the present study. Our study is unique in that it analyses the coordination difficulty the IoT-based recommerce CSC confronts during the processing of EoL/EoU electronic trash, which has not previously been covered in the literature.

6.2.4. Comparison of studies utilizing IOT in channel coordination context

Based on the background study, our observations are as follows:

- Much literature has concentrated on the issues of coordinating a supply chain, developing a recommerce circular business model, and applying IoTs in the recommerce context. However, very few studies focus on CSC coordination and even fewer look at applying a circular business strategy in an industrial setting. So far, no one has considered every possible research avenue in one go considering IoTs applications in recommerce.
- Literature discussing coordination issues using IoTs did not consider CE strategies (e.g., Li et al., 2021b; Zheng et al., 2022).
- Few literatures have discussed coordination issues utilizing game-theoretical settings and CE strategies. However, they did not use any IoTs technologies or consider EoL/EoU products for their study (e.g., Li et al., 2021a; Fang et al., 2021).

The preceding discussions illustrate that our research issues are significant yet underexplored. The difference between our study and the most relevant research that has used IoT technology in a channel coordination context is shown in Table 6-1.

Table 6-1. Comparison between this study and the most related studies using IoT technology in coordination.

Literature	Coordination mechanism	Types of SC	Industry
Zheng et al. (2022)	RS contract	FSC	Fresh products
Li et al. (2021b)	WP contract and Revenue-cost-sharing contract	FSC	General
Fang et al. (2021)	WP contract	Closed loop supply chain	Environmentally friendly goods
Sardar and Sarkar (2020)	Consignment contract	FSC	General
Yan et al. (2017)	RS contract	FSC	Fresh agriculture product
This study	Consignment contract and hybrid contract	CSC	Recommerce

6.3. Mixed Method Approach

This study uses a mixed-method research approach to explore the coordination issue of a two-tier CSC. A mixed-method research approach is one in which at least two distinct methods are used non-trivially to achieve the research objectives (Guo et al., 2020). It outperforms the single-method approach by allowing for a broader understanding of the issue and diverse views (Choi et al., 2016; Chan et al., 2020). It improves research rationality and connects research to real-world practices (Chiu et al., 2019; Choi et al., 2020).

Further, case study research is employed. Case study research is increasingly acknowledged as a valuable research technique (Yin, 2009). Our mixed-method approach includes interviews with all supply chain stakeholders (see Appendix A for more details on respondents), including a consumer, a case study, and game-theoretical modeling. This study conducted semi-structured interviews with stakeholders, including the consumer, using three sets of questionnaires (See Appendix A).

Sampling is finding and choosing a representative sample that appropriately reflects the population of interest. The chosen sample helps researchers draw significant findings and generalize the sample to the larger population. Sampling methods may differ, including probability sampling techniques and non-probability sampling approaches (Saunders et al., 2019). Given the limited number of experts in the recommerce industry and the fact that it is a relatively new industry, random sampling was not conceivable (Tieman, 2011). To attain representativeness, a non-probability purposive sampling strategy is adopted in this research. Purposive sampling entails selecting samples that are both conveniently available and willing to take part in the research. The research sample includes experts from the case study firms and consumer (Yeo et al., 2021). The validity evaluation focused on the content rather than the number of respondents (Al-Atesh et al., 2023). Limited interviews (only three samples) have been considered for the study. As for taking the inputs from a larger sample, kept it as a future study (Guo et al., 2020; Chan et al., 2020).

The questionnaires are designed for stakeholders of the proposed supply chain on common issues and involved activities in the operation of the recommerce business and the activities that top management has done to tackle these problems in a broad perspective. Similarly, questionnaires are designed to uncover consumers' broad perceptions of end-of-life and refurbished products. Second, a case study is employed of the same firm from which industry representatives were selected for the interviews

(Mohammadi et al., 2019). Third, an analytical study is conducted to derive theoretical insights based on our interviews and case study findings. The findings from interviews and a case study have improved the analytical model. Game theory is used to develop an analytical model in which decision-making interactions occur and measure the payoffs at equilibrium (Shekarian et al., 2021). Accordingly, a Stackelberg game model is developed to investigate the problem for different channel structures, namely: (i) centralized channel, (ii) decentralized channel in the non-cooperative game setting, and (iii) decentralized channel in the cooperative game setting. Further, Coordination through a hybrid contract model is developed.

6.3.1. Insights from interviews and case study

Interviews are conducted to understand how an industrial setup would implement the product-life extension business model and further use it to improve the development of the new model. Some key points from industrial interviews reflect real-world industrial practices on CSC coordination issues. First, the product-life extension business model can be used in the recommerce industry's CSC. To implement this model, the OEM collects used items from mobile phone end users in the primary market, following the guidelines of extended producer responsibility. These collected items are refurbished and resold in the secondary market by a recommerce company. In such cases, revenue-sharing contracts and two-part tariff contracts are commonly used. The coordination issue is critical when implementing a CE business model. The industry lacks an appropriate scientific mechanism to determine the best contract standards. These empirical results encourage us to investigate further the business model of extending product life to achieve a win-win situation for everyone involved in a CSC.

Furthermore, a case study is being conducted considering various serious challenges, including coordination between stakeholders in implementing EPR in India to streamline electronic waste (e-waste) to manage and dispose of used consumer electronics products effectively. The Government of India has mandated that every stakeholder in the e-waste value chain be held accountable for effective EPR under the E-Waste (Management) Rules 2016. Furthermore, millions of users in India purchase refurbished smartphones in this digital age, believing they would use an old phone with the desired features rather than a new phone with lower specifications. With the above in mind, a real case of the recommerce business operating in consumer electronics in India is investigated. Due to confidentiality issues, all channel members in this article have been renamed with different names. The Web-based recommerce platform named Beta company sells refurbished consumer electronics, including mobile phones. This company is a leading recommerce company in India with a registered office in New Delhi. It was launched in April 2013. It has 100 branches in major cities in India. This company contracts with an IoT-based original equipment manufacturer named Alpha company of reputed mobile phones to supply used mobile phones.

Further, the Beta company gets the used products from the Alpha company, refurbishes them, and reintroduces them in the secondary market via the company website as a refurbished mobile phone. Beta company has roughly 1000 employees and a revenue of approximately two million dollars. This case study examines how a product-life extension business model can be used in a CE. The coordination issue of channel players (i.e., Beta company and Alpha company) has been investigated. The case study reveals the parameters used in a real-life context in the recommerce business of smartphones.

The model variables are selected based on literature review, case study, and discussions with stakeholders through interviews (Section 3.1). Many literatures (e.g., Wang et al., 2004; Hu et al., 2017) have discussed that retail price and revenue shares of the product's retail price are considered decision variables for the consignment contract with revenue sharing. These literatures also selected cost share and total channel cost as parameters in their study. Raj et al. (2018) used slotting fees as a decision variable during the study of designing supply contracts for the sustainable supply chain using game theory. Decision variables improve supply chain coordination and performance. Other than decision variables, they also significantly impact the performance and profitability of the supply chain; however, they are directly controlled by the parties involved in the supply chain.

The parameters, such as demand sensitivity to price and total potential demand for refurbished items, are difficult to quantify (Hosseini-Motlagh et al., 2022). This information is derived from historical data of the firms evaluated in the case study, discussions with industry representatives, and previous research (Mohammadi et al., 2019; Li et al., 2009). The total potential demand for refurbished products is 100 units, and the price sensitivity of demand is 5. As a normalized cost parameter, the channel's unit variable cost is equal to 1 (Li et al., 2009; Wang et al., 2004). Based on proposition (4) of the present research, the cost share of the recommerce company is considered to be 0.75.

6.4. Analytical model development

Model development was based on insights revealed from interviews with industry representatives and a consumer and information received through a case study.

6.4.1. Model assumptions

1. A two-tier supply chain consisting of an OEM and an e-reseller that refurbishes discarded products and offers them as refurbished products in a secondary market over a single time-period.
2. The risk-neutral channel members access the same information.
3. The demand function is linearly price-dependent (Chen et al., 2008).
4. Sufficient customer returns are available with an OEM to provide them to the e-reseller for refurbishing and reselling. The unit cost of the buyback was the same for all the products used.
5. The unit cost of refurbishing is assumed to be known and constant. The unit cost of refurbishing includes transportation, cleaning, inspection, and remarketing costs.
6. Shortages are not permitted.

6.4.2. Notations used for the study

The notations used in this study are explained as follows:

p : Unit retail price of refurbished products

c : Denote the total channel cost per unit, which describes the sum of the unit acquisition cost of the used goods paid by the OEM to end-users and the unit cost of refurbishing by the e-reseller (Wang et al., 2004).

d : Market demand for refurbished items. Here, $d \geq 0$.

a : Market potential. Here, $a > 0$.

b : Consumer sensitivity to price. Here, b >0.

j : The e-reseller's revenue shares of the refurbished product's retail price. Here, $0 < j \leq 1$

f : Slotting fee

C : Centralized channel

DN : Decentralized channel under a non-cooperative setting

DC : Decentralized channel under a cooperative setting

H : Hybrid contract

O : OEM

M : Recommerce company or e-reseller

S : Circular supply chain

* : Indicates optimal model parameter values

Ω : Nash bargaining function

i : index

The cost share of the e-reseller (m) is expressed as:

$$m = \frac{\text{Unit cost of refurbishing}}{\text{Total channel cost per unit}} \quad \text{where } 0 < m \leq 1 \tag{1}$$

The expression for demand (d) is as:

$$d = a - bp \tag{2}$$

Profit function of channel player of the process (k) of supply chain model (i) = $\prod_k^i$, where i = {C, DN, DC, H} and k = {O, M, S}

Percentage of E-reseller's profit share under the decentralized channel = $(\frac{\text{E-reseller's profit share under the decentralized channel in a non-cooperat setting}}{\text{Total (supply chain) profit under the decentralized channel in a non-cooperati setting}})*100$

π_M^{DN*} : Profit of E-reseller'(M) under the decentralized channel in non-cooperative setting.

π_S^{DN*} : Profit of Supply chain (*S)* under the decentralized channel in non-cooperative setting.

The percentage of E-reseller's profit share under the decentralized channel is expressed as

$$\delta = \left(\frac{\prod_M^{DN*}}{\prod_s^{DN*}} \right) \times 100 \tag{3}$$

The percentage profit loss of the decentralized channel is expressed as

$$\theta = \left(\frac{\prod_s^{C*} - \prod_s^{DN*}}{\prod_s^{C*}} \right) \times 100 \tag{4}$$

6.4.3. Model description

The analytical model is proposed considering the findings from interviews and case study. A CSC is considered as detailed in this case study. This study considers a two-tier CSC model consisting of an OEM and an e-reseller. The OEM collects customer returns through a take-back scheme to comply with EPR guidelines.

This study considers a three-layered IoT architecture, including perception, network, and application layers (Fang et al., 2016). Various sensors and devices are used in the perception layer to collect data about the mobile phones being refurbished and recycled, such as the condition of mobile phones, including battery life and screen quality. These sensors and devices can transmit data in real-time to the OEM’s data management systems. The network layer transmits data collected in the perception layer to the application layer, which processes and analyzes the data to make decisions such as determining the optimal course of action for refurbishing or recycling mobile phones (Govindan et al., 2022). The application layer employs a range of software and applications that support the refurbishment and recycling process, such as tracking mobile phones' progress and identifying opportunities for process improvements (Domínguez-Bolaño et al., 2022). The e-reseller can use this data to optimize its refurbishment process, such as identifying common faults in mobile phones that require repair. The 3-layered IoT architecture provides real-time data on mobile phone status, enabling better decision-making and reducing supply chain inefficiencies while ensuring data privacy and security for sensitive information about refurbished and recycled phones (Voulgaridis et al., 2022). This study discusses the scenario where OEM integrates IoT devices into Recommerce CSC management.

Accordingly, the OEM uses RFID tags and sensors to track and identify products (Sharpe et al., 2018). IoT technology increases the rate of return of EoL/EoU mobile phones (Ullah and Sarkar, 2020). Information about EoL/EoU items collected through IoTs technology is shared with e-retailers, who will use this information in recovery activities (Garrido-Hidalgo et al., 2019). The OEM contracts with the e-reseller to refurbish products that customers have returned. E-reseller collects returned goods from OEM. The collected products were inspected and processed for data sanitization to clean hard drives. After data sanitization, the items underwent thorough refurbishment, if required. These items are then cleaned to preserve as much of their original appearance. They were then packed with fresh packaging that contained all of the attachments. The e-reseller finally remarkets these refurbished products through a web-based platform.

6.4.4. Model formulation and analysis

This study intends to understand the implications of channel coordination in a CSC utilizing CE's product-life extension business model. A game-theoretical approach is applied under the centralized channel, a decentralized channel with a consignment contract considering both non-cooperative and cooperative settings, and a hybrid contract model. Under the centralized channel, the decision variable is p (unit selling price). Two decision variables are considered in the decentralized channel: p and j (fraction of revenue share). Under a decentralized channel in a non-cooperative setting, the e-reseller acts as a leader and offers a consignment contract to the OEM. The OEM acts as a follower and can decide the unit selling price p to maximize her profit. Based on the above model assumptions, the following expressions are obtained:

The total variable cost, including acquisition and refurbishing = dc (5)

The acquisition cost of used products = $(1-m)cd$ (6)

Refurbishing cost of used products = mcd (7)

Total revenue received from selling refurbished products = dp (8)

The OEM's profit function is as:

$$\prod_{O}^{DN} = \left((1-j)\,p-(1-m)c\right)d \tag{9}$$

The e-reseller's profit function is as follows:

$$\prod_{M}^{DN} = \left(jp-mc\right)d \tag{10}$$

6.4.5. The Centralized channel (Model C)

In a centralized channel (hereinafter referred to as "model C"), an OEM and an e-reseller are vertically integrated with the same goal to maximize the profit of the entire supply chain and determine the corresponding optimal values of the decision variable. In a centralized channel, an OEM takes the refurbishing activity herself and sells refurbished products directly to consumers. A centralized model can resolve the double marginalization problem, a common problem in the decentralized model. The outcomes of Model C serve as a benchmark solution for subsequent analyses (Biswas et al., 2018). The profit function for the CSC is expressed as:

$$\prod_{S}^{C} = \left(p-c\right)d \tag{11}$$

Substituting Equation (2) into Equation (11), the centralized model's total profit function becomes:

$$\prod_S^C = (p-c)(a-bp) \tag{12}$$

After calculating the first derivative of Equation (12) for *p*, get the expression as follows:

$$\frac{\partial \prod_S^C}{\partial p} = a - b(2p - c) \tag{13}$$

Taking the second derivative of the centralized model's profit for *p* yields the following proposition.

Proposition 1. The unit retail price p^{C*} for a centralized channel is a unique optimal value.

Proof.

$$\frac{\partial^2 \prod_S^C}{\partial p^2} = -2b < 0 \tag{14}$$

Because the second derivative of the profit of the centralized model for *p* is always negative, the total profit of the centralized channel is concave for *p*. This indicates that for the centralized channel, a unique optimal value of the unit selling price exists.

Solving Equation (13), find the following proposition:

Proposition 2. The optimal retail price that maximizes the centralized channel profit is achieved at

$$p^{C*} = \frac{a}{2b} + \frac{c}{2} \tag{15}$$

Proof.

Equating the first-order derivative is equal to 0, obtain the expression for the optimal retail price.

After substituting Equation (15) into Equations (2) and (12), obtain the optimal demand and optimal profit under a centralized channel as:

$$d^{C*} = a - bp^{C*} = \frac{a - bc}{2} \tag{16}$$

$$\prod_{S}^{C*} = \frac{(a - bc)^2}{4b} \tag{17}$$

6.4.6. Decentralized channel under non-cooperative game setting (Model DN)

In a decentralized channel under the non-cooperative game setting (hereinafter referred to as "model DN"), an OEM and an e-reseller make decisions separately. The profits of an OEM and e-reseller in the decentralized condition can be stated in Equations (9) and (10), respectively. In this setting, the e-reseller decides the fraction of revenue (j) of the retail price, which keeps for himself, and the portion of the revenue (1- j) he shares with an OEM. An OEM sets the unit retail price depending on the decision of the e-reseller. The Stackelberg game model is used to resolve this issue. The inverse induction method is used to solve the Stackelberg equilibrium solution.

Accordingly, solve the OEM's profit function using Equation (9). Substituting Equation (2) into Equation (9) and solving for the first-order condition of Equation (9) for p, the following expression is obtained:

$$\frac{\partial \prod_{O}^{DN}}{\partial p} = b\left(\left(j-1\right)p - c\left(m-1\right)\right) + \left(j-1\right)\left(bp-a\right) = 0 \tag{18}$$

Solving Equation (9) yields the optimal price as a function of j:

$$p^{DN*}\left(j\right) = \frac{a}{2b} + \frac{c\left(1-m\right)}{2\left(1-j\right)} \tag{19}$$

Taking a further derivative of Equation (18) for p, obtain the following proposition.

Proposition 3. The unit retail price $p^{DN*}(j)$ for the decentralized channel in a non-cooperative setting is a unique optimal value.

Proof.

$$\frac{\partial^2 \prod_O^{DN}}{\partial p^2} = -2b(1-j) < 0 \tag{20}$$

Since the value of $\frac{\partial^2 \prod_O^{DN}}{\partial p^2}$ is always negative, the total profit under model DN is concave for p. This indicates that for a model DN, there exists a unique optimal value of the unit selling price $p^{DN*}(j)$.

Substituting Equation (19) into Equation (9), the profit function of the OEM is expressed as:

$$\prod_O^{DN} = \frac{\left(a - aj - bc(1-m)\right)^2}{4b(1-j)} \tag{21}$$

Substituting Equations (2) and (19) into Equation (10) and simplifying, obtain the profit function of the e-reseller as:

$$\prod_M^{DN} = \frac{\left(j^2 a - jbcm - jbc - ja + 2bmc\right)\left(aj - a - bcm + bc\right)}{4b\left(j-1\right)^2} \tag{22}$$

The first-order derivative of the profit of the e-reseller for j is expressed as follows:

$$\frac{\partial \prod_M^{DN}}{\partial j} = \frac{\left(a^2 j^3 - 3a^2 j^2 - \left(b^2 c^2 \left(m-1\right)\left(m+1\right) - 3a^2\right) j + 3b^2 c^2 m^2 - 4b^2 c^2 m + b^2 c^2 - a^2\right)}{4b\left(j-1\right)^3} = 0 \tag{23}$$

By calculating the second derivative of Equation (22) for j, derive the following proposition:

Proposition 4. (a) There exists a unique optimal value of revenue fraction j for the model DN for $0.5 < m < 1$.

Proof.

$$\frac{\partial^2 \prod_M^{DN}}{\partial j^2} = \frac{bc^2\left(m-1\right)\left(mj + j - 4m + 2\right)}{2\left(j-1\right)^4} \tag{24}$$

The e-reseller's profit function is strictly concave in j for $\frac{\partial^2 \Pi_M^{DN}}{\partial j^2} < 0$. This implies that $(mj + j - 4m + 2) > 0$ for $0 < j \leq 1$ and $0 < m \leq 1$. By solving this inequality, it is found that m should lie between 0.5 and 1, which indicates that the unit cost of refurbishing by the e-reseller is always greater than the unit acquisition cost of the used good from the end-user.

Three solutions are obtained by solving Equation (23) for *j*. Of the three, only one solution is real, and the other two are complex. Therefore, the optimum profit for the e-reseller is obtained only by the optimal real value of *j*. The optimal real value *j* is represented by Equation (25).

$$j^{DN*} = \left(\frac{b^2c^2(m-1)\sqrt{-(m-1)(b^2c^2m^3+3b^2c^2m^2+(3b^2c^2-27a^2)m+b^2c^2+27a^2}}{3^{3/2}a^3} + \frac{\frac{(3(a^2+(-3m^2+4m-1)c^2b^2}{a^2} - \frac{(3(3a^2+(-m^2+1)c^2b^2)}{a^2}}{6} + 1 \right)^{1/3} - \frac{\frac{(3a^2+(-m^2+1)c^2b^2)}{3a^2} - 1}{\left(\frac{b^2c^2(m-1)\sqrt{-(m-1)(b^2c^2m^3+3b^2c^2m^2+(3b^2c^2-27a^2)m+b^2c^2+27a^2}}{3^{3/2}a^3} + \frac{\frac{(3(a^2+(-3m^2+4m-1)c^2b^2}{a^2} - \frac{(3(3a^2+(-m^2+1)c^2b^2)}{a^2}}{6} + 1 \right)^{1/3}} + 1$$

(25)

By putting the value of j^{DN*} in Equation of $p^{DN*}(j)$, Π_O^{DN} and Π_M^{DN} , the optimal value of these functions may be found under model DN, represented by $p^{DN*}, \Pi_O^{DN*}, and\ \Pi_M^{DN*}$. Further, by setting the value of p^{DN*}, the optimal demand under the non-cooperative decentralized channel is expressed as $d^{DN*} = a - bp^{DN*}$.

Because the present model is highly complex, it is discussed with data collected through a case study: a = 100, b = 5, c = 1, and m = 0.75. For a system to work, it is studied that $p \geq c$. Table 6-2 shows the results of models C and DN.

Table 6-2. Optimal results

	$\boldsymbol{d^{C*}}$ $/\boldsymbol{d^{DN*}}$	$\boldsymbol{p^{C*}}$ $/\boldsymbol{p^{DN*}}$	$\Pi_{\boldsymbol{S}}^{\boldsymbol{C}*}$	$\Pi_{\boldsymbol{M}}^{\boldsymbol{DN}*}/$ $\Pi_{\boldsymbol{M}}^{\boldsymbol{DC}*}/$ $\Pi_{\boldsymbol{M}}^{\boldsymbol{H}*}$	$\Pi_{\boldsymbol{O}}^{\boldsymbol{DN}*}$ $/\Pi_{\boldsymbol{O}}^{\boldsymbol{DC}*}$ $/\Pi_{\boldsymbol{O}}^{\boldsymbol{H}*}$	$\Pi_{\boldsymbol{S}}^{\boldsymbol{DN}*}/$ $\Pi_{\boldsymbol{S}}^{\boldsymbol{C}*}$	$\boldsymbol{j^{DN*}}$ $/\boldsymbol{j^{DC*}}$	**Θ**	**δ**	**F**
Centralized channel	47.5	10.5	451.25	-	-	-	-	-	-	-
Non-cooperative decentralized channel	40	12	-	420	20	440	0.938	2.493	95.4	-
Cooperative decentralized channel	47.5	10.5	-	338.438	112.813	451.25	0.75	-	-	-
Hybrid contract model	47.5	10.5	-	425.625	25.625	451.25	0.75	-	-	87.188

From Table 6-2, supply chain profit under model C is higher than under model DN (i.e., $\prod_S^{C*} > \prod_S^{DN*}$). The percentage profit share of the e-reseller (δ^{DN*}) in model DN is 95.5% (Wang et al., 2004). The total profit of the supply chain in model DN is 440, which is 97.5% of the profit of model C. It represents that the percentage profit loss, Θ of the model DN, is 2.5%. These results are consistent with Wang et al. (2004). These findings reveal the potential for solving the issue using the model DN. In the next subsection, a decentralized channel based on the cooperative game model is designed to resolve this issue.

6.4.7. Decentralized channel under a cooperative game setting (Model DC)

To optimize the performance of a decentralized channel, channel participants must operate as a centralized system. Accordingly, the problem is formulated under cooperative game setting. Under the cooperative game-theoretic model, consumers and society will always benefit by setting retail prices equal to that of the centralized channel and increasing the entire channel's profit (Chen et al., 2011). In the decentralized channel under a cooperative game setting (hereinafter referred to as model DC"), the e-reseller will choose the value of the revenue fraction (j^{DC}) of the retail price to keep for himself and the rest of $(1-j^{DC})$ he shares with the OEM. By setting revenue fractions, the e-reseller induces the OEM to set the retail price p^{c*}.

The e-reseller's optimal decision is determined by taking p^{c*} equal to $p^{DN*}(j)$.

$$\frac{a}{2b}+\frac{c(1-m)}{2(1-j)}=\frac{a}{2b}+\frac{c}{2} \tag{26}$$

The optimum value of revenue fraction j for the decentralized channel under the cooperative model is determined by solving Equation (26) as follows:

$$j^{DC*}=m \tag{27}$$

Substituting Equation (27) into Equations (19), (21), and (22), and after simplification, obtain the optimal decision values and profits.

In the model DC, the optimal retail price of a refurbished product, the OEM's profit, and the e-reseller's profit are expressed as:

$$p^{C*} = p^{DC*} = \frac{a}{2b} + \frac{c}{2} \tag{28}$$

$$\prod_{O}^{DC*} = \frac{(1-m)(a-bc)^2}{4b} \tag{29}$$

$$\prod_{M}^{DC*} = \frac{m(a-bc)^2}{4b} \tag{30}$$

As per Equation (2), demand depends on the retail price, which is the same for the decentralized channel in the cooperative model and the centralized channel. Hence, the demand under the decentralized channel in a cooperative setting: $d^{DC*} = d^{C*}$

Proposition 5. The total profit of the channel under model DC with consignment contracts is the same as the optimal profit under model C.

Proof.

Summing Equations (29) and (30), obtain the total profit for the channel under model DC:

$$\prod_{S}^{DC*} = \frac{(a-bc)^2}{4b} \tag{31}$$

After comparing Equations (17) and (31), it is found that $\prod_{S}^{DC*} = \prod_{S}^{C*}$

The results achieved so far are illustrated using the same parameter values obtained through a case study. As reported in Table 6-2, the total profit of the channel under model DC with consignment contracts is the same as the optimal profit under model C. The e-reseller's profit share under the model DC (δ^{DC*}) is 0.75. The OEM gets more profit in model DC as compared to model DN; $\Pi_{O}^{DC*} = 112.813$ versus $\Pi_{O}^{DN*} = 20$, and the profit received by the e-reseller under the model DC is less than that of the model DN; $\Pi_{M}^{DC*} = 338.438$ versus Π_{M}^{DN*} = 420. In this situation, the e-seller would not accept this model. This result is in line with the discussion in Li et al. (2009). Thus, Pareto improvements were not obtained under the model DC. In this scenario, the e-reseller is reluctant to reduce its revenue fraction from 0.938 to 0.75. The OEM reacts by pricing a product higher than the optimal price under model C. A hybrid contract, a combination of a side-payment contract and a consignment contract, is considered in the next subsection to obtain Pareto improvements in the entire channel.

6.4.8. Coordination through hybrid contract model

The surplus profit is now divided using the Nash bargaining game. There may be opportunities for Pareto-improvement in the supply chain; that is, neither the recommerce platform nor the OEM would be worse off, and at least one would be better off (Panda et al., 2015). The hybrid contract negotiated through Nash bargaining is analyzed (Lippman et al., 2013).

Let Π_O^{DN*} and Π_R^{DN*} represent OEM's optimum profit and the e-reseller's optimum profit under the decentralized channel in a non-cooperative game framework. Let Π_O^H and Π_M^H represent Pareto-optimized profits of the OEM and the e-reseller under a hybrid contract model (hereinafter referred to as "model H"). Let $\Pi_S^{DN*}(= \Pi_O^{DN*} + \Pi_M^{DN*})$ and $\Pi_S^H(= \Pi_O^H + \Pi_M^H)$ represent the optimum total profit of the supply chain under model DN and the Pareto-optimized profit of the entire channel under model H. After applying the conditions of Pareto improvement, the expression is found as $\Pi_O^H \geq \Pi_O^{DN*}$and $\Pi_M^H \geq \Pi_M^{DN*}$. In addition to this, it is noted as: $\Pi_S^{DN*} < \Pi_S^H \leq \Pi_S^{C*}$.

According to the Nash bargaining model (Wei et al., 2019a; Wang and Choi, 2014), the Pareto optimal profit is obtained by maximizing the following Nash bargaining function (Ω):

$$Max\ \Omega = Max\ \left(\prod_O^H - \prod_O^{DN*}\right)\left(\prod_M^H - \prod_M^{DN*}\right) \tag{32}$$

Subject to constraints;

$$\begin{Bmatrix} \prod_O^H \geq \prod_O^{DN*} \\ \prod_M^H \geq \prod_M^{DN*} \\ \prod_s^{DN*} < \prod_S^H \leq \prod_S^{C*} \end{Bmatrix} \quad (33)$$

Let $\Pi_O^{H*}$and Π_M^{H*} represent the OEM's Pareto optimal profit and the e-reseller's Pareto optimal profit obtained under model H. The Nash bargaining model maximizes the gain of each channel member over the Nash disagreement point Π_O^{DN*} and Π_M^{DN*}. The term $(\Pi_O^H - \Pi_O^{DN*})(\Pi_M^H - \Pi_M^{DN*})$ is referred to as the symmetric Nash product. In Equation (32), Π_O^{DN*} and Π_R^{DN*}, both are constant**.** The maximum value Π_S^H is Π_S^{C*} when $p^{C*} = p^{H*}$. In such a situation, $\Pi_S^{C*} = \Pi_S^{H*}$.

The value of $\Pi_O^{H*}$is obtained by taking the first differentiation of Equation (32) for Π_O^H after replacing Π_M^H with $(\Pi_S^H - \Pi_O^H)$ and equating the resultant expression with zero and manipulating some algebraic operations. The optimal value of Π_O^H is expressed as

$$\prod_O^{H*} = \left(\prod_S^H + \prod_O^{DN*} - \prod_M^{DN*}\right) \Big/ 2 \quad (34)$$

Similarly, the optimal value of $\Pi_R^H$is expressed as;

$$\prod_R^{H*} = \left(\prod_S^H + \prod_M^{DN*} - \prod_O^{DN*}\right) \Big/ 2 \quad (35)$$

Proposition 6. The hybrid contract, a combination of a side-payment contract and a consignment contract, can coordinate model DC and achieve a win-win situation.

Proof.

The side-payment contract is coupled with a consignment contract under a decentralized channel in a cooperative model to implement the Pareto improvement concept. A side-payment contract coupled with a consignment contract is called a hybrid contract. When the supply chain operates under a model DC, then $p = p^{C*}$ and $j = m$. The only variable left to achieve Pareto optimality is the slotting fee. The slotting fee f is transferred from the advantaged party to the disadvantaged party (i.e., from the OEM to the e-reseller) under the hybrid model. The slotting fee is calculated based on a difference between profits under model H and model DC, i.e.,

$$f = \Pi_O^{DC*} - \Pi_O^{H*} = \Pi_M^{H*} - \Pi_M^{DC*}.$$

The results are illustrated below using the same parameter values as obtained through the case study. The results are presented in Table 6-2.

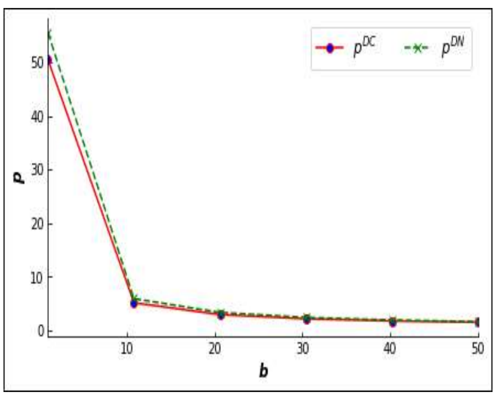
From the result, it is evident that in a decentralized channel, the optimal profit of the OEM is increased from $\Pi_O^{DN*} = 20$ to $\Pi_O^{H*} = 25.625$, and the optimal profit of the e-reseller is also increased from $\Pi_M^{DN*} = 420$ to $\Pi_M^{H*} = 425.625$ when a hybrid contract is applied. In this arrangement, the OEM will pay a slotting fee of 87.188 as a side payment to the e-reseller. Incorporating a hybrid contract led to the CSC's complete coordination and Pareto optimization. This result aligns with Chen et al.'s (2011) and Chen (2013) discussion. It is also observed that the profit share of the e-reseller under the model H (δ^{H*}) is 0.943, which is greater than 0.5. The results agree with those found by Wang et al. (2004).

6.5. Discussion of findings

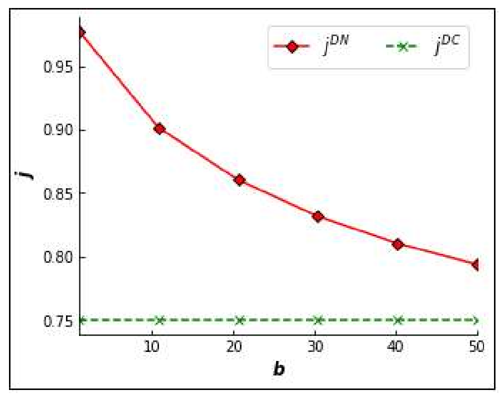
This section demonstrates how to do variable sensitivity studies and suggests further practical insights. The result through sensitivity analysis is discussed in the following section.

6.5.1. Sensitivity analysis

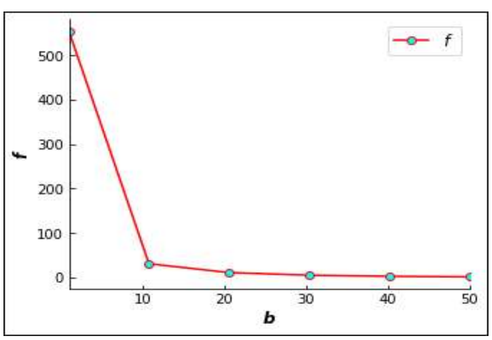
Here, a sensitivity analysis is conducted to determine how changing consumer sensitivity to price (*b*) in the proposed model affects the optimal decisions (i.e., retail price, fraction of revenue sharing, and slotting fee) and profits of channel members in four distinct channel structures: (1) a centralized channel (model C), (2) a decentralized channel in a non-cooperative game setting (model DN), (3) a decentralized channel in a cooperative game setting (model DC), and (4) a hybrid contract coordination model (model H). It is performed by keeping all key parameters constant except for one parameter whose effects are to be observed. To demonstrate the effect of price sensitivity on consumers, the following values for the relevant parameters are employed: $a = 100$, $c = 1,\ m = 0.75$. The value of *b* varies from 01 to 50; the effects are shown in Figure 6-1.



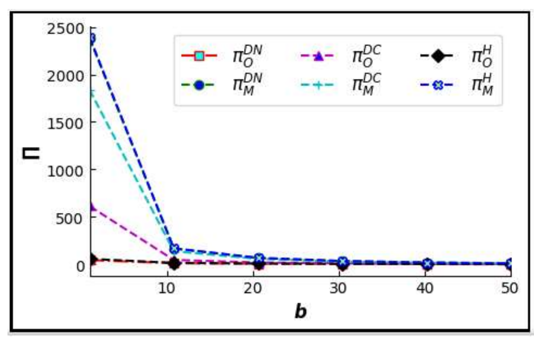
(a)



(b)



(c)



(d)

Figure 6-1 Impacts of price sensitivity *b* on the (a) optimal retail price; *p*, (b) revenue share of the e-reseller; *j*, (c) slotting fee; *f*, and (d) profits of the e-reseller and OEM; π .

Figure 6-1(a) shows that the optimal retail price decreases with an increase in the value of b. This is because demand decreases with increased consumer sensitivity to the price. The retail price must be reduced to sustain consistent market demand. Due to the lower retail price under model DC, market demand under model DC will be more than that of model DN due to lower retail price. It is also found that retail prices under model DC are lower than those under model DN (i.e., $p^{DN*} > p^{DC*}$). As shown in Figure 6-1(b), the revenue share of the e-reseller decreases with an increase in the value of b. The e-reseller under the decentralized channel tends to set a higher revenue share in the non-cooperative model than in the cooperative model ($j^{DC*} < j^{DN*}$). The e-reseller has decreased its revenue share under the model DC to set the retail price by the OEM at the optimal level for the entire channel.

Figure 6-1(c) shows that the slotting fee under model H decreases with increasing price sensitivity value b. This result aligns with the discussion in Zhang et al. (2010). According to Figure 6-1(d), as the value of b increases, the profits of all channel players in each model decrease. Profits for all stakeholders in models C, DN, DC, and H will reach zero if b increases to 100. It suggests that a product with a low price sensitivity is preferable to a high price sensitivity (Chen et al., 2021). Propositions 2, 5, and 6 can also attain an identical outcome. The profit of the e-reseller under model DN is always greater than profits under model DC but lower than profits under model H ($\Pi_M^{H*} > \Pi_M^{DN*} > \Pi_M^{DC*}$). Further, the profit of the OEM under model H is always lower than profits under the model DC but greater than the model DN ($\Pi_O^{DC*} > \Pi_O^{H*} > \Pi_O^{DN*}$). Thus, a hybrid contract can achieve perfect coordination. This finding aligns with the discussion in Chen et al. (2011).

The analysis indicates that prices and the economic capacity of technology consumers impact efficiency. However, several actions can be performed to maintain a constant demand without influencing the model's variables. These include implementing cost-saving measures in the production process, providing financing options to enhance users' economic capacity, enhancing the technology's design to increase efficiency and reduce costs, and promoting the CE to reduce waste and maximize resource use.

6.5.2. Implications

Based on the above findings, multiple implications are offered that might increase material/product circularity. The study noted that IoT implementation in the recommerce business is relevant for tracking and identifying EoL/EoU products sold by OEMs under EPR policy. The coordination of CSC has not been studied yet in the extant literature. Our study is one of the first indicating that the hybrid contract may realize CSC coordination and achieve Pareto improvement. Our study is to provide one of the first decision-making models integrating EPR with CSC. Our study will provide one of the first decision-making models of responsibility sharing for disposal (refurbishment and reselling) between the channel players, improving total supply chain profit. The findings prove that in a well-coordinated effort, nothing is wasted. Therefore, the results may be useful for managers and academics who want to increase circularity by eliminating waste. This research supports the CE's product-life extension business strategy to increase channel members' performance. Managers would learn how to implement these CE practices in their organizations. According to our findings, refurbished items may be sold at reduced prices using a hybrid contract. From the findings of this research, managers may understand that although a cooperative setup in the supply chain lowers the selling price, it cannot develop a coordinated structure without adding the side payment arrangement. The hybrid contract model may be used in supply chain logistics, manufacturing, procurement, inventory management, and service-level agreements. Hybrid contracts combine fixed-price and cost-reimbursable contracts to manage risks and reward performance. Buyers and suppliers may accomplish their objectives and work together via hybrid contracts.

6.6. Conclusion

This study investigates the coordination problem of an IoT-enabled recommerce CSC composed of an OEM and an e-reseller. This study finds a way to implement a product-life extension business model in the CE scenario in IoT-enabled recommerce CSC. A coordinated Recommerce CSC has been developed wherein each channel player gets an incentive. In this mixed-method research approach, the assumptions and findings of this study are supported by industrial practices through a case study and interviews with industry managers and a consumer. Based on the insights of industry practices done in the recovery of EOL/EOL electronic products, a Stackelberg game model was developed.

It is proved that under the decentralized channel in the non-cooperative game setting, the e-reseller tends to set a higher revenue share. The OEM is still choosing to sell a product at a higher price. As a result, demand is reduced, and overall channel profitability is reduced. A decentralized channel in a cooperative game setting generates the same profit as a centralized channel. However, the e-reseller obtains a lower profit under the cooperative model than the non-cooperative one. From this, it can be concluded that a decentralized channel cannot be coordinated through a consignment contract. Ye et al. (2022) argued that a centralized decision structure poses a high risk to the firm. Treiblmaier (2018) reported that decentralization might boost supply chain resilience and help organizations mitigate risk. From a resilience standpoint, equilibrium is the optimal state for a business. It is demonstrated that under the game-theoretical model, decision-making interactions occur and measure the payoffs at equilibrium. The decentralized channel achieves perfect coordination through the hybrid contract and achieves Pareto optimization.

Although this article has made a good research effort in CE business models, it still has some limitations, which are possible extensions for future research. The study considers two channel members: one e-reseller and one OEM. In the future, it may be interesting to consider multiple channel members considering the competition among them. Further, it is considered that all players have access to the same information. In some cases, the most critical information is private. A similar study may be carried out assuming that firms with asymmetric information, such as OEM, do not know the cost of refurbishing. IoT may be too pricey for low-value products. IoT needs further study to monitor EoL/EoU product recovery economically.

CHAPTER 7: CONCLUSION

7.1. Introduction

This chapter presents the contribution of this thesis by indicating contributions from the literature review and various studies concerning this thesis. The study investigates several different coordination mechanisms for RSC/CSC. This study will develop different coordination models for the efficient RSC/CSC. The study also assesses the influence of different coordination issues on the performance of RSC/CSC. The research investigates RSC/CSC coordination issues while taking a case study of the Indian consumer electronics sector into consideration.

7.2. Key findings from the research work

Contracts were considered the most important coordination mechanisms, followed by joint decision-making. Similar result was found by Arshinder et al. (2008). The most widely used contract is the RS contract, followed by the buyback contract, WP contract, etc. In the reviewed study, 36 articles have employed multiple coordination mechanisms to coordinate the RSC. These results are in line with the findings of Guo et al. (2017).

Measuring the effectiveness of the RSC is an important task for companies to maximize performance. Most of the authors used profit maximization as a yardstick to measure the performance of RSC. These results are in line with the findings of Rizova et al. (2020). A little research has focused on measuring channel performance through life cycle analysis, eco-footprint analysis, Triple bottom line analysis, quality analysis, and social improvement analysis.

A game-theoretic approach is used to investigate the coordination model of a two-echelon CSC. After comparing the centralized and decentralized model findings, it is observed that the decentralized model shows potential for improvement. This finding is consistent with the result of Mondal and Giri (2021). It is found that the coordinated structure can improve the performance of CSC. This finding is consistent with the result in Xu et al. (2020).

This study investigates the effects of extending product life and resource value of end-of-life/end-of-use products on channel performance in the era of Industry 4.0. However, it has been discovered that CSC lacks a sustainability effort and the application of cutting-edge technologies. The issues of channel conflicts, pricing of refurbished products, and improving the quality of refurbished items with a warranty have been addressed. The results show that the warranty period sensitivity coefficient favors total SC profitability and channel performance. The TPT contract has the potential to boost channel performance by optimizing channel decisions as well as improving channel player profitability. This fact demonstrates that the warranty and quality preferred consumer market offers chances for CSC participants to deliver warranty and quality level products. This will bring more advantages to SC members if the coordination system is designed appropriately. Similar results were found by Nouri-Harzvili et al. (2022), Ji et al. (2021), and Qu et al. (2021). It is found that the retail price, quality level, warranty period, and market demand under the TPT contract model are the same as in the centralized model. Thus, the TPT contract can create a win-win situation and lead to perfect coordination. This result agrees with the one obtained by Hosseini-Motlagh et al. (2022) and Xu et al. (2016).

A lack of coordination between channel participants is a significant hurdle to successfully adopting circular principles in the recommerce industry in India. A case study is conducted considering various serious challenges, including coordination between different stakeholders in implementing EPR in India to effectively streamline e-waste management and disposal of used consumer electronics products. The government of India has mandated that every stakeholder in the e-waste value chain be held accountable for effective EPR under the E-Waste (Management) Rules. It is found that there is a lack of sustainability initiatives and implementation of modern technology. Based on insights from interviews of stakeholders and case study findings, an analytical study is conducted to coordinate an IoTs-enabled CSC to achieve the goal of CE through recovering value from EOL/EOU electronic products of the recommerce platform. The recommerce platform achieves perfect coordination through the hybrid contract and obtains a unique Pareto optimization. This finding is in line with the discussion in Chen et al. (2011). It was found that IoTs-enabled system wherein resources are not wasted, thereby providing a way for businesses to use the CE concept to achieve sustainability goals.

7.3. Implications of the study

7.3.1. Theoretical implications

The study makes several theoretical contributions. Firstly, the study contributes to the RSC coordination literature by addressing critical issues unaddressed by previous similar work. As a result, from a scholarly standpoint, the work contributes to theory development while filling the research gap of a lack of comprehensive investigations on this subject. The study provides better knowledge and an overall image of RSC coordination through a detailed evaluation. Secondly, the study is the first to examine the issue of channel coordination of RSC/CSC considering technological development. Third, it has been shown that the centralized channel outperforms the decentralized channel. Finally, it is shown that RSC/CSC coordination has been impacted positively by technological development.

7.3.2. Practical implications

Results indicate that the RS contract cannot coordinate in a two-echelon CSC. This has managerial significance for practitioners who wish to apply for an RS contract in a similar situation. The TPT contract with the Nash bargaining model can determine the best profit-sharing system and ensure perfect coordination. CSC managers should focus on the cooperative game model. The study found that CSC coordination is critical for improving sustainability.

The mobile technology of Industry 4.0 may be used for coordination purposes. So SC managers engaged in re-commerce business may use this technology in collection work wherein CE strategies are considered. Refurbishment and recycling strategies may use SC managers, wherein sustainability is the goal of stakeholders. It is found that key parameters (e.g., pricing, warranty period, and quality of refurbished goods) critically impact the CSC's performance. To increase SC surplus, policymakers should address the interplay between these parameters to promote commercially viable product reuse and environmentally acceptable e-waste disposal. The usage of a TPT contract may make the whole supply chain more profitable and place each CSC member in a win-win scenario, as opposed to a WP contract.

The study noted that IoTs implementation in the recommerce business is very relevant for tracking and identification of EoL/EoU products sold by OEM under the EPR policy notified by the Government of India. The hybrid contract may realize CSC coordination and achieve Pareto improvement.

The findings prove that in a well-coordinated effort, nothing is wasted. Therefore, the results may be useful for managers and academics who want to increase circularity by eliminating waste. This research supports the CE's product-life extension business strategy to increase channel members' performance.

7.4. Limitations and future research

This thesis has some limitations. The study limits considering a two-echelon structure. In reality, a CSC may be a multi-player network. Therefore, considering multiple stakeholders can be an extension of the study for future research. This study assumed information symmetry. Analyzing models with asymmetric information may be considered in future research work. The study didn't consider the risk attitude of channel players, which is also observed in reality. So, the risk attitude of channel players may be considered in future studies. The current study has considered the linear demand function; a non-linear demand function may be assumed for further study. The current work has considered a deterministic demand function; a stochastic demand function may be assumed for further study.

One more possible direction for future research is to consider multiple stakeholders at the same level so that they can compete with each other. A survey may be undertaken to assess channel members' desired government incentives, and considering the survey, an intriguing extension to test the proposed models with policies of subsidizing recycling material and refurbished items and taxing virgin raw material consumption may be conducted. In normal circumstances, individuals may not always make the same decisions, so further research may be carried out considering heterogeneous consumer behavior. Blockchain technology, Artificial intelligence, and other digital technologies have a huge potential to monitor the return management of goods; however, the study has not used them. The development of a coordination paradigm based on these digital technologies should be the focus of future studies.

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Appendix

Appendix A – Industrial and Consumer Interviews

Limited and relevant interviews have been conducted with representatives from companies and consumer for this study (as listed in Table A1).

Table A1. Basic description of industry representatives and consumer and topics covered in the interview.

Interviewee	Date of interview	Description	Topics covered in the interview
Consumer: Potential customer of electronics items.			
C: Consumer	January 7, 2022	The consumer is a user of multiple items of the consumer electronics segment, including mobile phones. The consumer is aware of guidelines issued by the Government of India and social issues in and around him.	○ Awareness about possibilities to return of the used mobile phone, ○ Channel of return, ○ Availability of refurbished mobile, ○ Acceptance of refurbished mobile phone
Types of the firm: IOT-enabled-original equipment manufacturer			
OEM: General Manager	January 11, 2022	Alpha company is a big reputable original equipment manufacturer producing various consumer electronics items, including mobile phones in India. The company's business generates annual revenue of around USD 200 million. In Chennai, the company has a mobile handset manufacturing facility. Currently, the company operates approximately 500 stores and employs over 2,500 people. To comply with the extended producer responsibility guidelines, the company launched a take-back program. It collects used mobile phones from end-users in the primary market and disposes of them properly.	○ Implementation of EPR guidelines, ○ Product collection schemes, ○ Coordination issue
Types of the firm: Web-based recommerce company			
R: Additional General Manager	January, 18, 2022	The web-based recommerce company named Beta company engaged in refurbishing consumer electronics, including mobile phones, and selling them in the secondary market through an online channel. This company is a leading recommerce company in India with a registered office in New Delhi. It was launched in April 2013. It has 100 branches in different major cities of India. The total no of employees in Beta company is about 1000. The total revenue of the Beta company is around two million dollar.	○ The business model of circular economy, ○ Sales channel, ○ Processing of used products.

Appendix A1- Consumer

Q1. Which electronic devices do you replace the most? How often do you replace your electronic devices? Why do you switch electronic devices frequently?

Q2. How often do you replace your mobile phone? Why do you frequently switch mobile phones?

Q3. What happens to use mobile phones that have reached their end of life or can no longer be used by you?

Q4. Have you purchased a refurbished mobile phone? If yes, then, from where have you purchased? Why are you interested in purchasing a refurbished mobile phone?

Q5. Why are you interested in purchasing a refurbished mobile phone?

Q6. What characteristics are the most important when buying a refurbished mobile phone?

Q7. Are you aware of the effect of poor disposal of e-waste on the environment and human health?

Appendix A2- IOT-based original equipment manufacturer- General Manager

Q1. Is your company facing challenges in managing used products?

Q2. Is your company following EPR rules and regulations?

Q3. Is your company facing any problem in the execution of EPR guidelines?

Q4. Which stakeholder is responsible for the collection of used products?

Q5. Which stakeholder is responsible for the refurbishment of used products?

Q6. How you handle returned used products?

Q7. Do you have a contract with a recommerce company? Which types of contract(s) are adopted?

Q8. What are the different schemes used by other companies to collect end-of-use products under EPR in India?

Q9. Does the system include safeguards to ensure that discarded products are handled following the law and regulations during collection, sorting, dismantling, and treatment?

Q10. Is there IoT technology used in your company? If, yes, then what system have used"

Q11. Are you noticed that IoT technology benefiting your company?

Appendix A3- Web-based recommerce company – Additional General Manager

Q1. Are you following the business model of the circular economy? If yes, then which model is you using?

Q2. Which strategy is used to prolong the lifetime of used products?

Q3. Which type of problem are you facing while managing a circular supply chain?

Q4. What are the sales channels for the refurbished products?

Q5. What do you expect as a consequence of the implementation of EPR?

Q6. Is the role of different stakeholders clearly and sufficiently defined in the EPR guidelines in India?

List of Publications Based on the Research Work

(I) List of Papers Published / Accepted in International Journals

- Agrawal, S., Kumar, D., Singh, R.K. and Singh, R.K. (2023), "Coordination issues in managing the RSC: a systematic literature review and future research directions", Benchmarking: An International Journal, 30(4), 1259-1299. https://doi.org/10.1108/BIJ-08-2021-0467 **(Pub: Emerald)**
- Agrawal, S., Kumar, D., Singh, R. K., & Singh, R. K. (2023). Analyzing coordination strategy of circular supply chain in re-commerce industry: A game theoretic approach. Business Strategy and the Environment, 32(4), 1680– 1697. https://doi.org/10.1002/bse.3212 **(Pub: Wiley)**
- Kumar, D., Agrawal, S., Singh, R. K., & Singh, R. K. (2023). Coordination of circular supply chain for online recommerce platform in industry 4.0 environment: A game-theoretic approach. Operations Management Research, 16, 2081–2103. DOI: 10.1007/s12063-023-00384-x. **(Pub: Springer)**
- Kumar, D., Agrawal, S., Singh, R. K., & Singh, R. K. (2024). IoT-enabled coordination for recommerce circular supply chain in the industry 4.0 era. Internet of Things, 26. https://doi.org/10.1016/j.iot.2024.101140 **(Pub: Elsevier):** accepted for Published on 24.02.2024.

(II) List of Papers published/ Presentation made in Conference Proceedings

- D. Kumar., presented a paper titled as 'The role of government in RSC: a Bibliometric review' in the 3rd International Conference on "Recent Advances in Materials, Manufacturing and Thermal Engineering (RAMMTE-2022)" organized by Mech. Eng. Dept., DTU during 08-09 July, 2022
- D. Kumar., presented a paper titled as 'RSC coordination considering quality and warranty of a remanufactured product: A Game theoretic approach' in the 3rd International Conference on "Advances in Materials, Manufacturing and Thermal Engineering (RAMMTE-2022)" organized by Mech. Eng. Dept., DTU during 08-09 July, 2022.

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Dharmendra Kumar is currently a research scholar in Delhi Technological University, Delhi in the Department of Mechanical Engineering. He graduated from BIT Sindri, Dhanbad, Jharkhand in Mechanical Engineering and post graduated from IIT Roorkee in Production & Industrial Systems Engineering. He has more than 18 years of experience in various fields like administration, management, teaching and industry in government set up. He is presently working as Director in the Ministry of Defence, Government of India. His research interests include Industry 4.0 Technologies, Circular Economy, Supply Chain Management, and Game Theory. He has published various research articles in International Journals and Conferences.