Circular economy practices, antecedents and firm performance in the Chinese manufacturing industry

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Abstract

This thesis aims to investigate the Circular Economy (CE) practices, and their antecedents and the relationship with firm performance in the China's manufacturing industry through meta-analysis and secondary data analysis methods. This thesis consists of four essays to address the research objectives.

Essay 1 develops a conceptual model based on four themes identified through systematic literature review, and illustrates the relationship between them. Moreover, two major challenges, including circular supply chain execution and collaborative relationship building and interaction with circular supply chain execution, in the implementation of circular economy are highlighted to come up with feasible suggestions for managers in the textile and apparel industry.

Essay 2 is the first meta-analysis on the relationship between CE practices and firm performance based on 41 papers published between 2005 and 2021 in this field. The findings demonstrate that the environmental practices of CE have a positive effect on firm financial performance. Additionally, nation, firm size, and industry type also pose an impact on the relationship between CE practices and firm performance.

Essay 3 provides solid evidence on the relationship between firm-level digital transformation (DT) and CE performance by using fixed effects model with a panel dataset containing 238 Chinese listed high-tech manufacturing companies from 2006–2019. The regression results indicate that DT positively affects CE performance at the firm level. Moreover, based on institutional theory, Essay 3 further identifies that this relationship will be strengthened when the level of regional institutional development and industry competition is higher. However, the firm's political connection does not affect the DT - CE performance relationship.

Essay 4 is the first essay that provides empirical evidence for the relationship between firm-level green innovation (GI) and circular supply chain management (CSCM) adoption by using panel data regression analysis on the secondary data of 284 Chinese manufacturing companies from 2008 to 2020. The regression results indicate that GI has a positive impact on CSCM adoption at the firm level. This essay also finds that R&D level measured by the proportion of R&D personnel (RDPR) positively moderates this key connection, while financial performance measured by return on equity (ROE) does not.

Overall, the thesis makes a significant contribution to CE literature through a comprehensive literature review, identifying two antecedents (Digital transformation and Green innovation) and the relationship between CE practice and sustainability performance of a firm.

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Declaration

I declare that the thesis I have presented for examination for the PhD degree in Management of the University of York is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References. I wish to confirm that there are no known conflicts of interest associated with the studies in this thesis.

There are four essays in total.

Chapter 2: Jia, F., Yin, S., Chen, L. and Chen, X. (2020). The circular economy in the textile and apparel industry: A systematic literature review. *Journal of Cleaner Production,* 259, 120728. I am the second author of this paper, Prof. Fu Jia and I jointly selected this topic, having discussed topic and keywords with co-authors for each search string and themes. Then I collected the paper to review, scanned and coding the papers and written up the paper by myself. All coauthors provided advice and comments during the development of the work and were involved in editing the paper. A previous version of Chapter 2 was presented at PhD conference at the University of York, 2019. I contributed 40% of the whole paper.

Chapter 3 "Circular economy practices and sustainable performance: A meta-analysis" is accepted by Resources Conversation & Recycling. This paper is co-authored with Prof. Fu Jia, Prof. Lujie Chen and Qinru Wang. I am the first author of this essay, having defined the key words and coding strategy, assembled the data, identified the variables, carried out the analysis and written up the paper. All coauthors provided advice and comments during the development of the work and were involved in editing the paper. I contributed 80% of the whole paper.

Chapter 4 "Does Digital Transformation Improve Circular Economy Performance?" is under second round review in International Journal of Operations and Production Management. This paper is co-authored with Prof. Fu Jia, Prof. Lujie Chen and Mengqi Jiang. I am the first author of this essay, having defined the gaps and research questions, assembled the data, identified the variables, carried out the empirical analysis and written up the paper. All coauthors provided advice and comments during the development of the work and were involved in editing the paper. I contributed 80% of the whole paper.

Chapter 5 “Green innovation and circular supply chain management adoption” is a working paper. This paper is co-authored with Prof. Fu Jia. I am the first author of this essay, having defined the gaps and research questions, assembled the data, identified the variables, carried out the empirical analysis and written up the paper. I contributed 80% of the whole paper. Prof. Jia edited the paper, which we intend to submit it to a conference (e.g., EurOMA).

Chapter 1. Introduction

1.1. Research Background

In the fierce global competition, every firm wants its supply chain to be more sustainable from an economic, environmental, and social perspective (Nosratabadi et al., 2019). The take-make-consume-dispose model of the linear economy serves as the foundation of the conventional industrial production and consumption system (Goyal, and Ferrara, 2018), which is also named Cradle-to-Grave manufacturing and consumption (Gregson et al., 2015). The linear economic model consumes a large amount of natural resources, and produces considerable waste, while greatly polluting the environment. Thus, this model cannot be considered sustainable (Genovese et al., 2017). By 2025, the world's urban population will produce 2.2 billion tons of solid waste annually, compared with 1.3 billion tons at present (Frangoul, 2014). If the current consumption trends continue, with the unchanged methods of product sourcing, production, delivery, usage, recycling, and reclamation, the world may soon run out of numerous natural resources (Hazen, Mollenkopf and Wang, 2017). All manufacturing companies are inevitably facing the issues of waste generation and environmental deterioration (Braun et al., 2018). In order to address these concerns, the supply chain must be rapidly upgraded to a more sustainable production form, or circular economy (CE) (Homrich et al., 2018).

The concept of circular economy (CE) has been widely accepted as a superior alternative to the prevalent linear (take, make, and dispose) economic paradigm (Vinante et al., 2021; Farooque, Zhang and Liu, 2019; Upadhyay et al., 2021; Corvellec, Stowell and Johansson, 2022). The CE philosophy is developing into a significant driving force for sustainability, which has been gradually recognised as having great potential to help organisations make breakthroughs in sustainable development performance both in the literature and in practice.

The Ellen MacArthur Foundation (EMF) (2014) recommended CE as a more sustainable industrial system than the widely used make-use-dispose linear economic model (Stahel, 2016). Throughout the biological and technical cycle, CE aims to maximise the availability and value of products, components, and materials. This may entail the safely adding of nutrients or biological components back to the biosphere, thereby increasing natural capital. Similarly, geographically produced technical nutrients can be recyclable (for remanufacturing, refurbishment, and recovery), allowing them to circulate and contribute to the economy with little waste (EMF, 2013; 2014; 2017). Many governments, including China, the EU, Japan, Australia, and New Zealand, have embraced CE because of its good prospect.

As a sustainable development strategy, circular economy is thoroughly reforming the whole human activity system, which consists of consumption and manufacturing operations of supply chain (Sehnem et al., 2019). This innovative CE method is centred on 6Rs: Reuse, Reduce, Recycle, Redesign, Remanufacture, and Repair used goods and services (Ludeke-Freund, Gold, and Bocken, 2019). Supply chain is considered as the fundamental activity unit of CE implementation to support such concepts (Ripanti and Tjahjono, 2019).

Benefits may be resulted from the integration of CE into supply chain management from a sustainability standpoint (Genovese et al., 2017; Nasir et al., 2017). As a result, interest in and excitement for integrating supply chain management into CE are expanding (Ying and Li-jun, 2012; Aminoff and Kettunen, 2016; Darom and Hishamuddin, 2016; Batista et al., 2018a; Batista et al., 2019; Bressanelli et al., 2018; De Angelis, Howard and Miemczyk, 2018; Kittipanya-Ngam and Tan, 2020; Bressanelli, Perona and Saccani, 2019; Del Giudice et al., 2020; Kumar, Singh and Kumar, 2021; Govindan and Hasanagic, 2018). The research on supply chain management is still in the early stage of conceptualising how to develop supply chain theory and practice to assist in realising the goals and promise of CE.

CE is quickly emerging as a key factor in the supply chain sustainability research and practice (Nayal et al., 2022; Bag et al., 2022; Hussain and Malik, 2020), which has opened up a completely new area for sustainability in supply chain management. As a result, the supply chain now incorporates a new area of sustainability, that is, circular supply chain management (Farooque, Zhang and Liu, 2019). When moving from conventional to circular supply chains (CSC), all aspects of sustainability should be brought into consideration, including design for circularity and CSC collaboration (Farooque et al., 2019; Farooque, Zhang, and Liu, 2019), regenerative design (Franco, 2017), reverse logistic (Bernon, Tjahjono and Ripanti, 2018), closed-loop supply chain (Ponte et al., 2019), green supply chain (Liu et al., 2018a), industrial symbiosis (Patricio et al., 2018), producers liabilities and responsibility (Farooque et al., 2019), cradle-to-cradle approach (Kalmykova, Sadagopan and Rosado, 2018), packaging recovery ecosystems (Batista et al., 2018b), eco-industrial park (Zeng et al., 2017), industry 4.0 and artificial intelligence (Hidayatno, Destyanto and Hulu, 2019).

Sustainable supply chain and circular economy

The evolution of Green and sustainable supply chain management strategies in recent years aims to reduce unintentional environmental harm from manufacturing and consumption processes and to integrate environmental problems within enterprises. The industrial ecology literature and practice have embraced the circular economy paradigm, which emphasises the notion of altering products in a manner with workable interaction between ecosystems and economic growth, so as to push the boundaries of environmental sustainability. Consequently, the circular economy features the development of self-sustaining manufacturing systems in which resources can be reused. Moreover, the risk of regarding the environment as a residue can be minimised (Alkhuzaim, Zhu and Sarkis, 2021).

All supply chain operations, as well as the results of economic, social, and environmental performance, are included in sustainable supply chain management. The goal is to achieve targeted economic performance while upholding high social and ethical standards and stakeholder norms in environmental practices. For SSCM design and implementation, the integration of sustainable practices within the supply chain has taken precedence (Kusi-Sarpong et al., 2019). Sustainability performance metrics, such as resource and energy use efficiency, manufacturing effectiveness and reliability, transportation and consumption carbon footprint, waste management, and reverse logistics valuation, are taken into account in designing and evaluating production and consumption systems (Sarkis and Zhu, 2018).

Circular economy has gained traction in assisting with the addressing of environmental sustainability challenges in the increasingly complicated supply networks. In order to boost economic performance, the circular economy model focuses on lowering waste and enhancing resource efficiency (Ghisellini et al., 2016). According to Webster (2017), circular economy is a business model that aims for higher resource utilisation by keeping resources and components in a closed-loop business system. Circular economy stresses on reusing waste and end-of-life resources to create new components for the purpose of optimizing environmental and economic advantages (Murray et al., 2017). The procedures could involve recycling waste by products to make profits and to achieve industrial co-production.

The most two common mentioned concepts of CE is cradle to cradle and industrial ecology. Cradle to Cradle is a comprehensive framework with the goal of developing effective, long-lasting, and waste-free solutions, with its notion extending beyond manufacturing and design processes, in spite of the use of microscale implementations. In order to facilitate implementation, social certification standards given by Cradle-to-Cradle certied.org should be incorporated in due courses of architecture, urban planning, and infrastructure design. By far, cradle-to-cradle and CE, owing to the most similarities, are frequently used interchangeably (Esposito et al., 2017). In order to reorganise industrial processes compatible with natural ecosystems, industrial ecology should investigate industrial processes in terms of biological ecosystems (Allenby, 2000). Industrial ecology is concerned with the environmental effects of new methods, rather than merely profitability, according to the conclusion of Geyer and Jackson (2004).

Future study can benefit greatly from discoveries drawn from previous literature's junction of the SSCM and circular economy (Genovese et al., 2017). Similar paradigms have been used to explore SSCM and the circular economy, in both theory and practice (Liu et al., 2018a). The current research uses SSCM performance metrics to evaluate circular economy activities. However, conflicts and inconsistencies might persist. SSCM could not always be consistent with the growth of circular economy. For instance, a large portion of literatures on sustainable supply chains expressly aims to enhance environmental performance, hence the circular economy may be deemed successful in the absence of essential improvements.

Green supply chain management and circular economy

Circular economy (CE) and green supply chain management (GSCM) are two new sustainability ideas that somewhat overlap to work well in combination (Genovese et al., 2017; Zhu, Geng and Lai, 2011). The similar goals of GSCM and CE practices could be reflected in the concerted efforts of enhancing economic and environmental performance. Although economic performance can potentially be correlated with the notion, GSCM primarily focuses on enhancing environmental performance (Sarkis, 2012). Meanwhile, circular economy idea has been proposed as a strategy that may foster economic growth while easing resource consumption and environmental problems (Geng et al., 2009). Both GSCM and circular economy have been taken into account in previous studies (Zhu and Sarkis, 2004; Su et al., 2013; Brandenburg et al., 2014; Dubey et al., 2016; Ghisellini et al., 2016), nevertheless, conceptual and theoretical linkages should be clarified in the study literatures GSCM may be viewed as an organisational component that promotes circular economy practices in most of these studies.

Currently, the phrase "circular supply chain" is used in the published literature to refer to the incorporation of CE into the supply chain (Farooque, Zhang and Liu, 2019; De Angelis, Howard and Miemczyk, 2018; Lahane, Kant and Shankar, 2020). The application of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems is known as circular supply chain management (CSCM). Through the system-wide innovation of business models and supply chain functions from product/service design to end-of-life and waste management, circular supply chain can systematically regenerate biological materials and restore technical materials towards ‘zero waste’, while taking into account all stakeholders in the product/service life cycle, including parts/product manufacturers, service providers, consumers and users. According to Gartner's 14th Annual Global Supply Chain 25 Report 2018, the move to circular supply chains is one of the most common trends among global supply chain giants, including Apple, Coca-Cola, HP, Schneider Electric, Cisco Systems, Colgate Palmolive, and BASF. According to a well-respected Goldner study, the future of supply chains is "circular rather than linear" (Aronow, Ennis and Romano, 2018). According to a well-respected Goldner study, the future of supply chains is "circular rather than linear" (Aronow, Ennis and Romano, 2018).

CE scholars are truly enthusiastic about and increasingly interested in supply chain management (SCM) (Batista et al., 2019; Kittipanya-Ngam and Tan, 2020; Bressanelli, Perona and Saccani, 2019; Del Giudice et al., 2020; Kumar, Singh and Kumar, 2021). For instance, Awasthi et al. (2018) advocated for an e-waste recycling approach that views e-waste as an opportunity to recycle or recover important metals as the worldwide volume of e-waste rises with economic expansion. Numerous terms have been created and occasionally used interchangeably to indicate the integration of sustainability concepts in supply chain management in the literature on the subject (e.g., sustainable supply chains, green supply chains, environmental supply chains, and closed-loop supply chains) (Gurtu, Searcy and Jaber, 2015; Ahi and Searcy, 2015). Environmental/ecological implications, corporate governance, and social challenges are the focal points of green, environmental, and sustainable supply chain management methods, respectively (Batista et al., 2018b). The phrase "closed-loop supply chain" also refers to both forward and reverse supply chain operations (Govindan and Soleimani, 2017).

These existing supply chain sustainability phrases undoubtedly reflect different levels of sustainability thinking. However, only circular supply chain (Lahane, Kant and Shankar, 2020; Mastos et al., 2021; Farooque, Zhang and Liu, 2019) incorporates circular thinking (i.e., the core of CE philosophy) into SCM. CE, on the other hand, significantly enhances the story of supply chain sustainability (Batista et al., 2018b). The CE's vision of "zero waste" represents another significant distinction between circular thinking and current sustainability thinking (Veleva, Bodkin and Todorova, 2017). Because circular supply chains perceive wastage as a resource, they are created to replenish the natural capital of the biosphere. As a result, materials can be employed endlessly through the subsequent ecological cycles of plants and animals.

Industry, academics, policy-makers, and consumers have been increasingly concerned about circular economy (Bag et al., 2021a; Youn et al., 2013). In particular, it is evident that academic research is required to establish whether corporate performance activities result in desired firm performance (Kuei et al., 2013; Bag et al., 2021a). In recent decades, the awareness of sustainable and circular practices has been arising among people, organisations, and governments to create the groundwork allowing for regulatory changes and increasing demand for the transformation of a sustainable business (Taticchi et al., 2015; Soderstrom and Weber, 2020). The significance of sustainability and circular practices has been motivating researchers and practitioners to provide pertinent management tools and apply various metrics to raise the environmental standards for supply chain participants.

By managing sustainable and circular practices and related strategies, organisations have created and implemented performance indicators to evaluate the sustainability of their supply chains (Bai et al., 2020; Kazancoglu et al., 2018). From the perspective of resource-based and dynamic capabilities, the ultimate goal is to achieve a competitive advantage and to improve environmental performance (Khan et al., 2020).

The addition of inter-organisational and extended non-business performance elements facilitates sustainable supply chain management to necessitate an evolution in performance assessment in the sustainable supply chains. Such a development not only poses problems to academic research but also to practical management (Bai, et al., 2020; Nudurupati et al., 2011). In this context, accumulating evidence has demonstrated that it is crucial to incorporate multidimensional performance metrics into both concrete and abstract measures of sustainability to evaluate the overall performance of the supply chain (Taticchi et al., 2015).

The evolution of performance assessment has gone through many stages, transforming from a traditional and conventional view to a more balanced modern and strategic approach. A variety of causes, including stakeholder pressure and competitiveness, have been pressing forward such transformation (Schaltegger and Burritt, 2014). The strategic and socio-ecological viability of traditional economic measures, such as return on investment (ROI) and gross margin (Van Hoek, 1998), has been constrained, particularly for "robust sustainability" (Nikolaou et al., 2019). More thorough performance measurements are required, considering that traditional metrics may impede the anticipated advancement and practical utility of strategic planning (Jabbour et al., 2020; Tian and Sarkis, 2020).

In order to evaluate the supply chain, more balanced performance indicators, including both financial and non-financial criteria, are applied (Taschner and Charifzadeh, 2020). Consequently, a wider range of performance measures are included in the assessment criteria that cover economic, environmental, and social factors. Such an approach drifts away from traditional sustainability indicators, which are characterized by the lack of sustainability indicators and measurements at the micro or organisational level (Kristensen and Mosgaard, 2020).

Greenhouse gas (GHG) emission during supply chain activities is a typical indicator of environmental supply chain performance (Nidhi and Pillai, 2019). The other indicators are related to the ecological consequences of various supply chain activities and processes in generating a product or service (Shokravi and Kurnia, 2014). Environmental performance measurement can be used in assisting with both practice and research. The possible range of environmental performance measurements can be best illustrated by outcome metrics, such as water and energy consumption, land footprint, waste generation and hazardous emissions, and food security measures (Ardito and Dangelico, 2018; Kucukvar and Samadi, 2015; Park et al., 2016; Tian et al., 2020).

Operations, engineering, marketing, finance, human resources, information systems, and accounting are some of the organisational functions that concentrate on the particular environmental impacts requiring for certain performance measurements (Hong et al., 2019). Given that many services frequently interact with or management supply chains, a large variety of metrics are applicable. Environmental performance measurement is extensively analysed in the literature on green supply chain management, yet additional improvement could be made, according to Mollenkopf et al. (2010). The above mentioned definitions are summarised in Table 1.1 below.

Additionally, empirical research on how corporate CE practices affect firm performance has had mixed findings. For instance, Lo (2013) observed that the adoption of CE techniques in Chinese industrial enterprises does not lead to financial development, which is still at its early stage. Thus, high investment expenditures may raise firms' operational expenses and, thereby lowering their profitability. However, current research has investigated whether a favourable association between CE practices and financial advantages exists (e.g., Moric et al., 2020; Nuraini, Sarkum and Halim, 2021; Mitra and Datta, 2014).

Table 1.1 Key Definitions

Green Supply Chain Management	GSCM primarily focuses on enhancing environmental performance (Sarkis, 2012).
Sustainable Supply Chain Management	The goal of SSCM is to achieve targeted economic performance while upholding high social and ethical standards and stakeholder norms in environmental practices (Sarkis and Zhu, 2018).
Circular Economy	Circular economy idea has been proposed as a strategy that may foster economic growth while easing resource consumption and environmental problems (Geng et al., 2009).
Cradle to Cradle	Cradle to Cradle is a comprehensive framework with the goal of developing effective, long-lasting, and waste-free solutions, with its notion extending beyond manufacturing and design processes, in spite of the use of microscale implementations (Esposito et al., 2017).
Industrial Ecology	In order to reorganise industrial processes compatible with natural ecosystems, industrial ecology should investigate industrial processes in terms of biological ecosystems (Allenby, 2000). Industrial ecology is concerned with the environmental effects of new methods, rather than merely profitability, according to the conclusion of Geyer and Jackson (2004).
Environmental Performance	The possible range of environmental performance measurements can be best illustrated by outcome metrics, such as water and energy consumption, land footprint, waste generation and hazardous emissions, and food security measures (Ardito and Dangelico, 2018; Kucukvar and Samadi, 2015; Park et al., 2016; Tian et al., 2020).
Financial Performance	The strategic and socio-ecological viability of traditional economic measures, such as return on investment (ROI) and gross margin (Van Hoek, 1998), has been constrained, particularly for "robust sustainability" (Nikolaou et al., 2019). More thorough performance measurements are required, considering that traditional metrics may impede the anticipated advancement and practical utility of strategic planning (Jabbour et al., 2020; Tian and Sarkis, 2020).

1.2. Research Context: the circular economy in China

The environmental problems in China, the largest developing nation with the fastest-growing economy, have become much worse (Zhu, Sarkis and Geng, 2005). Economy (2007) showed that there has been a significant environmental degradation along with China's accession to the WTO and its recent spectacular economic expansion. Chinese organisations must launch industrial and corporate environmental management initiatives if China is to maintain its fast economic development (Tseng and Chiu, 2013; Bai, Sarkis and Dou, 2015). Since 1992, China has incorporated sustainable development into its national strategy. To improve environmental and economic performance, many Chinese manufacturers have begun to implement organisational strategies, such as environmental management systems, cleaner production, and green production (He et al., 2012; Zhu, Sarkis and Geng, 2005; Tseng et al., 2014). Chinese academics first adopted the idea of CE in 1998 (Zhu, Geng and Lai, 2010), and the central government formally endorsed it as a new development strategy in 2002. CE aims to resolve the conflict between rapid economic expansion and the lack of raw resources and energy (Su et al., 2013). The idea has been pursued by Chinese environmental policy-makers as a viable approach to resolving current environmental issues, which is rooted in the industrial ecology paradigm and is based on the closed-loop notion stressed in German and Swedish environmental policies. The government has made great efforts to guarantee that CE is used in China, although it is not a miracle cure.

Even without a generally agreed-upon definition of CE, its fundamental elements include the multistage usage of energy and raw materials and the circular (closed) flow of resources. The "3R" philosophy, which stands for "reduce, reuse, and recycle," is frequently used to define three different practical strategies (Feng, 2004). This strategy claims to reduce pollution while being economically effective. In practice, this approach requires a complete revamping of all human activity, including production and consumption processes.

To date, either the reduction of environmental pollution or the conservation of resources and energy have received most of the scholarly attention. Environmental protection is becoming more of an economic strategy than just an environmental one, as recent efforts show. The government's primary goal is to encourage sustainable social and economic growth that also helps conserve the environment.

By combining the theories and techniques of industrial economics, systems engineering, bionics, and physics, several academics have tried to create a CE paradigm (Wu, 2003). However, they encountered challenges in creating wholly innovative ideas and approaches for the analysis of industrial and social systems (Huang, 2004). In practice, industrial ecologists and specialists in related sectors have applied most of the techniques, such as life cycle assessment and material flow analysis.

In this regard, most academics studying CE are engineers with environmental, chemical, mineral processing and other backgrounds, focusing on the development of new technologies to reduce waste (Heshmati, 2017; Suchek et al., 2021; Rosa et al., 2019). Due to the lack of scientific analysis on the costs and technical viability of planned initiatives, they are technically or financially restricted and challenging to achieve. In fact, those pursuing a CE frequently take inspiration from past efforts without engaging in additional contemplation or investigation. These initial experiments, however, later served as a source of collected experience for the project and forced researchers to reconsider CE from every angle.

With the growth of CE, it is becoming more widely acknowledged that this strategy would increase resource productivity more successfully if the emphasis move away from recycling waste resources towards reorganising industries, creating new technologies, and changing industrial policy. As a result, promoting the spread of the CE across the country is the responsibility of the National Development and Reform Commission (NDRC; established by the State Council in 2004 to study and analyse China's economic situation and to develop and implement strategies, annual plans, and medium- and long-term development plans). This change indicates that the central government aims to make the development of CE a complete national policy, not just an environmental strategy, even though the State Environmental Protection Administration of China (SEPA) still plays an important role in promoting and implementing it. In this way, CE will receive a boost and play a greater role in China's economic growth as one of the country's fundamental strategies in the 21st century.

This change has had a significant influence on CE development. First, CE is being planned across the nation and are being taken more seriously at all levels of government. Second, environmental experts have improved their comprehension of environmental pollution concerns, and scholars in the domains of sociology, law, economics, and management have started to put forward their own distinct viewpoints on environmental pollution challenges. As a result, ideas such as green supply chain management and green building are becoming more well-known across the country.

The central government is drafting many rules and regulations to support the growth of CE. Accordingly, local governments are developing their own rules and directives. The Law on the Promotion of Circular Economy and the Regulations on the Management of Electronic Waste have been drafted in large part by the National Development and Reform Commission.

1.3. Research Gaps and Objectives

Over the last few decades, sustainable practices have drawn growing attention from academics, businesses, and politicians (Sadhukhan et al., 2020; Stahel, 2007). The international agreements to reduce greenhouse gas emissions, address resource shortages, and reconsider waste management has made this movement more intense than ever before (EMF, 2016; EMF, 2017; Fuso Nerini et al., 2019; Zhang et al., 2019). Contracts must comply with sustainability-related activities, and thus making the adoption of sustainable initiatives more advantageous in the market (EC, 2015; Filippini, Mazzocchi and Corsi, 2019; Juste Ruiz, 2020). Rashed and Shah (2021) believed that businesses are crucial stakeholders with the potential to speed up the sustainable practices outlined in the United Nations Agenda 2030.

The United Nations Agenda 2030 takes innovation, skilled labour, and responsiveness into the account of private sector's participation. However, private engagement, more often than not, can only yield a win-win situation for their business, society, and the environment (Scheyvens, Banks and Hughes, 2016). In this situation, industries are inclined to abandon traditional manufacturing techniques and to adopt modern ones that cater to consumer needs. They prefer to employ cutting-edge technology to achieve sustainable goals (Fuso Nerini et al., 2019).

Silvestre and Tîrca (2019) contended that innovations are necessary to attain sustainable performance. Transformations brought forth by technological advancement and innovation can yield a holistic effect from individual lives to whole supply networks and societies. Hence, advanced technologies incorporated into the Industry 4.0 (I4.0) framework and green innovation may propel progress in the direction of accomplishing sustainable goals, particularly with regard to the industrial sector (Hidayatno, Destyanto and Hulu, 2019). Similarly, the new opportunities enabled by I4.0 technologies may support the CE to achieve sustainable goals (Schroeder et al., 2019).

While maintaining socioeconomic growth, CE would encourage the minimisation of resource usage and waste, and reduce emissions (Ghisellini, Ripa and Ulgiati, 2018). Lieder and Rashid (2016) believed that resource scarcity, environmental consequences, and economic advantages are the three primary CE subjects. These three domains are clearly reflected in production activities and were formerly covered under the sustainable development banner. Through the life cycle of services and goods, this new approach seeks to reduce waste production, resource consumption, and other environmental consequences while preserving socioeconomic growth (Ghisellini, Ripa and Ulgiati, 2018; Murray, Skene and Haynes, 2017). In this way, CE is developed around the idea of system-wide change directly linked to resource extraction, waste generation, product design, environmental consciousness, innovative business models, and integrative policies (Bocken et al., 2017; Kalmykova, Sadagopan and Rosado, 2018; Korhonen, Honkasalo and Seppälä, 2018).

I4.0's proposed transition to digitalisation and development of cutting-edge technologies will surely open up new opportunities to cut down the use of raw materials, thereby maximising the yield of applied resources and shortening production cycles (Garcia-Muiña et al., 2018; Lopes de Sousa Jabbour et al., 2018; Pham et al., 2019). Therefore, the examination of the sites of convergence between digitalisation and technology innovation from a sustainability-focused perspective is essential and enlightening for decision-makers, policy-makers, and the academic community.

The potential of digital transformation (DT) to achieve CE has only been recognised by academics in recent years (e.g., Kristoffersen et al., 2021; Chauhan, Parida and Dhir, 2022; Okorie et al., 2023). Digital transformation (DT) is the process of redesigning the company model by using digital technology to produce more value and create greater possibilities (Verhoef et al., 2021). In the era of Industry 4.0, the development and application of digital technology have become one of the most widely debated topics in professional and academic circles (Li, Dai and Cui, 2020; Koh, Orzes and Jia, 2019). In the era of Industry 4.0, the main digital technologies used in DT are identified as blockchain, cloud computing, the Internet of Things (IoT), and artificial intelligence (AI) (Chen et al., 2021b). Many sectors are altering the way of managing conventional production and operations, owing to the broad use of these digital technologies, which might help with pollution reduction and productivity growth (Nasiri, Saunila and Ukko, 2022; Sheng, Feng and Liu, 2022).

Although DT has been seen as a crucial precursor to effective CE adoption (Kristoffersen et al., 2020; Antikainen, Uusitalo and Kivikytö-Reponen, 2018; Pagoropoulos, Pigosso and McAloone, 2017), its exact role remains disputable. For instance, DT might generate additional carbon dioxide emissions due to data management, considering that the adoption of those cutting-edge digital technologies will consume more energy (Cohen, 2018). A significant vacuum in the body of current research is caused by the paucity of empirical studies into the conceptual underpinnings of DT - CE connection (Alcayaga, Wiener and Hansen, 2019; Rosa et al., 2019; Uçar, Dain and Joly, 2020). The generalisability of few case studies on the subject (e.g., Ingemarsdotter, Jamsin and Balkenende, 2020) is often poor since they only concentrate on a specific company or industry. Other empirical studies on DT typically ignore CE performance, but stress how DT enhances firm-level sustainability (Sharma et al., 2021; Chen and Hao, 2022). A Gartner research of 1374 supply chain leaders found that 70% of them planned to invest in CE, but only 12% had connected their DT plans with their circular economy ambitions (Kristoffersen et al., 2020). In other words, a paucity of information on how to use DT to enhance productivity and resource efficiency for better CE results remains to be explored, and thus few research has been done on how DT affects CE.

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Due to the substantial mounting DT publications, academics are paying attention to how DT impacts organisational performance. While several research examine the beneficial impact of DT on firm performance (Nasiri, Saunila and Ukko, 2022; Chen et al., 2022b); and innovation enhancement (Nambisan, Wright and Feldman, 2019); the potential of DT on sustainability issues, particularly on CE, remains to be examined. The shift to CE is mostly facilitated by sophisticated digital technologies, including IoT and AI (Chauhan, Parida and Dhir, 2022). However, no quantitative empirical study has been conducted to explore the association between DT and CE. Instead of using a complete CE performance evaluation, the empirical study on the link between DT and environmental performance focuses on a specific environmental factor, such carbon emission (e.g., Sheng, Feng and Liu, 2022). Additionally, a large number of studies suggested that DT exposes businesses to fresh dangers, including energy waste and increasing carbon emissions (Dubey et al., 2019a). As a result, whether DT aids businesses in improving CE performance remains controversial.

Enterprises are using technological applications to initiate innovation for a greater cost-and-service efficiency in order to better implement CSCM (Chen et al., 2021b). Green innovation (GI), which has been defined as the process of creating and implementing new products and technologies to address environmental issues (Jiang et al., 2018; Sun et al., 2019; Zhang et al., 2017; Castellacci and Lie, 2017), can encourage the adoption of CSCM because it improves resource efficiency, lowers waste, conserves energy, and boosts recycling (Takalo and Tooranloo, 2021). The beneficial impact of such an innovation approach on a firm's environmental performance and sustainability has been examined recently in GI research from both theoretical and empirical perspectives (e.g., Cuerva, Triguero-Cano and Córcoles, 2014; González - Benito and González - Benito, 2006; Jabbour et al., 2019). For instance, Zailani, Amran and Jumadi (2011) described GI as the process of an ongoing search that gives every link and participant in the supply chain the chance to achieve a competitive advantage while minimising environmental damage. To uncover the beneficial impact of GI on recycling to achieve sustainability, Aid et al. (2017) interviewed managing executives from Swedish commercial and public waste management enterprises. Soewarno, Tjahjadi and Fithrianti (2019) used structural equation modelling to demonstrate how GI can create long-term competitive benefits for companies.

The relationship between GI and the adoption of CSCM is still developing. Although the beneficial effects of GI on various aspects of environmental sustainability (such as recycling, energy conservation, and emission reduction) have been frequently reported, there is no empirical data examining the direct correlation between GI and CSCM adoption at the firm level. This forms a critical research gap. Few studies focus on GI in the context of supply chains, whereas the literature based on the CE principle can better inspire broad innovation activities than GI (Takalo and Tooranloo, 2021). Although GI has the potential to create a more circular economy, Suchek et al. (2021) noted that innovation may come with extremely unaffordable price for many businesses, and thus preventing the adoption of CSCM. As a result, it is necessary to examine the association between GI and CSCM adoption as well as the influencing factors. Albort-Morant et al. (2017) analysed the variables used in empirical research, and pinpointed the issues in this area to produce information and ideas for further study. Therefore, an empirical study should be conducted to examine the function of GI in CSCM adoption, thereby motivate practitioners and policy-makers to achieve sustainability by encouraging CSCM adoption.

Although market research data indicate that the aforementioned techniques are increasingly being used (Moric et al., 2020), there seems to be a dearth of information regarding their practical application, as well as the variables that influence business acceptance and financial performance throughout the circularity production cycle (Ashby, 2018). Besides, the empirical research on how businesses apply these techniques after incorporating them into their sustainability procedures is also lacking. These deficiencies, together with the desire for a deeper theoretical foundation for comprehending the effects of existing CE practices on firm performance (Schroeder, Anggraeni and Weber, 2019; Garza-Reyes et al., 2018), have prompted the establishment of the following research questions (RQs), which I aim to answer through my thesis.

1. What are the CE practices employed by firms?
2. How do CE practice affect firm performance?
3. How do digital transformation and green innovation affect CE performance?

To answer the RQs, four essays were produced and explained in the next section.

1.4. Four Studies

In this research, four studies are conducted to investigate a variety of variables in the relationship between corporate CE practices and company performance in the setting of CE in China. Essay 1 and Essay 2 review the existing literature from different aspects, showing the understanding of CE practices that answer RQ1. Essay 2 conducts a statistical analysis on the comprehensive results of multiple empirical studies through uses meta-analysis, aiming to obtain a pooled estimate closest to the unknown common truth through statistical methods based on how this error is perceived. The relationship between CE practices and firm performance is examined in Essay 2 through a review of the literature and subsequent meta-analysis. The results show that CE's environmental practices are beneficial to both the environment and the firm performance. Thus, Essay 2 also answers RQ2, which also inspires the topic selection, and the theoretical selection of Essay 3 and Essay 4. Essay 3 and Essay 4 provide two empirical studies by using secondary data analysis. Essay 3 focuses on the antecedent of CE (DT) which answer RQ3. Essay 4 investigates the relationship between GI and CSCM adoption which answers RQ3 as well. All four investigations are connected. Each essay and its connections are presented in this section. Table 1.2 summarises the main findings of the four essays.

According to the literature review performed, sustainable supply chain management techniques have been developed to integrate environmental concerns into business by minimising the inadvertent environmental damage caused by production and sourcing procedures. Circular economy, as the inspiration for Essay 1, has also pushed the limits of environmental sustainability by emphasising the idea of novel products that successfully link ecological health and economic growth. The use of circular economy in the textile and clothing sector is discussed in Essay 1 based on the the following four themes identified by a systematic literature: drivers, impediments, practices, and sustainable performance indicators. Around these four themes, a conceptual model is created to show the relationship between them. Essay 1 identifies two key obstacles to the adoption of circular economy and offers suggestions for managers in the textile and apparel sector to overcome them. Future research directions are then suggested.

Essay 2 uses a meta-analysis methodology based on previous empirical studies. Essay 2 studies the connection between circular economy practices and firm performance. Through an assessment of the literature, 41 pertinent publications between 2005 and 2021 were found, which were then analysed through meta-analysis. The findings demonstrate that the environmental practices of CE have positive effects on the environment and company. Additionally, the findings imply that nation, company size, and industry type affect the association between corporate CE practices and firm performance. This may be the first meta-analysis on the subject to address the inconsistent findings in the body of research.

The CE practices and connections between firm performance and its ambitions for a sustainable future are explained in Essays 1 and 2. Essays 1 and 2 provide a theoretical foundation and support the topic selection of for Essays 3 and 4, which also address technical innovation, a key topic in the discussion of the acceptance and spread of CE practices.

In Essay 3, the link between digital transformation and CE performance is examined, as well as how various moderators may affect this relationship. I4.0 principles are regarded as being practically implemented via digital transformation (DT), a term for the digitalisation of the entire industrial and consumer market at the organisational level (Schroeder et al., 2019; Ghobakhloo, 2020). DT may enhance a company's resource management throughout the product lifecycle by utilising cutting-edge technologies to track component activities and make outcome data accessible. DT, which serves as an umbrella term for the organisational adoption of digital technologies, is consequently viewed as an essential condition for the effective implementation of a CE (Kristoffersen et al., 2020; Antikainen, Uusitalo and Kivikytö-Reponen, 2018; Pagoropoulos, Pigosso and McAloone, 2017). However, DT-based circular methods are currently more of a possibility than a reality, although researchers have offered examples of DTs that accomplish circularity (Nobre and Tavares, 2019; Rosa et al., 2019). A noteworthy gap in the literature is the dearth of empirical investigations on the conceptual character of DT - CE interactions (Alcayaga, Wiener and Hansen, 2019; Rosa et al., 2019; Uçar, Dain and Joly, 2020).

Essay 4 examines the link between the adoption of circular supply chains and green innovation, as well as potential moderators that may affect this relationship. Circular supply chain management (CSCM), described as "the management of supply chains and their surrounding industrial and natural ecosystems by incorporating circular thinking", has been created by academics to achieve circularity at the supply chain level (Farooque, Zhang and Liu, 2019. p.884). Companies are leveraging technological applications to seek innovations to increase cost and service efficiency to better implement CSCM (Chen et al., 2021b). In particular, green innovation (GI), which has been identified as promoting the adoption of CSCM, as it helps to improve resource efficiency, reduce waste, save energy, and increase recycling, has been defined as the process of developing and adopting new products and technologies to solve environmental problems (Jiang et al., 2018; Sun et al., 2019; Zhang et al., 2017; Castellacci and Lie, 2017; Takalo and Tooranloo, 2021).

Table 1.2 Key elements of four essays in this thesis.

Essay	Research Subject	Research Design	Sample Size	Analytical Model	Findings	Relationship with Other Papers/publishing stage
1	The circular economy in the textile and apparel Industry: A systematic literature review	Systematic literature review	109 papers	Systematic literature review	The use of the circular economy in the textile and clothing sector is discussed in this study in terms of the following four themes: drivers, impediments, practices, and sustainable performance indicators. Based on these four themes, the author creates a conceptual model that demonstrates how they are related. This paper identifies the two primary obstacles to implementing the circular economy and offer some suggestions to help managers in the textile and clothing sector overcome them.	Published in Journal of Cleaner Production (an ESI highly cited paper)
2	Circular economy practices and sustainable performance: A meta-analysis	Meta-analysis	41 papers	Meta-analysis	The results show that the environmental protection practices of CE have brought performance gains in the following two aspects: commercial and ecological. The results also show that industry type, enterprise scale, and country have a moderating effect on the relationship between CE practices and business performance. This may be the first meta-analysis on this topic, resolving the mixed results in the literature.	Accepted by Resource, Conservation and Recycling; Inspired by findings in Essay 1.
3	Does Digital Transformation Improve Circular Economy Performance?	Secondary data	238 Chinese high-tech manufacturing enterprises listed in the A-share markets of the Shanghai and Shenzhen Stock Exchanges over the 2006-2019 period.	Fixed-effects model	The regression results indicate that DT positively affects CE performance at a firm level. Moreover, this research further identifies that this relationship is enhanced when the level of regional institutional development and industry competition are higher. However, a firm's political connection does not affect the DT - CE performance relationship.	Under the second round of review with International Journal of Operations and Production Management (Revise and Re-submit). Extension of Essay 1 and Essay 2.

4	Green innovation and circular supply chain management adoption	Secondary data	284 companies in the manufacturing industry listed on the A-share markets of both the Shanghai and Shenzhen Stock Exchanges in China during the 2008–2020 period.	Regression	This paper finds that GI positively affects CSCM adoption at the firm level, and further observes that financial performance measured with return on equity (ROE) does not positively moderate the relationship between GI and CSCM adoption, while R&D level measured with the proportion of R&D personnel (RDPR) positively moderates this central relationship.	Under preparation to submit to a conference. Extension of Essay 1and Essay 2.

1.5. Research Contributions

This work contributes to the CE literature in a number of different ways.

First, regarding the circular economy, several literature evaluations have been conducted. The majority, however, have examined CE techniques at a macro level of analysis (such as the 6Rs: redesign, reduce, reuse, recycle, remanufacture, and repair); some have found distinctions between CE and sustainable supply chains (Genovese et al., 2017; Zhu, Geng and Lai, 2010). When adopting a thorough CE in manufacturing, very few studies have concentrated on CE practices and the enablers and constraints associated with them (e.g., Lieder and Rashid, 2016). Essay 1 uses a systematic literature review to identify the following four topics in the implementation of the CE in the textile and apparel industry, one of the most polluting industrial sectors: drivers, barriers, practices, and sustainable performance indicators. Based on these four themes, a conceptual model is created to show the connections between them. The essay identifies two key obstacles: (1) circular supply chain execution in the T&A industry and (2) relationship management with suppliers and stakeholders. Both are related to implementation of practices in building SSCM towards a CE. This essay provides suggestion to help managers in the textile and apparel industry overcome these obstacles. For instance, the supervisory framework should be updated, from time to time, to guarantee consistency with the innovation that the policymakers are not aware of during the period. The regulatory framework should not be restricted to the settings of specific eco-industrial parks in the same region because the development of eco-industrial parks requires a frequent technique for the implementation of CE. The research directions for the future are also revealed.

Second, the industry, academics, policy-makers, and consumers are increasingly concerned about the problems related to circular economy (Bag et al., 2021a; Youn et al., 2013). In particular, academic research is required to determine whether corporate activities would lead to expected company performance (Kuei et al., 2013; Bag et al., 2021a). Additionally, the empirical research on how corporate CE practices affect company performance has produced different findings. In Essay 2, the findings of meta-analysis offer solid proof that CE practices have a large and favourable impact on company performance. This research reveals that sample size, economic situation, industry type, and company size may be to blame for the discrepancies in this study, even though there are negative or controversial associations in the current literature from a statistic perspective. This is in line with the findings of Svensson (2007) and Walker, Di Sisto and McBain (2008). In this research, CE implementation has no significant effect on firm performance in non-manufacturing sectors, however it poses a significant effect on that of manufacturing sectors. Of these six industry categories selected in Essay 2, three showed very strong effects: oil, chemicals, and plastics ($r = 0.375$, $p = 0$), metal working ($r = 0.545$, $p = 0$) and mixed manufacturing ($r = 0.598$, $p = 0$). Such findings are in line with result of a meta-analysis conducted by Zhu, Sarkis, and Lai (2007b), which discovered that mixed industries could exert a greater impact than any single industry across all regions (Lee, Kim, and Choi, 2012). This could be attributable to the fact that mixed industries have drawn a lot of attention in terms of ecological conservation activities. Lai, Wong, and Lam (2015) pointed out that while Chinese businesses have embraced supplier collaboration in terms of circular economy practices, consumer engagement is yet to be improved. As a result, the practices of circular economy yielded huge financial benefits, but only slightly enhanced ecological and operational performance (Wong et al., 2012; Rao and Holt, 2005). Consequently, the manufacturing applications of circular economy principles is most effective on raising company performance. Several potential theories have been proposed by academics. In the industrial industry, CE practices are widely acknowledged at first (Zailani et al., 2012b). Lee, Kim, and Choi (2012) reported that the manufacturing industry is the pioneer in the use of the CE. In addition, firm performance in underdeveloped countries is more affected than that in developed regions. This supports the findings of Franco (2017) and Baxter et al. (2018). The outcomes of Essay 2 support the decision to collect data on China's manufacturing industry for an in-depth empirical analysis.

Third, there is still much debate on the relationship between CE practices and firm performance. According to Lo (2013), CE practice adoption did not result in financial development in Chinese industrial enterprises. Since CE practice adoption is still in its early stages, high investment expenses may raise operational costs for firms and therefore lower profits. However, current research has examined whether a favourable association between CE practices and financial advantages exists (e.g., Moric et al., 2020; Nuraini, Sarkum and Halim, 2021; Mitra and Datta, 2014). Given the nature of CE practices, Essay 2 also supports the idea that these practices have a greater positive effect on business performance than non-business performance for enterprises. To produce goods in an ecologically friendly manner, manufacturing companies may gain a competitive edge and make intangible profits by using CE practices, which also improves consumer loyalty and buyer–seller interactions (Franco, 2017; Baxter et al., 2018). Environmental protections must be put into place; however, doing so demands major resources and commitment that might not be immediately profitable. The intricate link between CE practices and corporate success is made clearer by this research. Consequently, Essay 2 proposes that there could be unexpected factors affecting manufacturers' CE practices and commercial performance, which prompted the additional research presented in Essays 3 and 4.

Fourth, Essay 3 presents actual data to demonstrate the association between DT and CE performance as well as the ramifications of such impact. The literature analysis in Essay 3 reveals that no thorough empirical investigation has been done to show firm-level proof of the beneficial impact of DT on CE performance. However, owing to inconsistent results in studies on DT and CE, it is important to investigate how DT effect CE performance. This study responds to the need of secondary data analysis on this subject (Chen et al., 2022a; Chauhan, Parida and Dhir, 2022; Barbieri et al., 2021). Essays 3 adds to the body of knowledge on CE performance in the research by exposing the DT - CE performance relationship at the firm level in the context of an emerging economy (in this case, China), as well as the variables affecting this relationship. The few case studies on this subject (e.g., Ingemarsdotter, Jamsin and Balkenende, 2020) usually concentrate on specific businesses or sectors, making them less generalisable. Additionally, there is debate concerning the efficacy of DT solutions. For instance, Dalenogare et al. (2018) discovered that DT had little impact on sustainability in Brazil due to the country's industry prioritising productivity above resource efficiency. The measurement of CE and DT in this essay was built by using digital technology and firm-level data on environmental activities. Additionally, the findings are added to DT and CE literatures by confirming the favourable impact of DT on CE performance. Essay 3 applies institutional theory to describe how DT impacts enterprises' CE performance in a variety of manners. Currently, no study has been performed to examine how institutional forces may moderate the connection between DT and CE performance. In order to reflect these three institutional pressures—coercive pressure, normative pressure, and mimetic pressure—that are discovered to alter the primary relationship, Essay 3 identifies three variables, including political connection, institutional development, and industrial competitiveness. This study responds to the function of institutional elements in the DT - CE connection by presenting the background that may impact on the link between DT and CE performance (Bag et al., 2021a; Chauhan, Parida and Dhir, 2022). This study is in favour of the beneficial impact of DT on CE performance at the business level, therefore it has practical ramifications. DT can help businesses to monitor their whole supply chain and production process more closely to reduce waste and to optimise resource inputs. For example, the company can enhance municipal garbage collection and disposal technologies via the use of three-dimensional (3D) printing technology and Industry 4.0. It also encourages a culture of reuse and recycling. Due to the fact that many procedures will be automated, important stakeholders may concentrate on the technical aspects of recycling and make stronger commitments to R&D and innovation. Moreover, policy-makers' understanding of how DT affects CE performance could be advanced.

Fifth, Essay 4 investigates how the adoption of CSCM relates to GI at the company level. The association between the adoption of CSCM and GI at the company level has never been empirically supported. Although academics have emphasised the beneficial impact of technological innovation in CE (e.g., Lopes de Sousa Jabbour et al., 2018; Dubey et al., 2019a), less attention has been paid to GI and empirical data demonstrating the link between GI and CSCM adoption. Regarding Essay 4, there are few empirical studies at the supply chain level that take circular economy and green innovation into account (Khanra et al., 2022). Albort-Morant et al. (2017) found that only 14 empirical studies in the Web of Science database employ GI as a study framework. Furthermore, although certain research (e.g., Takalo and Tooranloo, 2021) views green innovation as a requirement for more circular systems, no studies have shown empirical support for how green innovation affects the circular economy or CSCM. Thus, there is a need for an in-depth study of how the CE is adopted in developing nations given the major variations in economic development, environmental concerns, and policy implementation between emerging and developed economies. In the context of China, this study demonstrates the beneficial effects of GI on the adoption of CSCM, offering timely insights into CE adoption in emerging economies and motivating other emerging economies (such as Brazil and India) to encourage CE adoption and achieve sustainable development. The gap of additional empirical study is filled by this study (Chen et al., 2022a; Chauhan, Parida and Dhir, 2022; Barbieri et al., 2021). Resource base view theory (RBV) theory is used in Essay 4 to examine how various enterprises are impacted by GI. However, there exists a research vacuum in the area of CSCM, since no empirical investigation to address the possible moderating impact of GI on CSCM adoption has been performed. This essay fills this gap by responding to how the diversity of internal resources and competencies affects CSCM (Lopes de Sousa Jabbour et al., 2018). The analysis examines how financial performance and R&D level, two possible firm-level moderators, impact the main link based on RBV. By exposing GI - CSCM adoption at the company level in the context of emerging economies (i.e., China), this research contributes to the studies of sustainability and CE. This study provides certain useful applications, affirming that GI has a favourable impact on CSCM adoption at the company level. By using sophisticated green technologies, recycled goods, and renewable energy, GI may enhance green practices and increase the adoption of CSCM. Meanwhile, this study shows that the primary connection is favourably moderated by the R&D level. Therefore, the use of green technologies should be encouraged to enhance the firm's capacity for absorption. Policy-makers have a better knowledge of how GI affects the adoption of CSCM, according to the findings in Essay 4. The difficulty of sustainable development affects all humanity. The findings recommend that policy-makers continue to support corporate GI and R&D levels by devising more suitable policies to further the cause of environmental protection, without jeopardising financial stability.

1.6. Summary and Structure of the Thesis

This chapter first introduces the research background in Chapter 1.1, highlight the importance of sustainable transition and sustainable innovation, followed by an introduction of the research context (i.e., CE development in China) in Chapter 1.2. After providing a brief overview of the existing studies, Chapter 1.3 identifies several gaps in the literature, which lead to the development of research questions and statement of the research objectives. To address these research questions, Chapter 1.4 introduces the four studies, as well as their connections. The theoretical contributions of this thesis are summarised in Chapter 1.5.

The remaining parts of this thesis are structured as follows. Chapter 2 presents Essay 1 (*The circular economy in the textile and apparel industry: A systematic literature review*). Through a thorough analysis of the literature, this essay intends to pinpoint four themes—drivers, impediments, practices, and measures of sustainable performance—when implementing a circular economy in the textile and clothing industry. Essay 2 (*Circular economy practices and sustainable performance: A meta-analysis*) is presented in Chapter 3. This essay aims to investigate the relationship between circular economy (CE) practices and firm performance based on existing empirical studies by adopting a meta-analysis method. Essay 3 (*Does Digital Transformation Improve Circular Economy Performance?*) is located in Chapter 4. This essay analyses panel data from 2006–2019 on 238 Chinese listed high-tech manufacturing companies. The regression results indicate that DT positively affects CE performance at the firm level. Moreover, this research further identifies that this relationship is enhanced when the level of regional institutional development and industry competition are higher. However, a firm's political connection does not affect the DT - CE performance relationship. Chapter 5 presents Essay 4 (*Green innovation and circular supply chain management adoption*). This essay focuses on the antecedents of and influencing mechanism for GI in CSCM adoption, which is one direction of circularity development. The final chapter (Chapter 6) summarises the key findings derived from the four essays, followed by a discussion of the theoretical contributions and practical implications, as well as the directions for future research.

Chapter 2. The Circular Economy in the Textile and Apparel Industry: A Systematic Literature Review

Abstract

Over the past few decades, sustainable supply chain management practices have been developed to incorporate ecological issues into business by decreasing unintentional destructive effects on the environment in the process of manufacturing and purchasing. At the same time, circular economies push the boundaries of environmental sustainability by highlighting the notion of innovative goods, creating a viable relationship between ecosystems and economic growth. Through a systematic literature review, this paper identifies four themes—drivers, barriers, practices, and indicators of sustainable performance when applying a circular economy in the textile and apparel industry. We establish a conceptual model based on these four themes, which illustrates the relationship between them. We highlight two main challenges in circular economy implementation and provide some suggestions for managers in the textile and apparel industry. We conclude by suggesting several future research directions.

Keywords: circular economy; closed-loop supply chain; literature review; sustainable supply chain; textile and apparel industry

2.1 Introduction

The circular economy (CE) is an industrial economy targeting enriched sustainability through restorative objects and design (Ghisellini, Cialani and Ulgiati, 2016). Ashby (2018) stated that the core of CE is recovering value from tangible commodities through a narrower closed-loop of reuse and restoration which could increase both economic and environmental performance to recycling and energy recovering. In circular economy, the notion of waste could be reduced by redesigning products, manufacturing procedures, and supply chains to keep resources continuously flowing in a closed loop.

In this regard, Van Wassenhove and Guide (2009, p.10) defined closed-loop supply chains as: “the design, control, and operation of a system to maximise value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time”. Some researchers likened these loops to the manufacturing metabolism (McDonough and Braungart, 2002a; Ellen McArthur Foundation, 2013). Savaskan, Bhattacharya and Van Wassenhove (2004) proposed that a comprehensive review of the entire manufacturing supply chain is an essential step towards a more environmentally friendly and sustainable production system based on resource reuse and remanufacturing (Svensson, 2007; Angelis-Dimakis, Alexandratou and Balzarini, 2016). Such a model can be built on a cradle-to-cradle basis, inspiring the use of technologies and bio-nutritive raw materials that have no damaging influence on ecosystems (Braungart, McDonough and Bollinger, 2007).

However, Sarkis, Zhu and Lai (2011) explained that CE represents the boundary of environmental sustainability by creating awareness about transforming commodities in a way that develops an effective relationship between environmental protection and economic development (Francas and Minner, 2009). This may be accomplished through the revenue stream redesign on the basis of long-term economic development and innovation (Mutingi, 2013). It has been stated that the CE is not only focused on decreasing landfill residuals (Dubey et al., 2019b) or delaying the cradle-to-cradle grave material flows; but also is concerned with the establishment of a metabolism that allows for approaches to manufacture that are self-sustaining and true to nature, and for resources to be recycled over and over again (McDonough and Braungart, 2002b).

Lowe (1993) found that the notion of green and sustainable supply chain management (SSCM) has grown in parallel with the CE (though there are some essential differences in their principles), which has appeared in the manufacturing ecosystem literature for the last ten years. SSCM seeks to combine various eco-friendly interests into associations by minimising resource flows and decreasing the unintended destructive effects of supply chain operations practices (Srivastava, 2007).

Methods to associate SSCM approaches with CE ethics are important because there are restrictions of ecological sustainability methods. Moreover, the CE has a principal focus on resource flows through commercial procedures (Matos and Hall, 2007). Thus, further vital problems like the acceptance of eco-friendly effects (e.g., those associated with energy efficiency and air pollution emissions) and the implications of other effects are unsolved from a social sustainability perspective.

The textile and apparel (T&A thereafter) industry is one of the most crucial customer merchandise industries with a long supply chain (EURATEX, 2017). It is also regarded as one of the world's most polluting industries (Fieldson and Rai, 2009). For instance, apparel manufacturing requires enormous volumes of energy and water in fabric production. Pollution is another initial problem in the T&A industry. Without proper treatment before discharge, wet processing wastewater contains harmful chemical substances which can lead to serious ecological damage by polluting waste gas, wastewater and the fabric itself (Alkaya and Demirer, 2014; Hasanbeigi and Price, 2015).

The problems outlined above are common in the T&A supply chain across domains including design, source procurement, fiber and clothing production, packing and delivery, usage and restoration, and waste management (Lorek and Spangenberg, 2014). Boscacci (2018) believed that the input and output of the fashion industry's "textile product life cycle" had an influence on the environment, but the scale of the effect was astonishing. Boscacci (2018) stated that part of the reason is the huge scale of the T&A industry, which is believed to be a $1.3 trillion industry, and the third largest manufacturing industry in the world, after automobiles and technology (House of Commons Environmental Audit Committee, 2019). Moreover, Ellen MacArthur Foundation (2017) published a report confirming that the greenhouse gas emissions from T&A production exceed the combined emissions from international aviation and maritime transport. If emission of T&A industry continues along this path, it is expected that it will account for a quarter of the world's carbon emissions by 2050 (Ellen MacArthur Foundation, 2017). Further, the annual carbon footprint of the fashion industry's product life cycle (3.3 billion tons of CO_2 emissions) is almost equal to the carbon footprint of the EU's 28 countries / regions (3.5 billion tons) (House of Commons Environmental Audit Committee, 2019). This demonstrates the difficulties in adjusting the circularity of the T&A supply chain through sustainable innovation, which is worthy of studying.

The objective of this paper is therefore to discover the present state of research concerning SSCM toward a CE in the T&A industry. Throughout this systematic literature review, we summarise enablers and barriers in the application of a circular supply chain; list practices in different supply chain stages; and identify some indicators for evaluation of sustainable performance in a CE oriented sustainable supply chain in the textile industry.

Some literature reviews have focused on the CE. However, most have reviewed CE practices (e.g., 6R: redesign, reduce, reuse, recycle, remanufacturer, repair) at a macro-analytical level; some have identified differences between a sustainable supply chain and a CE (Genovese et al., 2017; Zhu, Geng and Lai, 2010). Only a small number have focused on CE practice and its enablers and barriers when implementing a comprehensive CE in the manufacturing industry (e.g., Lieder and Rashid, 2016). This paper differs from the existing reviews and makes a unique contribution to the CE literature by focusing on practices, enablers, barriers, and indicators to evaluation of sustainable performance in the T&A industry.

The rest of the paper is structured as follows. Following the introduction, the methodology, the results of both descriptive and thematic findings and discussion section are addressed. The final section concludes the paper, identifies gaps in the literature and recommends areas for future research. A conceptual model regarding the textile industry and the CE is proposed. Drawing on the findings of the review, the paper highlights areas for future research.

2.2 Methodology

To achieve the research purpose, a systematic literature review was selected as an appropriate approach to a detailed analysis of the literature. According to Seuring and Gold (2012), a literature review is a systematic, explicit, and reproducible design for identifying, evaluating and interpreting the existing body of recorded documents. We adopted Okoli and Schabram's (2010) methodology to conduct this review. This involved a comprehensive exploration of the literature and a determined collection procedure. To analyse the themes synthetically, we developed some analysis techniques, as recommended by Gold (2010), to logically code the articles. The selected papers were examined in two steps: a descriptive analysis based on publication information; and a thematic analysis, which involved identifying research themes within the topic.

This literature review aims to evaluate the existing research associated with sustainable supply chains toward a CE in the T&A industry. CE and sustainability are related terms. Some studies use the term sustainability to refer to the CE; thus, to be comprehensive, we included sustainability-related keywords. Keywords were divided into three categories: supply chain, circular economy/sustainability, and textile industry. Related keywords within each category were identified according to existing literature review and related articles searched in the main databases. We combined the textile industry with the supply chain and CE separately to create two categories of search strings to capture both topics simultaneously (Figure 2.1).

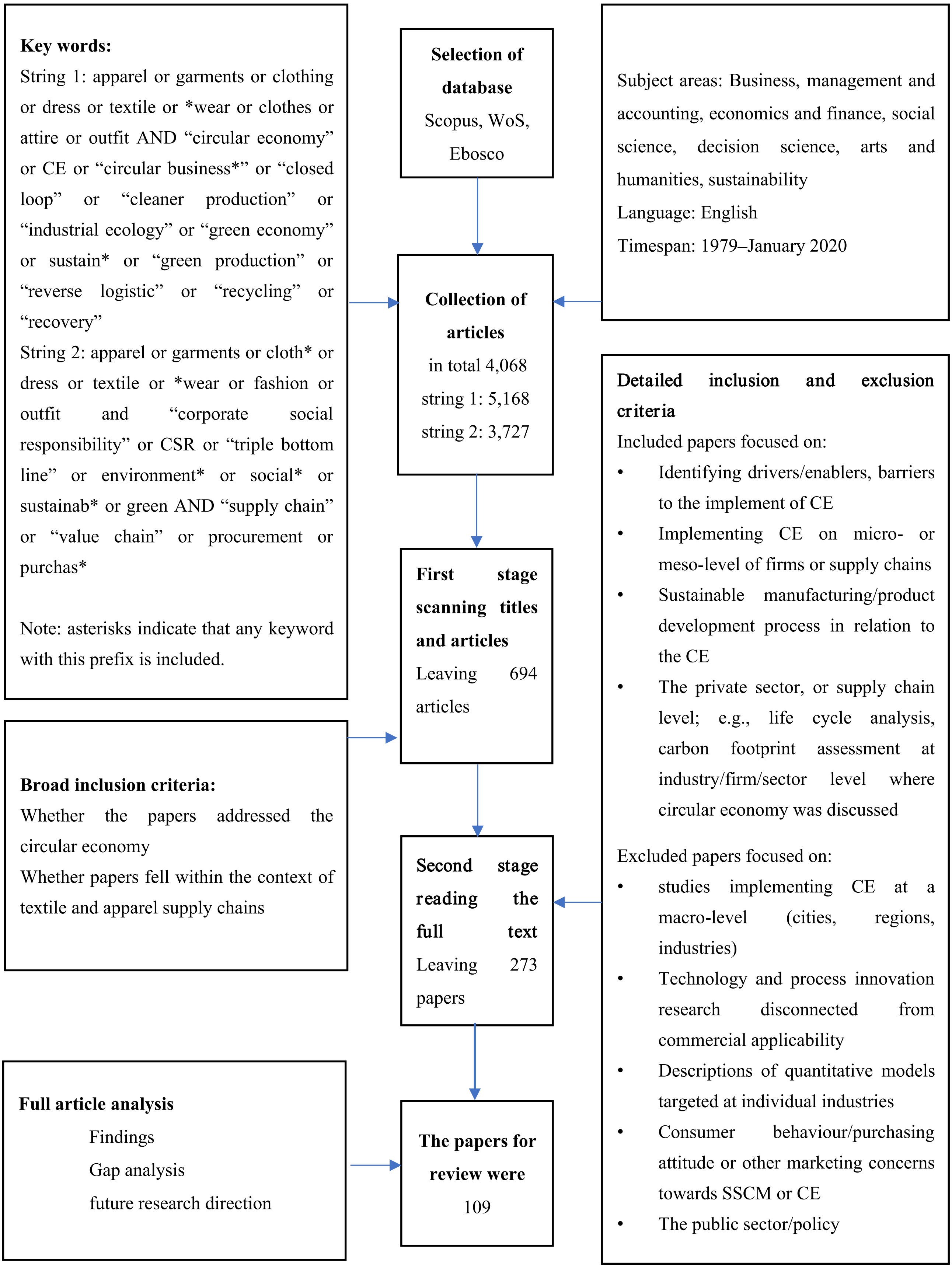

Figure 2.1 Review methodology

2.2.1 Material collection

A broad-based search was conducted through Scopus, Web of Science and EBSCO. Research papers published between 1979 and January 2020 were included in the initial review. The last search was carried out in January 2020. The reviewed articles were available online and in the English language. The selection of materials was limited to journal articles and seven specific subjects (shown in Figure 2.1). We limited materials selection to 7 subject areas (shown in Figure 2.1), which are commonly adopted in the supply chain management related literature review papers (e.g., Masi, Day and Godsell, 2017; De Jesus and Mendonça 2018; Lieder and Rashid, 2016). According to the aim of this literature review, those subject areas which are related to new technological development such as biological sciences, chemical engineering, physics and astronomy are excluded. Lately published reviews on related themes were considered to represent guidelines for this research (Govindan and Hasanagic, 2018). The articles accepted from the primary search were selected with the guidance of a series of processes, as illustrated in Figure 2.1 (Reim, Parida and Örtqvist, 2015).

2.2.2 Practical screening based on keywords

Systematic selection criteria were identified. Only peer-reviewed journal articles written in the English language were selected for this review. The search was accomplished using two search strings with different groups of keywords. Some logical operators (i.e., OR, AND) and wildcards (i.e., *) were used with keywords to recover the largest number of articles. In the first search string, keywords related to the 'circular economy' were combined with a set of textile industry-related keywords. In the second search string, keywords related to 'textile' were combined with those related to 'supply chain'. After a broad search using the two sets of search strings in the afore-mentioned three databases, 5,168 and 3,727 related articles were identified respectively for each search string after discarding the duplicate articles. A total of 694 articles was selected after the first round of evaluation, which involved scanning article titles based on the broad criterion that the articles should address the CE and SSCM in the T&A industry.

To further refine the set of articles in terms of relevance, papers were selected by reading the abstract and conclusion; 273 articles were retained for the next round of full-text review applying inclusion and exclusion criteria (Figure 2.1). The aim of this paper was to review practices and performance aspects of building a sustainable supply chain toward a CE; thus, the papers we reviewed need to focus on micro- or meso-level issues such as barriers, enablers, manufacturing process development, and performance evaluation in the private sector—rather than macro- or regional-level issues (e.g., policy, public sector). This review focused on operation management, so papers related to consumer attitude towards CE were excluded. Finally, 109 papers were identified for inclusion in the review.

The final selected articles were then analysed in two steps. The first involved recording essential descriptive data for each article (e.g., source, publication year and methodology). The next analytical step is classifying and coding each of the articles based on the broad themes and linked subthemes identified.

Coding was conducted inductively. However, for the theme of circular supply chain execution in the T&A industry, this review adopted Hart's three strategies. The Natural-Source-Based View (NRBV) (Hart, 1995) requires that the value, rarity, and inimitability of resources and abilities should decide the competitive position with consideration of the environment (Barney, 1991). The NRBV identifies important solutions of tacit and complicated social resources, a common vision, and ethical management in solving environmental problems (Ashby, 2018; Amini and Bienstock, 2014). Hart (1995) suggested three interrelated approaches: pollution prevention, product stewardship, and sustainability. On the basis of these principles, enterprises need to develop an ability in environmental sustainability to maintain their competitiveness. So that these three strategies could be used to classify circular supply chain executions.

2.3 Descriptive analysis

The 109 selected papers were analysed in terms of their publication year, journal, distribution sector, and research methodology to trace the development and knowledge structure of the topic.

2.3.1 Publication year

The 109 articles were published from 2002 onwards. A small temporary peak is apparent in 2013, when eight articles were published. After 2013, the number of publications shows a stable increase. Despite the cut-off point of 2014, that year nevertheless only had 6 publications, and in 2018 the number of publications was 24, which shows a steady growing trend, as shown in Figure 2.2.

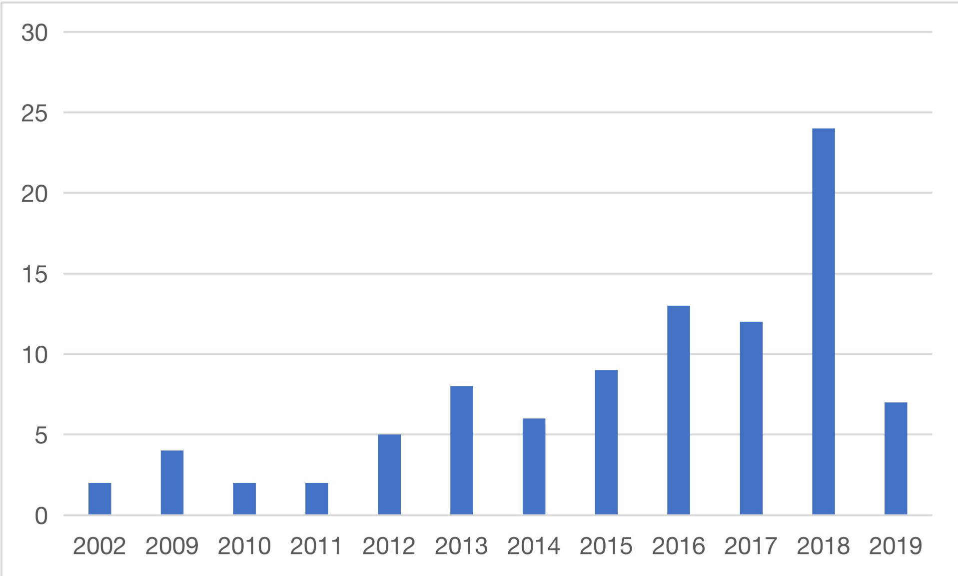

Figure 2.2 Distribution of publications per year (N = 109)

2.3.2 Article source

The analysis of the reviewed articles shows that there are 38 journals in total. Twenty-five of these journals had each published only one article within the scope of this research. Among journals that had published more than one article, the *Journal of Cleaner Production* had the peak number (47), followed by *Resource, Conservation, and Recycling* (8), *International Journal of Fashion Design, Technology, and Education* (7), and *Textile Outlook International* (6). The remainder had published no more than three in the review period (see Figure 2.3). This suggests that publication on the CE and SSCM in the T&A industry is a subject attracting attention across a variety of disciplines and journals. It is worth noting that the *Journal of Cleaner Production* contributed 50% of the papers, which reflected the journal's aim to publish in research fields of SSCM, closed-loop SCM, and sustainable performance indicators in the T&A industry.

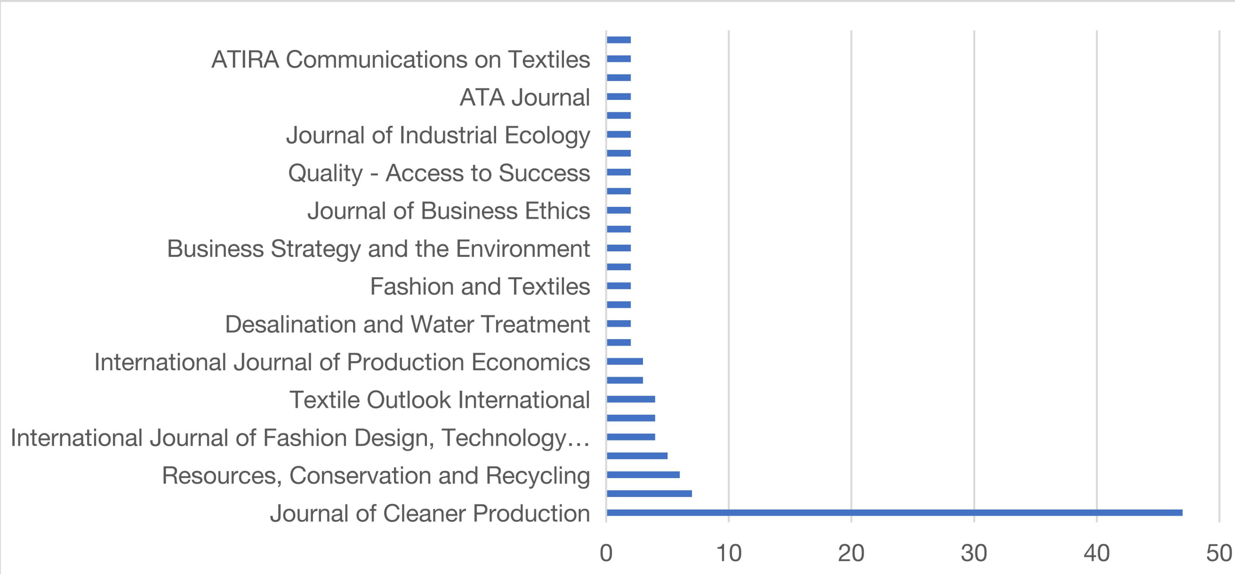

Figure 2.3 Article sources

2.3.3 Distribution of research methods

This section analyses the methodologies applied to study the CE and SSCM in the T&A industry. Figure 2.4 outlines the use of different methodologies in the reviewed literature.

The analysis results show that researchers have preferred to apply qualitative methodologies when researching the CE and SSCM. The case study was the most frequently used method. Researchers selected particular textile companies as cases to analyse particular factors that affect reverse logistics (RL) and sustainable performance. Quantitative methods have not been commonly applied in the field because of the lack of a systematic database of the T&A industry for researchers to use (Resta et al., 2014).

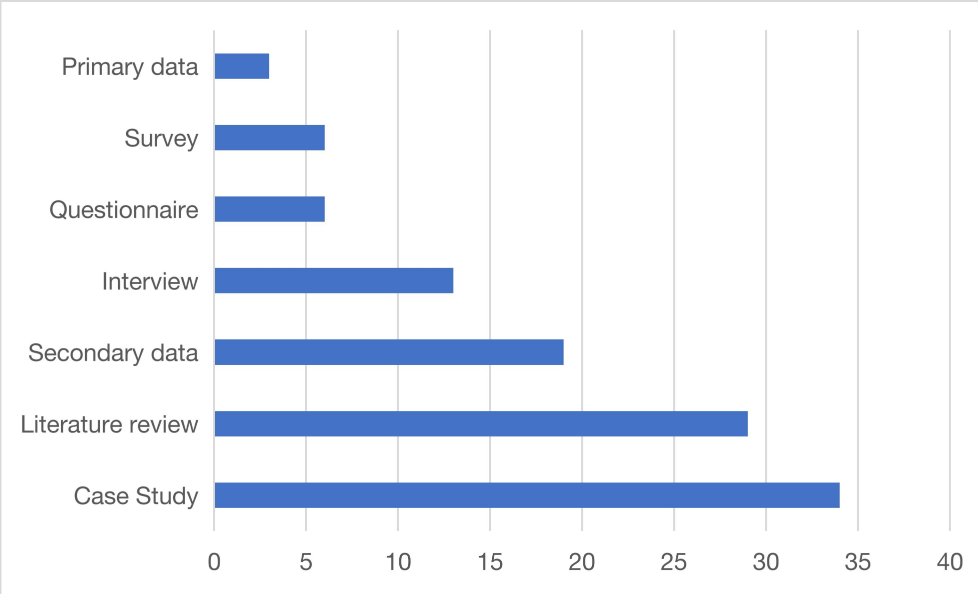

Figure 2.4 Distribution of research methods

2.4 Thematic analysis

This section includes four main themes relating to the development of SSCM toward a CE in the T&A industry: drivers, barriers, practices, and indicators of sustainable performance. Table 2.1 displays the main contribution of the 109 reviewed articles and lists our coding.

Table 2.1 Thematic coding

				Drivers		
Author	Year	Country of research	Research Methods	Organisational Driver	Institutional Drivers	Customer Drivers
Pinheiro et al.,	2019		Questionnaire	x		
Bhamra et al.,	2018	UK	Case Study	x		
Burzyńska Jabłońska and Dziuba,	2018	Poland	Primary and secondary data	x	x	
Dissanayake and Sinha,	2015	Sri Lanka	Literature review	x	x	
Miemczyk, Howard and Johnsen,	2016	Europe	Case Study	x		x
Clancy, Fröling and Peters,	2015	Sweden	Literature review, Interview	x		
Diabat, Kannan and Mathiyazhagan,	2014	India	Literature review, Questionnaire	x	x	x
Garcia-Torres et al.,	2019	Europe	Literature review	x		
Fischer and Pascucci,	2017	EU	case study	x	x	
Rizos et al.,	2016	UK, Netherlands	case study	x	x	
Desore and Narula,	2018	India	Literature review		x	
Ngai et al.,	2013	China	Literature review, case study		x	
D'Amato et al.,	2017	Global	Literature review		x	
De Jesus and Mendonça,	2018	Global	Literature review, Survey		x	

Govindan and Hasanagic,	2018		Literature review		x	x
Lopes de Sousa Jabbour et al.,	2018		Literature review, case study		x	x
Cao, Scudder and Dickson,	2017	South Africa	Interview			x
Salvia et al.,	2002	Italy	Secondary data			x
Huq, Chowdhury and Klassen,	2016	Bangladesh, UK	Case Study			x
Moktadir et al.,	2018	Bangladesh	case study	x		x
Boiten, Han and Tyler,	2017	EU	case study			x

				Barrier		
Author	**Year**	**Country of research**	**Research Methods**	**Organisational barrier**	**Financial barrier**	**Policy Barrier**
Hur and Cassidy,	2019	UK	Interview	x		
Başaran,	2013	Turkey	Survey	x		
Burzyńska Jabłońska and Dziuba,	2018	Poland	Primary and secondary data	x	x	
Desore and Narula,	2018	India	Literature review	x		x
Dissanayake and Sinha,	2015	Sri Lanka	Literature review	x	x	
Ülgen and Forslund,	2015	Sweden	Case Study	x	x	

Rizos et al.,	2016	UK, Netherlands	case study	x	x	
Boiten, Han and Tyler,	2017	EU	case study	x	x	
Moorhouse and Moorhouse,	2017	EU	Literature review	x		
Mair, Druckman and Jackson,	2016	BRIC Countries	Secondary data		x	
Hole and Hole,	2018		Literature review		x	
Garcia-Torres et al.,	2019		Questionnaire		x	x
Power,	2012	UK	Secondary data		x	x
Miemczyk, Howard and Johnsen,	2016	Europe	Case Study		x	
De Jesus and Mendonça,	2018	Global	Literature review, Survey		x	
Fischer and Pascucci,	2017	EU	case study		x	
Moktadir et al.,	2018	Bangladesh	case study		x	
Abdulrahman, Gunasekaran and Subramanian,	2014	China	Literature review			x
Govindan and Hasanagic,	2018		Literature review			x
Lihong,	2011	China	case study			x

				Practice				
Author	Year	Country of research	Research Methods	Product design	Product Stewardship	Closing the loop	Relationships and resources	Pollution Prevention
Hur and Cassidy,	2019	UK	Interview	x				
Clarke-Sather and Cobb,	2019	US, Sri Lanka	Secondary data	x			x	
Ashby,	2018	UK	Case Study	x		x		
Baxter et al.,	2018	Norway	Survey	x		x		
Bhamra et al.,	2018	UK	Case Study	x				
Cuc and Tripa,	2018	Romania	Case Study	x	x			
Dissanayake and Sinha,	2015	Sri Lanka	Literature review	x	x			
Franco,	2017	Switzerland	Case Study	x	x	x		
Fresner,	1998	Austrian	Case Study	x				
Lewis et al.,	2017	USA	Interview	x	x			
Styles, Schoenberger and Galvez-Martos,	2012	Spain	Literature review, secondary data	x				
Clancy, Fröling and Peters,	2015	Sweden	Literature review, Interview	x				
Mair, Druckman and Jackson,	2016	BRIC Countries, Europe	Secondary data	x				
Pawęta and Mikołajczyk,	2016	Russia	Secondary data	x		x		
Phadnis and Fine,	2017	Malaysia	Secondary data	x		x		

Govindan and Hasanagic,	2018		Literature review	x	x			
Boiten, Han and Tyler,	2017	EU	case study	x	x		x	
Moorhouse and Moorhouse,	2017	EU	Literature review	x	x			
Ballie and Woods,	2018	EU	case study	x	x	x		
Hole and Hole,	2018		Literature review		x			
Power,	2012	UK	Secondary data		x		x	
Abraham,	2011	India	Interview		x	x		
Alkaya and Demirer,	2014	Turkey	Secondary data		x			
Başaran,	2013	Turkey	Survey		x			
Chen and Burns,	2006	China	Case Study		x			x
Chico, Aldaya and Garrido,	2013	Spain	Case Study		x		x	
Joa et al.,	2014	Bangladesh, Turkey	Case Study		x			
Meksi and Moussa,	2017	Tunisia	Literature review		x			
Ozturk and Cinperi,	2018	Turkey	Secondary data		x			
Paras, Pal and Ekwall,	2015	Sweden	Literature review		x	x		
Parisi et al.,	2015	Europe	Primary data		x			
Raj et al.,	2017	India	Interview		x			
Fischer and Pascucci,	2017	Netherlands	Literature review		x			
Ülgen and Forslund,	2015	Sweden	Case Study		x			

Wiedemann et al.,	2016		Case Study, Secondary data	x			
Crocker et al.,	2018	China	case study	x	x		
Lihong,	2011	China	case study	x			
Lopes de Sousa Jabbour et al.,	2018		Literature review, case study	x			x
Cao, Scudder and Dickson,	2017	South Afrca	Interview		x		
Choi,	2013	Asia	Case Study		x		
Ciarapica et al.,	2015	Italy	Literature review		x		
Desore and Narula,	2018	India	Literature review		x		
Köhler,	2013	Global	Secondary data		x		
Kozlowski,	2012				x		
Maia, Alves and Leão,	2013		Case Study		x		
Miemczyk, Howard and Johnsen,	2016	Europe	Case Study		x	x	
Pal and Gander,	2018	Europe	Literature review		x	x	
Rakib et al.,	2017	Bangladesh	Case Study		x		
Salvia et al.,	2002	Italy	Secondary data		x		
Sas et al.,	2019	USA	Survey		x		
van der Velden and Vogtländer,	2017		Secondary data		x		
Winter and Lasch,	2016	Germany	Literature review		x		

Ali and Haseeb,	2019	Malaysia	Questionnaire	x		
Huq, Chowdhury and Klassen,	2016	Bangladesh	Case Study	x		
Börjeson and Boström,	2018	Sweden	Case Study	x		
Choi,	2013	Global	Literature review, secondary data	x		x
Diabat, Kannan and Mathiyazhagan,	2014	India	Literature review, Questionnaire	x		
Egels-Zandén and Hansson,	2016	Sweden	Case Study	x		
Eryuruk,	2012	Turkey	Literature review	x		
Garcia-Torres et al.,	2019	Europe	Literature review	x		
Hemphill and White,	2018	Bangladesh	Case Study	x	x	
Islam, Deegan and Gray,	2018	Bangladesh	Interview	x		
Masoudipour, Amirian and Sahraeian,	2017	Iran	Case Study	x		
Nouira et al.,	2016	France	Case Study	x		x
Perry, Wood and Fernie,	2015	Sri Lanka	Interview	x		
Rieple and Singh,	2010	India	Literature review, Interview	x		
Stojanović and Bašić,	2013	Serbia	Survey	x		
Svensson,	2009	Scandinavian	Case Study	x		
Winter and Lasch,	2016	Global	Literature review, case study	x		

De Jesus et al.,	2018	Global	Literature review, Survey	x		
Witjes and Lozano,	2016		Literature review	x	x	x
Fischer and Pascucci,	2017	EU	case study	x	x	
Pinheiro et al.,	2019		Questionnaire		x	
Mair, Druckman and Jackson,	2016	BRIC Countries	Secondary data		x	x
Garcia-Torres et al.,	2019		Questionnaire		x	
Muthukumarana et al.,	2018	Sri Lanka	Case Study		x	
Anner,	2012	Vietnam	Case Study		x	
Shen and Li,	2015	China	Case Study		x	x
Xu et al.,	2013	India	Literature review, Questionnaire		x	
Zhu, Geng and Lai,	2010	China	case study		x	
Ozturk and Cinperi,	2018	Turkey	Case Study			x

Author	Year	Country of research	Research Methods	Performance						
				Environmental				economic		
					Air pollution	Solid/water pollution	Hazardous materials consumption		Materials purchasing/ energy cost;	Fee/discharge for waste treatment
Hur and Cassidy,	2019	Austrian	Case Study					x		x
Garcia-Torres et al.,	2019	France	Case Study					x	x	
Power,	2012	UK	Secondary data	x	x		x			
Abraham,	2011							x		x
Alkaya and Demirer,	2014	Turkey	Secondary data	x	x	x				
Ashby,	2018	UK	Case Study	x			x			
Astudillo Thalwitz and Vollrat.,	2014	India	Primary data	x		x		x		x
Başaran,	2013	Turkey	Survey	x	x			x	x	
Chen and Burns,	2006	China	Case Study	x			x			
Chico, Aldaya and Garrido,	2013	Spain	Case Study	x		x		x	x	x
Ciarapica et al.,	2015	Italy	Literature review	x	x	x				
Cuc and Tripa,	2018	India	Primary data					x		x
Dissanayake and	2015	Spain	Case Study					x	x	x

Sinha,										
Fahimnia, Jabbarzadeh and Sarkis.	2018	Italy	Literature review					x		x
Fresner,	1998	Austrian	Case Study	x	x		x			
Joa et al.,	2014	Bangladesh, Turkey	Case Study	x		x				
Ozturk and Cinperi,	2018	Turkey	Case Study	x		x		x		x
Köhler,	2013	Global	Secondary data	x	x					
Maia, Alves and Leão,	2013		Case Study	x		x		x	x	
Muthukumarana et al.,	2018	Sri Lanka	Case Study	x		x				
Ngai et al.,	2013	China	Literature review, case study	x	x		x			
Parisi et al.,	2015	Europe	Primary data	x			x	x		x
Pinheiro et al.,	2019	Brazil	Survey, questionnaire	x	x					
Rakib et al.,	2017	Bangladesh	Case Study	x		x				
Soundararajan and Brammer,	2018							x	x	x
Styles, Schoenberger and Galvez-Martos,	2012	Spain	Literature review, secondary data	x	x					

Targosz-Wrona,	2009	Europe	Secondary data	x			x			
Winter and Lasch,	2016							x	x	
Börjeson and Boström,	2018							x	x	x
Choi,	2013	Global	Literature review, secondary data	x	x			x	x	
Eryuruk,	2012	Turkey	Literature review	x		x				
Fischer and Pascucci,	2017	Netherlands	Literature review	x	x		x			
Mair, Druckman and Jackson,	2016	BRIC Countries, Europe	Secondary data	x	x			x	x	x
Nouira et al.,	2016			x		x		x		x
Perry, Wood and Fernie,	2015	Sri Lanka	Interview	x			x			
Shen and Li,	2015	China	Case Study	x		x	x	x	x	x
Wiedemann et al.,	2016		Case Study, Secondary data	x	x					
Winter and Lasch,	2016	Global	Literature review, case study	x		x				
Xu et al.,	2013	India	Literature review, Questionnaire	x	x	x	x	x	x	

D'Amato et al.,	2017	Global	Literature review	x	x			x	x	
De Jesus et al.,	2018	Global	Literature review, Survey	x		x	x	x		x
Rizos et al.,	2016	UK, Netherlands	case study	x			x	x	x	x
Boiten, Han and Tyler,	2017	EU	case study	x	x					
Crocker et al.,	2018	China	case study	x		x				
Sandvik,	2017	Scandinavia	case study	x	x		x			
Zhu, Geng and Lai,	2010	China	case study	x		x	x	x	x	

2.4.1 Drivers of adoption of circular economy practices

2.4.1.1 Organisational drivers

Diabat and Govindan (2011) stated that employee participation and inspiration in different businesses may be a driving force to increase information on the CE. If staff volunteer and take the opportunity to advise the top management of the advantages of applying a CE, both the staff and the top management might gain information on this topic, which would thus become a motivating element (Bechtel, Bojko and Völkel, 2013).

Pressure from competitors to become green might be a crucial driver in accepting a CE. As part of the leadership team, the top management could play an essential role in modelling cleaner skills for use in the enterprise's industrial processes (Ghazilla et al., 2015). An evolved top management leadership ensures a firm's economic advantage. Financial risks can be predictable, ups and downs in the economy can be measured, and the sustainability of profits can be maintained through active management by firms' leaders (Moktadir et al., 2018). Long-term financial assistance can push T&A companies to adopt sustainable practices (Tibben-Lembke and Rogers, 2002).

2.4.1.2 Institutional drivers

Government reinforcement and legislation is an essential driving force behind sustainable procedures and a CE (Chowdury and Hossain, 2015). In some developing countries, governments are already paying attention to sustainable practice in the T&A industry and enact policy to encourage CE innovation. It is also acknowledged that government support and law implementation are essential to guarantee sustainable manufacturing practices (Mann et al., 2010).

The European commission has announced that CE has been a priority policy since 2015 and it is foreseeable that the EU may have removed the most pressing CE regulatory obstacles (Kirchherr et al., 2018). Government intervention can reduce the high up-front investment costs of a circular business model (these costs have also become a core market barriers) by providing financial support (Stahel, 2013). Financial support has become a widely adopted policy instrument in the EU, especially in the agricultural sector (Hodge, Hauck and Bonn, 2015). If the investment cost in a circular business model is similar to that of a linear business model, then at least the excuse that "CE is too expensive" can no longer be used.

Governments can also enforce legislation relating to recycling and remanufacturing and packaging. Recycling and reuse of ingredients and packaging are part of the CE and are considered ecological actions, on which government support and regulation are focused (Tay et al., 2015).

Environmental involvement with suppliers is a principal driver of the CE. Suppliers are likely to be conscious of the outcomes of their ecological exercises. The government can support suppliers to undertake those actions to guarantee the sustainability of commodities. In addition, the government regulations require the companies to select suppliers based on sustainability standards. Furthermore, the government fund both suppliers and manufacturers to enable them to adopt green manufacture approaches (Nordin, Ashari and Hassan, 2014; Moktadir et al., 2018).

2.4.1.3 Customer drivers

Consumer awareness is one of the essential driving forces for the T&A industry to accept a CE (Siemieniuch, Sinclair and Henshaw, 2015). Consumers are increasingly interested in moving from a linear economy to a circular one. Consumers expect environmentally friendly commodities as they received sustainable development information from the government or through improved public awareness. In this regard, environmental cooperation with customers has also become a critical driver for building a closed-loop supply chain (CLSC).

Community pressure is another motivation for implementing the CE, as it can inspire the government to enact strong legislation to ensure implementation of sustainable practices. It may be the most significant pressure for the manufacturers to accept ecological exercises and the CE (Siemieniuch, Sinclair and Henshaw, 2015).

These main drivers and sub-drivers are listed in Table 2.2.

Table 2.2 Drivers for building SSCM toward CE

Drivers	Sub-drivers	References
Organisational	Availability of information	Bechtel, Bojko and Völkel, 2013; Ghazilla et al., 2015; Lieder and Rashid, 2016; MacArthur, 2013; Siemieniuch, Sinclair and Henshaw, 2015; Mutingi, 2013;
	Employee involvement/ motivation	Wu, Cheng and Huang, 2010; Bechtel, Bojko and Völkel, 2013; Mudgal et al., 2009; van Raaij and Schepers., 2008; MacArthur, 2013; Diabat and Govindan, 2011;
	Knowledge sharing in supply chain	Bechtel, Bojko and Völkel, 2013; Ghazilla et al., 2015; Lieder and Rashid, 2016; MacArthur, 2013
	Interests about ecological effects and the situation of the environment	Bechtel, Bojko and Völkel, 2013; Ghazilla et al., 2015; Lieder and Rashid, 2016; MacArthur, 2013
	Collaboration among organiations	Wu, Cheng and Huang, 2010; Bechtel, Bojko and Völkel, 2013; Mudgal et al., 2009; Mutingi, 2013
	Competitive advantage	Wu, Cheng and Huang, 2010; Bechtel, Bojko and Völkel, 2013
	Economic benefit	Bechtel, Bojko and Völkel, 2013; Diabat and Govindan, 2011; Ghazilla et al., 2015
	Environmental collaboration with customer	Wu, Cheng and Huang, 2010; Bechtel, Bojko and Völkel, 2013; Mudgal et al., 2009; Mutingi, 2013; van Raaij and Schepers, 2008
	Worldwide environment stress and environmental shortage of properties	van Raaij and Schepers, 2008; Siemieniuch, Sinclair and Henshaw, 2015
Consumer	Community pressure	Bechtel, Bojko and Völkel, 2013; Hanna, Newman and Johnson, 2000; Walker, Di Sisto and McBain, 2008
	Customer awareness to green initiatives	Mudgal et al., 2009; Bhool and Narwal, 2013;
	Funding from government	Walker, Di Sisto and McBain, 2008; Hanna, Newman and Johnson, 2000
	Reusing and recycling materials and packaging	Bechtel, Bojko and Völkel, 2013; Bhool and Narwal, 2013;
Institutional	ISO 14001 certification	Bechtel, Bojko and Völkel, 2013; Tay et al., 2015
	Environmental collaboration with suppliers	Nordin, Ashari and Hassan, 2014; Mudgal et al., 2009

2.4.2 Barriers

2.4.2.1 Organisational barriers

Organisational barriers include the company's strategy, planning, participation, recruitment and training of personnel, digestion of extended responsibility, requirements for performance evaluation systems, desire to acquire the best practice, and appropriate support organisational structures (Zhou, Naim and Wang, 2007). A lack of clear corporate structures and procedures prevents companies from effectively addressing sustainability problems; for instance, there may be no budget control procedures.

Company policies

Restrictive company policies can be a major concern in RL (Witjes and Lozano, 2016). Firms want to establish a sustainable brand image for consumers. Managers are not willing to compromise the quality of the end product by utilising recycled materials. Therefore, rules established by firms to manufacture only novel products crucially influence not only the handling of refunded commodities, but also the recovery of the hidden secondary value of returned goods. With the emergence of extended producer responsibility, many T&A enterprises have begun to participate in the recycling chain for commodities in the supply chain (Fischer and Pascucci, 2017). There seems to have been a paradigm shift by enterprises in relaxing their rules for integrating returned products to cost-effectively improve value, which might provide companies an advantage over their rivals.

Lack of appropriate performance metrics

Lack of a performance index is the main obstacle in a RL project (de Jesus and Mendonça, 2018). A performance measurement formula is the foundation of an integrated work management system. D'Amato et al. (2017) stated that companies would be more likely to be successful if they connect their performance assessment method to their CE practices (Miao, Cai and Xu, 2011; Baxter et al., 2018).

Lack of training and education

A lack of employee resources is one essential obstacles to successful RL (Moktadir et al., 2018). Shortage of learning and education is a primary challenge in profitable cycling (Govindan and Hasanagic, 2018). Education and training are the first requests for any organisation. The demand for training in RL spreads through a firm by moving up and downstream. Innovative or modified technology requires adjustment of skillset and staff should get suitable training about the innovative technology and procedures that are applied (Rizos et al., 2016).

Lack of strategic planning

In the application of RL, the function of strategic planning in accomplishing the aims is crucial for the survival of the company in the international market (Macchion et al., 2018; Mangla et al., 2018). Strategic planning for RL is the link between RL objectives and long-term plans' requirements and requires efforts of the director identifying those practices necessary for the realisation of RL (Macchion et al., 2018).

2.4.2.2 Financial barriers

Financial constraints are the main obstacles in RL projects. Cost concerns are a significant challenge for business recovery (Ülgen and Forslund, 2015). Investment is crucial to maintain the infrastructure and human resources requests of RL (Dibenedetto, 2007; Tibben-Lembke and Rogers, 2002). The existence of suitable RL infrastructure gives an enterprise the ability to rapidly and effectively manage returned and/or recalled products (Freise and Seuring, 2015). Information and technology systems require more capital because without sufficient capital, it is not possible in the current environment to track returned products through various processes such as reuse, remanufacturing, recycling, and product recovery (Jack, Powers and Skinner, 2010). The training of personnel involved in RL is also essential for economically managing and ultimately creating profitable RL. Nevertheless, all these need financial support.

2.4.2.3 Policy barriers

A principal barrier to the CE that is apparent in the T&A supply chain is a lack of enforceable laws and regulations for circularity manufacturing practices. Those laws and regulations for CE do not only focus on recycling or waste management but also provide a guideline for companies to follow at every stage in their supply chain (e.g., eco-design, trace recyclable products and build collection mechanism) (Lazarevic and Valve, 2017). This lack of systematic regulation creates a lack of appreciation of RL. Even if firms are aware of it, the relative insignificance given to RL has been seen as the most significant barrier to its application (Chowdury and Hossain, 2015; Dangelico, Pontrandolfo and Pujari, 2013). Today, many garments have a shorter life cycle as a consequence of the enlargement of 'fast fashion.' While consumers benefit from the variety of products, it increases unsold commodities, return rates, packaging materials, and waste (Hyder, Chowdhury and Sundström, 2017; Wang and Bi, 2013). This has led to an increase in the amount of returned commodities in the form of RL. Consequently, managing components or goods being returned to the supply chain network from the outbound side becomes an increasingly important issue in the T&A industry (Sivaprakasam, Selladurai and Sasikumar, 2015).

Although many companies and the policy-makers have announced support for CE (Boström and Micheletti, 2016; Egels-Zandén and Hansson, 2016), its implementation seems to be in its infancy (Ghisellini, Cialani and Ulgiati, 2016; Stahel, 2013). The EU has adopted a series of ambitious CE policies, such as the "Circular Economy Package" (published in 2015 and updated in 2018), which aims to close product life cycles through improved reusability and recycling (European Commission, 2015; Lazarevic and Valve, 2017). Despite these policy measures, the implementation of CE in most EU member states has so far been limited (McDowall et al., 2017; Stahel, 2013).

Another critical obstacle to RL is the unwillingness of suppliers, distributors, and sellers to encourage RL actions. A return strategy that allows customers to return products to retailers in any form can enhance risk sharing between retailers and customers. RL can bring benefits to the economy by reusing returned products, remanufacturing, recycling, or combining these options to add value to commodities. The implementation of RL also has direct advantages for the environment. Therefore, the lack of supportive policies and understanding of these benefits are the main obstacles to RL.

These main barriers and sub-barriers are reviewed in Table 2.3.

Table .2.3 Barriers to building SSCM toward CE

Barriers	Sub-barriers	References
Organisational	Company policies	Dibenedetto, 2007; Zhou, Naim and Wang, 2007;
	Lack of appropriate performance metrics	Rogers and Tibben-Lembke, 1999; Masi, Day and Godsell, 2017
	Lack of training and education	Orsato, 2006; Zhou, Naim and Wang, 2007; Lau and Wang, 2009
	Lack of strategic planning	Gold et al., 2010; Ravi and Ravi, 2005; Paras, Pal and Ekwall, 2018
	Lack of training and education	Dibenedetto, 2007; Jack, Powers and Skinner, 2010
Financial	Lack of financial support	Orsato, 2006; Min and Galle, 2001; Freise and Seuring, 2015; Jack, Powers and Skinner, 2010; Paras, Pal and Ekwall, 2018; Lewis et al., 2017
	Lack of working capital	Dibenedetto, 2007; Paras, Pal and Ekwall, 2018; Lewis et al., 2017; Masi, Day and Godsell, 2017
	Lack of information and technological systems	Desore and Narula, 2018; Hur and Cassidy, 2019; Lim et al., 2017; Sandin and Peters, 2018; Tibben-Lembke and Rogers, 2002; Dibenedetto, 2007
	Unwillingness of suppliers, distributers, and sellers to provide support	Paras, Pal and Ekwall, 2018; Lewis et al., 2017; Dangelico, Pontrandolfo and Pujari, 2013
Policy	Lack of systematic regulation	Sivaprakasam, Selladurai and Sasikumar, 2015; Masi, Day and Godsell, 2017
	Lack of enforcement laws	Chowdury and Hossain, 2015; Perry, Wood and Fernie, 2015; Hyder, Chowdhury and Sundström, 2017

2.4.3 Practices

The NRBV offers a suitable framework for understanding various CLSC practices and has been commonly adopted in research (Ashby, 2018; Jakhar, 2014; Miemczyk, Howard and Johnsen, 2016) incorporating the probable arrangement or importance of its application, the nature and degree of collaboration, and how this, then, combines to create a completely coordinated CLSC. There are three competencies in hart's NRBV that determine a company's capability to accomplish its planned competitiveness: pollution prevention, product stewardship, and sustainable development. These three capabilities rely on different resources and are influenced by pressures from different stakeholders, enabling enterprises to gain a unique advantage in marketing competition (Amini and Bienstock, 2014).

2.4.3.1 Product design

The design function is the foundation of the CLSC because it is the first step of designing a supply chain, allowing certain green practices to be effectively adopted. Design for the environment (DfE) systematically considers the design performance associated with ecological objects throughout the product life cycle (Tsoulfas and Pappis, 2006). It allows enterprises to solve environmental problems (Li et al., 2017) and improve recyclable commodities that are long lasting, recyclable, and environmentally compatible with non-hazardous recycling and disposal (Mascle and Zhao, 2008). The main purpose of DfE is to increase revenue, maximise the amount of components recycled, and minimise waste (Tsoulfas and Pappis, 2006).

2.4.3.2 Product stewardship

The importance of the design in the CLSC is emphasised in the reviewed literature. It enables key practices such as reuse and remanufacturing in the CLSC, and supports a company's resilient approach to product management (Preuss, 2005; Miemczyk, Howard and Johnsen, 2016; Sas et al., 2019).

The notion of product stewardship integrates these design-related reactions to the ecosystem, and clearly reflects the green influence of harvests—from material consumption to how products are handled at the end of their life, aiming to decrease the burden on the environment of purchasing (Seuring and Müller, 2008). It highlights the cradle-to-cradle liability of a commodity's life cycle and focuses on 'product-based green supply' (Alkaya and Demirer, 2014). The objective of product stewardship is to maintain each constituent or module of a product in the life cycle and decrease flows into the exterior environment (Styles, Schoenberger and Galvez-Martos, 2012). Therefore, it encompasses the ecological effects of products in their design, packaging, and raw material utilisation, and encourages the reuse, remanufacturing, and recycling of materials/constituents, along with the use of recyclable components (Angell and Klassen, 1999).

2.4.3.3 Pollution prevention

Angelis-Dimakis, Alexandratou and Balzarini (2016) and Alkaya and Demirer (2014) found that T&A firms seek to decrease the ecological effects of the commodities manufactured in their supply chain. These firms incorporate ecologically responsible procedures that require them to collaborate with suppliers that could meet these criteria and enthusiastically extend the use of their usage of resources and constituents to guarantee that minimum waste is produced and maintained in the supply chain.

The CE paradigm assigns new responsibilities to customers, which is also reflected in the results of our stakeholder negotiations. In the French focus group, proposals were made to empower customers and mobilise them to classify each fibre type of textile before discarding of them. The limited reliability of clothing labels does raise important issues for customer participation in textile classification. However, efforts to improve the life and environmental performance of textiles should begin at the earliest stages of design and well before the consumption and disposal stages. So harmonised standards must be agreed to ensure that products are designed and produced with an eye to the subsequent end-of-life phases. These standards impact the selection of yarns and fabrics, mixed materials (with particular consideration given to the greater feasibility of single material recovery), dyes, solvents and finishing processes.

2.4.3.4 Closing the loop

Traditional logistics management involves the supply of products from the manufacturer to the customer (Tsoulfas and Pappis, 2006), whereas RL involves consumers' returning commodities to focal companies. RL offers the maximum use of used goods, because each product becomes a resource in production of another commodity (Lippman, 2001). Goods, portions, assemblies, and resources represent increasing value and commercial chances in a CLSC (Lynch and Cross, 1991), and the reversal loop positively targets at reducing raw materials in the forward production; in this way, fewer resources flow in the chain and remanufacturing and reuse targets can be achieved (Zhu, Sarkis and Lai, 2007a). Therefore, RL is a tool that closes the supply chain loop and allows for environment-focused recycling, reuse, remanufacturing, and repair operations.

Usually, T&A firms apply a CLSC framework as shown in Figure 2.5. This includes entire apparel production and distribution steps, and clearly recognises the importance of design and the customer's role in CLSC. When remanufacturing and reusing close the production loop, design becomes a key to create reliable choices at the start of the manufacturing process and allow efficient CLSC practice, e.g., recycling. Figure 2.5 briefly illustrates the production and circularity processes of the complete supply chain of the textile industry. The main recycling and sustainability are reflected in the recovery and reuse of products purchased by customers. This figure only presents the main "R" techniques used in each production stages. It is not a complete, closed-loop diagram of the circular economy of the textile industry.

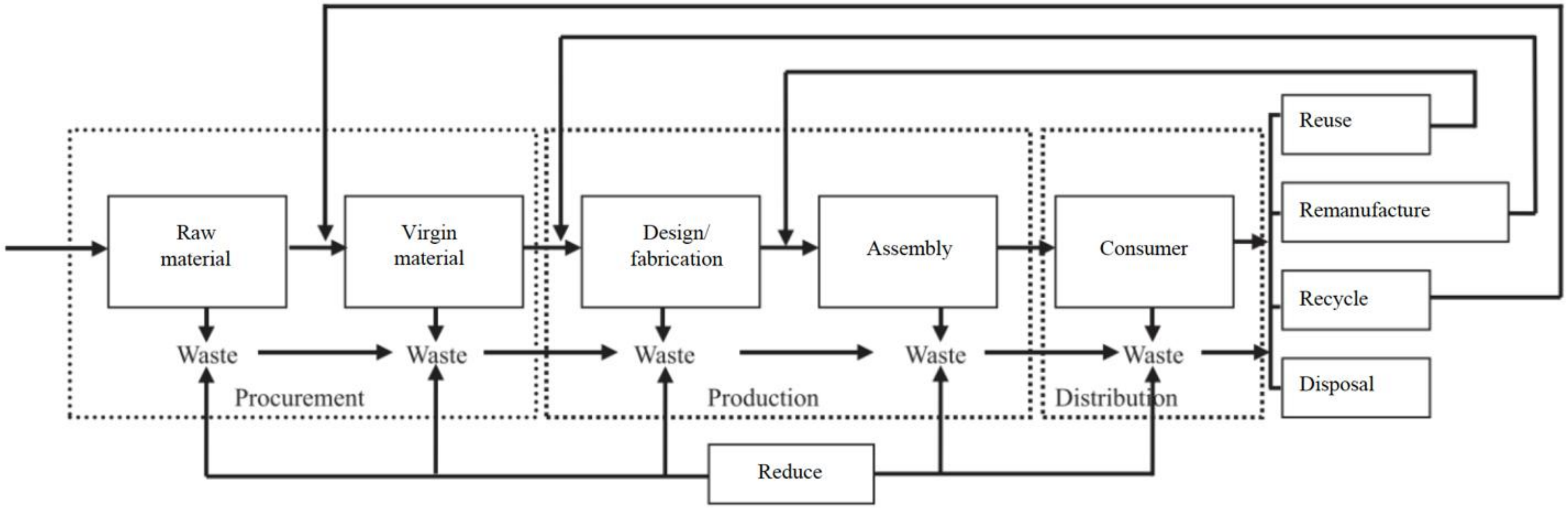

Figure 2.5 Circular economy model in T&A industry

2.4.4 Performance

There are three aspects of performance in SSCM: environmental performance, social liability, and commercial growth. However, according to the articles reviewed, most studies focused on environmental and economic contributions after applying a CE in the T&A industry. This section summarises the key performance indicators in each dimension to evaluate the CE's targeted performance.

2.4.4.1 Economic performance

Reliability, flexibility, finance, and quality are four common aspects that are used to assess economic performance from aspects of product/service quality, production, stock, delivery, supplier and supply chain (Supply Chain Council, 2010; Vachon and Klassen, 2008).

Gunasekaran, Patel and Tirtiroglu (2001), Blumberg (2004), Supply Chain Council (SCC) (2010), and Carter and Ellram (1998) have emphasised reliability throughout design, raw material purchasing and sourcing, production process, product delivery and return, consumer service, suppliers' service, and reliable predictions for sales and stock. SCC (2010) provided a detailed analysis of flexibility. SCC maintained four subareas involved in assessing the effects of practices: the supplier, supply, manufacturing, and distribution tractability.

Finance is a broad expression whose meaning is often investigated. The literature (Global Reporting Initiative (GRI), 2007; Rao et al., 2006; SCC, 2010) on economic performance of supply chain practices could be assessed in terms of product/service design costs, raw material/constituent acquisition costs, raw material/constituent source expenses, product/service manufacture fees, shipping expenses, refund expenses, and distribution expenses.

'Evaluation of quality' is one of the less well-known sectors in terms of performance. According to

Matos and Hall (2007), in supply chain operations reference (SCC, 2010), and Vachon and Klasse's (2008) publication, product/service quality, supplier quality presentation, and production quality were defined as three sub-indicators that can help meet customer expectations and thus improve economic performance. Product/service quality can be used to assess the effect of a practice on the capability of commodities/services to reach customer expectancies. A supplier's quality statement could be utilised to measure the effect of practices on the supplier's ability to meet consumer expectancies. Production quality aims to assess the effect of the practices on production delivered products/services.

2.4.4.2 Environmental performance

It is obvious that the choices and actions of firms inevitably influence the natural environment, no matter where they are implemented. Krajnc and Glavič (2005), and DeBenedetto and Klemes (2009) responded to GRI's (2007) circularity proposition, which allowed us to define indicators related to resource usage. The percentage of recycled water is a significant indicator in CE performance measurement. It assesses the influence of a practice on recycled water. The volume of recycling inputs are used to determine the input utilisation (primary materials, wrapping, consumables, etc.) (Gauthier, 2005; Michelsen, Fet and Dahlsrud, 2006). The amount of recyclable waste is a criterion used to estimate the efficiency of recycling of waste production in the manufacturing cycle (Azapagic and Perdan, 2000; Michelsen, Fet and Dahlsrud, 2006). The amount of renewable energy consumed measures the effect of practices on renewable energy utilisation.

GRI (2007), SCC (2010), Zhu and Sarkis (2004), De Benedetto and Klemes (2009) and Jash (2000) identified three types of pollution including air, water, and solid pollution. The content in air emission is a way to calculate the impacts on air pollution (e.g., CO_2, NOx, SOx) (Matos and Hall, 2007). Water pollution is another way to assess the influence of sustainable practices, particularly on overflows of surface water—and the uncontrolled movement of surface water and infiltration in groundwater (Krajnc and Glavič, 2005). The degree of land pollution is a criterion used to calculate the effect of such practices on soil contamination; especially for releases of heavy metals (Tam, Tam and Tsui, 2004). It is also desirable to assess the effects of other kinds of pollution, such as sound, light pollution, vibration and radiation (Zhu, Sarkis and Lai, 2007a).

Very few authors have analysed the measurement of pollution to environment, but have analysed the pollution classification as much detail as possible (De Benedetto and Klemes, 2009; Krajnc and Glavič, 2005; Tam, Tam and Tsui, 2004). Measures of dangerous inputs include the effect of hazardous inputs such as essential materials, wrapping and consumables. Estimates of hazardous discharges can be used to calculate the effect of a practice on hazardous outputs such as finished goods and packaging. Dangerous waste includes hazards, chemicals, rubbish, and so on.

The main measurement items for evaluating CE's targeted performance are illustrated in Table 2.4.

Table 2.4 Indicators for evaluation of CE performance

Performance	Measurement indicators	References
Environmental	Reduced air emissions	Azapagic and Perdan, 2000; Krajnc and Glavič, 2005
	Reduced waste water	Jash, 2000; Matos and Hall, 2007
	Reduced solid wastes	Parisi et al., 2015; Krajnc and Glavič, 2005
	Decreased consumption of hazardous/harmful/toxic materials	Warhurst, 2002; Gauthier, 2005; Parisi et al., 2015; GRI, 2007;
	Decreased frequency of environmental accidents	Parisi et al., 2015; Krajnc and Glavič, 2005; Darnall and Edwards., 2006
	Improvement in company's environmental situation	Darnall and Edwards., 2006; Jash, 2000; Michelsen, Fet and Dahlsrud, 2006
Economic	Reduced expense of materials merchandising	GRI, 2007; Krajnc and Glavič, 2005;
	Reduced expense of energy utilisation	GRI, 2007; SCC, 2010; Matos and Hall, 2007
	Decreased fees for waste treatment	GRI, 2007; Krajnc and Glavič, 2005; Matos and Hall, 2007
	Decreased fees for waste discharge	SCC, 2010; Matos and Hall, 2007
	Decreased fines for environmental accidents	Matos and Hall, 2007; Gauthier, 2005

2.4.5 Challenges in Applying Circular Supply Chain Management in T&A industry

Applying the CE at a single firm level is a difficult project in the T&A industry because of the common awareness of using linear supply chain. This section focuses on two parts—circular supply chain execution; and relationship management with suppliers and stakeholders—that are related to implementation of practices in building SSCM towards a CE.

2.4.5.1 Circular supply chain execution in the T&A industry

Circular supply chain (CSC) is a complex system, which offers an infinite cycle of reutilise, remanufacturing and recycling of materials and resources (Mangla et al., 2018). Circular SCM

(CSCM) is part of circular economy, which targets at enhancing the use of resources through whole products lifecycle by applying circular remanufacturing (Lieder and Rashid, 2016). Besides CLSC, CSCs are also an open system that allows resources to flow between different supply networks, and within different technological and natural material loops. CSC/CSCM could also be well utilised to addressing issues such as pollution, hard-to-achieve manufacturing and merchandising patterns, shortening of materials and changing of climate. This is because by accepting circular models for flow of goods, resources and waste, associations would be able to reduce waste and damaging environmental influences in supply chain exercises (Lieder and Rashid, 2016; Tsoulfas and Pappis, 2006). The circular supply chain execution delivers a suitable framework for operating the various CLSC practices that have been discussed and reviewed in the thematic finding section, including the potential order of application, the degree of their collaboration, and then, contributes to succeeding the completely coordinated CLSC. Understanding circularity execution in SCM is crucial to achieving innovation practices in CLSC objectives. This section introduced circular supply chain execution into two sections and addressed the difficulties in each stage while building a circularity supply chain in T&A industry.

2.4.5.1.1 Product design and manufacture

Product design is important in accomplishing the CE goals because numerous life cycles need to be considered for circularity of products (Genovese et al., 2017). The sustainable production of goods depends largely on the selection of manufacturing resources and manufacturing processes (Nasir et al., 2017). In product design, two aspects are observed: the complication of basic materials and constituents, and the complication of product function and aesthetics. The combination of these two issues not only limits the range of recycled commodities provided to end consumers but also determines the extent to which goods could be recycled after use.

Complication in basic materials and parts

The availability of elementary (such as dyes, fibres, yarns) and other constituents (such as zippers, buttons) is not the only design-limiting component for understanding recyclable goods. Equally important is the supply of complementary components (such as packaging solutions, label inks) and manufacturing technologies (such as weaving and dyeing). All of these features affect the speed and scope of developing new products, which in turn determines the variety of commodities that can be developed with existing resources, and eventually defines the full scope of recycled commodities to be sold and redeveloped (Eryuruk, 2012).

Complication in functionality and aesthetics

The functionality of textile products are added for fabrics through diverse physical and biochemical finishing processes to accomplish many required properties, involving ultraviolet and microbial protection, protection against insects, water resistance, and fire retardant (Kim and Ko, 2010). Aesthetics and function performance means the visual attractiveness that is understood through distinctive resources, structures, and dye treatment approaches when designing fabrics. Appearance and aesthetic would affect customers' perception on commodities in the T&A industry (Gardetti and Torres, 2013).

2.4.5.1.2. Closing the loop in the T&A supply chain

The goal of a circular production system is to recycle raw materials from products and reuse them in subsequent production cycles. Several challenges with this are discussed in the literature.

Mix of resources

Design represents a fundamental function in merchandise recycling as it determines the level of difficulties that recyclers would experience in arranging and dividing resources into fabrics and clothes. At this point, a distinction must be made between product flows that are currently produced without a cyclic attitude and those established particularly to close the loop. In the first scenario, recycling values are estimated to be low because now, fabrics are produced from a mixture of non-recyclable and low-cost resources. The combination of manmade and natural yarns, which are frequently coloured and processed with toxic dyestuffs, makes the classification, separation, recycling, and remanufacturing become very challenging. Nike began building a collection mechanism in their physical store to achieve a circular supply chain in 2008. However, it has faced problems with sorting the received garments. It needs to know what kind of waste it is accepting. If it receives a dyed T-shirt of a different brand, remanufacturers do not know which dyeing chemicals the producer utilised. Some synthetises may adversely affect their recycling production (MacArthur, 2017). In the second scenario, where products are developed specifically to close the loop, it will only be feasible to create CE if eco-criteria are applied at the start of the merchandise's design period (e.g., through design rules and garment identification). Companies have expressed concern about having to collect secondhand clothes, both circular and non-circular, because this would significantly confuse the future material recovery procedure.

Quantity, quality, timing

Van Wassenhove and Guide (2009) argued that the CLSC demands sufficient secondhand commodities with appropriate quality, timing, and pricing. Based on the amount of cradle to cradle merchandises recovered, a distinction should be made among commodities flowing in natural and technical material cycles. Biodegradable clothing is designed for the biological world. Post-treatment includes collection and composting of clothing and fabrics. A well-known concern is that regulations at a local level could inhibit industrial-level clothes compost from all stages of production. For example, WorkCo, indicated that regulations in Germany do not admit fabrics to be involved in waste compost (Franco, 2017). The company is presently leading technical analyses to demonstrate to local experts that its clothes are appropriate for composting so that in future this company's garments could be dropped to dustbins or plants for composting. However, technical commodities need to be classified and disassembled for subsequent reproducing cycles. As there is a limited number of cradle-to-cradle clothes and fabrics on the market, firms like Gap Inc. and H&M Group have argued that the amount of recycled clothing is still limited and they need plenty of time to innovate recycling and remanufacturing technologies (Morlet et al., 2016).

Tracking systems

To date, no instruments have been developed for manufacturers or recyclers to trace and evaluate the lifespans of commodities sold, and to forecast the quantity and value, of returned merchandise and frequency of collection. Thus, tools for textile traceability need to be enabled in the production and distribution network. Traceability for CE can be applied by utilising exclusive identifiers allocated to track source components. Universal product codes, radio frequency identifiers, and 2-D barcodes are the most commonly used identifiers. As these tags become intelligent through sensors, and data are collected via Internet protocols (i.e., Internet of Things), logistic workers can have information about asset status, location, and accessibility, which will be conductive to product protection, recycling, and remanufacturing along the value chain (Franco, 2017). Ultimately, in association with identification and reusing technologies, the products' labels will report the exact fabrics and manufacturing procedures of recyclable part applied in the merchandise production process. In general, manufacturers assume that the development of information sharing and communication technology will play a significant role in tracing products and managing product life cycles in future (Lee and Kim, 2011).

2.4.5.2. Collaborative relationship building and interaction with circular supply chain execution

The first subsection here defines the challenges an enterprise faces in finding existing materials to turn classic products into recycled products. Nevertheless, to accomplish the circularity of manufacturing, a strong association among partners throughout the T&A supply chain is needed.

Lately, there is an indication that T&A companies should cooperate with other partners in manufacturer–supplier and retailer–manufacturer relationship of the manufacturing network to improve innovation capability (Lieder and Rashid, 2016).

2.4.5.2.1. Power balance in the manufacturer–supplier relationship

Manufacturing enterprises have always recognised the importance of good relations and clearly identified the need for trusted supplier relationships. A company's effective engagement with suppliers, consumers, and society shows that it is in a good position to reach the product stewardship phase of NRBV. In addition, suppliers are important in the circularity execution by linking the various phases in manufacturer's long supply chain (Hyder, Chowdhury and Sundström, 2017).

A manufacturing company's long-term business plan brings extra profits, and some suppliers are eager to take lower profits as they believe a sustainable image could improve profitability in the long run. Common commitment is also shown in the flexibility and reciprocity of suppliers, who hope to offer solutions and solve difficulties for the company. This emphasises the function of trust and collaboration as a complicated social resource and demonstrates the cooperative relationship involved in strategic profit-making (Kadarusman and Nadvi, 2013).

While some T&A companies presently purchase key resources from suppliers abroad, the present review shows that companies aspire to bring supply chains closer to home, to better fulfil their ecological commitment, e.g., reduction of energy consumption and CO_2 emissions in delivery (Oelze, 2017). A case in point is the invention and commercialization of original Merino yarn: in 2008, a British textile company identified a particular British farmer as having the essential associations, knowledge, and expertise for offering higher performance fibres and raw materials. This new material could be combined with the company's own technologies and design skills to achieve the recyclable production in the textile mills. This led to a very long-lasting cooperative partnership. The Merino story emphasises how companies are constantly striving to produce sustainable goods and demonstrate that continuous development is not limited to internal operations, e.g., pollution prevention, but includes how companies attempt to involve suppliers in the use of both tangible and implicit capitals (Bhool and Narwal, 2013).

2.4.5.2.2. Power balance in the buyer–supplier relationship

There are two elements that could affect the motivation for supply chain partners to participate and invest in cooperative innovation efforts towards CE in T&A industry: the position of an enterprise in the supply chain, and the scope and strength of the involved enterprise (Hyder, Chowdhury and Sundström, 2017). For instance, a company may face a struggle in persuading a supplier (e.g., a focal chemical provider) to adopt certain additives and dyes to meet sustainable and circular requirements for its fibers and fabrics. The refusal of the supplier to do so may arise from the fact that the sustainable chemical recourse demands from enterprises accounts for only a very small portion of their chemical sales. Thus, it is not attractive for a chemical producer to cooperate with the manufacturer, owing to the insufficient economic benefits.

Under the different context, some multinational companies have been working closely with suppliers to develop an innovative CE material for interior decoration projects. The results of this stable relations can facilitate the improvements in T&A supplies. There are three reasons that encourage the suppliers to accept the requirement of CE. First, the upcoming requirements from fabric firms are regard to be important. Second, these small manufacturers benefit from the CE's positive publishing reports. Third, if companies turn down the chance to be involved, other suppliers will seize it. Above all, the experience of engaging companies shows that the comparative bargaining power of buyers and suppliers influences their tendency to start cooperative revolution (Rizos et al., 2016), which represents another key aspect to be considered when understanding an enterprise's adoption of CE.

Although there is high degree of cooperation among supply chain participants in the development of circular innovation, Franco's research (2017) showed that these collaborative relationships still have some constraints. Frequently, buyers' and suppliers' innovation efforts have been defined by a participant's position in the manufacturing process; the bargaining power between buyers and suppliers; and whether the partner shares a common image for the future and/or previous working experiences, and enjoys a high level of trust. For example, Levi's sustainable development department manager reported on how longstanding relations with suppliers and consumers facilitated collaborative innovation. Levi stated that cooperation with the supplier account for 50% of their success (Dubey et al., 2019b). The company invested money and time to build trust and facilitate information sharing and this allows the supplier to follow their vision to achieve competitive advantage over its rivals.

2.5 Discussion of sustainable SCM toward a circular economy in the T&A industry

2.5.1 An integrated conceptual framework

According to the thematic findings, we now develop a conceptual framework that offers a synthesis and clearer understanding of the topic (Figure 2.6).

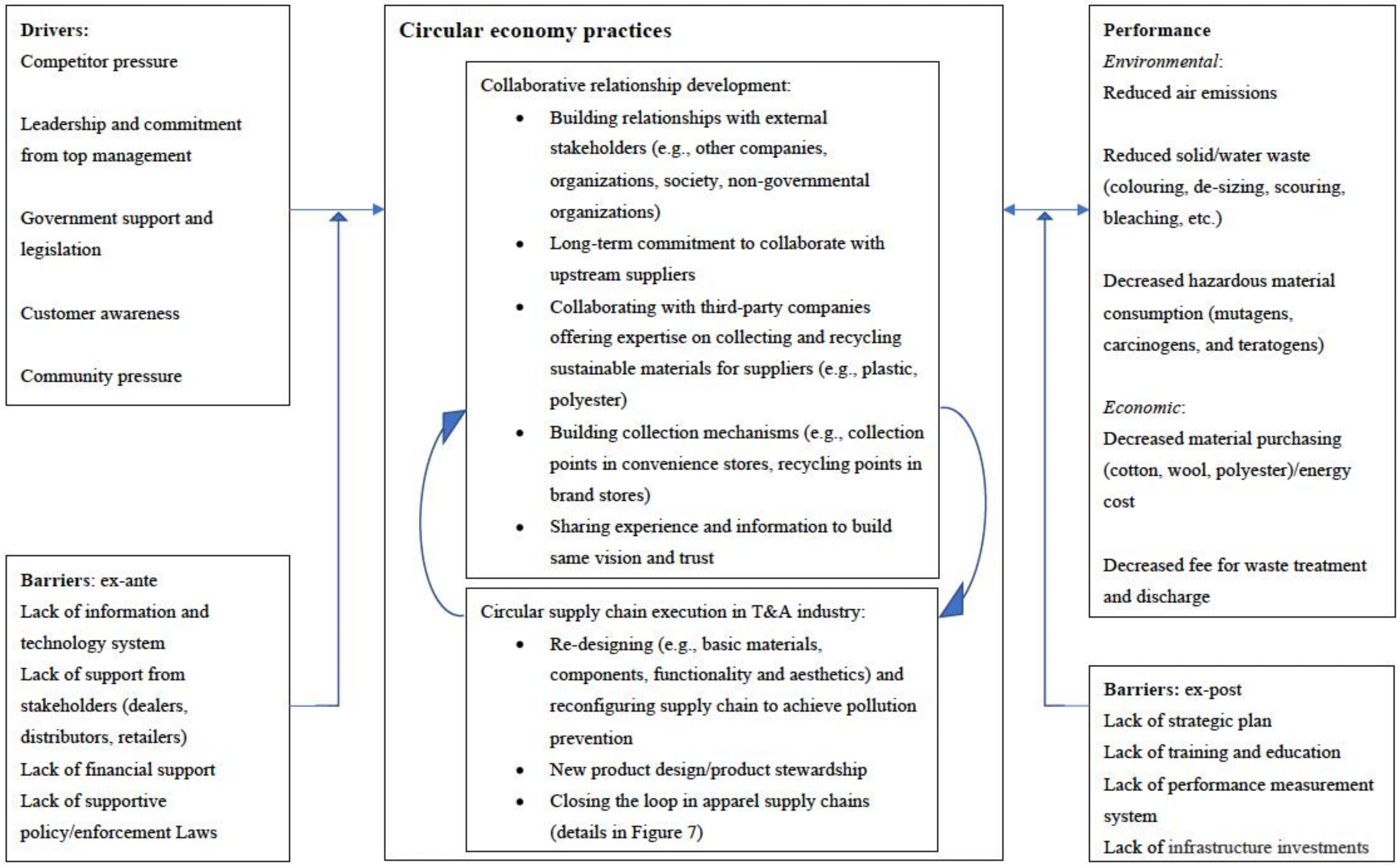

Figure 2.6 Conceptual framework

On the upper left side of the model, we classify four significant drivers for firms in the T&A supply chain to adopt CE practice. Customer awareness of sustainable products is considered the major driver because textiles and apparel belong to an essential consumer goods industry. Knowledge about the CE also increases the possibility of transitioning to a CLSC. Additionally, the ever-growing leadership and commitment from top management requests firms to have a reliable attitude towards SSCM. The increasing number of government funding and regulation is also a primary driving force for companies to adopt CE because they have rules and guidelines to follow and may obtain the financial assistance needed from government.

Barriers to implementing closed-loop practices are mentioned in two subsections. Ex-ante barriers are concentrated more in the preparation or investment stage of implementation, while ex-post factors focus on detailed constraints in building a long-term CLSC during the adoption process. We observed that the main obstacles for the T&A industry to apply a CE were financial constraints, especially for small and medium-sized enterprises (SMEs). Significant financial support is required in the infrastructure implementation and staff training, which enable the adoption of the CE. Accepting new sustainable certificates also requires specific financial funding.

Once a company understands the drivers and barriers, it begins to participate in building a CLSC to reach sustainable goals. Based on the literature review, practices are divided into two types: collaborative relationship development and dynamic supply chain execution. First, collaborative relationship development requires knowledge of the necessary innovative materials (i.e., new technology) deriving from these partnerships. Second, dynamic supply chain execution summaries how supply chains act to these practices to accomplish financial and ecological goals. One of the most important practices in CE implementation is to close the supply chain loop. Figure 2.7 lists the main steps in building a circular supply chain in the T&A industry. The arrows linking these two kinds of practices indicate that stable relationship building would lead to more effective supply chain execution; by the same token, dynamic supply chain execution would help a company to establish a better and more long-lasting relations with its stakeholders.

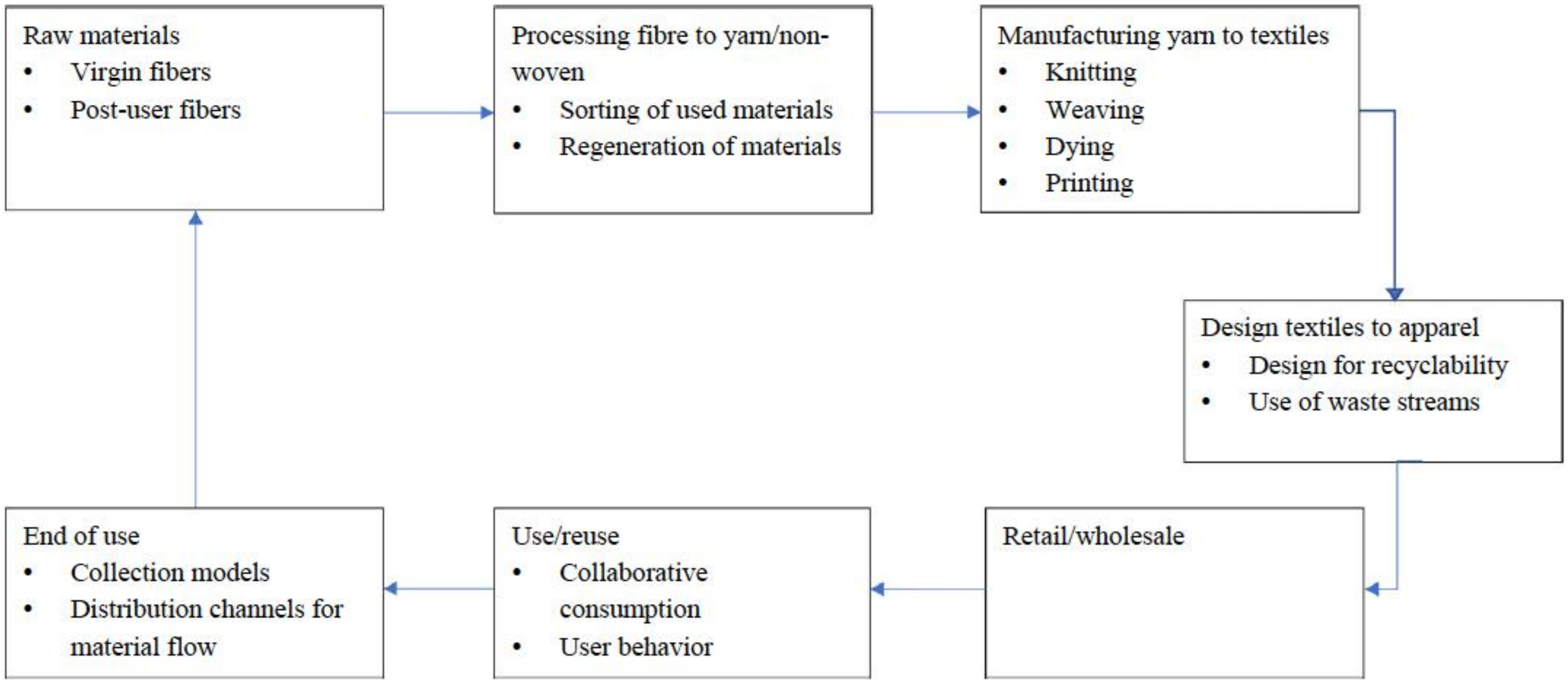

Figure 2.7 6R Closed-loop supply chain (synthesis of literature)

The last section in the conceptual framework shows targeted CE performance when applying a CE in the T&A SCM. The review of the selected articles revealed that most studies only mentioned environmental and economic performance to evaluate CE practices that could measure improvements after applying CE practices. These performance evaluation indicators could also guide the implementation of practices to be more comprehensive and systematic; such advanced practices will lead to better sustainable performance.

This conceptual model offers some managerial implications for the T&A industry.

For policy-makers and practice, one implication of our work involves regulation and the impact of fiscal and commercial stimulus on CE development. The literature emphasises the necessity to coordinate these measures to stimulate rather than impede organisational innovation (Ballie and Woods, 2018). Regarding the role of the organisational innovation process, this means that the supervisory framework needs to be regularly revised to ensure consistency even when policy-makers are unaware of the innovation at the time of regulation. It is also important to ensure that the regulations do not impede innovation, for example, by making alternative usages of waste too complicated because of the high specificity of waste treatment.

Developing eco-industrial parks is a common strategy to implement CE and consistency in the regulatory framework should not be limited to these settings of individual eco-industrial parks in the same region (Zeng et al., 2017). Since industrial symbiosis does not only need to be created in this environment, it also requires policy-makers to have a regulatory framework that allows for collaboration between different institutions (Tseng et al., 2018). In this case, consistency of the regulatory framework within the territory is important, as differences in territorial regulation can create barriers to cooperation.

As far as the role of incentives is concerned, actions should not only target the recycling of waste resources, but also take measures to support cooperative business organisations (for example, joint research and development strategies, resource exchange or other possible options), which may also stimulate the birth of CE projects. The inter-organisational cooperation may require a new participant who did not play a role initially. The implication here is to consider the possibility that after innovation, a new entity enters the scene, making industrial symbiosis possible, and collecting resources from existing entities.

2.5.2 Future research directions

According to the literature review results and the proposed conceptual model, we identified several research gaps, which include the lack of social factors in CE measurements and diversity of research methodology and ignore organisational obstacles in the application of the CE model and so on. A series of future research directions can be proposed in building a CE in the T&A supply chain.

First, according to the descriptive review results, it is obvious that the most frequent methodology applied in research in this field is single case study. Their findings might provide unique perspectives on the effective application of a circular supply chain, and the role played by tactical capitals and shareholder relations; however, they are not representative of all typical apparel company and thus are not generalisable to the entire T&A industry. Therefore, it is expected to see more multiple case studies on companies that implements a CLSC to achieve sustainable goal; to increase the universality of discoveries regarding CLSC exercise in other companies and industries. In future research, multi-case studies could be used to gather more data and reflective information to analyse the actors in the CE; alternatively, such studies could be extended through comparisons of multicultural cases or by enlarging cases to concern additional institutional backgrounds.

Second, our review of the literature indicated that numerous articles focus on relationship between environmental sustainability and CE, whereas very few articles analysed relationship between social sustainability and CE. Social dimensions are also an important indicator when building a sustainable supply chain. However, previous studies did not pay attention to social influences when applying a CE in the T&A CLSC. Thus, a second future research direction might be the analysis of how social factors influence the application and performance of companies' CE implementation. A systematic or fuzzy hierarchy process might be applied to rank the elements in future related analyses and further the ranked elements can be utilised to measure social performance in the CE.

Some studies purposefully examined the dynamics associated with products and projects, ignoring organisational obstacles that inhibit the application of the CE model. Thus, a third direction for upcoming studies of CE might focus on organisational obstacles to explore how the internal structure of a firm and tasks can be differently arranged or designed to accommodate the CE adoption. Other significant problems identified in this stream of the literature are the degree of sustainable entrepreneurship, the sustainability of product design, CLSC, environmentally friendly marketing, sustainability of cooperative innovation, sustainable business model, and industrial ecology, which may suggest the research in the application of a CE at the micro-level is needed in the future.

Fourth, after reviewing the literature, it was clear that technological innovation is an important enabler in applying a CE. Most studies have focused on what kind of technologies are used in the implementation and then analysed the effect of reducing waste emission, reusing materials, or remanufacturing recycled products. However, little research has focused on the effect (e.g., profitability or other financial performance) of adopting technologies in a CE. This could be a fourth future research direction for a CE.

The fifth and last area for future research is the dependence of traditional companies on their supplier networks for innovations. When existing manufacturers desire to modify their commodities, they prefer to use their current dealer system to meet the requirements of a CE. Future studies might employ network concept to consider how different vendor system structures affect the ecological innovation outputs of key companies, and how diverse industries with distinctive network configurations may bring different innovations to a CE. Ultimately, the dynamic behaviour of a CE could be quantitatively reviewed through system dynamics models. Distinctive situations could be constructed to quantitatively evaluate the transitions of economies, industries, and enterprises towards a CE, including variables such as time delays and feedback mechanisms.

2.6 Conclusion

This review has conducted a systematic literature review of the previous research regarding the CE in the T&A industry. It makes several contributions to the literature of the CE. First, it is the first literature review of CE focusing on T&A industry. Previous reviews selected several different manufacturing industries and provided general analyses of CE implementation. This study selected one of the most polluting industries that requires more efforts to become sustainable; and performed an in-depth analysis of how to build a CLSC in this selected industry. Second, this paper establishes an integrated conceptual model. The framework shows the drivers, ex-ante and ex-post barriers, circularity practices such as relationship building and dynamic supply chain execution, and performance measurement indicators. Two main actions are included in the CE practices section of the framework: building relationships; and executions in the supply chain. These two actions are integrated and promote each other to achieve a higher level of CE performance. A strong relationship with recyclers or manufacturers will help building closed-loop supply chain for used materials. A systematic CLSC will encourage stakeholders to invest in their own sustainable applications. Based on these two kinds of practices, the discussion section analysed the current practices and challenges in existing circular supply chain execution. Third, five actionable research directions are proposed on the basis of literature review.

The paper doesn't exempt from limitations. The major constraint of this review is that we used only one database to select the articles; for the circular execution section, future studies could employ more databases to find relevant articles. Another limitation is that in this conceptual model, we did not explore recycling steps in detail. Future studies could apply more detailed tools, e.g., 6R elements (redesign, reduce, reuse, recycle, remanufacturer, repair) to come up with a conceptual model for a

CE in the T&A industry.

Chapter 3. Circular Economy Practices and Sustainable Performance: A Meta-Analysis

Abstract

This paper aims to investigate the relationship between circular economy (CE) practices and enterprise performance based on existing empirical studies adopting a meta-analysis method. By systematically reviewing the literature, we identify 41 papers published on this topic between 2005 and 2021. The key finding supports that CE practice has benefited both firms' commercial and ecological sustainability. The results also show that industry type, enterprise scale, and country have a moderating effect on the relationship between CE practices and sustainable performance. In addition, the results of this study can support managers to have greater confidence in adopting CE practices in order to improve both commercial and environmental performance. Further, this may be the first meta-analysis on this topic resolving the mixed results in the existing literature.

Keywords: meta-analysis, circular economy, firm performance

3.1 Introduction

Industrial modernisation has produced damaging impacts on the ecosystem, such as carbon emissions, hazardous chemical leakages, and pollution (Walker and Jones, 2012). The CE practices are among the various methods developed mainly to promote economic development and sustainable performance (Singh and Singh, 2019). In a circular economy, the value of products and materials is maintained for as long as possible. In addition, waste and resource use are minimised, and resources are kept within the economy when a product has reached the end of its life (Kristoffersen et al., 2021). Firms configure and coordinate the organisational functions of marketing, sales, production, logistics, IT, finance, and customer service within and across firms to close material and energy loops and minimise resource input into and waste and emission leakage out of the system, which in turn improve firm performance (Del Giudice et al., 2021; Bai et al., 2019; Chen et al., 2021a). Meanwhile, a growing awareness of the ecological effects of manufacturing is exerting rising pressure on producers in both emerging markets and developed countries (Kayikci et al., 2021; Kuei et al., 2013). However, the expectation for producers to achieve continuous contribution to their home countries' financial development is also gradually increasing. Thus, there is a general consensus that management practices need to strike a balance between commercial development and environmental damage, as the manufacturing industry is predicted to maintain its rapid development over the next 10 years (Lai and Wong, 2012; Fernandez et al., 2021). As a result, manufacturers have begun to comprehend the urgent need to adopt an environmental approach, including recycling activities, alongside consumers and suppliers, to decrease the negative ecological effects of their services and commodities (Lee et al., 2013).

The topic of the CE is receiving growing attention from industries, academics, policy-makers and consumers (Bag et al., 2021a; Youn et al., 2013; Chen et al., 2022a). Specifically, there is an apparent demand for academic studies to determine whether CE activities result in desired firm performance (Kuei et al., 2013; Bag et al., 2021a). In addition, empirical research results on the influence of CE practices on enterprise performance are inconclusive. For example, Lo (2013) found that the implementation of CE practice has not led to financial growth for Chinese industrial enterprises; CE practice implementation was still in their infancy, implying heavy investment costs that may have increased firms' operating costs and hence decreased commercial profits. However, the latest research has explored a positive correlation between CE practices and financial benefits (e.g., Mitra and Datta, 2014).

Driven by these mixed results, our research seeks to better understand the correlation between CE practices and enterprise performance. This experiential generalisation is necessary because the implementation of CE practices is a complex and multi-faceted phenomenon. Therefore, we develop the following two research questions.

1. What is the impact of CE practices on firm performance?

2. What contingent factors influence the relationship between CE practices and firm performance?

In this study, a meta-analysis method is used to assist in exploring the relationship between CE practices and their impact on commercial and environmental performance (Hunter and Schmidt, 2004). We identify 41 empirical articles published between 2005 and 2021 through a systematic literature review, to produce the first meta-analysis that explores the correlation between CE practices and enterprise performance.

In this study, we discuss how the environmental protection practices of the CE have resulted in performance gains in both commercial and ecological aspects. The novelty of this study lies in that it provides a verifiable map of the integration of circular economic practices into the production process toward sustainable performance. Furthermore, the results indicate that industry type, enterprise size, and country moderate the relationship between CE practices and sustainable performance. It is also the first meta-analysis of this topic, resolving the mixed results found in the existing literature.

This study can be divided into five main sections. This section provides an overview of the research. Section 3.2 provides the literature review and hypothesis development. Section 3.3 presents the methodology for the research project, including the sampling, data coding, and study design. In Section 3.4, the research results are presented, including statistics on representative characteristics of the study sample, as well as a description of the findings of the moderator analysis. In Section 3.5, we present the research findings, discuss the conclusions, outline the limitations, and suggest areas for future research based on the findings.

3.2 Hypotheses development

Numerous studies have highlighted the importance of economic factors in determining CE practices. According to Gusmerotti et al. (2019), cluster analysis is used to examine the implementation level of CE practices, and logit regression is used to identify the most relevant factors to facilitate their implementation in the manufacturing industry; it is found that economic efficiency is the most important factor and CE practices simultaneously achieve environmental and financial benefits. In this section, we propose our hypotheses on the relationship between CE practices and firm performance and the effects of different aspects of CE practices. Following a discussion of the meta-analysis approach, we propose hypotheses on the moderating effects of different countries, industries and firm sizes.

Many of the selected articles discussed the correlation between CE practices and company performance in both commercial and ecological aspects. Zailani et al. (2012b) stated that a CE is applied by enterprises to obtain better supply chain performance. Though corporations' main objective remains commercial gain (Gimenez and Tachizawa, 2012), rising worldwide attention on ecological problems is forcing the manufacturing industry to develop its environmental performance (Zhu et al., 2008; Gimenez and Tachizawa, 2012). Consequently, governments are developing more stringent regulations or laws for manufacturers aimed at ensuring environmental performance (Gimenez and Tachizawa, 2012; Delbufalo, 2012; Mohanty and Prakash, 2014; Huo, Zhao and Zhou, 2014). Additionally, while researchers who study CEs generally focus on commercial, operational, and environmental performance, in recent years, some have also considered social problems (e.g., safety and working conditions; Delbufalo, 2012). Thus, we propose our first hypothesis:

H1: CE practices are positively correlated with company performance.

For the six types (industries) of manufacturing companies (oil, chemicals, and plastics, apparel and textiles, gadgets, computers and transportation, food production, metal working and mixed manufacturing), achieving commercial objectives is the foundation for accepting CE practices (Mathiyazhagan, Govindan and Haq, 2014; Del Giudice et al., 2021). However, several previous studies have stated that CE practices cannot have a positive influence on companies' commercial performance (Kamboj and Rahman, 2015; Zhu and Sarkis, 2004). In the early stage of implementation, investment is usually required, which may raise operating costs and negatively affect financial performance. In contrast, Mathiyazhagan, Govindan and Haq (2014), Zhu, Sarkis and Geng (2005), Lee, Kim and Choi (2012), and Kamboj and Rahman (2015) highlighted a significant positive correlation between CE practices and corporate performance.

Contrary to the findings on the effects of CE on firm performance, the reviewed papers indicate a clear positive relationship between CE practices and environmental performance in manufacturing industries (e.g., Matos and Hall, 2007; Parisi et al., 2015; Zailani et al., 2012a; Redjeki, Fauzi and Priadana, 2021). In this regard, Mitra and Datta (2014) demonstrated that significant environmental performance improvement can be accomplished by reducing waste. In addition, Lee et al. (2013) assessed several CE practices, such as new product design, recyclable manufacturing procedures, and management innovation, and revealed a positive correlation with environmental performance. Nevertheless, Zhu, Sarkis and Lai (2013) and Nkundabanyanga, Muramuzi and Alinda (2021) noted that producers did not actively think about these activities during the design stage, and indicated that CE practices within a supply chain exert a negative impact on environmental performance. A number of articles have explored a positive relationship between CE practices and operating performance (e.g., Abdullah and Yaakub, 2014; Wu, 2013; Dou, Zhu and Sarkis, 2014; Liu et al., 2012; Sardana et al., 2020). Adopting CE practices can improve the effectiveness of waste treatment and recycling, avoiding fines from the relevant environmental protection agency, and reduce the cost of waste disposal and future compliance costs (Sardana et al., 2020). Thus, Lai and Wong (2012) found that CE practices can improve efficiency, allowing companies to reduce elements such as scrap rate, distribution period, and stock holdings, thus improving operating performance.

Based on the above discussion, we propose the second and third hypotheses:

H1a: CE practices are positively correlated with economic performance.

H1b: CE practices are positively correlated with environmental performance.

In the literature review, some scholars drew samples from diverse industries and firms that have distinctive corporate positioning. According to Min et al. (2005), the degree of collaboration varies among industries. There is a need for industries to rethink the way they manage relationships in order to prosper in their businesses without exhausting primary materials and energy (Rajala et al., 2018). Most of the selected articles collected data from a single industry. Nagarajan et al. (2013) argued that data collected from mixed industries have more variation than those collected from a single industry. Hence, we investigate whether the type of industry moderates the correlation between CE practices and company performance.

We therefore propose that:

H2: The CE practice and business performance relationship varies according to industry types.

Likewise, country factors may alter the implementation of CE practices, and therefore change the effect of CE practices on firm performance (Wong et al., 2012; Kim and Rhee, 2012). Kim and Rhee (2012) found that, in developed countries such as Korea, there are policy factors affecting the relationship between CE practice and firm performance; the impact of CE practices on environmental and commercial performance is strengthened by country factors. Under the globalisation of production, electronics manufacturers manage inherently complex CE activities that involve a multitude of partners located in different geographical countries (Wong et al., 2012).

Based on the above discussion, we propose that:

*H3: The CE practice and business performance relationship varies accor*ding to countries.

We find mixed results for the moderating effect of firm size on the relationship between CE practices and company performance in the literature. Nasir et al. (2017) concluded that the scale of the firm does not affect the application of CE practices. However, Wu (2013) found that firm size was positively related to green product and process innovations. In addition, Zhu et al. (2008) found that company scale in the Taiwanese garment manufacturing industry is positively correlated with green procurement and ecological design. The number of employees (organisation size), regulatory pressures, source reduction policies and high environmental costs played a significant role in the application of green purchasing practices (Zhu et al., 2008). We argue that the firm size moderates the relation between CE practices and company performance. SMEs perform better in this situation on environmental matters than on social and economic grounds if they follow the principles of CE. When it comes to purchasing decisions, SMEs generally focus on keeping the production costs low, unless they have specific requirements from the customer.

Based on the above discussion, we propose the final hypothesis:

H4: The CE practice and business performance relationship varies according to firm size.

3.3 Methodology Framework

3.3.1 Sampling

This paper examines the effect of CE practices on corporate performance through a meta-analysis – a procedure to analyse the coefficients of previously published research comprising a quantitative synthesis of the results from a number of identified relevant empirical studies (Vandermerwe and Rada, 1988; Baines et al., 2009; Golicic and Smith, 2013; Chen et al., 2021d). The technique is an externally validated, rigorous approach that allows the accumulation of outcomes from numerous studies to produce comprehensive and effective results. It therefore provides strong support for a proposed framework and justifies the differences in earlier experimental results. This meta-analysis is mainly concentrated on empirical studies where the independent variables are CE indicators and the corresponding dependent variables relate to enterprise performance. We calculate the corrective correlations between constructs according to the guidelines and processes discussed by Hunter and Schmidt (2004).

To explore the correlation between CE activities and enterprise performance, we searched English peer-reviewed journal articles using a combination of search keywords related to CE and company performance. As the 'circular economy' concept was proposed in the 1970s (Damanpour, 1991), we searched for all relevant articles published in peer-reviewed journals from January 1970 to August 2021 in the following databases: Web of Science, Scopus and Business Source Complete (EBSCO). The Web of Science, for example, is one of the most influential databases for obtaining scientific and technological information (Abreu-Ledón et al., 2018). Over thirty thousand journals in top-level subject areas are included in Scopus, which is the largest database of peer-reviewed literature in the world.

The search strings for CE and company performance were taken from previous studies. In particular, the CE search terms were drawn from literature reviews that provide sustainability-oriented definitions and cover all key terms (Liu and Bai, 2014; Gusmerotti et al., 2019; Ünal and Shao, 2019; Bartolacci et al., 2019; Wong et al., 2012; Batista et al., 2018a). Keywords used as search strings can be seen in Table 3.1. In this paper, we propose that CE practices are related to firm performance in two aspects: commercial and environment. Therefore, search terms related to company performance were obtained from existing articles (Younis and Sundarakani, 2019; Choi and Hwang, 2015), which are mentioned in Table 3.1.

Table 3.1 Key words in the meta-analysis

Field	Key words
CE practices	'circular economy' or 'green economy' or 'sustainable economy' or 'recycling economy' or 'cyclic economy' or 'circular business' or 'green business' or 'sustainable business' or 'cyclic business' or 'recycling business' or 'green production' or 'circular production' or 'sustainable production' or 'cyclic production' or 'environmental management practices' or 'green practices' or 'environmental management practices' or 'green supply chain' or 'recycling production' or 'reuse' or 'remanufacture' or 'refurbish' or 'redistribute' or 'maintain/prolong' or 'share' or 'recycling' and 'resource conservation'.
Company performance	'sustainable performance' or 'green performance' or 'firm performance' or 'enterprise performance' or 'business performance' or 'corporate performance' and 'company performance'.

We used the combination of the above CE and business performance keywords to search the database from EBSCO, Scopus, and Web of Science through titles, keywords, abstracts, and article topics. A primary sample of 8,610 papers was identified after eliminating duplication and browsing for relevancy by reading abstracts. We then used three inclusion criteria to select valid papers. First, the paper must conduct empirical research on the effect of CE performance, so as to provide effective quantitative data for subsequent analysis. Second, the paper must analyse the relationship between independent variables (CE practices) and dependent variables (company performance). In this study, the Pearson product-difference correlation coefficient was utilised to indicate a relationship between CE practices and enterprise performance (Hedges and Olkin, 2014). If such correlation was not explicitly evident, we used the formula in Appendix A to convert other data (including Student's *t*, F ratio, χ^2 value, Cohen's d, and β coefficient) to provide a corresponding correlation (Peterson and Brown, 2005; Cohen, West and and Aiken, 2014). Third, the paper must employ a unique dataset. If several papers use the same dataset, only one was selected for the sample. In total, 41 papers met these criteria, exceeding the requirement for a minimum sample size (2 articles) for a meta-analysis (Valentine et al., 2010). Table 3.2 summarises these 41 selected empirical papers.

Table 3.2 Coding results of sample studies

No.	Study	Year	Data	Analysis method	Theoretical lens	Country	Industry	Firm size	CE practices	Performance	Sample size	Effect size
1	Aranda-Usón et al.,	2019	Survey	PLS-SEM	RBV	Spain	Food Production	SMEs	Eco-design	Environment performance: waste reduction	87	0.198
2	Bag, Dhamija and Foropon,	2018	Survey	EFA	RBV	South Africa	Oil, Chemicals, and Plastics	Mixed	Cleaner production	Environment performance: pollution discharge	150	0.138
3	Bartolacci et al.,	2019	Survey	Regression analysis	RBV	EU	Gadgets, Computers, and Transportation	Mixed	Waste management	Environment performance: waste reduction	52	0.224
4	Başaran,	2013	Survey	Categorical regression analysis	Not specific	Turkey	Oil, Chemicals, and Plastics	Mixed	Eco-design	Environment performance: energy conservation	255	0.113
5	Bassia and Diasb,	2019	Survey	Regression analysis	Not specific	EU	Metal Working	SMEs	Waste management	Economic performance: improvement of sales	441	0.123
6	Biswas,	2019	Survey	SEM	RBV	India	Oil, Chemicals, and Plastics	Mixed	Cleaner production	Environment performance: waste reduction	87	0.423
7	Botezat et al.,	2018	Survey	Cronbach's alpha and factor analysis	RBV	Romania	Apparel and Textiles	SMEs	Waste management	Economic performance: market share	98	0.487
8	Dodescu et al.,	2018	Survey	Cronbach's alpha and factor	RBV	Romania	Gadgets, Computers, and Transportation	SMEs	Eco-design	Economic performance: improvement of sales	98	0.445

				analysis								
9	Chan,	2005	Survey	Various regression and multi-group analysis	NRBV	China	Oil, Chemicals, and Plastics	Mixed	Cleaner production	Environment performance: pollution reduction	429	0.376
10	Choi and Hwang,	2015	Survey	Hierarchical regression	NRBV	South Korea	Metal Working	Mixed	Waste management	Economic performance: market share	230	0.502
11	Ferro-Soto, Macías-Quintana and Vázquez-Rodríguez,	2018	Survey	SEM	Not specific	Columbi a	Mixed	Mixed	Eco-design	Economic performance: market share	279	0.492
12	Fondevila et al.,	2017	Survey	Regression analysis	RBV	Spain	Food Production	SMEs	Waste management	Environment performance: waste reduction	297	0.254
13	Gusmerotti et al.,	2019	Survey	Cluster analysis	RBV	Italy	Metal Working	SMEs	Cleaner production	Economic performance: improvement of sales	821	0.275
14	Hájek and Stejskal,	2018	Survey	Confirmator y factor analysis	Not specific	Czech Republic	Oil, Chemicals, and Plastics	SMEs	Eco-design	Economic performance: market share	523	0.434
15	Hojnik et al.,	2017	Survey	Cross-section analysis	RBV	Slovenia	Metal Working	SMEs	Eco-design	Environment performance: energy conservation	98	0.335
16	Hojnik et al.,	2018	Survey	Cross-section	RBV	Slovenia	Gadgets, Computers, and	SMEs	Waste management	Environment performance:	125	0.034

				analysis			Transportation			pollution reduction		
17	Ionascu and Ionascu,	2018	Case study	Regression analysis	RBV	Romania	Metal Working	Mixed	Eco-design	Economic performance: market share	266	0.034
18	Liu and Bai,	2014	Survey	ANOVA	Not specific	China	Apparel and Textiles	SMEs	Cleaner production	Environment performance: waste reduction	157	0.023
19	Pamfilie et al.,	2018	Survey	ANOVA	Not specific	Romania	Mixed	Mixed	Customer responsibility	Environment performance: pollution reduction	74	0.546
20	Sinnandavar, Wong and Soh,	2018	Survey	PLS-SEM	RBV	Malaysia	Gadgets, Computers, and Transportation	Mixed	Cleaner production	Environment performance: pollution reduction	110	0.145
21	Ünal and Shao,	2019	Survey	ANOVA	RBV	China	Apparel and Textiles	Mixed	Eco-design	Economic performance: improvement of sales	187	0.854
22	Varshneya and Das,	2017	Survey	SEM	Not specific	India	Apparel and Textiles	SMEs	Customer responsibility	Economic performance: market share	152	0.535
23	Varshneya and Das,	2017	Survey	SEM	Not specific	India	Apparel and Textiles	SMEs	Customer responsibility	Economic performance: market share	152	0.825
24	Vijayvargy, Thakkar and Agarwal,	2017	Survey	ANOVA	RBV	India	Oil, Chemicals, and Plastics	SMEs	Cleaner production	Economic performance: improvement of sales	161	0.256
25	Wang et al.,	2014	Survey	Statistical analysis	RBV	China	Mixed	Mixed	Eco-design	Economic performance: market share	111	0.553

26	Wong et al.,	2012	Survey	SEM	NRBV	Taiwan	Mixed	SMEs	Waste management	Economic performance: improvement of sales	122	0.576
27	Yi,	2014	Survey	Regression analysis	Not specific	The US	Apparel and Textiles	Mixed	Cleaner production	Environment performance: energy conservation	48	0.067
28	Younis and Sundarakani,	2019	Survey	Comprehensive statistical analysis	RBV	China	Food Production	SMEs	Waste management	Economic performance: market share	117	0.257
29	Zeng et al.,	2017	Survey	EFA	Not specific	China	Metal Working	Mixed	Waste management	Economic performance: improvement of sales	363	0.565
30	Zhang and Wang,	2014	Survey	Regression analysis	RBV	China	Apparel and Textiles	Mixed	Cleaner production	Environment performance: pollution reduction	258	0.287
31	Zhang et al., 1	2012	Survey	Regression analysis	RBV	China	Apparel and Textiles	Mixed	Eco-design	Environment performance: waste reduction	85	0.034
32	Zhang et al., 2	2019	Survey	ARDL model	RBV	China	Metal Working	Mixed	Cleaner production	Economic performance: improvement of sales	30	0.565
33	Zhu, Geng and Lai,	2010	Survey	ANOVA	RBV	China	Oil, Chemicals, and Plastics	Mixed	Eco-design	Environment performance: pollution reduction	334	0.234
34	Zhu et al.,	2011	Survey	Data analysis	Not specific	China	Metal Working	SMEs	Waste management	Environment performance: energy conservation	396	0.775
35	Zhu, Sarkis and	2012	Survey	ANOVA	Not	China	Apparel and	Mixed	Waste	Environment performance: waste	117	0.796

	Lai,				specific		Textiles		management	reduction		
36	Kayikci et al.,	2021	Survey	Fuzzy DEMATEL	Not specific	Turkey	Oil, Chemicals, and Plastics	SMEs	Cleaner production	Economic performance: improvement of sales	34	0.334
37	Kristoffersen et al.,	2021	Survey	PLS-SEM	Not specific	EU	Mixed	Mixed	Cleaner production	Economic performance: improvement of sales	125	0.209
38	Fernandez de Arroyabe et al.,	2021	Survey	Data analysis	Not specific	EU	Mixed	Mixed	Eco-design	Economic performance: market share	870	0.034
39	Blasi, Crisafulli and Sedita,	2021	Survey	Regression analysis	Not specific	Italy	Food Production	SMEs	Cleaner production	Economic performance: improvement of sales	168	0.498
40	Bag et al.,	2021a	Survey	PLS-SEM	RBV	South Africa	Gadgets, Computers, and Transportation	Mixed	Waste management	Environment performance: waste reduction	35	0.385
41	Nag, Sharma and Govindan,	2021	Survey	Grey-DEMATEL	RBV	India	Oil, Chemicals, and Plastics	Mixed	Eco-design	Environment performance: waste reduction	68	0.835

3.3.2 Data coding

Coding variable metadata, necessary to ensure the comparability and heterogeneity of meta-analysis studies, is a challenging task. A common problem is guaranteeing that the dissimilar metrics for the same construct are constant across the initial papers; for example, problems with the boundaries of the structures may be present. Regarding this, the literature review in this paper found the term 'performance' was widely applied in varying evaluations. We solved this problem by assessing whether the indicators in the definition of commercial performance were coherent. Through discussions among the co-authors, we confirmed that three-quarters of the projects strictly matched the definition of that construct (Geyskens et al., 2009). First, the co-authors agreed on the various dimensions of CE practices and the theoretical description of enterprise performance categories. Using carefully selected definitions for the constructs, the sample was coded to minimise deviations, and any lingering disagreement was resolved via further discussion. In general, when there were over 75% of the elements in every construct that strictly fitted our definition, we divided the construct into related aspects of performance types or CE practices (Gebauer et al., 2012). The coding was conducted by two researchers who have knowledges in CE practices and meta-analysis. The two researchers worked independently and then compared their results after completing the coding process. Inconsistent results were solved through discussion and re-coding until a complete agreement is reached. If the two researchers cannot agree on each other, then a third expert was consulted.

3.3.2.1 Dependent variables

After analysing the empirical research sample selected for the meta-analysis, we coded corporate performance based on two aspects to measure the precise impact of CE practices—economic performance and environmental performance—defined as follows:

(1) Economic performance—effectiveness in obtaining profit—is an important motivation for corporations to apply CE practices. Consequently, we coded studies that used this goal detected as two aspects (an improvement of sales, revenue and an improvement of market share) to measure financial performance, and then analysed the relationship between CE

practices and financial performance (Lieder and Rashid, 2016; Bai et al., 2019; Nag, Sharma and Govindan, 2021).

(2) Environmental performance is usually associated with three aspects (energy conservation, waste reduction and pollution reduction). In addition, linking supply chain performance with production processes and environmental performance can reduce discharge of gas, liquid, and landfill waste and consumption of hazardous materials (Lee, Kim and Choi, 2012). Indicators for measuring environmental performance include energy conservation and reduction of waste and pollution (Nasir et al., 2017). This paper thus states enterprise performance as the sum of financial and environmental performance.

3.3.2.2 Independent variables

The independent variables of this meta-analysis comprise CE practices. It is argued that two relevant aspects of CE are the most important, i.e., the front (eco-design) and the back end in production (Kayikci et al., 2021). In addition, it is imperative for firms to take a view of consumers' responsibility and waste management. Of the 41 review articles, 29 assessed the acceptance of CE practices using Bechtel, Bojko and Völkel's (2013) measurement methods as a guide, which is based on Maxwell's Model. According to Ghisellini, Cialani and Ulgiati (2016), there are four types of CE practices: eco-design, cleaner production, consumers' responsibility, and waste management.

(1) In terms of eco-design, Prendeville et al. (2014) have demonstrated that this stage plays a central role in CE to enhance its advantages (primarily focusing on resource utilisation), as eco-design is designed to reduce all environmental impacts in the product life cycle. Since eco-design takes into account all the environmental impacts of a product since the early stages, it has the potential to improve the CE approach by facilitating the use of materials and resources (Prendeville et al., 2014; Geissdoerfer et al., 2017).

(2) Cleaner production has been the most effective measure and more widely adopted than other practices especially after the enactment of China's "Cleaner Production Promotion Law" in January 2003 (Nag et al., 2021). This is a strategy designed to address pollution generation in all states of production and the efficient use of resources. For enterprises with

serious pollution, cleaner production is mandatory and plays an outstanding role in reducing environmental externality and energy intensity (Kayikci et al., 2021). Su et al. (2013) on the promotion of clean technology barriers in China's SMEs research showed that external barriers of policy and financial barriers rather than the inner barriers of technical and managerial barriers should be emphasised.

(3) Consumers' responsibility is an important element to encourage the acceptance of environmentally friendly activities, the CE and sustainable performance (Hanna, Newman and Johnson, 2000; Zheng et al., 2021). Customers are concerned about whether manufacturers are shifting from a linear to a circular production model. Ecological cooperation with consumers is a key driver because consumers prefer to purchase sustainable commodities in line with information on the importance of sustainability provided by the government or community awareness raising campaigns (Narwal, 2018).

(4) In the area of waste management, it encourages companies to design their products for return at the end of their life and to establish product recycling systems to maximise the use of recycled parts and equipment produced (Bartolacci et al., 2019). CE is mainly recognised as a strategy for waste management or for implementation of environmental policies at the maturity stage of economic development. Waste management becomes an important sub-sector of circular economy, with the emergence of new typologies of operators and processes, among which the so-called "scavengers" and "decomposers" refer to those firms capable of extracting resources out of waste by applying innovative recovery technologies (Del Giudice et al., 2021).

3.3.2.3 Moderating variables

The moderators of a meta-analysis are significantly different from standard moderators, which are usually derived from the control variables in empirical research (Chan et al., 2016). The moderating variable in a correlation examination is a third variable that influences the zero-order correlation between independent variables and dependent variables (Bassetti, Blasi and Sedita, 2020). In the reviewed articles, scholars emphasised a number of aspects that can influence CE practice acceptance and corporate performance (Rasool and Shah, 2015; Khan et al., 2021; Golicic and Smith, 2013; Abdulrahman et al., 2014). In line with these findings, the moderators considered in this paper include firm size, industry type, and country.

Some scholars have pointed out that enterprise size is an important issue affecting the firm performance with CE practices (Siemieniuch, Sinclair and Henshaw, 2015; Mittal and Sangwan, 2014; Dodescu et al., 2018; Jia et al., 2020); however, results remain inconclusive. We decided that firm size should be considered a moderator when analysing the implementation of CE practices. To code the size of the firm, we categorised articles based on whether the data were drawn from small or medium-sized enterprises or mixed enterprises.

To code type of industry, we divided the papers into two groups of whether the data were gathered from a single industry or mixed industries. The majority of articles focused on a particular industry category using data from the oil, chemicals and plastics industry, apparel and textiles, gadgets, computers, transportation, food production or metal working industry, few focused on mixed industries.

In addition, some researchers have argued that country can exert an effect on the application of CE practices. Based on Wong et al. (2012) and Kim and Rhee (2012), examples of such surveys taken from developed countries indicated a high correlation. Therefore, we divided articles into two groups based on whether the data were drawn from developing countries or developed countries.

3.3.3 Meta-analysis process

According to Hunter and Schmidt (2004), meta-analysis refers to a kind of quantitative accumulation designed to examine the effect size of an entire sample of articles. Experimental studies on CE practices and enterprise performance are categorised by a large amount of small-scale ground research, and the influence on performance is controversial. Chiou et al. (2011) noted that such empirical research lacks universality due to differences in sampling standards. The empirical findings of previous research can be summarised via meta-analysis (Raudenbush, Rowan and Kang, 1991).

Borenstein, Hedges and Rothstein (2009) mentioned two conditions that need to be met to apply fixed effects model. First, all the studies included in our analysis are functionally identical. Second, the effect size is computed for an identified population, not for other populations. In our case, the 41 studies were carried out by different researchers independently. It is unlikely all the studies are functionally equivalent. In addition, the 41 studies investigated the impact of CE practices on firm performance among different populations. That says, the two conditions for fixed effects model are violated. We should therefore apply random effect model, which is favored by National Research Council (Hunter and Schmidt, 2004). We follow Hunter and Schmidt's (2004) meta-analysis process. First, we used Pearson product-moment correlations in every paper, aiming to evaluate the mean effect size. If no correlation is presented, Hunter and Schmidt (2004) offered several formulae to convert statistics (e.g., Student's *t*, χ^2, Cohen's d, and F ratio) into correlations (see Appendix A). Commercial performance was widely utilised, via various indexes. We coded research that included goals or expected gains in sales, revenue, or market share to measure financial performance. During the coding process, if a paper included various correlations for a single dimension, we computed the average of these correlations.

Regarding sample-weighted correlation, the sampling error will be little if the sample size of each individual study is large enough (Mackelprang and Nair, 2010; Abreu-Ledón et al., 2018; George, Walker and Monster, 2019). Since our sample is large and assembled (see Table 3.2), we did not consider the sample-weighted correlation in our meta-analysis. In our research, confidence intervals are chosen, because the confidence interval comes into play in a frequentist confidence interval before collecting the data. Credibility intervals come into play in a Bayesian credible interval after collecting the data (Hunter and Schmidt, 2004). In addition, z-scores were calculated to evaluate whether effect sizes within different groups were statistically significant. Ultimately, we analysed the *Q*-statistic, a χ^2 distributed value with $k-1$ degrees of freedom, which is helpful to evaluate heterogeneity (Stam, Arzlanian and Elfring, 2014). *Q*-statistic are values related to χ^2 for determining the heterogeneity. Moreover, we used the fail-safe N to measure the opportunity for publication bias (Orwin, 1983). The fail-safe N (or *Nfs*) is a 'file drawer' evaluation that decides how many zero-effect size analyses are needed to produce a non-significant *p*-value (Hunter and Schmidt, 2004), as shown below:

$$N_{fs} = \frac{N(d - d_c)}{d_c}$$

where N is the sample size of the meta-analysis, d represents the mean of the effect size in the comprehensive study, and d_c is the standard value. The threshold of fail-safe N at 95% confidence level is 5*sample size + 10. The Nfs of our study is 9461, which significantly exceeds the threshold value (5*41 + 10 = 215) and suggests no significant publication bias.

In this study, we selected comprehensive meta-analysis (CMA) to run the above formula for the meta-analysis.

3.4 Results of the meta-analysis

3.4.1 CE practices–performance relationship

We used Cohen et al.'s (2003) guiding principles to describe the correlation effect size in the meta-analysis results, such that less than 0.10 indicates a weak correlation, 0.10 – 0.30 a moderate correlation, and over 0.30 a strong correlation.

A number of theoretical lenses were applied in the sampled papers (see Table 3.3). Some (39.02%) did not apply a theoretical lens, while the resource-based view (RBV) (53.66%) was the most commonly utilised theory. Table 3.3 also lists the analysis methods used in the sample. Regression analysis was one of the most common methods to evaluate data in this sample (19.51%), while SEM and ANOVA were also widespread (12.2% and 14.63% respectively).

Table.3.3 Theoretical lens and analysis methods in sampled articles

Theoretical lens	Number	Percentage (%)	Analysis method	Number	Percentage(%)
RBV	22	53.66%	Regression analysis	8	19.51%
Not specific	16	39.02%	ANOVA	6	14.63%
NRBV	3	7.32%	SEM	5	12.20%
			PLS-SEM	4	9.76%
			EFA	2	4.88%
			Cronbach's alpha and factor analysis	2	4.88%
			Cross-section analysis	2	4.88%
			Data analysis	2	4.88%
			Categorical regression analysis	1	2.44%
			Various regression and multi-group analysis	1	2.44%
			Hierarchical regression	1	2.44%
			Cluster analysis	1	2.44%
			Confirmatory factor analysis	1	2.44%
			Statistical analysis	1	2.44%
			Comprehensive statistical analysis	1	2.44%
			ARDL model	1	2.44%
			Grey-DEMATEL	1	2.44%
			Fuzzy DEMATEL	1	2.44%

PLS-SEM: Partial least squares-structural equation modelling

EFA: Exploratory factor analysis

ANOVA: Analysis of variance

SEM: Structural equation modelling

Table 3.4 shows the outcomes of the meta-analysis for the correlation between CE practices and company performance. The CMA calculation results demonstrate that the correlation between CE practices and enterprise performance (the sum of commercial and environmental performance) is significant ($r = 0.374$, $p = 0$). The confidence interval (0.303, 0.463) does not contain 0, which implies moderators are not present (Hunter and Schmidt, 2004). Therefore, the overall effect of CE practices on firm performance is confirmed (H1). Though the acceptance of environmental protection activities requires a large initial investment, the profits from saving energy, reducing waste, and improving operating efficiency may exceed this cost (Zhu, Sarkis and Lai, 2013; Borenstein, Hedges and Rothstein, 2009; Bag et al., 2021a).

This result indicates that collaboration with consumers for environment protection objectives can increase financial profits for producers (Brax and Visintin, 2017). This study further proves that cooperating with consumers to implement CE activities helps the company to better understand consumers' needs for eco-friendly products, so that manufacturers can deliver better goods and services for commercial benefit (Lee, Kim and Choi, 2012).

3.4.1.1 CE practices and economic performance

In Table 3.4, the results show that there is a strong positive correlation between CE practices and Economic performance in two aspects, which are improvement of sales ($r = 0.365$, $p = 0$) and market share ($r = 0.345$, $p = 0$), supporting hypothesis H1a. In terms of finance, when an enterprise invests in CE practices, it can reduce warehouse investment, facilitate asset returns, control the budget, and improve financial performance (Gimenez and Tachizawa, 2012; Chen et al., 2021a). Thus, these data verify previous findings on the association between CE practices and commercial performance, evaluated based on growth in sales, turnover, and market share.

Table.3.4 Meta results of the economic and environment performance

Random-effects analysis	Subsamples	n	K	r	Lower limit	Upper limit	Z	P	Q	I^2 (%)	SE
Company Performance		9461	41	0.374	0.303	0.463	1.357	0.000	1986.634	94.248	0.022
Economic Performance	Improvement of sales and revenue	2550	11	0.365	0.256	0.456	3.458	0.000	256.553	93.486	0.035
	Improvement of market share	2798	9	0.345	0.166	0.378	3.646	0.000	253.455	92.435	0.034
Environment Performance	Energy conservation	797	4	0.175	0.063	0.239	1.538	0.000	53.955	92.576	0.027
	Waste reduction	985	9	0.354	0.245	0.449	2.562	0.000	145.365	87.440	0.035
	Pollution reduction	1480	7	0.277	0.147	0.556	4.077	0.000	246.644	92.028	0.024

This research also identifies distinctive metrics that might affect the strength of the correlation between CE practices and company performance. These results agree with previous arguments that the effective implementation of a CE relies on building relations with external shareholders (Zhu and Sarkis, 2004; Kuei et al., 2013). Thus, we conclude that a long-lasting association with stakeholders can increase flexibility and improve financial performance.

Close cooperation with suppliers in delivering ecological practices can decrease unnecessary costs and increase quality of merchandise, leading to higher commercial benefits (Chan et al., 2016; Huang, Wu and Rahman, 2012). Additionally, cooperation with suppliers to achieve environment protection objectives allows producers and dealers to work together to develop a suitable strategy to meet end-consumer demands (Luoto, Brax and Kohtamäki, 2017).

3.4.1.2 CE practices and environmental performance

In Table 3.4, CE practices show a moderating correlation with environmental performance in three aspects, which include energy conservation ($r = 0.175$, $p = 0$), waste reduction ($r = 0.354$, $p = 0$), pollution reduction ($r = 0.277$, $p = 0$); therefore, H1b is partly supported.

Corporations can adjust manufacturing, service, and shipping processes with suppliers (Chan et al., 2016); for example, producers could review eco-friendly design of their commodities with suppliers at the start of the manufacturing phase (Wong et al., 2014), and suppliers could utilise ecologically friendly resources and packaging to meet manufacturers' environmental protection requests (Rao and Holt, 2005).

3.4.2 Moderator analysis

Table 3.5 lists the effects of the three moderators (industry type, country, and enterprise size).

Table 3.5 Meta results of the moderating effects

Random-effects model	Factors	Subsamples	*n*	*K*	r	Lower limit	Upper limit	*Z*	*P*	*Q*	I^2 (%)	*SE*
Control variable	Firm size	Mixed	4563	21	0.376	0.249	0.547	5.675	0.000	334.947	94.462	0.034
		SMEs	4047	20	0.345	0.256	0.448	5.487	0.000	253.543	92.564	0.039
	Industry	Oil, Chemicals, and Plastics	2041	9	0.375	0.265	0.485	3.573	0.000	154.456	92.450	0.034
		Apparel and Textiles	1254	9	0.234	0.153	0.350	2.743	0.000	145.445	86.464	0.015
		Gadgets, Computers, and Transportation	420	5	0.298	0.042	0.356	1.324	0.000	89.745	87.548	0.023
		Food Production	669	4	0.123	0.045	0.298	1.598	0.000	55.935	92.576	0.056
		Metal Working	2645	8	0.545	0.235	0.735	7.486	0.000	364.745	95.053	0.035
		Mixed	1581	6	0.598	0.455	0.556	13.894	0.000	153.535	96.575	0.004
	Country	Developed	3700	14	0.254	0.153	0.398	4.856	0.000	375.035	84.653	0.022
		Developing	4910	27	0.475	0.376	0.735	8.147	0.000	593.436	93.657	0.056

First, it presents the results of the moderating effect of type of industry. In terms of industry types, we categorised the sample into oil, chemicals, and plastics, apparel and textiles, gadgets, computers and transportation, food production, metal working and mixed manufacturing. The results show that the correlation between CE practices and corporate performance is the strongest in metal working industries (r = 0.545, p = 0), while the correlation is weakest in food production industries (r = 0.123, p = 0). Of six industry categories, three showed very strong effects: oil, chemicals, and plastics (r = 0. 375, p = 0), metal working (r = 0.545, p = 0) and mixed manufacturing (r = 0.598, p = 0). In addition, findings vary widely among companies of different industries. Thus, hypothesis H2, that the CE practices–business performance relationship varies according to industry type, is supported.

This is consistent with the meta-analysis conducted by Zhu, Sarkis and Lai (2007b), which discovered that, in all areas, mixed industry exerted a larger impact than any single industry; perhaps because mixed industries had received great attention regarding ecological protection activities (Lee, Kim and Choi, 2012). However, Lai, Wong and Lam (2015) noted that while Chinese manufacturers accept cooperation with suppliers regarding CE practices, collaboration with consumers lags behind. As a result, CE practices only slightly increased ecological and operational performance, but did bring significant financial improvement (Wong et al., 2012; Rao and Holt, 2005). Our research confirms that the application of CE practices in the manufacturing industry has the greatest bearing on improving corporate performance. Scholars have offered various possible explanations. First, CE practices are commonly accepted in the manufacturing industry (Zailani et al., 2012b). Second, the manufacturing industry is the leader in CE implementation (Lee, Kim and Choi, 2012).

In addition, the meta-analysis results indicate that all countries had significant correlations, but companies in developing countries (r = 0.475, p = 0) had a stronger correlation than companies in developed countries (r = 0.254, p = 0). Thus, H3 is supported. The reason for this may be that corporations in developing countries are required to obey laws and regulations enforced by diverse governments to enter the international market, which bring them more profits than domestic markets.

Our meta-analysis results consider the relationship between CE practices and corporate performance for both SMEs and mixed companies. The outcomes reveal that the correlation between CE practices and firm performance in mixed enterprises (r = 0.376, p = 0) is similar to that in SMEs (r = 0.345, p = 0). This implies that the CE practices–business performance relationship may not vary according to firm size. Therefore, H4 is rejected.

Previous research has claimed that the scale of the company does not affect the correlation between CE practices and performance (Suryanto and Mukhsin, 2020). One explanation for these results may be that the majority of SMEs lack the personnel and commercial capital to adopt CE practices (Golicic and Smith, 2013). Under this context, they usually strive to implement management reforms to meet ecological and social standards (Zailani et al., 2012a). In addition, Zhu, Geng and Lai (2010) claimed that SMEs implement ecological protection activities under pressure from ecological requirements and market supervision.

3.5 Discussion and conclusion

This meta-analysis discovered a number of relationships between CE practices and business performance. In this meta-analysis, we classified and evaluated 41 papers involving 8,610 firms. Our meta-analysis results show that CE practices have resulted in better financial and environmental performance. More specifically, the strongest correlation between CE practices and performance is financial performance, followed by environmental performance. Further, the results indicate that the correlation between CE practice and performance is moderated by several factors (economic country, industry type, and firm size). Mohanty and Prakash (2014) argued that adopting CE practices has become an essential and profitable strategy, as a CE not only reduces costs, but also meets the requirements of diverse shareholders. The findings of this research have also significant practical implications. In recent years, CE has been widely implemented across industrial supply chains in accordance with most countries' climate change policies.

3.5.1 Theoretical implications

The existing literature has yielded inconsistent and even contradictory outcomes regarding CE practices' impact on enterprise performance. This study is based on the synthesis of findings from the existing literature on the relationship between CE practices and company performance, and further analysis of the impact of moderator variables on this relationship. This study contributes to the emerging topic of a circular supply chain in the operations management literature from the following aspects.

More than one-third (39.02%) of the reviewed articles did not apply any underpinning theory. Nevertheless, after analysing the selected samples, we notice that research that had a theory showed a stronger correlation between CE practices and performance than research without a theory. Some studies have tried to clarify the correlation between CE practices and corporate performance based on NRBV or RBV theory. According to the existing literature and meta-analysis findings, we suggest that applying a theory to the research design process may result in more robust results, therefore future research is advised to adopt a theoretical lens.

First, the results of the meta-analysis deliver convincing evidence that the impact of CE practices on corporate performance is significant and positive. Though there are negative or debatable relations in the existing literature, the listed analysis of this study indicates that the inconsistencies in the research may be attributable to sample size, economic country, industry type, and enterprise size. This supports the findings of Montabon, Sroufe and Narasimhan (2007), as well as Van Weelden, Mugge and Bakker (2016), that customers are not only required to return commodities after use, but are also willing to purchase remanufactured stuffs if enterprises adopt CE practices. In addition, many scholars have studied the topic of consumer awareness and other shareholder collaboration models to discover the efficient accomplishment of a CE and improvement of company business performance (Blasi, Crisafulli and Sedita, 2021; Su et al., 2013). In the subgroup evaluation, although many scholars believe that establishing a cooperative supplier relationship is important for CE implementation in the supply chain (Circulair, 2015; Ghisellini, Cialani and Ulgiati, 2016; Zhou et al., 2007; Yu et al., 2022), the effect of customer responsibility on financial performance and environmental performance measurements is generally greater than that of supplier collaboration. This suggests that consumer responsibility of CEs plays a more significant role in improving commercial performance. However, the sample size for consumer responsibility is smaller than that of supplier collaboration, indicating few studies are devoted to customer responsibility effects on firm performance. This calls for further empirical studies on customers' responsibility of CEs.

Second, this study also confirms that CE practices have a stronger positive impact on company commercial performance than non-commercial performance, because of the nature of CE practices. For environmentally friendly production, CE practices are an efficient method for manufacturing companies to gain competitive advantage and produce intangible profits, like improving consumer loyalty and strengthening the relationship between buyers and sellers (Franco, 2017; Baxter et al., 2018). However, the implementation of CE practices requires significant resources and investment, which may not be reciprocated in the short term. This finding helps to clarify the complex relationship between CE practices and commercial performance. Therefore, we consider that there may be unexpected factors that affect manufacturers' CE practices and commercial performance, which require further study. In addition, social performance is a gap in extant CE studies. Therefore, future research could pay closer attention to these relationships, examining how CE practices affect company social performance.

Third, regarding moderating effects, the results indicate that, compared with studies that collect data from companies in one industry, studies that collect data from mixed industries find a stronger relationship between CE practices and performance. The reasons why some industries find it easier to produce profits by implementing CE practices than others may be worth investigating. For example, unit budgets, average industry profitability, revenue, and competition intensity in diverse industries may affect the effectiveness of CE implementation. Collecting data from diverse industries rather than a single industry may offer a better understanding of the correlation between CE practices and performance.

Fourth, moderating variables can also explain the differences in the correlation between CE practices and performance. In previous research, the contextual variables, such as industry and country, have often been considered control variables (Svensson, 2007; van Raaij and Schepers, 2008). In terms of industry, our results show that CE implementation in non-manufacturing industries has no significant effect on performance, while CE implementation in manufacturing industries has a significant and positive impact on corporate performance. This finding may be explained by differences in product and service positioning (Chen, Wu and Wu, 2015). However, the effectiveness of CE implementation for manufacturing vs. service industries is far from clear; thus, we call for further empirical studies on this topic.

Fifth, the results of the meta-analysis indicate that the effect of CE practices on corporate performance varies by country types. More specifically, the performance impact was significant in developing countries, while the impact in developed areas was insignificant. This finding is not entirely consistent with previous research. It allows individual SMEs, consortia of SMEs, and policy-makers to make decisions that enhance CE implementation (e.g., prioritising initiatives through formulating strategies, implementing policies, the allocation of resources, and capacity building). For instance, Lungu (2020) found that consumer awareness had a significant impact on business performance in developed areas, but not in developing countries. It is worth noting that the sample of developing countries in this study only include China and India, which represent two special developing country cases. Further research in other developing countries could lead to a more robust meta-analysis examining the correlation between CE practices and company performance in developing countries.

3.5.2 Managerial implications

This study poses practical significance for the manufacturing industry. First, our research provides significant empirical indication that CE practices can impact company performance, in spite of firm scale, industry, and geographic location. Our results show that when manufacturers consider ecological factors in their Supply Chain Management (SCM), they can not only reach greater performance in terms of sales, revenue, and market share, but also achieve energy conservation, waste reduction, and a decrease in pollution reduction. In addition, the company's operational efficiency (such as scrap rate, distribution period, stock holdings, and capacity utilisation) may also improve (Chen et al., 2022b). The positive correlation between adopting CE practices and ecological and commercial performance may encourage managers to consider the CE as a business approach to develop company performance. Golicic and Smith (2013) indicated that sustainable supply chain initiatives can increase many facets of enterprise performance. Confidence in implementing CE practices should be strengthened, as many results come from organisations already following such practices. For instance, many industries have rapidly adopted green manufacturing activities such as total quality management and ISO9000 certification (Diabat, Kannan and Mathiyazhagan, 2014), which appear to produce similar positive results when dealing with ecological problems, such as reducing waste, shortening and adjusting lead-times, and improving product and service quality.

Second, the study provides managers in the manufacturing industry with insight into the diverse performance improvements after adopting each CE practice. Thus, enterprises could identify the significance of government support and legislation in obtaining benefits from CE implementation (Yu, Khan and Umar, 2022). Additionally, policy-makers should actively participate in the formulation of ecological guidelines and legislations to encourage manufacturers to adopt ecological principles, as they prefer to adopt ecological activities with appropriate standards and principles (Zhu, Sarkis and Lai, 2012). Therefore, policy-makers could use a 'carrot and stick' strategy to incentivise manufacturers to apply CE practices (Zailani et al., 2012b).

Finally, the meta-analysis results offer some performance measurement metrics to help managers more easily clarify the benefits of adopting a CE. Manufacturers have started to pay their attention to balancing commercial improvement and ecological protection because of stakeholders' demands for ecological products and services. In addition, subsequent workshops and additional communications through research articles and webinars may be of benefit to SMEs.

Jawaad and Zafar (2019) claimed that corporations are becoming more efficient at evaluating the expenses and profits of integrating with consumers and supplier collaborators. The techniques they now use to plan and manage transactions with supply chain collaborators are likely to be utilised to evaluate similar opportunities related to ecological sustainability and potential results for corporate performance. Although this may seem obvious, many companies are slow to adopt sustainable practices (Huang and Yang, 2014). This situation has been exacerbated by inconsistent results in academic research. The results of our meta-analysis deliver a more comprehensive indication that companies will receive progressive commercial outcomes from their circular supply chain efforts. This analysis should thus encourage manufacturing corporations to adopt a CE to increase the utilisation rate of resources.

3.5.3 Limitations and future research directions

This study has some limitations. First is the inherent constraints of a meta-analysis. Particularly, different studies draw data from varying sources at varying times, and reach multiple subjective findings. There has been limited empirical research on the CE so far. To the best of our knowledge, we analysed all valid research based on the existing literature. It is feasible to expand the sample size and re-test the robustness of the hypotheses as the amount of empirical research on CE increases in future. In addition, this study only investigates some of the many contextual issues. It is recommended to include factors such as product features in future research. Moreover, meta-analysis can only examine linear relationships between CE and firm performance. The method is not able to investigate non-linear effects of CE practices on performance, which require alternative method (e.g., survey) to explore it. Finally, in further empirical studies on the correlation between CE practices and performance, scholars are advised to propose detailed measurements for both CE practices and business performance. This will support more comprehensive meta-analysis in the future, thus developing the theory of CE.

Chapter 4. Does Digital Transformation Improve Circular Economy Performance?

Abstract

Purpose – Digital transformation (DT) has been recognised as promoting a circular economy (CE). However, there is little empirical evidence on the effect of DT on CE. This research aims to explore the relationship between DT and CE, and how this relationship is affected by potential institutional pressures.

Design/methodology/approach – To analyse this relationship, we collected panel data from 238 Chinese listed high-tech manufacturing companies from 2006–2019. Based on the institutional theory, we develop a research framework and hypotheses, including the moderating effect of three variables: political connection, regional institutional development and industry competition.

Findings – The regression results indicate that DT positively affects CE performance at a firm level. Moreover, we further identify that this relationship is enhanced when the level of regional institutional development and industry competition are higher. However, a firm's political connection does not affect the DT - CE performance relationship.

Originality – This study provides solid evidence on the firm-level DT – CE performance relationship. The results of this paper provide both theoretical and practical implications, and should inspire future research on this topic.

Keywords: circular economy, digital transformation, institutional theory, sustainability, secondary data analysis

4.1. Introduction

A circular economy (CE) has become an alternative to the prevailing economic development paradigm to deal with the surging demand for natural resources and the accompanying environmental pressure since it allows for the sustainable adoption of productive systems and resource utilisation (Ghisellini, Cialani and Ulgiati, 2016; Jia et al., 2020). According to Geissdoerfer et al. (2017, p.14), a CE can be defined as "the regenerative system in which resource input, waste emission and energy leakage are minimised by slowing, closing, and narrowing material and energy loops". To that end, the CE strategy aims to convert the linear supply chains into circular supply chains (Lüdeke-Freund, Gold and Bocken, 2018). In traditional consumption systems, natural resources are depleted, causing shortages and pollution of the environment (Genovese et al., 2017). On the contrary, a circular supply system shapes a restorative production system. Resources are reused, remanufactured, and recycled throughout the product's life cycle in an endless loop (Mangla et al., 2018). Moreover, by giving firms new options to create value, earn income, cut costs, be resilient, and establish legitimacy, the CE strategy decouples economic growth from limiting resource restrictions (Manninen et al., 2018). Therefore, managers, policy-makers, and academics now perceive the CE strategy as an essential means to achieve sustainability (Geng et al., 2009).

Recently, scholars have realised the potential of digital transformation (DT) in achieving CE (e.g., Kristoffersen et al., 2021; Chauhan, Parida and Dhir, 2022; Okorie et al., 2023). DT has been defined as a process of reshaping the business model through digital technologies to create additional value and opportunities (Verhoef et al., 2021). The creation and use of digital technology has emerged as one of the most popularly discussed issues in both academic and professional circles in the current frontier of Industry 4.0 (Li, 2020; Koh, Orzes and Jia, 2019). Blockchain, cloud computing, Internet of Things (IoT), and artificial intelligence (AI) has been considered as the primary digital technologies involved in DT in Industry 4.0 era (Chen et al., 2022c). Due to the widespread use of these digital technologies, many industries are changing the way they handle their traditional production and operations, which could benefit both pollution prevention and productivity improvement (Nasiri, Saunila and Ukko, 2022; Sheng, Feng and Liu, 2022).

Specifically, DT may overcome barriers to a CE, such as inadequacy of product life cycle information (Lopes de Sousa Jabbour et al., 2018). The IoT technologies, for example, enable automatic item location monitoring and natural resource tracking (EMF, 2016). Implementing big data analysis and

AI may improve real-time data processing (i.e., waste and resource matching) to help manufactures improve production efficiency and reduce resource waste (Low et al., 2018). These beneficial effects of DT can also be reflected in some practical examples. Google, for instance, has adopted AI-based resource management approach in its data centers to reduce the energy consumption for cooling by 40% (Wakefield, 2016). Moreover, SF Express, the largest express logistics service provider in China, has adopted big data analytics and IoT technologies to optimise its automated sorting process to achieve better storage resources allocation and energy consumption reduction (Sheng, Feng and Liu, 2022).

However, although DT has been considered as an essential antecedent of successful CE adoption (Kristoffersen et al., 2020; Antikainen, Uusitalo and Kivikytö-Reponen, 2018; Pagoropoulos, Pigosso and McAloone, 2017), disagreement also exists in the literature. For example, DT may produce greater carbon dioxide emissions as a result of data management because the adoption of those advanced digital technologies involves more energy consumption (Cohen 2018). Moreover, there have been scant empirical investigations into the conceptual nature of the DT – CE relationship, which represents a substantial gap in the existing literature (Alcayaga, Wiener and Hansen, 2019; Rosa et al., 2019; Uçar, Dain and Joly, 2020). The few case studies on the topic (e.g., Ingemarsdotter, Jamsin and Balkenende, 2020) tend to focus on single organisations or industries, so their generalisability is low. Other empirical study on DT tend to focus on how DT improves firm level sustainability (e.g., Belhadi et al., 2021; Chen and Hao, 2022), ignoring CE performance. Meanwhile, 70% of respondents to a Gartner study of 1374 supply chain leaders said they planned to make investments on CE, while just 12% have linked the DT strategies and their circular economy visions (Kristoffersen et al., 2020). In other words, there is lack of guidance on how to leverage DT to maximise resource efficiency and productivity for a better CE outcome. It should be noted that how DT influence CE is still under-investigated.

In response to calls for more empirical studies on the relationship between DT and CE (Chen et al., 2022a; Chauhan, Parida and Dhir, 2022; Barbieri et al., 2021), we explore the role of DT in CE performance by adopting firm-level secondary data from the Chinese high-tech industry. Meanwhile, we also identify factors that have moderating effects on the DT – CE performance relationship to contribute to the literature. In particular, we adopt institutional theory to explore the potential moderating effects of the institutional pressures, as those external pressures may significantly affect the decision making of a firm. According to institutional theory, an institution is a form of governance based on laws, customs, standards, and cultural significance (Scott, 1987). Given that each context is unique, organisational behaviours in the business sector must be described in terms of context. Business decisions are consequently impacted by external pressures in addition to being reasonable economic decisions (DiMaggio and Powell, 1983). Although the adoption of DT and CE practices are typically facilitated by these external forces (Bag et al., 2021c), there is currently no study providing empirical evidence on the potential moderating effect of institutional pressure on DT – CE performance relationship, which represents another research gap (Chauhan, Parida and Dhir, 2022). Therefore, this study aims to explore the relationship between DT and CE performance in firm-level and how this relationship is affected by institutional factors. We thereby proposed the following research questions to guide this research:

1. What is the impact of firms' DT on their CE performance?
2. How do different institutional pressures affect the DT - CE performance relationship?

By conducting a rigorous regression analysis on the sample data, this study contributes to the existing DT - CE debate in the following three aspects. First, we are the first to provide empirical evidence to confirm a positive DT - CE relationship in Chinese context. This study thereby extends previous DT literature that only focus on environmental performance. Second, we explore the potential moderating effects on DT - CE relationship and find that regional institutional development and industry competition have positive moderating effects on the DT - CE relationship, while political connection does not affect the DT - CE relationship. Third, by considering the Chinese context, our study provides inspirations to other emerging countries or regions to promote CE.

The rest of the paper is organised as follows. Chapter 4.2 examines the critical constructions and theoretical underpinnings of resource-based view theory and formulates the hypotheses. The research design including data collection and model formulation is described in Chapter 4.3. Chapter 4.4 presents the regression results. In Chapter 4.5, a discussion of the results and the potential contributions are provided, while Chapter 4.6 concludes this research.

4.2. Literature review and hypotheses development

4.2.1 Conceptual development of digital transformation

DT is a multidisciplinary topic that has been discussed in the marketing, strategic management, and information systems literature (Nambisan, Wright and Feldman, 2019; Gong and Ribiere, 2021; Chen et al., 2021a; Li, 2020). In earlier definitions, the concept of DT was used as a synonym for the traditional definition of digitisation or digitalisation (Verhoef et al., 2021). According to Gartner's IT Glossary, digitisation refers to the change from analogue to digital form, whereas digitalisation refers to using digital technologies to provide new revenue and value-producing opportunities (Gong and Ribiere, 2021). With the extensive adoption of advanced digital technology in the era of industry 4.0, the concept of DT has emerged as the result of the action of "going digital" (Gong and Ribiere, 2021). Therefore, scholars have generally realised that DT is more than digitisation, and is not equivalent to digitalisation, although the results or effects of digitisation may feed back into digitalisation and DT. For example, some scholars highlight the value creation of DT, such as improved operation efficiency and customer experience (e.g., Fitzgerald et al., 2013), while others focus on the transformation of business models (e.g., Kane et al., 2015). Chen and Hao (2022) argued that DT refers to the transition through which businesses evolve from previous industrialization stage to smart manufacturing in current industry 4.0 era. Therefore, DT is also considered as the adoption of those emerging technologies such as IoT technology, big data analysis approach, and blockchain (Chen and Hao, 2022). To avoid confusion and make clear the concept of DT, this study adopts the definition of DT developed by Verhoef et al. (2021, p.889) "a change in how a firm employs digital technologies, to develop a new digital business model that helps create and appropriate more value for the firm". Table 4.1 presents the comparisons among digitisation, digitalisation and DT in terms of definitions and examples.

Table 4.1 Comparison among digital transformation, digitisation and digitalisation (adapted from Verhoef et al., 2021; Gong and Ribiere, 2021)

Type	Definition	Examples
Digitisation	The technical process of converting analog signals into a digital form (Legner et al., 2017).	Automated routines and tasks; Conversion of analog into digital information.
Digitalisation	A sociotechnical process of applying digitising techniques to broader social and institutional contexts that render digital technologies infrastructural (Tilson, Lyytinen and Sørensen, 2010).	Use of robots in production; Addition of digital components to product or service offering; Introduction of digital distribution and communication channels.
Digital transformation	A change in how a firm employs digital technologies, to develop a new digital business model that helps create and appropriate more value for the firm (Verhoef et al., 2021).	Introduction of new business models like 'product-as-a-service', digital platforms, and pure data–driven business model.

With a sharp increase in DT publications, scholars have started to focus on how DT affect organisation's performance. While many studies explore the positive effect of DT on business success (Nasiri, Saunila and Ukko, 2022; Chen et al., 2022c) and innovation improvement (Nambisan, Wright and Feldman, 2019), only few studies focus on the potential of DT on sustainability aspects, especially on CE. According to a literature review conducted by Chauhan, Parida and Dhir (2022), advanced digital technology, such as IoT and AI play a key role in the transition towards the CE. However, no study provides empirical evidence to quantify the relationship between DT and CE. Existing empirical research exploring the relationship between DT and environmental performance tends to focus on single environmental dimension such as carbon emission (e.g., Sheng, Feng and Liu, 2022) instead of a comprehensive CE performance measurement. Moreover, several studies proposed that DT exposes companies to new risks, such as energy waste and increased carbon emission (Dubey et al., 2019b). Therefore, there is a controversy regarding whether DT helps firms to achieve better CE performance. In the next section, we specifically discuss the connection between the DT and CE in the manufacturing industry. Table 4.2 summarises selected literature that relates to this study.

Table 4.2 Studies related to the topic of DT and CE

Studies	Research type	Performance type	Findings
Li et al. (2022)	Empirical	Sustainable performance	DT fosters economic performance at an accelerating rate, it depicts an inverse U-shaped relationship with environmental performance.
Lopes de Sousa Jabbour et al. (2018)	Conceptual	Circular economy	Unveiling how different digital technologies emerged in Industry 4.0 era could underpin CE strategies.
Chen and Hao (2022)	Empirical	Environmental performance	DT can significantly improve corporate environmental performance. This relationship is affected by board characteristics.
Sheng, Feng and Liu (2022)	Empirical	Carbon performance	Low-carbon operations management practices mediate the impact of DT on carbon performance.
Chauhan, Parida and Dhir (2022)	Review	Circular economy	IoT and AI play a key role in the transition towards the CE.
Okorie et al. (2023)	Conceptual	Circular economy	21 identified digital technology-based core competencies are categorised as forms of competitive advantage that may be possible for manufacturing firms pursuing net-zero emissions.
Kristoffersen et al. (2020)	Conceptual	Circular economy	Developing the Smart CE framework that supports translating the circular strategies into the business analytics requirements of digital technologies.

4.2.2 CE performance measurements

Both industry and academics are paying more attention to the idea of circular economy, yet its definition, measurements, and implications remain disputable (Murray et al., 2017). For instance, the idea has been incorporated into government programmes in diverse ways in numerous countries. According to Marino and Pariso (2020) and Skrinjaric (2020), European countries have mostly concentrated on commercial prospects, notably resource allocation management. In response to pollution, China launched its circular economy strategy (Mathews and Tan, 2016; Yong, 2007). However, a generally acknowledged and exhaustive list of performance indicators is yet to be devised to enable a larger range of applications and assessments in a number of scenarios, owing to the complicated scenarios and different contexts.

Performance measurement for circular economy is being developed through several projects. The International Organisation for Standardisation (ISO), the Global Reporting Initiative (GRI), the Circular Gap Reporting Initiative (CGRI), and the Ellen MacArthur Foundation are some of the involved organisations which strive to harmonise the efficient assessment of circular economy operations. They present guidelines, structures, tools of assistance, and standards for the implementation of circular activities inside the organisations, with the ultimate goal of enabling companies to compete while addressing concerns associated with sustainable development.

The performance measurements from these efforts are summarised by Kouhizadeh, Zhu, and Sarkis (2023). Some researchers concentrate on certain economic operations, such as public procurement, while others focus on environmental sustainability, such as product life cycle evaluation and waste management. There is not a systematically consistent category of performance measurement.

The E.U. has accepted the idea of CE as a promising approach for realising the broader sustainable development goals (Hartley et al., 2020; Mhatre et al., 2021). The prioritised indicators for performance measurement have changed over time along with organisational and political policies.

When the CE performance indicators were created by the European Commission in 2015, they emphasised on increasing resource, material, and product value while avoiding waste creation. As a result, carbon footprint, resource efficiency, and renewable energy became the crucial performance metrics in 2017. Therefore, minimising carbon emission became the priority. However, after the CE goal was changed by the European Commission (EC) to sustainability in 2018, circular economy policy initiatives began to involve the reduction of waste and the use of plastic.

Although the guiding principles of circular economy are understandable and persuasive, particularly in Europe, China, and Japan, and the idea has widespread popularity in policy regulations, the assessment of its implementation success is nevertheless a cause for worry. This is mostly attributable to the absence of a comprehensive and consistent set of performance measurements. The circular economy approach, which was made public by the EU in its Circular Economy Action Plan from 2015, profoundly influenced the main performance measures considered in this analysis (Mayer et al., 2019). The use of these indicators could be justified by their thoroughness, broad coverage of the various stages of circular economy, and the meticulous quantification of each indicator.

Production and consumption, waste management, second-hand raw materials, competitiveness and innovation, and trash management are the four fundamental stages of circular economy that are closely connected with logistics and supply chain operations. Sub-metrics are included in certain measures. One submetric used to measure waste generation is municipal waste generation per person. The dependent variable for this study was chosen on the basis of these metrics.

4.2.3 Digital transformation and CE performance

There is a consensus that I4.0-related DT can help accelerate the transition to a more circular economic system (Rosa et al., 2019). Specifically, DT contributes to environmental sustainability by improving resource management efficiency. For example, the emergence of additive manufacturing technology, intelligent material planning and allocation systems, and intelligent robotics have contributed to production efficiency and the development of circular and environmentally friendly products (Niaki, Torabi and Nonino, 2019). With Big Data analytics, IoT collects real-time input-output data to help industrial symbiosis systems better transform waste into resources (Bin et al., 2015).

Meanwhile, DT helps overcome potential barriers to successful CE adoption in organisations or supply chains. For example, scholars have argued that the lack of information on product life cycles and the shortage of advanced technologies for clear production diminish the use of CE principles (Geng et al., 2009). Purchasing remanufactured or recycled products may lead to sub-optimal quality or higher remanufacturing additional costs (Bag et al., 2021b). In addition, uncertainty about cost, return on investment, and timing of implementation often leads to initial reluctance to adopt such an ambitious target (Lopes de Sousa Jabbour et al., 2018). However, due to the spread of emerging technologies based on I4.0 principles, it is feasible to overcome the obstacles of CE adoption. For example, Bag et al. (2021b) argued that DT in supply chains brings visibility, resilience, and flexibility while reducing uncertainty and risks in the production system, which helps overcome the challenges in CE operations. Therefore, DT can be seen as an enabler of a CE.

A digital cockpit created by Voith, a multinational technology company, is to visualise complicated processes and to enable wise decision-making with the ultimate objective of boosting process efficiency.

Dewatering, retention, and flocculation operations may be stabilised and coordinated by using a cockpit in the paper industry to keep track of the whole process. The increased material efficiency (up to 2.5%), decreased variation in paper quality (formation, porosity, and opacity), effective retention agent use, energy savings of up to 35% (drives, stock, and vacuum pumps), decreased abrasion on forming filaments, and reduced need for raw materials (fibres, starch) jointly meet the requirement of paper strength.

Robots and sensors are expected to change the method of recycling and sorting of rubbish. Big Belly, Enevo, and SmartBin are the examples of technical solutions with smart assets now available in the market (Hong et al., 2014). By using artificial intelligence, AMP Robotics has created Clark the Robot, a waste management tool that can recognise and classify food and beverage containers. It can also recognise and redirect milk, drink, and food cartons from the garbage to the right recycling facilities by using cutting-edge vision systems based on deep learning capabilities. According to Digital Trends 2017, Clark achieved a high accuracy of 90% in gathering recyclable materials and is around 50% faster than people. The use of Clark lowed the sorting expenses by 50%.

IBM is the global leader of consulting and IT services. In order to aid industrial managers to increase the reuse of goods, parts, and resources, IBM recently created a reuse optimisation tool (The Ellen MacArthur report, 2016) that can combine and evaluate information on market trends, availability and accessibility of components, technical qualities of materials and products. It is now possible to effectively comprehend the actual potential worth of reusing goods, parts, or materials. The data may be further refined to maximise business profitability, improve resource management, and boost resource productivity. The use of reuse selection techniques allows businesses to develop business cases for recycling assets, thereby cascading them into other use cycles, and preventing them from being wasted.

Another common perspective is that DT enables circular business models (CBMs) (Rosa et al., 2019). Frishammar and Parida (2018) described CBM as a cognitive schema that focuses on companies, together with partners, adopting circular practices to improve resource efficiency and thereby create, capture, and deliver value while promoting sustainability. From this perspective, DT plays a strategic role by integrating stakeholders, such as customers and co-providers, to achieve a CE vision. Specifically, DT promotes existing CBMs by promoting value creation, delivery, and acquisition. For example, the introduction of 3D manufacturing facilities can enhance the development of customized goods and services, adding value for CBMs (Turner et al., 2019). Moreover, DT makes a CBM possible, and triggers new business models that facilitate CE (Uçar, Dain and Joly, 2020; Paolucci, Pessot and Ricci, 2021). According to Lopes de Sousa Jabbour et al. (2018), DT integrates value chains through data sharing and exchanging, contributes to sustainable operational management decisions and business model innovation, promotes the design of renewable goods, and drives supply chain redesign.

Based on the above discussion, we argue that DT helps manufacturing enterprises improve production efficiency, reduce resource waste, and develop a new CE business model. Therefore, we propose:

H1: A firm's DT has a positive impact on CE performance.

4.2.4 Institutional theory

Institutional theory holds that the structures, policies, and practices within a firm are determined by external institutional context (Meyer and Rowan, 1977). As a result, any firm's business reflects not only the technical requirements of a specific activity, but also the expectations of its institutional stakeholders and the rules and norms of the institutional environment (DiMaggio and Powell, 1983; Meyer and Rowan, 1977; Scott, 1987). Such expectations, rules and norms then generate institutional pressures, forcing firms to adopt advanced practices. As Dowling and Pfeffer (1975, p.122) noted, "organisations seek to establish congruence between the social values associated with or implied by their activities and the norms of acceptable behaviour in the larger social system".

Institutional theory further explains the sources of institutional pressure and the mechanism underlying their influence. For example, regulatory agencies and civil society groups can force firms to behave in a certain way, professional groups exert normative influence on firms, and peer interaction leads to mutual imitation (DiMaggio and Powell, 1983).

As discussed in the literature review, although DT has been considered a potential antecedent of CE, some researches do not concur with this viewpoint. The heterogeneity of businesses and industries may be to blame for these discrepancies, while a firm's institutional pressures exhibit this heterogeneity as well. (Zhu and Sarkis, 2007). Therefore, institutional theory has been wildly adopted in operations management to understand the differences of firm-level results (Shou et al., 2020; Zhu and Sarkis, 2007; Bag et al., 2021c).

According to institutional theory, there are three different types of institutional forces that could have an impact on corporate actions: normative pressure, coercive pressure and mimetic pressure

(DiMaggio and Powell, 1983). First, coercive pressure is the term used to describe pressure coming from governments or other political institutions to revise the organisation's policies or structures. For instance, governments have an impact on a company’s operations through legislation (Shou et al., 2020). Second, since emulating peers with good performance is viewed as a secure move to minimise risk caused by uncertainty, mimetic pressure therefore attempts to lessen uncertainty for a corporation. Finally, professionalization puts normative pressure on organisations. It enables organisations to acknowledge the legitimacy of particular procedures. In the following sections, we use the institutional theory as our theoretical lens to analyse the potential moderating effects on the DT – CE performance relationship in Chinese context.

4.2.5 Coercive pressure and political connection

To address the widely criticised environmental problems, Chinese central government has set the ‘Circular Economy Promotion Law of the People’s Republic of China’ in 2009 (Farooque et al., 2019). Since central government generally plays a key role in developing national level strategies, especially in a Chinese context, we consider the coercive pressure as a critical factor in promoting firm level CE adoption (Chen et al., 2021c). For example, since many businesses are only motivated by profit, Xue et al. (2010) highlighted that the laws and regulations enacted by the central government significantly drive the implementation of CE practices in firm level. In this perspective, we believe that political connections can help firms resist the coercive pressure. Specifically, the term “political links” describes the close personal relationships between government officials and major corporate executives (Lo et al., 2018). In China, a senior management who has political background may be assigned for a state-owned company to decide its development strategies, while some private-owned company may actively hire managers with political connections to obtain opportunities and benefits from governments (Wang and Qian, 2011). In fact, the literature has discussed the potential negative effect of political connection on corporate social responsibility (CSR) and sustainability issue, including CE practices (Chen and Hao, 2022). Companies with strong political connections may face fewer restrictions and regulations (Arnoldi and Villadsen. 2015). Since they enjoy favourable regulatory treatment in the environmental aspects, they may focus on pure financial benefits rather than environmental practices or CSR issues, such as CE practices.

Moreover, the political connection may result in a better position for the company to acquire crucial resources, which cause organisational inertia (Arnoldi and Villadsen, 2015). For example, they frequently experience fewer competitiveness owing to such an advantage, which reduce their motivations to adopt DT to obtain competitive advantages. Meanwhile, the political connected firms may also remain complacent and be too wary to invest in activities with additional risk, such as DT and CE practices. Moreover, to build and maintain political relationships, companies have to provide government officials additional remuneration, which adds the cost for the firm's business operation (Shou et al., 2020). As a result, companies that try to establish strong political background probably limit fundings for DT projects. Therefore, in terms of the DT - CE performance relationship, stronger political connection means weaker coercive pressure from central government policy. Based on the above discussion, we proposed that:

H2: Political connection negatively moderates the DT - CE performance relationship.

4.2.6 Normative pressure and institutional development

Within China's subnational areas, institutional development varies significantly (Shou et al., 2020). According to Zhou et al. (2017, p.6), institutional development refers to "the degree to which market fundamentals support economic activities, including the proportion of resources allocated through the market, the percentage of products with market-based prices, and the development of market intermediaries and legal systems". In this study, regional-level institutional development has been considered as the normative pressure that can significantly affect how DT promotes CE performance.

First of all, developed markets provide enterprises with more favourable opportunities for DT, because markets with a higher degree of institutional development provide contract enforcement and intellectual property protection, thus reducing the risks of firms' DT adoption (Zhou et al., 2017). In contrast, in regions with immature institutional environments, firms are at higher risk of carrying out DT because the adopted digital technologies may be imitated by competitors. In addition, the risk of CSR evasion is higher in regions with higher level of institutional development, because these markets have more standardised and transparent regulatory procedure. Thus, when companies face the same DT needs and environmental pressures, those companies operating in regions with higher level of institutional development have a stronger incentive to adopt DT and thus improve CE performance.

Second, regions with high level institutional development tend to have comprehensive resources for companies' actives (Luo et al., 2018). Therefore, firms located in mutual markets are more convenient to obtain resources related to DT, such as financial resources. For instance, the expansion of private banks offers growing chances for businesses to receive financing (Zhou et al., 2017). Additionally, firms have a greater chance to hire professionals, talents related to advanced digital technologies, or skilled employees who are familiar with DT. Therefore, we believe that regional-level institutional development reflects the normative pressures that companies face to adopt DT to improve their CE performance. Based on the above discussion, we proposed that:

H3: Regional institutional development positively moderates the DT - CE performance relationship.

4.2.7 Mimetic pressure and industry competition

Following existing literature, we consider industry competition as the source of mimetic pressure that enhance the main relationship (e.g., Chen et al., 2021c; Zhu and Sarkis, 2007). According to institutional theory, firms attend to imitate successful competitors because being a "second mover" can reduce risks caused by the uncertainty of the market response (DiMaggio and Powell, 1983). Meanwhile, a high level of competition may force the firms imitate successful competitors to obtain advantage parity to survive in the market. As a result, companies under more competitive pressures may experience higher mimetic pressures.

Specifically, CE performance may be heavily influenced by competitive pressure. For instance, manufacturers are compelled to optimise their power usage and production efficiency in the production process to remain competitive advantages (Ridaura et al., 2018). Moreover, firms may increase their resource allocation in innovation activities (e.g., DT) for pollution control under higher level competition (Hofer, Cantor and Dai, 2012; Zhu and Sarkis, 2007). Meanwhile, other firms may imitate such a DT adoption due to mimetic pressures and thereby obtain a better CE performance. In other words, the mimetic pressure from industry competition has forced firms to adopt DT to improve their CE performance to obtain sustainable competitive advantages. Therefore, we argue that a firm in a more competitive industry may face greater mimetic pressure, and hence be more active to adopt DT to improve CE performance. We proposed that:

H4: Industry competition positively moderates the DT - CE performance relationship.

Based on the above proposed hypotheses, we present a research framework that capture the relationship among each construct for this study, as shown in Figure 4.1.

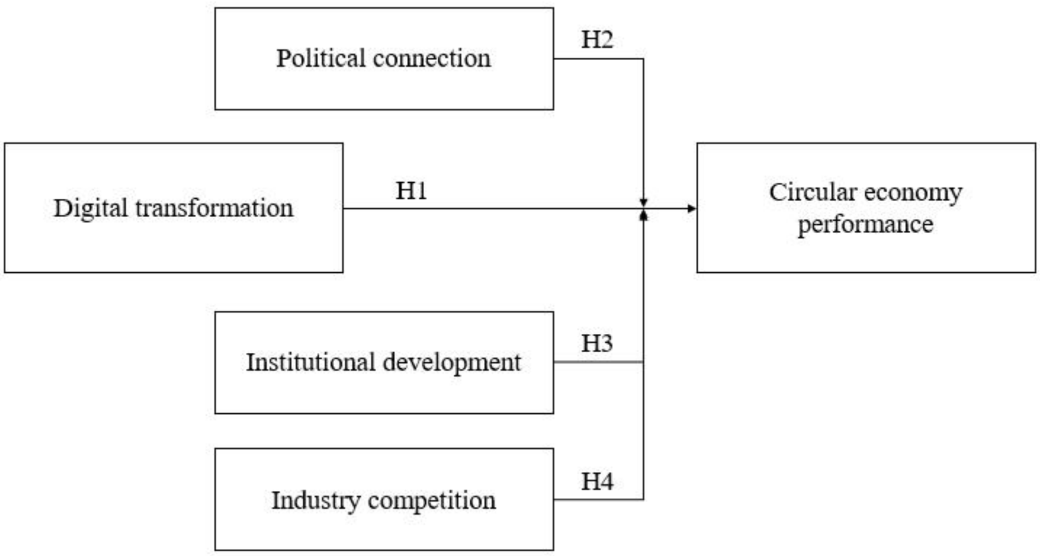

Figure 4.1 The research framework

4.3 Methodology

To address the proposed research questions and explore the hypothesis, we adopt a secondary data analysis approach. There were several reasons for using secondary data analysis. As explained in the literature review, there is currently no empirical evidence on the relationship between DT and CE performance. Meanwhile, a case study or field interview approach could have been used to obtain in-depth insights of the proposed relationships; however, this research aims to provide empirical evidence for the proposed relationships to reach a more convincing conclusion. Therefore, secondary data analysis is a logical choice as the data are objective. Specifically, we use two databases, which are, Chinese Research Data Service (CNRDS) platform and China Stock Market and Accounting Research (CSMAR) database as our primary data sources. Both of them have been wildly used in operation management literature (e.g., Shou, Shao and Wang, 2020; Chen et al., 2021c).

4.3.1 Sample and data

To explore the relationship between DT and CE performance, we included firms listed on the A-share markets of the Shanghai and Shenzhen Stock Exchanges from 2006 to 2019. We exclude observations in 2020 because the Covid-19 pandemic may seriously affect the firms' activities in various aspects, such as DT and CE practices. We focus on firms in high-tech manufacturing industries since these firms are more likely to conduct research and development on digitisation than traditional manufactories (Hong et al., 2016). Table 4.3 presents the 2-digit industry codes of high-tech manufacturing industries of Chinese listed companies issued by China Securities Regulatory Commission (CSRC). We search all the listed firms with these 2-digit industry code in CSMAR database and CNRDS platform to identify our sample firms. After removing firms with missing values (i.e., independent variable, dependent variable, moderates and control variables), there were 238 remaining firms. Since our data is panel data, the 238 firms result in 1075 firm-year observations for the further regression analysis.

Table 4.3 Classifications of Chinese high-technology manufacturing industries for listed companies (adopted from Shou, Shao and Wang, 2020)

2-digit industry code	Industries
C26	Raw chemical materials and chemical products
C27	Pharmaceutical manufacturing
C34	General equipment manufacturing
C35	Special equipment manufacturing
C37	Railway, shipbuilding, aerospace, and other transportation equipment manufacturing
C38	Electrical machines and apparatus manufacturing
C39	Computer, communication, and other electronic equipment manufacturing
C40	Instrument and meter manufacturing

4.3.2 Measures

4.3.2.1 Dependent variable

To construct the measurement of CE performance of the sample firms, we selected eight indicators from the CNRDS' sub-level database, the Chinese Corporate Social Responsibilities (CCSR) database, as suggested by existing empirical studies of firm level CE performance in a Chinese context (Chen et al., 2021c; Yang et al., 2019; Yang, Jiang and Chen, 2021) and literature that summarises key indicators to measure the CE performance (Farooque, Zhang and Liu, 2019; Govindan and Hasanagic, 2018). The CCSR database provides information about firm-level activities across different aspects of CSR. If the company has adopted a certain activity, this indicator is coded as 1; otherwise, this indicator is coded as 0. To determine a total score as a measurement of CE performance, we sum the scores from each indicator. Specifically, the eight indicators are: *circular economy strategy*, *green product*, *waste reduction strategies*, *energy conservation*, *and green office*, *ISO 14001 certification*, *environmental recognition* and *other advantages*. The explanation of selecting these indicators is shown below.

First, the term *circular* economy strategy refers to the general policies and measures adopted by a firm to achieve a CE vision. We select this indicator because CE success is primarily tied to management's understanding of sustainability and CE insight (Batista et al., 2018a). Second, eco-design, clean production, and product recycling have been a focus of CE research (Ghisellini, Cialani and Ulgiati, 2016; Su et al., 2013). The indicator of green product measures eco-design and product recycling; that is, whether a company has developed environmental products, equipment, or technology. Hence, we include this indicator as our second indicator to measure a firm's CE performance. In terms of clean production, it is necessary to consider if a firm has a strategy to reduce environmental damage by reducing pollution in production and utilising resources efficiently to produce products and services (Su et al., 2013; Koh et al., 2017). We thereby adopt the three indicators, waste reduction strategies, energy conservation, and green office to measure if a company has clean production strategies. Specifically, the term waste reduction strategies refers to whether a company has policies, practices or technologies to reduce emissions of waste gas, waste water and waste residue. Energy conservation refers to whether a company has policies, measures or technologies to save energy. The indicator green office refers to whether a company has a green office policy or measures. Next, as a tool for environmental management, ISO 14001 integrates CE principles to help businesses reduce their environmental impact (Kristensen, Mosgaard and Remmen, 2021; Liu et al., 2018b). Thus, the indicator of *ISO 14001 certification* is included in the measurement of CE performance. Further, as Ghisellini, Cialani and Ulgiati (2016) pointed out, the efficiency of CE strategies depends on the proactive policies by the government to stimulate societies to manage all resources in more sustainable ways. Therefore, we include environmental recognition to measure government recognition or other positive evaluations of a company's environmental performance. Finally, we look at other advantages in the environmental aspects that are not reflected in the above indicators. The above eight indicators form the measurement of a firm's CE performance, with the score range from 0 to 8.

4.3.2.2 Independent variable

The independent variable in this study is DT at a firm level. The CSMAR database provides DT data based on a content analysis on the Chinese listed firms' annual financial reports (CSMAR, 2022). This approach is solid because the quantity of the disclosure affects the disclosure's significance, as suggested by existing content analysis research (Unerman, 2000; Nasiri, Saunila and Ukko, 2022). Specifically, the CSMAR database provides the total number of DT-related keywords in a firm's annual financial reports. Those DT-related keywords were categorised into five groups: *artificial intelligence technology, blockchain technology, cloud computing technology, Big Data technology, and digital technology application.* This classification method has been wildly adopted in existing DT literature (e.g., Chen et al., 2022c; Chauhan, Parida and Dhir, 2022). Appendix B indicates all keywords for each group. Following previous empirical studies investigating the effect of DT, we adopt the natural logarithm of the final number of DT-related keywords identified in corporate financial reports to measure sample firms' DT level (Chen and Hao, 2022; Zhai, Yang and Chan, 2022; Nasiri, Saunila and Ukko, 2022).

4.3.2.3 Moderating variables

According to our hypothesis development, we identify three factors that may moderate the main relationship: *political connection, institutional development*, and *industry competition*. Following prior studies (Lo et al., 2018; Shou, Shao and Wang, 2020), we use the top management team members' affiliation with the government to measure a firm's *political connections*. Specifically, we assign this variable from 0 to 4 according to whether the CEO or president of a company has served or currently serves in different positions of government, Party committee (discipline inspection commission), standing committee of People's Congress or Chinese People's Political Consultative Conference, procuratorate and court. A higher score means a stronger political connection, while 0 indicates no political connection.

Regional institutional development was measured using the marketisation index issued by National Economic Research Institute (NERI) in China (Shou et al., 2020). This index measures the institutional development along the following five dimensions in all 31 Chinese provinces, municipalities, and autonomous regions:

(1) the relationship between the government and the market;

(2) the development of the nonstate sectors;

(3) the development of the product market;

(4) the development of commodity and the factor market;

(5) the development of market intermediaries and the legal environment.

The weighted sum of the scores for the five indicators makes up the marketisation index score. Following Shou, Shao and Wang (2020), we adopt the total score of the province where a company's headquarters are located to measure the level of the company's institutional development.

Finally, we use 1 minus the industry Herfindahl index (Chen et al., 2021c) to measure industry competition. The Herfindahl index is computed by summing the square of market shares for all companies with the same industry code.

4.3.2.4 Control variables

To ensure the rigor of our regression model, we control for several variables that may affect CE performance. First, we control for firm size and firm age. Firm size is measured as the natural logarithm of a firm's total assets, while firm age is measured as the natural logarithm of the total years of the company since its registration. Second, we control for ownership concentration, as companies with more concentrated equity are more likely to ignore sustainability practices in favour of individual shareholder interests (Lefort and Urzúa, 2008). Ownership concentration is measured as the total shareholding ratio of the top 3 shareholders of the company. Third, we control for cash ratio and inventory turnover for a firm's operation performance, as suggested by Chen and Hao (2022). Cash ratio is measured as cash and cash equivalents balance divided by total assets, while inventory turnover is measured as operating cost divided by inventory balance. Fourth, firms with higher financial risks may not care about environmental issues (Bhattacharya et al., 2020). Therefore, leverage, measured as a firm's long-term debt divided by total assets, is used to control for a firm's financial risk. We also control for asset-liability ratio, measured as total liabilities divided by total assets (Chen et al., 2022c). Fifth, the independent director ratio can influence a firm's attention to environmental practices (McGuinness, Vieito and Wang, 2017). Therefore, we control for independent director ratio measured as the number of independent directors to the total number of directors. Finally, as financial performance may affect a firm's CSR and environmental practices (Clarkson, et al., 2008), we control for return on assets (ROA).

4.3.3 Model specification

Model estimation was conducted using panel data since our dataset contains 1075 firm-year observations. As suggested by Shou, Shao and Wang (2020), we conduct the Hausman test to determine if we should apply a fixed-effects model or a random-effects model. The results of the Hausman test indicate that the fixed-effects model is more suitable here ($p < 0.01$), and we hence adopt this model to conduct the panel data regression analysis. We develop Model 1 for the main effect and Model 2 for the moderating effect to test the proposed hypotheses. In particular, we add interaction terms between DT and potential moderators (i.e., political connection, institutional development, and industry competition) to explore potential moderating effects.

$$CE\ performance = \beta_0 + \beta_1 DT + \sum_{k=2}^{7} \beta_k Controls_k + YearDummy + \varepsilon \quad (1)$$

$$CE\ performance = \beta_0 + \beta_1 DT + \beta_2 DT * political\ connection + \beta_3 DT * institutional\ development + \beta_4 DT * industry\ competition + \sum_{k=5}^{13} \beta_k Controls_k + YearDummy + \varepsilon \quad (2)$$

4.4. Results

4.4.1 Descriptive statistics

Description of the variables used in the regression analysis as well as the correlation matrix are presented in Table 4.4 and Table 4.5. The fixed and year effects of our models ensure that any common trend in CE performance over time was not eliminated and that unobservable firm-level heterogeneity in CE performance was minimised. Meanwhile, variance inflation factor tests were conducted to identify possible multicollinearity. The results of these tests indicate that multicollinearity does not pose a problem in the proposed models because the maximum variance inflation factor is lower than the threshold value ($1.52 < 10$) (Kennedy, 2008).

Table.4.4 Descriptive statistics and correlation matrix

	Mean	SD	Performance	DT	Size	Concentration	Cash
Performance	3.258	1.683	1.000				
DT	2.053	1.135	0.068**	1.000			
Size	22.666	1.303	0.351***	0.143***	1.000		
Concentration	47.678	15.311	0.005	-0.129***	0.033*	1.000	
Cash	0.168	0.118	-0.056***	0.083***	-0.106***	0.122***	1.000
Inventory	4.384	5.128	0.091***	0.030	0.076***	0.051***	0.022
Leverage	1.426	2.097	0.049**	0.000	0.058***	-0.074***	-0.161***
Liability	0.442	0.201	0.146***	0.041*	0.460***	-0.034*	-0.306***
Director	0.373	0.055	-0.081***	0.005	0.086***	0.046**	-0.001
ROA	0.054	0.073	0.025	0.021	-0.052***	0.157***	0.294***
Age	2.877	0.354	0.145***	0.017	0.239***	-0.200***	-0.219***

Note: Pearson Correlation: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Performance = CE performance; DT=digital transformation; Size=firm size; Concentration=ownership concentration; Cash=Cash ratio; Inventory=inventory turnover; Leverage=leverage; Liability=asset-liability ratio; Director=independent director ratio; ROA=return on assets; Age=firm age.

Table 4.5 Descriptive statistics and correlation matrix (Continued)

	Inventory	Leverage	Liability	Director	ROA	Age
Inventory	1.000					
Leverage	0.023	1.000				
Liability	0.065***	0.198***	1.000			
Director	0.018	0.033*	0.011	1.000		
ROA	0.001	-0.196***	-0.371***	-0.052***	1.000	
Age	0.082***	0.064***	0.162***	-0.029	-0.158***	1.000

Note: Pearson Correlation: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Performance = CE performance; DT=digital transformation; Size=firm size; Concentration=ownership concentration; Cash=Cash ratio; Inventory=inventory turnover; Leverage=leverage; Liability=asset-liability ratio; Director=independent director ratio; ROA=return on assets; Age=firm age.

Moreover, a winsorization was applied to all continuous variables to examine the potential effects of outliers. As part of regression analysis, winsorization is an effective method of data processing (Lien and Balakrishnan, 2005). Outliers in the data are set to a particular percentile by the operator; for example, winsorizing at the 5th and 95th percentile results in setting all data below the 5th or above the 95th percentiles to these values. In this study, winsorization at the 1st and 99th percentiles was applied to all continues variables.

4.4.2 Regression results

As shown in Table 4.6, the first model indicates that the coefficient of DT is significantly positive ($\beta = 0.210$, $p < 0.05$), suggesting that DT positively affects CE performance at the firm level. Therefore, H1 is supported.

Table.4.6 Regression results

	Main effect			Moderating effect			
VARIABLES							
DT	0.210**	0.206**	0.205**	0.210**	0.156*	0.202**	0.201**
	(0.092)	(0.093)	(0.093)	(0.092)	(0.091)	(0.092)	(0.093)
PC		0.062	0.059				
		(0.066)	(0.068)				
DT*PC			-0.031				
			(0.040)				
ID				0.113	0.109		
				(0.205)	(0.193)		
DT*ID					0.091**		
					(0.041)		
IC						2.685	2.620
						(3.776)	(3.884)
DT*IC							2.996*
							(1.635)
Size	0.563**	0.568**	0.554**	0.557**	0.507**	0.582**	0.582**
	(0.237)	(0.234)	(0.231)	(0.236)	(0.234)	(0.238)	(0.236)
Concentration	0.010	0.010	0.011	0.011	0.014	0.011	0.011
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Cash	-0.117	-0.044	-0.044	-0.137	-0.069	-0.130	-0.133
	(0.765)	(0.767)	(0.766)	(0.766)	(0.771)	(0.764)	(0.756)
Inventory	0.003	0.004	0.005	0.003	0.010	0.002	0.002
	(0.040)	(0.039)	(0.039)	(0.040)	(0.041)	(0.040)	(0.041)
Leverage	0.021	0.023	0.021	0.024	0.023	0.022	0.020
	(0.080)	(0.081)	(0.081)	(0.077)	(0.077)	(0.080)	(0.081)
Liability	-1.296*	-1.142*	-1.167*	-1.343*	-1.496**	-1.304*	-1.255*
	(0.704)	(0.685)	(0.691)	(0.702)	(0.697)	(0.706)	(0.709)
Director	-2.044	-1.993	-2.134	-1.951	-2.001	-2.044	-2.086
	(1.847)	(1.821)	(1.797)	(1.826)	(1.862)	(1.857)	(1.867)
ROA	-1.705	-1.559	-1.582	-1.776	-1.881	-1.693	-1.827
	(1.772)	(1.849)	(1.863)	(1.810)	(1.768)	(1.768)	(1.784)

Age	0.396	0.121	0.143	0.368	0.190	0.628	0.655
	(1.189)	(1.184)	(1.188)	(1.209)	(1.103)	(1.279)	(1.319)
Constant	-8.411	-9.497	-9.231	-9.374	-7.604	-11.851	-11.848
	(6.154)	(6.270)	(6.213)	(6.440)	(6.293)	(8.278)	(8.341)
Observations	1,075	1,073	1,073	1,075	1,075	1,075	1,075
Number of firms	238	238	238	238	238	238	238
Firm FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES
R-squared	0.125	0.127	0.128	0.126	0.134	0.126	0.129
F statistic	7.388***	7.303***	7.141***	7.096***	7.025***	7.112***	7.271***

Notes: The robust standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Performance = CE performance; DT=digital transformation; PC=political connection; ID=institutional development; IC=industry competition; Size=firm size; Concentration=ownership concentration; Cash=Cash ratio; Inventory=inventory turnover; Leverage=leverage; Liability=asset-liability ratio; Director=independent director ratio; ROA=return on assets; Age=firm age.

In the second model exploring the effects of moderators, the coefficient of the interaction term between DT and PC is negative but not significant ($\beta = -0.031$, $p > 0.1$), suggesting that political connection has a non-significant moderating effect on the relationship between DT and CE performance. Therefore, H2 is rejected.

In terms of institutional development, the interaction term coefficient between DT and regional institutional development is significantly positive ($\beta = 0.091$, $p < 0.05$), implying that institutional development has a positive moderating effect on the primary relationship, supporting H3.

Finally, the interaction term coefficient between DT and industry competition is positive and insignificant ($\beta = 2.996$, $p < 0.1$). Therefore, the results suggest that industry competition has a positive and significant moderating effect on the primary relationship, supporting H4.

To present the moderating effect of regional institutional development and industry competition, we plot the effects of low and high level of regional institutional development and industry competition on the relationship between DT and CE performance, where 'low' implies one standard deviation below the mean value, and 'high' implies one standard deviation above the mean value. As shown in Figure 4.2, a higher level of regional institutional development results in a higher slope for the main effect. Meanwhile, Figure 4.3 indicates that a higher level of industry competition indicates a steeper slope for the main effect. Therefore, both H2 and H3 are supported.

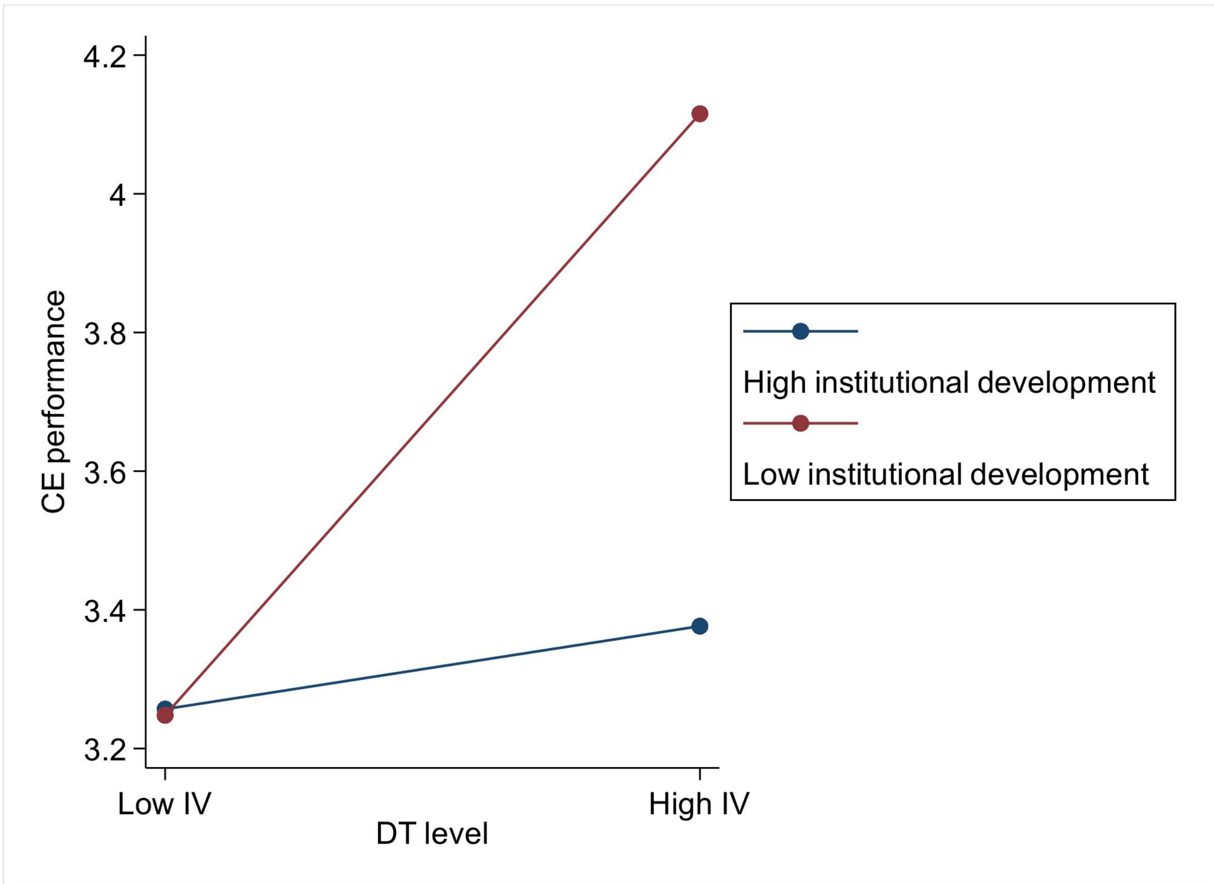

Figure 4.2 Moderating effect of institutional development

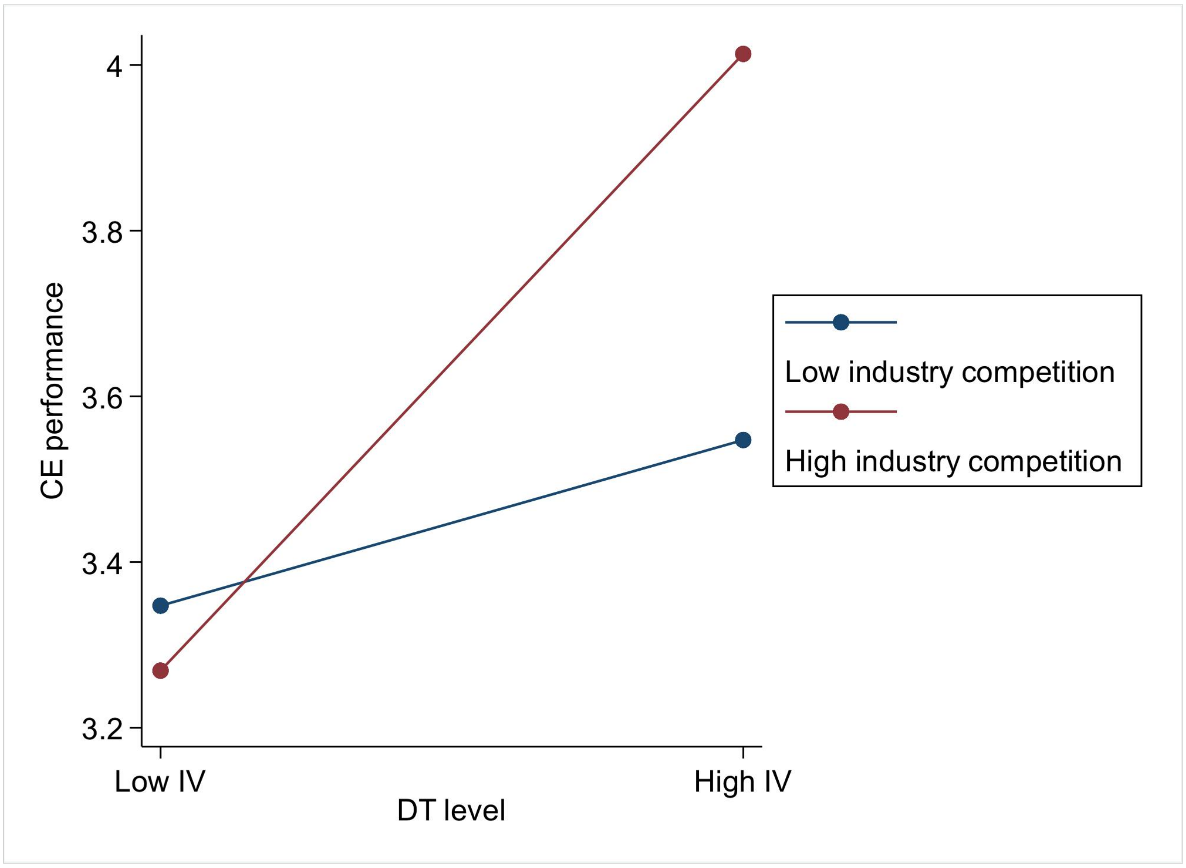

Figure 4.3 Moderating effect of industry competition

4.4.3 Robustness checks

To verify that our results are robust, we perform two additional tests. First, we adopt an alternative measure of CE performance. Following Yang, Jiang and Chen (2021), we include two additional indicators related to firms' environmental concerns, which are, *environmental penalties* and *pollutant discharge*. Each item is coded as 1 if the firm has such a concern and 0 otherwise. We subtracted the two concerns from the previous CE score to measure overall CE performance. Second, to check the sensitivity of this variable, we adopt the natural logarithm of a firm's market value as a measure of firm size. Winsorization at the 1st and 99th percentiles was applied to all continuous variables for both of the two additional robustness checks. As shown in Table 4.7, the results of the two robustness checks are consistent as our previous models. Therefore, the proposed regression analysis is robust.

Table.4.7 Robustness check

	CE performance (strength and concerns)				Firm size (Market value)			
VARIABLES								
DT	0.204**	0.198**	0.152*	0.193**	0.236**	0.238**	0.175*	0.230**
	(0.093)	(0.094)	(0.092)	(0.094)	(0.097)	(0.097)	(0.096)	(0.098)
PC		0.063				0.059		
		(0.067)				(0.069)		
DT*PC		-0.034				-0.034		
		(0.040)				(0.041)		
ID			0.109				0.089	
			(0.193)				(1.964)	
DT*ID			0.091**				0.108**	
			(0.041)				(0.042)	
IC				3.339				1.367
				(3.866)				(4.164)
DT*IC				2.923*				3.210*
				(1.636)				(1.755)
Size	0.624**	0.628***	0.561**	0.657***	0.194	0.186	0.137	0.192
	(0.246)	(0.241)	(0.242)	(0.246)	(0. 195)	(0.192)	(0.188)	(0.194)
Concentration	0.012	0.012	0.016	0.014	0.013	0.013	0.018	0.014

	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.131)	(0.013)	(0.013)
Cash	-0.188	-0.125	-0.123	-0.207	-0.168	-0.155	-0.079	-0.178
	(0.747)	(0.736)	(0.761)	(0.741)	(0.782)	(0.776)	(0.789)	(0.777)
Inventory	0.005	0.006	0.005	0.004	0.005	0.006	0.006	0.005
	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)
Leverage	0.038**	0.039**	0.038**	0.037**	0.040*	0.039*	0.040**	0.039*
	(0.018)	(0.018)	(0.018)	(0.018)	(0.020)	(0.021)	(0.020)	(0.021)
Liability	-1.183*	-1.232*	-1.339**	-1.172*	-1.097	-1.005	-1.355*	-1.036
	(0.661)	(0.660)	(0.669)	(0.662)	(0.717)	(0.719)	(0.708)	(0.719)
Director	-1.844	-1.940	-1.785	-1.898	-2.283	-2.348	-2.198	-2.361
	(1.758)	(1.710)	(1.784)	(1.778)	(1.876)	(1.819)	(1.905)	(1.895)
ROA	-0.831	-0.464	-0.998	-0.901	-2.326	-2.313	-2.347	-2.460
	(1.308)	(1.530)	(1.299)	(1.324)	(1.859)	(1.874)	(1.772)	(1.882)
Age	0.467	0.193	0.286	0.792	0.478	0.315	0.285	0.639
	(1.224)	(1.208)	(1.143)	(1.347)	(1.196)	(1.206)	(1.093)	(1.358)
Constant	-8.134	-9.268	-7.182	-12.748	-1.563	-1.161	-0.461	-3.126
	(6.411)	(6.524)	(6.489)	(8.666)	(4.287)	(-0.1762)	(-0.079)	(-0.397)
Observations	1,064	1,062	1,064	1,064	1,043	1042	1043	1043
Number of firms	233	233	233	233	236	236	236	236
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

Year FE	YES	YES	YES	YES	YES	YES	YES	YES
R-squared	0.126	0.130	0.135	0.131	0.114	0.118	0.126	0.119
F statistic	7.30***	7.26***	7.00***	6.99***	4.62***	5.86***	4.70***	4.40***

Notes: The robust standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Performance = CE performance; DT=digital transformation; PC=political connection; ID=institutional development; IC=industry competition; Size=firm size; Concentration=ownership concentration; Cash=Cash ratio; Inventory=inventory turnover; Leverage=leverage; Liability=asset-liability ratio; Director=independent director ratio; ROA=return on assets; Age=firm age.

4.5. Discussion

4.5.1 DT as a driver of CE performance

According to our literature review, there remains a lack of empirical evidence on this relationship, while ambiguous results have been obtained in recent studies (e.g., Dalenogare et al., 2018). By adopting firm-level secondary data analysis, we fill this gap by providing empirical evidence indicating that DT positively affects a firm's CE performance.

First, DT is a critical enabler of CE adoption by tracking the flow of products, components, and materials, and making the resultant data available for improved resource management and decision making across different stages of the industry life cycle (Kristoffersen et al., 2020). Specifically, the emergence of advanced data analysis approaches, including various forms of AI, cloud computing, and extensive data analysis, can optimise the allocation of resources in the production process to reduce unnecessary waste (Kristoffersen et al., 2020). For example, the recycling of items can create new goods to bring about a positive influence on the environment as it utilises fewer resources and yields less waste. The recycling approach keeps hazardous items out of landfills and waterways to prevent damages on the ecosystem survival. Nascimento et al.'s (2019) study found that cast iron and plastic make up the bulk of municipal garbage, and that there is still space for improvement when it comes to boosting the recycling of scrap metal and other comparable products. Second, the circular business model enhances municipal garbage collection and disposal technologies by using three-dimensional (3D) printing technology and applying Industry 4.0. It encourages a culture of reuse and recycling. Considering that many procedures will be automated, the key stakeholders may concentrate on the technical aspects of recycling in their commitments to R&D and innovation. Moreover, blockchain, as an emerging digital technology, can improve transparency throughout the supply chain to achieve better resource optimisation and waste management (Kouhizadeh et al., 2020). Therefore, DT can directly improve CE-related environmental practices and thus improve CE performance.

Second, corporate investment in DT can effectively lower the technical barriers that CE adoption faces. DT provides a new IT infrastructure for the company's internal operations management and production processes, promoting its ability to apply CE-related technologies (Garrido-Hidalgo et al., 2020). For example, adopting IoT and blockchain technologies requires companies to digitise their production lines, which is beneficial for Big Data or cloud computing to monitor production to optimise resource inputs and allocation, thereby improving CE performance (Parida et al., 2019; Ancarani et al., 2019).

Finally, DT allows transparent access to product data and resource consumption and facilitates product life cycle optimisation (Antikainen, Uusitalo and Kivikytö-Reponen, 2018). Therefore, the increased transparency of the supply chains allows companies to optimise their resource allocation in existing sourcing, manufacturing, and distributing processes to improve their CE performance. Based on the above discussion, DT can serve as an essential tool for promoting CE adoption at the firm level.

4.5.2 Moderating effects

Our regression results reveal that the positive effect of DT on a firm's CE performance is enhanced when institutional development level is higher or industry competition is higher. Regions with more developed institutions tend to have more mature regulatory systems, intellectual property protection systems and contract models, which reduces the risk of DT and increases the incentive for companies to use DT to improve CE (Shou et al., 2020). In addition, these markets tend to have more mature supporting resources (Luo et al., 2018). Since DT requires technicians skilled in digital technology, it is easier for companies located in regions with higher levels of institutional development to recruit such technicians to improve their DT. In terms of industry competition, stronger competitive pressures may force companies to adopt DT and CE measures to achieve sustainable competitive advantage. Moreover, the imitation of outstanding peers is also seen as a safety strategy to stay competitive in the fierce competition.

However, according to our regression results, political connection does not significantly moderate the main effect. This interesting result may be explained by two reasons. First, as the Chinese government continues to pay attention to sustainable development and environmental protection, listed companies face the similar strict supervision. Therefore, the coercive pressures from the central government encourage all listed companies to take various measures to improve CE performance. Second, politically connected companies may cater to the political goals of officials in order to cement their political relationships (Wu, 2011). As a result, these companies may act as bellwethers and respond positively to central government's policies. However, such an action could also be symbolic. In other words, political connections provide companies with looser environmental regulations (Arnoldi and Villadsen, 2015), which makes it possible for these companies to ignore CE policies even though they claim to have taken some CE measures. Therefore, the influence of political connection on DT and CE adoption remains to be further investigated.

4.5.3 Theoretical contributions

This empirical study makes two significant contributions to the DT - CE relation stream of operations and SCM literature. First, it provides empirical evidence on the relationship between DT and CE performance and the contingencies of this effect. Our literature review indicates that no rigorous empirical study has presented firm-level evidence to identify the positive effect of DT on CE performance. For example, Bai, Orzes and Sarkis (2022) adopted case study to predict how specific digital technologies support CE practice; however, their study does not support or determine causality between DT, CE, and sustainable development goals. Meanwhile, research on DT and CE indicate a contradictory result. Although DT has been considered as an antecedent of CE practices, several scholars disagree with this perspective. For example, Cohen (2018) indicated that DT increase energy consumption, thereby increase carbon emission and at the same time decrease CE performance. Therefore, it is necessary to explore how DT affect CE performance. Our research answers such a call for more secondary data analysis on this topic (Chen et al., 2022a; Chauhan, Parida and Dhir, 2022; Barbieri et al., 2021). We obtained firm-level data on environment activities and adopted digital technologies to construct the measurement of CE and DT, respectively. Our results confirm the positive effect of DT on CE performance, enriching both the DT and CE literature.

Second, we adopt institutional theory to explain the heterogeneity of DT's effect on firms' CE performance. According to institutional theory, a firm's actions or strategy choices are affected by not only economic and technical drivers, but also external pressures from institutional context (Scott, 1987). Although institutional pressures may affect the adoption of both DT and CE practices (Bag et al., 2021c), there is currently no research exploring the potential moderating effects of institutional pressures on the relationship between DT and CE performance. Therefore, we identify three variables (i.e., political connection, institutional development, industry competition) to reflect the three institutional pressures (i.e., coercive pressure, normative pressure, and mimetic pressure) which are found to affect the main relationship. Our regression confirms the positive moderating effect of institutional development and industry competition; however, political connection does not affect the main relationship. Therefore, this study provides the background conditions that may affect the DT – CE performance relationship, contributing to this literature by responding to the call of exploring the role of institutional factors in DT – CE relationship (Bag et al., 2021c; Chauhan, Parida and Dhir, 2022).

4.5.4 Practical implications

This study has two practical implications. First, we confirm the positive effect of DT on CE performance at the firm level. DT can strengthen enterprises' monitoring of the production process and the whole supply chain to optimise resource inputs and improve waste management and reverse supply chain management. Moreover, DT provides the infrastructure for enterprises to introduce advanced data analysis technologies, such as artificial intelligence and cloud computing. Therefore, DT also helps companies overcome technical barriers to implementing CE practices. Our study highlights the positive role of DT in improving company CE performance to achieve sustainable development, suggesting that managers who want to gain a competitive advantage by improving CE performance should increase their investment in DT.

Second, we conclude that our findings give policy-makers a greater understanding of how DT influences CE performance. Sustainable development is a challenge common to all humanity. To further improve the environment without compromising financial performance, we suggest that policy-makers continue to promote corporate DT by developing appropriate policies since we have provided empirical evidence on the positive effect of DT on CE performance at the firm level.

4.5.5 Limitation

This research also has limitations, suggesting areas for further research. First, we adopt a secondary data analysis approach to explore the DT – CE performance relationship due. However, this approach only quantifies a superficial connection between DT and CE performance, lacking a detailed analysis of the mechanism of how different digital technologies affect CE performance. Therefore, it is necessary to adopt other methods (e.g., case study) to obtain a more in-depth insight of DT – CE performance relationship at a firm level. Moreover, we adopt the natural logarithm of the total word count for DT-related keywords of the firms' annual year report to measure the DT level of our sample firms. However, there may be a significant gap between what a firm disclose and what they actually do. Therefore, it is necessary to develop a more solid approach to measure the level of a firm's DT. Second, due to data availability, we construct the institution-related variables using political ties, institutional development, and industry competition. However, other institutional factors may also affect the main relationship, such as local government policies and customer pressures. Therefore, future research may explore other the potential moderating effects of institutional factors on the DT – CE relationship. Third, according to the resource-based view, a firm's unique resources or capabilities are clearly important in contributing to its success (Grant, 1996). Therefore, it is necessary to explore how resources and capabilities, such as financial resources, information technology resources, and innovation capabilities affect the DT – CE performance relationship. Fourth, our research considers the high-tech manufacturing industry to assure a high level of internal effectiveness. However, the findings of this research may not be applicable to other industries, such as traditional manufacturing or retail. These industries represent a large proportion of production businesses in the Chinese context and, thus, should not be ignored. Therefore, future research could explore the DT – CE performance relationship in other contexts to obtain a more comprehensive conclusion. Finally, our results are limited to Chinese enterprises, which further constrains the generalisability of this study. This study may not be universal in light of differences in politics, culture, and institutions. Future research could examine whether DT affects CE performance in other developing countries or emerging nations.

4.6. Conclusion

The present study aims to build the relationship between DT and CE performance at the firm level. We adopt secondary data from 238 Chinese listed firms in the high-tech manufacturing industry over 2006–2019. By applying a panel data regression analysis, we reveal DT's positive effect on CE performance at the firm level. In addition, we explore the potential moderating effects of three institutional variables: political connection, regional institutional development and industry competition. Our results confirm the DT – CE performance relationship is enhanced when the level of regional institutional development and industry competition are higher, supporting our proposed hypothesis. However, a firm's political connection does not affect the DT – CE performance relationship, which may be caused by looser regulations and scrutiny from the government. By providing solid empirical evidence on DT – CE debate, this study contributes to both operation management literature and practical implications.

Chapter 5. Green Innovation and Circular Supply Chain Management Adoption

Abstract

Green innovation (GI) has been anecdotally recognised as an antecedent of circular supply chain management (CSCM) adoption. However, there is little empirical evidence to support this effect. This research explores the relationship between GI and CSCM adoption and any moderators affecting this relationship. To do so, we adopt panel data regression analysis on secondary data of 284 Chinese manufacturing firms listed on the A-shares markets of both the Shanghai and Shenzhen Stock Exchanges in China from 2008 to 2020. Using the resource-based view, we further explore the potential moderating effects of two firm-level variables: financial performance and research and development (R&D) level. We find that GI positively affects CSCM adoption at the firm level. Counterintuitively, we further observe that financial performance measured with return on equity (ROE) does not positively moderate the relationship between GI and CSCM adoption, while R&D level measured with the proportion of R&D personnel (RDPR) positively moderates this central relationship. This study is the first to provide empirical evidence on the firm-level GI - CSCM adoption relationship. The results of this paper provide both theoretical and practical implications and inspire future research on this topic.

5.1. Introduction

The circular economy (CE) has attracted increasing attention in both academics and industries in recent years in response to the massive resource wastage across various industries, given the background of the traditional linear economy (Jia et al., 2020; Agrawal, Atasu and Van Wassenhove, 2019; Bai et al., 2019; Genovese et al., 2017; Govindan et al., 2020; Nasir et al., 2017; Van Wassenhove, 2019). The Ellen MacArthur Foundation claimed that a CE as an industrial economy is restored or regenerated through planning and design (Geissdoerfer et al., 2017) and is distinguished from the traditional linear economy via its "resource – product – renewable resource" material recycling model. Scholars have summarised the "3R" principle of CE to achieve sustainable development, namely, "reduce, reuse, and recycle" (Birat, 2015; Lüdeke‐Freund et al., 2018). Based on these 3R principles, a CE presents many advantages, such as reducing the use of natural resources, reducing waste, reducing greenhouse gas and other harmful emissions, promoting the development of renewable and sustainable energy, reducing pressure on suppliers, enhancing the value conservation of each node of the system, and creating environmental and economic benefits (Barros et al., 2021; Cherrafi et al., 2018).

To achieve circularity at the supply chain level, scholars have proposed the concept of circular supply chain management (CSCM), defined as "the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems" (Farooque, Zhang and Liu, 2019. p.884). The zero-waste vision (Veleva, Bodkin and Todorova, 2017) and the ability to recover value across different industrial sectors can make substantial differences between CSCM and traditional supply chain sustainability (Genovese et al., 2017; Weetman, 2016). Therefore, CSCM has been considered a practical means to achieve sustainability while maintaining economic growth.

To better adopt CSCM, enterprises are employing technology applications to seek innovation for improved cost and service efficiency (Chen et al., 2021a). In particular, green innovation (GI), defined as a process of developing and adopting new products and technologies to address environmental issues (Jiang et al., 2018; Sun et al., 2019; Zhang et al., 2017; Castellacci and Lie, 2017), has been considered to promote CSCM adoption because it contributes to augmenting resource efficiency, reducing waste, saving energy, and increasing recycling (Takalo and Tooranloo, 2021). Recent work focusing on GI has also explored the positive role of such an innovation practice on a firm's environmental performance and sustainability from both theoretical and empirical perspectives (e.g., Cuerva, Triguero-Cano and Córcoles, 2014; González‐Benito and González‐Benito, 2006; Jabbour et al., 2019). For example, Zailani, Amran and Jumadi (2011) proposed GI as the process of a continuous search for methods to provide every node and participant in the supply chain with the possibility of gaining a competitive advantage while reducing environmental degradation. Aid et al. (2017) conducted expert interviews with managing executives from Swedish private and public waste management organisations to reveal the positive role of GI on recycling to achieve sustainability. Soewarno, Tjahjadi and Fithrianti (2019) utilised structural equation modelling to reveal that GI creates sustainable competitive advantages for the firm.

However, the link between GI and CSCM adoption is still underdeveloped. Although there is literature that reveals the positive role of GI on different aspects of environmental sustainability (e.g., recycling, energy conservation, and emission reduction), we found no empirical evidence that the direct relationship between GI and CSCM adoption at the firm level has been explored, which represents a critical research gap. According to Takalo and Tooranloo (2021), few studies place GI as the research focus in the supply chain context, while the literature on the CE principle refers to general innovation activities instead of GI. Meanwhile, Suchek et al. (2021) pointed out that, although GI has the potential to build a more circular economy, innovation may come with extremely high costs that are not affordable by many companies, which in turn destroys their CSCM adoption. Therefore, we do not yet understand how GI affects CSCM adoption and the factors influencing this relationship. According to Albort-Morant et al. (2017), an analysis of the variables involved in empirical research allows us to identify the problems in this field, contributing to the generation of ideas and knowledge for future research. Therefore, to achieve sustainability by promoting CSCM adoption, it is necessary to conduct an empirical study to explore the role of GI in CSCM adoption, inspiring practitioners and policy-makers.

By examining the impact of GI on CSCM adoption, this research aims to fill the research gap related to exploring the role of GI in the CE context (Khanra et al., 2022). It is generally accepted that firms' resources affect businesses' internal strategy adoption (Cuerva, Triguero-Cano and Córcoles, 2014), and both GI and CSCM adoption require significant firm resources. Thus, we use a resource-based view (RBV) to identify potential factors affecting the link between GI and CSCM adoption. Our research specifically addresses the following two research questions:

1. How does green innovation influence Chinese firms' circular supply chain management adoption?

2. What are the factors affecting this relationship?

We adopt panel data regression analysis on secondary data of 284 Chinese manufacturing firms listed on the A-shares markets of both the Shanghai and Shenzhen Stock Exchanges in China from 2008 to 2020. We selected the Chinese context for three reasons. First, China is one of the pioneers in formulating CE policy at the national level. As early as 2009, China introduced the CE framework through the Circular Economy Promotion Law of the People's Republic of China to consolidate its vision of developing CE (Lieder and Rashid, 2016). Second, China has clear policies and regulations supporting GI activities. For example, China is the largest investor in the world in the renewable energy sector (Zhang, Cao and Zhou, 2016). Moreover, in the 13th Five-year Plan (2016–2020) for the nation's economic and social development, the Chinese government highlighted GI as the fundamental principles for the future (Song, Zheng and Wang, 2017). Finally, China's economic development relies heavily on energy consumption, especially fossil fuel energy, which has led to serious environmental problems. As the largest emerging economy, China has also become the "largest carbon emitter" and the "largest energy consumer" (Chinese Academy of Sciences, 2012). Therefore, exploring the relationship between GI and CSCM in the Chinese context can provide insights for other emerging economies facing environmental pressures, such as Brazil and India, to promote CSCM adoption.

The rest of the paper is laid out as follows. Chapter 5.2 examines the literature on critical constructs, the theoretical underpinnings of RBV, and the formulation of crucial assumptions. The research design, which includes explanations for sample selection, data collection, variables, and model development, is discussed in Chapter 5.3. The findings are presented in Chapter 5.4, and a discussion of the study's contributions and limitations, as well as future research directions, is presented in Chapter 5.5.

5.2. Literature review and hypotheses development

5.2.1 GI and supply chain management

The discussion of GI began in the late 1990s to develop innovative products and processes to transform existing industry procedures in response to growing environmental pressure (Tantayanubutr and Panjakajornsak, 2017). In addition, consumers concern over ecological issues and integrating green consumerism into their purchasing decisions are growing (Chen et al., 2021c). Therefore, the concept of GI has provided an opportunity for firms to develop green products, create markets, and improve their images (Fontoura and Coelho, 2022). However, according to a systematic literature review conducted by Albort-Morant et al. (2017), there is currently a lack of a clear definition of the GI concept, which marks the immature development of this field. Similarly, Schiederig et al. (2012) argued that the GI concept is often mixed with other concepts, such as ecological innovation, environmental innovation, and sustainable innovation, as they only have slight differences in the description of innovation behaviour. Therefore, to clarify this concept, Albort-morant et al. (2017, p.3) defined GI as "a type of innovation whose main objective is to mitigate or avoid environmental damage while protecting the environment and enabling companies to satisfy new consumer demands, create value, and increase yields".

In essence, GI has been considered a firm-level strategy that may address environmental issues related to sustainable firm practices (Du, Li and Yan, 2019). Moreover, by reducing manufacturing costs and increasing compliance with regulatory requirements, GI may lead to sustainable competitive advantages for companies (Wong, Wong and Boon-itt, 2020). However, GI adoption is not constrained to the firm level. At the supply chain level, the literature highlights the positive role of suppliers, customers, and other stakeholders in promoting GI. For example, Choi et al. (2019) argued that to benefit from GI, organisations should establish close partnerships with all stakeholders. Meanwhile, some scholars have proposed green supply chain management (GSCM) and regard it as a critical antecedent for GI adoption. According to the literature review by Khanra et al. (2022), GSCM has become the primary topic at the supply chain level in the GI literature. GSCM integrates environmental management with internal supply chain processes and its links with suppliers and customers, a collaborative approach that will facilitate significant advances in sustainability and green practices (Srivastava, 2007). Therefore, some scholars have explored how to promote GI to achieve better environmental performance in the context of GSCM. For example, Wong, Wong and Boon-itt (2020) adopted structural equation modelling to prove the positive effect of supply chain integration on GI; Chiou et al. (2011) discussed that greening suppliers could promote GI to improve corporate environmental performance; and Fontoura and Coelho (2022) used questionnaires to explore the positive effects of supply chain integration and supply chain leadership on GI.

However, there is a lack of empirical research at the supply chain level that uses GI as one of the variables, especially for research related to CE (Khanra et al., 2022). According to Albort-Morant et al. (2017), only 14 empirical studies in the Web of Science database adopt GI as a research construct. Moreover, although various studies regard GI as an antecedent of a more circular system (e.g., Takalo and Tooranloo, 2021), no study provides empirical evidence on the impact of GI on CE or CSCM. Therefore, the conceptual nature of the GI literature represents a significant research gap.

In the following sections, to develop our hypotheses, we discuss the relationship between GI and CSCM adoption and how it may be affected by other factors.

5.2.2 GI and CSCM adoption

In the existing research on CSCM, innovation has been identified as a significant antecedent (Suchek et al., 2021). For example, Farooque, Zhang and Liu (2019) conducted an extensive review of the literature and summarised that innovation could be a method for CSCM to achieve material recycling and zero-waste goals. Agyemang et al. (2019), listed innovative strategies as a critical success factor in enterprises' CSCM implementation. In particular, with the increasing attention on environmental protection and sustainable development, environmentally friendly ideas have been integrated into traditional innovative behaviours, which has led to the formation of the concept of GI. A large body of literature has illustrated the advantages of GI, such as increasing cost efficiency, reducing pollutant emissions, incentivising environmentally friendly behaviour, promoting waste recycling, and saving energy, as well as enhancing social responsibility performance and the ecological reputation (Albort-Morant, Leal-Rodríguez and De Marchi, 2018; Castellacci and Lie, 2017; Dangelico, 2017). These positive effects of GI are consistent with the purposes of CE strategy and CSCM adoption, both of which aim to achieve the goals of environmental protection, recycling, and sustainable development. Consequently, GI is a critical method to assist firms in achieving successful CSCM adoption, improving economic efficiency, and enhancing competitiveness (Chu, Wang and Lai, 2019).

Coca-Cola made an announcement about its road paving project in Pakistan in 2021 as part of its promotion activity of circular economy for waste materials. The usage of plastic-based road materials has been embraced by the local communities (Swallow, 2022).

An environmentally friendly technology called vertical farming has the potential to address the problem of food production. Instead of growing fruit horizontally, the idea is to stack it vertically. Vertical farming has the advantage of increasing production sustainability. Some vertical farms use less water and do not even require soil. The most recent developments in vertical farming enable them to use 95% less water than conventional fields. For example, smart root spraying systems could be used for indoor crops (Kalantari et al., 2018).

With minimal use of water and land, vertical farms could feed the overpopulated cities. It can also help cut down greenhouse gas emissions because it is no longer necessary to transport agricultural goods across large distances. Vertical farms, like Aerofarms, have emerged recently all over the world, even in some of the most environmentally friendly cities, including Vancouver, Singapore, and Amsterdam. In order to create a more independent and sustainable food supply system, more and more people are resorting to vertical farming at home.

One of the environmentally damaging human activities is transportation of goods. The majority of automobiles rely on fossil fuels to operate, thus resulting in enormous carbon dioxide emissions into the atmosphere. Of course, this is expected to change after it is switched to green automobiles, A green vehicle is a car, van or truck that runs on alternative energy sources, such as electricity, hydrogen or synthetic fuels, rather than traditional fuels like diesel or petrol. Numerous businesses have already demonstrated that the application of new vehicle technology may bring down carbon emissions and remain profitable at the same time. Previous research forecasted the environmental impacts of China's growing electric car market. According to the World Bank (2016), China may cut its CO2 emissions by 13.2 million tons in 2020 and 29.2 million tons in 2025, amounting to around 0.16% and 0.36% of its total carbon emissions in 2012, respectively (Wu, Y and Zhang, 2017).

Moreover, GI has been the key to addressing current barriers to CSCM implementation (Cao, Scudder and Dickson, 2022). According to De Jesus et al. (2018), the barriers to CSCM implementation can be divided into technical barriers (i.e., lack of expertise and technology) and nontechnical barriers (i.e., resistance from organisations and lack of funding). As a unique mechanism of technological innovations, GI provides advanced technology and processes to develop green products, which overcomes technical barriers to CSCM adoption. Moreover, Seman et al. (2012) found that GI can stimulate new ideas in organisations and increase internal stakeholder support for CSCM adoption. Therefore, GI promotes CSCM adoption from both technical and nontechnical aspects. Based on the above discussion, we propose the following:

H1: A firm’s green patent acquisition positively affects its CSCM adoption.

5.2.3 The resource-based view

According to the RBV, firms' strategy and performance heterogeneity can be explained by different internal resources possessed by each firm instead of the environment, industry, and strategic group. Therefore, the RBV holds that companies may have a sustained competitive advantage if they have valuable, rare, inimitable, and nonsubstitutable resources (Barney, Wright and Ketchen, 2001; Barney, 2012; Grant, 1996). Meanwhile, a unique capability that effectively transforms those resources into competitive advantages is also the key to success (Mahoney and Pandian, 1992). Therefore, better resources and unique abilities lead to better performance in a particular activity, further contributing to the firm's superior performance.

The RBV has been adopted to explain the heterogeneity in business and environmental and sustainable dimensions (e.g., Jakhar et al., 2019; Padgett and Galan, 2010). For example, Ju, Lin and Zhou (2018) emphasised the contingent view of resources and capabilities in promoting better sustainability. They argued that it would be difficult for companies to adopt innovation to improve sustainability performance without exploring whether and how resources and capabilities are deployed to enable this performance. Therefore, in the context of GI, we apply the RBV to explore the heterogeneity of the company-level GI - CSCM adoption relationship. Specifically, we consider how two internal resources or capabilities—namely, financial performance and research and development (R&D) level—affect GI's effect on CSCM adoption.

5.2.4 The moderating effect of firm financial performance

Financial performance generally refers to a firm's profitability, which is considered the first moderator of the main effect. First, based on the RBV, an enterprise's financial performance represents a beneficial resource in its innovation efforts (Voss, Sirdeshmukh and Voss, 2008), which is consistent with previous studies that relate a company's financial performance to its innovation success

(Bourgeois, 1981; Nohria and Gulati, 1996; Zajac, Golden and Shortell, 1991). Cyert and March (1963) put forward the idea that firms were allowed to employ more experimental and innovative activities with a higher degree of financial resources. In particular, it is often considered risky for an enterprise to engage in innovation activities because innovation may not be successful, and the output of innovation activities may not improve the company's operational performance. Therefore, firms with better financial performance are more likely to conduct innovation than those with poor financial performance because organisations with sound financial health are more confident in taking the risk of innovation failure (Mangla et al., 2018; Gao, Leichter and Wei, 2012).

Second, better financial performance allows firms to hold more surplus resources to focus on sustainable issues. For example, Sefert et al. (2004) found a positive effect of firms' net profit on corporate social performance through an empirical study of firms in developed economies. In particular, companies with higher financial performance are more likely to invest in GI to better implement CSCM. Because of resource constraints, companies with limited financial ability may ignore the importance of sustainability and use critical resources for profitability to support the company's fundamental purpose of survival. According to Ambec and Lanoie (2008), any practices adopted to improve a firm's environmental performance may increase operational costs. Zheng et al. (2021) also emphasised the mounting pressures stemming from an upfront investment in sustainability. Based on this perspective, companies with poorer financial performance may not invest critical resources in GI and CSCM or may seek only financial benefits rather than environmental advantages from innovation. Therefore, based on the above discussion, the following hypothesis is proposed:

H2: Financial performance positively affects the relationship between GI and CSCM adoption.

5.2.5 The moderating effect of R&D level

CSCM adoption represents continuous progress in reducing waste and improving production efficiency through a series of firm-level innovation practices (Chen et al., 2021c). However, firms should also pay more attention to R&D to promote innovation (Cohen and Levinthal, 1990; Wallace, 2004). In particular, R&D could promote GI by creating new, environmentally friendly technologies or products, increasing the absorptive capacity to identify, assimilate and exploit outside knowledge and improving productivity by absorbing the spillover from other firms (Cohen and Levinthal, 1990). Prior research on absorptive capacity has suggested R&D as critical to developing technological knowledge, which contributes to absorptive capacity (Cohen and Levinthal, 1990; Schoenecker and Swanson, 2002). As a result, firms with a lower level of R&D find it challenging to recognise and understand knowledge from external partners and benefit from existing GI knowledge because they lack the ability to extend their existing knowledge to other areas, including CSCM adoption (Tsai et al., 2011).

Meanwhile, knowledge spillovers and public benefit attributes may reduce the motivation of a firm to adopt GI because it involves higher uncertainties and expensive innovation costs, while the firm cannot achieve a return in the short run and fails to reap all innovation benefits (Aghion and Jaravel, 2015; Ahuja, Lampert and Tandon, 2008; Gao, Leichter and Wei, 2012). However, firms with a higher level of R&D may generate more profits from GI, reducing the cost of CSCM adoption because they have the ability to understand, modify and assimilate the knowledge generated by scientific progress to commercialize products (Ahuja, Lampert and Tandon, 2008; Cohen and Levinthal, 1990).

Moreover, R&D promotes the application of GI in the CSCM context. For example, Fei, Rasiah and Shen (2014) pointed out that technological progress caused by R&D promotes the adoption of clean energy by improving the use of renewable energy and thereby reducing carbon emissions. Furthermore, as a critical CSCM practice in the production back end (Yang et al., 2019), waste management benefits from R&D, as advanced green technology helps prevent waste generation (Voulvoulis and Burgman, 2019). Therefore, R&D has been considered a crucial factor for organisations to better adopt GI and related green technologies to promote CSCM adoption. Based on the above discussion, we propose the following:

H3: A firm's R&D level positively moderates the relationship between GI and CSCM adoption.

5.3. Methodology

5.3.1 Sample and data

The data used in this research were collected from multiple secondary databases containing information on companies in the manufacturing industry listed on the A-shares markets of both the Shanghai and Shenzhen Stock Exchanges in China during 2008–2020. Companies in the manufacturing industry were identified by the digital codes issued by the China Securities Regulatory Commission (2012). We obtained firm-level secondary data from the Chinese Research Data Services Platform (CNRDS) and Chinese Stock Market and Accounting Research (CSMAR) databases. Specifically, the dependent variable was drawn from both the CNRDS and CSMAR databases, while the independent variable was drawn from the CNRDS database. Meanwhile, the moderating and control variables were drawn from the CSMAR database. After removing firm observations with missing performance data for all variables, we finally obtained 1,213 firm-year observations covering 284 listed companies from 2008 to 2020.

5.3.2 Dependent variable

In this research, we construct the dependent variable, *CSCM* adoption, by combining indicators from the Chinese Corporate Social Responsibilities (CCSR) database of CNRDS and the China Listed Company Social Responsibility Research (CLCSRR) Database in the CSMAR.

In the CCSR database, the indicators from the ESG (i.e., environmental, social and governance) evaluation of a company are described across six dimensions: charity, corporate governance, diversity, employee relations, environment, and products. Each dimension contains indicators pertaining to strengths and concerns from positive and controversial aspects, respectively. Following previous studies related to CSCM (Chen et al., 2021c; Yang et al., 2019; Yang, Jiang and Chen, 2021; Farooque, Zhang and Liu, 2019; Govindan and Hasanagic, 2018; Lahane, Kant and Shankar, 2020), we took eight indicators of environmental strength to measure CSCM adoption. The first indicator is *Environmentally Friendly Products*, referring to whether the company has developed or utilised innovative products, equipment, or technologies that are beneficial to the environment. *Measures to Reduce Three Types of Waste* indicates policies, measures, or technologies adopted by the company to reduce emissions of waste gas, wastewater, waste residue, and greenhouse gases. *Circular Economy Strategy* illustrates whether the company has adopted policies and measures to use renewable energy or engage in the CE. *Energy Conservation* refers to whether a company has policies, measures, or technologies to save energy. *Green Office* indicates whether the company has green office policies or measures. *ISO14001 Certification* indicates whether the company's environmental management system is ISO14001 certified. *Environmental Recognition* demonstrates whether the company has received environmental recognition or other positive reviews. *Other Advantages* refers to other advantages in the company environment not covered in the above indicators.

In addition, we selected several indicators from CLCSRR in the CSMAR database related to sustainable development and supply chain management. The first indicator, *GRI*, represents whether the company refers to the GRI Sustainability Reporting Guidelines. Similarly, from a sustainable development perspective, *Environment Protection* captures whether the company discloses environment and sustainable development. From a supply chain management perspective, *Delivery Protection* indicates whether the company discloses the protection of supplier rights and interests, and *Customer Protection* refers to whether it discloses customer and consumer rights protection.

Overall, we selected 12 indicators to measure the CSCM adoption of a company. The first eight are drawn from the environmental strength of the ESG measurements, and the latter four are taken from the company's CSR sustainable development and supply chain management strength. Each indicator is coded 1 if the firm has demonstrated this initiative and 0 otherwise. *CSCM adoption* is measured as the sum of the 12 scores.

5.3.3 Independent variable

The key independent variable of this research is the company's GI capability. In line with Brockhoff (1991), we believe that patent information is the timeliest means to identify technological evolutions; hence, green patent acquisition (*Pat*) is adopted to represent the GI capability of the firm (Dong et al., 2021). We measure *Pat* as the total number of green patents that the company gained in a year, including green inventions and green utility models independently and jointly obtained by the company. The data were collected from the Green Patent Research Database (GPRD) in the CNRDS database.

5.3.4 Moderating variables

We include two moderating variables: financial performance and R&D level. We select return on equity (*ROE*) as our indicator of firm financial performance (Peng and Yang, 2014). ROE is the percentage of net profit to average shareholder equity. Generally, corporate assets comprise two parts: shareholders' investment, representing the firm's own capital, and borrowed and temporarily occupied funds. ROE reflects the level of return on shareholders' equity and usually measures the utilisation efficiency and net profitability of a firm's own capital. A higher ROE value demonstrates a higher return gained from the investment. Generally, an increase in both net profit and liabilities leads to a higher ROE.

We measure R&D level by using the proportion of R&D personnel (*RDPR*), as suggested by Song and Oh (2015) and Schmid et al. (2014). The R&D personnel ratio refers to the proportion of employees engaged in R&D work to the total number of employees in a firm. To a certain extent, this indicator reveals the degree of significance attached to R&D work by the firm. A higher proportion of R&D personnel suggests a larger investment and a higher degree of emphasis on R&D activities.

5.3.5 Control variables

Several factors that may affect the studied variables and relationships were included as control variables to ensure the precision and efficiency of the research. First, we control for firm age, measured as the natural logarithm of the current year minus the establishment year plus 1, for all sample listed firms. Second, we consider the company management potential influence with three control variables: board size (*LnBS*), calculated as the natural logarithm of the total number of the board of directors; supervisor size (*LnSupS*), measured as the logarithm of the total number of supervisors; and CEO duality (*Dual*), coded 1 if the CEO and the firm's chairperson are the same individual and 0 otherwise. Moreover, we controlled for two potential financial factors: the book-to market ratio (*BM*), measured as market value/book value of equity, and growth ability (*Growth*), described as the operating income growth rate of the firm. Additionally, the studied manufacturing companies are dispersed across different industries and subdivisions of the overall manufacturing category, and situations differ to some extent in each such subdivision. Therefore, we control for industry market concentration with the variable Herfindahl-Hirschman Index (*HHI*), calculated by adding the squares of the sales of all firms in the same industry.

5.3.6 Model specification

To test the effect of GI on firms' CSCM adoption and the moderating effects of financial performance and R&D level, the following regression models were built to test the hypotheses raised in this research. Model 1 tests the main effect of GI on CSCM adoption, Models 2 and 3 test the moderating effect of financial performance, and Models 4 and 5 test the moderating effect of R&D level. We also mean-centred the variables before model construction to avoid multicollinearity.

$$CSCM = \beta_0 + \beta_1 Pat + \sum_{k=2}^{8} \beta_k Controls_k + \varepsilon \quad (1)$$

$$CSCM = \beta_0 + \beta_1 Pat + \beta_2 ROE + \sum_{k=3}^{9} \beta_k Controls_k + \varepsilon \quad (2)$$

$$CSCM = \beta_0 + \beta_1 Pat + \beta_2 ROE + \beta_3 Pat * ROE + \sum_{k=4}^{10} \beta_k Controls_k + \varepsilon \quad (3)$$

$$CSCM = \beta_0 + \beta_1 Pat + \beta_2 RDPR + \sum_{k=3}^{9} \beta_k Controls_k + \varepsilon \quad (4)$$

$$CSCM = \beta_0 + \beta_1 Pat + \beta_2 RDPR + \beta_3 Pat * RDPR + \sum_{k=4}^{10} \beta_k Controls_k + \varepsilon \quad (5)$$

5.4. Results

5.4.1 Descriptive statistics

Tables 5.1 and 5.2 present the descriptive statistics, including the mean and standard deviation, along with the correlation matrix of the variables used in the regression analysis. Furthermore, we apply the variance inflation factor (VIF) test to check the existence of potential multicollinearity among the variables. The result shows that the VIF values for all variables are approximately 1, below the threshold value of 10, suggesting that multicollinearity is not a significant concern for our models (Kennedy, 2008).

Table 5.1 Descriptive statistics and correlation matrix

Variable	Mean	SD	CSCM	Pat	ROE	RDPR	Fage
CSCM	9.552	1.583	1				
Pat	9.325	40.130	0.148***	1			
ROE	0.082	0.547	0.025	0.023	1		
RDPR	1.048	0.898	-0.050	0.042	0.048	1	
Fage	0.343	3.896	0.137***	0.034	-0.016	-0.085***	1
LnBS	0.228	0.419	0.038	-0.024	-0.039	-0.013	0.162***
LnSupS	0.137	0.098	-0.019	0.018	-0.005	-0.066**	0.117***
Dual	2.984	0.280	0.062**	0.164***	0.037	0.011	-0.113***
BM	0.112	0.093	0.203***	0.054	-0.044	-0.171***	0.212***
Growth	2.176	0.198	-0.058**	-0.012	0.015	-0.047	-0.028
HHI	1.310	0.297	0.078***	0.092***	-0.060**	-0.096***	-0.052

Notes: **Significant at the 5% level. ***Significant at the 1% level.

Table 5.2 Descriptive statistics and correlation matrix (continued)

Variable	LnBS	LnSupS	Dual	BM	Growth	HHI
LnBS	1					
LnSupS	0.316***	1				
Dual	-0.124***	-0.174***	1			
BM	0.081***	0.194***	-0.104***	1		
Growth	0.028	0.021	0.031	0.052	1	
HHI	-0.031	0.003	0.032	0.094***	0.046	1

Notes: **Significant at the 5% level. ***Significant at the 1% level.

5.4.2 Regression results

Table 5.3 summarises the regression results for the five models outlined above. In Model 1, the significantly positive coefficient of *Pat* ($\beta = 0.005$, $p < 0.01$) indicates that GI measured by green patent acquisition positively affects the CSCM adoption of a firm, which supports Hypothesis 1.

Models 2 and 3 test the moderating effect of financial performance. In Model 2, financial performance measured as *ROE* is not a significant explanatory factor of CSCM adoption due to the insignificant coefficient, which accords with the moderating variable requirements. In Model 3, the interaction term between *Pat* and *ROE* is significantly negative ($\beta = -0.03$, $p < 0.05$), revealing that an increase in ROE may reduce the positive relationship between green patent acquisition and CSCM adoption. We also plot the moderating effects on the relationship with high and low ROE values measured as 1 unit of standard deviation below and above the mean, respectively. As shown in Figure 5.1, when ROE changes from low to high, the slope of the relationship between *Pat* and *CSCM* changes from positive to negative. Thus, the studied relationship is reversed when the moderating effect of ROE is considered, which rejects Hypothesis 2.

Similarly, Models 4 and 5 test the moderating effect of R&D level measured as *RDPR*. The insignificant coefficient of *RDPR* in Model 4 implies that *RDPR* is not a significant influencing factor of CSCM adoption and meets the requirement of a qualified moderating variable. In Model 5, the interaction term of *Pat* and *RDPR* is significantly positive ($\beta = 0.042$, $p < 0.1$), suggesting that *RDPR* positively moderates the effect of green patent acquisition on CSCM adoption. Figure 5.2 illustrates the moderating effects of RDPR. The slope of the relationship between *Pat* and *CSCM* becomes steeper as the *RDPR* of a firm increases. Therefore, Hypothesis 3 is supported.

Table.5.3 Regression results

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Pat	0.005***	0.005***	0.008***	0.005***	0.005***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
ROE		0.104	-0.168		
		(0.080)	(0.149)		
Pat*ROE			-0.030**		
			(0.014)		
RDPR				-0.276	-0.187
				(0.456)	(0.458)
Pat*RDPR					0.042*
					(0.023)
Fage	0.582***	0.583***	0.595***	0.576***	0.560***
	(0.162)	(0.162)	(0.162)	(0.163)	(0.163)
LnBS	0.345	0.356	0.387*	0.347	0.367
	(0.234)	(0.235)	(0.235)	(0.235)	(0.235)
LnSupS	-0.379**	-0.383**	-0.437***	-0.383**	-0.414***
	(0.159)	(0.159)	(0.161)	(0.159)	(0.160)
Dual	0.252**	0.249**	0.250**	0.251**	0.264**
	(0.108)	(0.108)	(0.108)	(0.108)	(0.108)
BM	0.335***	0.337***	0.325***	0.330***	0.332***
	(0.051)	(0.051)	(0.051)	(0.052)	(0.051)
Growth	-0.028**	-0.028**	-0.027**	-0.028**	-0.028**
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
HHI	0.983**	1.022**	0.925*	0.958**	0.932*
	(0.477)	(0.478)	(0.479)	(0.479)	(0.479)
Constant	0.000	0.000	0.015	0.000	-0.007
	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)
Observations (n)	1,213	1,213	1,213	1,213	1,213
R-squared	0.086	0.087	0.091	0.086	0.089
F-statistic	14.16***	12.79***	12.01***	12.62***	11.71***
Number of firms	284	284	284	284	284

Notes: Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

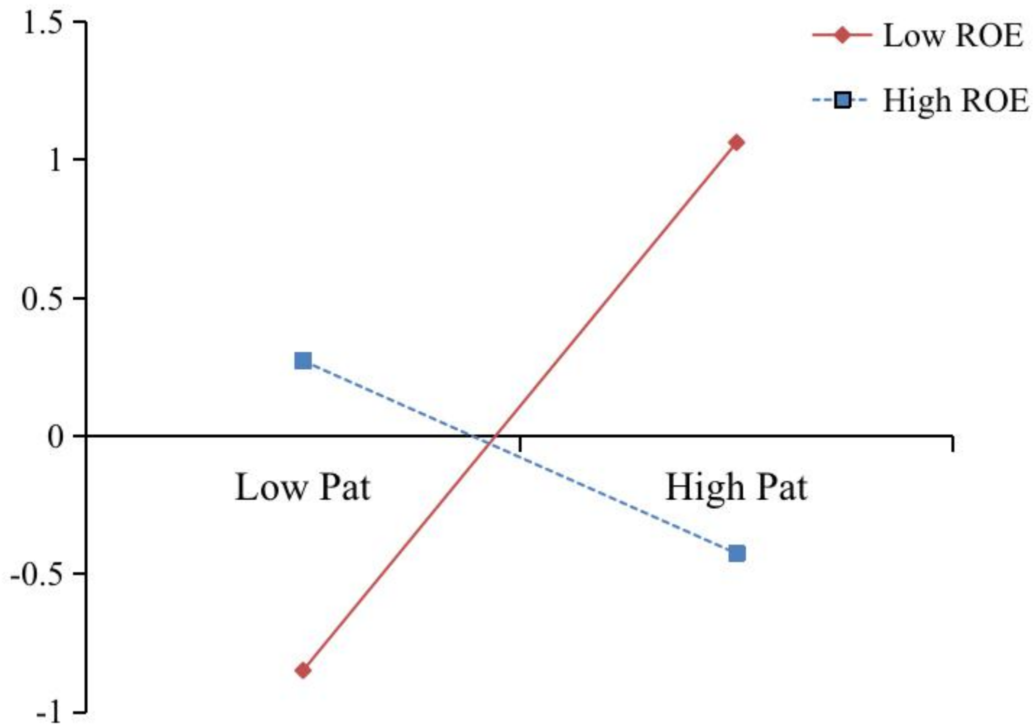

Figure 5.1 Moderating effect of ROE on the relationship between green patent acquisition and CSCM adoption.

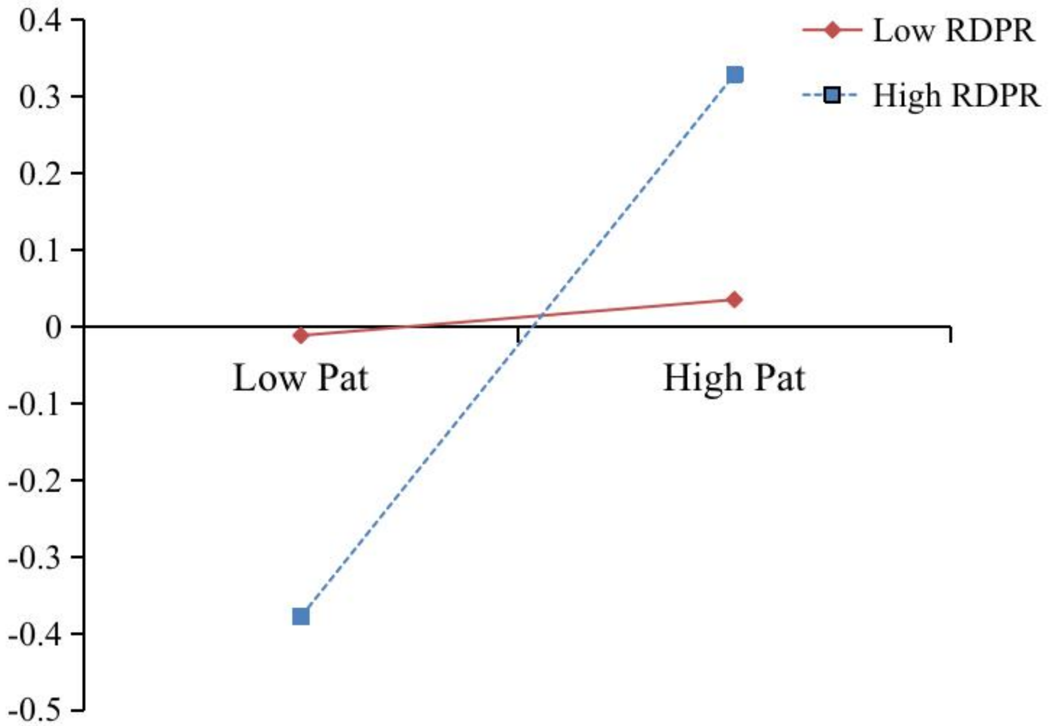

Figure 5.2 Moderating effect of R&D personnel proportion on the relationship between green patent acquisition and CSCM adoption.

5.4.3 Robustness check

Furthermore, we perform two additional robustness checks to validate our results. First, we replace the dependent variable. As described in the dependent variable construction, *CSCM* is measured by 12 indicators. To check the robustness, we replace *CSCM* with a new variable, *ENVI*, which is only measured by the first eight indicators from ESG environmental strength. Second, we shortened the sample period. Previously, after the data integration, the sample included information from 2008 to 2020. Here, we repeat the regressions with the sample starting from 2015. The results of the two robustness checks are presented in Tables 5.4 and 5.5, respectively, indicating that the studied relationship and moderating effects are still efficient and that the models in our research are rational and robust.

Table.5.4 Robustness test results: Replace CSCM with ENVI

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Pat	0.007***	0.007***	0.013***	0.007***	0.007***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
ROE		0.131	-0.371**		
		(0.087)	(0.162)		
Pat*ROE			-0.055***		
			(0.015)		
RDPR				-0.043	0.091
				(0.497)	(0.499)
Pat*RDPR					0.063**
					(0.025)
Fage	0.488***	0.489***	0.512***	0.487***	0.463***
	(0.177)	(0.177)	(0.176)	(0.177)	(0.177)
LnBS	0.427*	0.442*	0.498*	0.428*	0.457*
	(0.256)	(0.256)	(0.255)	(0.256)	(0.256)
LnSupS	-0.342**	-0.347**	-0.447**	-0.343**	-0.390**
	(0.173)	(0.173)	(0.175)	(0.174)	(0.174)
Dual	0.188	0.183	0.186	0.188	0.208*
	(0.118)	(0.118)	(0.117)	(0.118)	(0.118)
BM	0.284***	0.287***	0.265***	0.283***	0.286***
	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)
Growth	-0.027**	-0.027**	-0.026**	-0.027**	-0.028**
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
HHI	1.841***	1.889***	1.711***	1.837***	1.798***
	(0.521)	(0.521)	(0.521)	(0.523)	(0.522)
Constant	0.000	0.000	0.027	0.000	-0.010
	(0.048)	(0.048)	(0.048)	(0.048)	(0.048)
Observations	1,213	1,213	1,213	1,213	1,213
R-squared	0.087	0.089	0.099	0.087	0.092
F-statistic	14.37***	13.03***	13.21***	12.76***	12.15***
Number of firms	284	284	284	284	284

Notes: Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5.5 Robustness test results: Shortening the sample period to 2015–2020

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Pat	0.005***	0.005***	0.008***	0.005***	0.005***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
ROE		0.105	-0.170		
		(0.080)	(0.149)		
Pat*ROE			-0.030**		
			(0.014)		
RDPR				-0.200	-0.116
				(0.458)	(0.460)
Pat*RDPR					0.041*
					(0.023)
Fage	0.591***	0.592***	0.604***	0.587***	0.571***
	(0.168)	(0.167)	(0.167)	(0.168)	(0.168)
LnBS	0.334	0.346	0.377	0.336	0.355
	(0.236)	(0.237)	(0.237)	(0.237)	(0.237)
LnSupS	-0.394**	-0.397**	-0.452***	-0.396**	-0.426***
	(0.159)	(0.159)	(0.161)	(0.160)	(0.160)
Dual	0.252**	0.248**	0.249**	0.251**	0.264**
	(0.109)	(0.109)	(0.109)	(0.109)	(0.109)
BM	0.334***	0.336***	0.324***	0.330***	0.332***
	(0.051)	(0.051)	(0.051)	(0.052)	(0.052)
Growth	-0.027**	-0.028**	-0.027**	-0.028**	-0.028**
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
HHI	0.968**	1.006**	0.909*	0.949**	0.923*
	(0.479)	(0.480)	(0.481)	(0.481)	(0.481)
Constant	-0.000	-0.000	0.015	-0.000	-0.007
	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)
Observations	1,203	1,203	1,203	1,203	1,203
R-squared	0.085	0.087	0.090	0.085	0.088
F-statistic	13.90***	12.55***	11.81***	12.37***	11.46***
Number of firms	284	284	284	284	284

Notes: Robust standard errors in parentheses
*** p < 0.01, ** p < 0.05, * p < 0.1

5.5. Discussion

5.5.1 Positive effect of GI on CSCM adoption

With increasing regulatory and market pressures to address environmental protection and sustainable development, CSCM adoption has been widely used as an ecological modernisation instrument to maintain the balance between the environment and profits (Zhu et al., 2011). Previous research has investigated several factors that might affect CSCM adoption, including the innovation degree of the firm (e.g., Agyemang et al., 2019; Yang, Jiang and Chen, 2021; Farooque, Zhang and Liu, 2019; Govindan and Hasanagic, 2018; Lahane, Kant and Shankar, 2020). However, how GI affects firm-level CSCM adoption has not been explored. In this study, we concentrated on the manufacturing industry in China and applied green patent acquisition to measure the degree of GI at the firm level. Our regression results indicate that GI positively affects CSCM adoption, in accordance with historical work on cases in developed countries (e.g., Du, Li and Yan, 2019). First, GI measured as green patent acquisition refers to the adoption of various green technologies and practices, including alternative energy, environmental materials, energy conservation, emissions reduction, pollution control, and recycling technologies, which accord with the ultimate aim of CSCM adoption to save resources, improve energy efficiency, prevent and control pollution, and achieve sustainable development. For example, Du, Li and Yan (2019) identified that green patents significantly reduce carbon dioxide emissions, which achieves pollution control and sustainable development. Moreover, patents that may be characterized as seeking to save resources and improve energy efficiency promote the development and utilisation of clean and renewable energy, which may also benefit firm CSCM adoption.

Second, knowledge is a vital strategic resource for an enterprise and the key to gaining a competitive advantage (Zhu and He, 2017). GI accumulates corporate knowledge reserves, and firms with a higher degree of GI have more knowledge and technology autonomy, reducing the cost of introducing innovative technologies from other institutions or companies due to insufficient technology. Therefore, GI has been proven to be a critical antecedent of firm-level CSCM adoption, contributing to sustainability.

5.5.2 Moderating effect of ROE and R&D personnel proportion

According to our hypothesis development, firms' financial performance, measured as ROE, positively affects the relationship between a firm's GI and CSCM adoption, given the assumption that a firm with higher profitability may have more financial resources to invest in technology development, such as the GI process. However, the results of the regression models indicate that financial performance weakens the positive effect of GI on CSCM adoption and reverses such a relationship so that this effect is negative in direction. This finding contradicts previous studies that explored the effect between GI and green supply chain adoption (e.g., Aguilera-Caracuel and Ortiz-de-Mandojana, 2013; Feng, Lai and Zhu, 2022). A possible explanation for this contradiction is the diversity of GI approaches. In particular, firms with higher financial performance can invest more in directly purchasing or exchanging technologies developed by other firms or institutions, which may cost more than independent research. Therefore, a higher ROE, indicating better financial performance, may reduce the positive effect of green patents on CSCM adoption. Moreover, if the higher ROE is caused by a decrease in average shareholders' equity, the company's own capital may decrease if borrowed, and temporarily occupied funds may increase, resulting in incremental financial leverage. Although a certain degree of leverage can improve the efficiency of a firm's fund utilisation, excessive debt increases financial risk and brings uncertainty to the company's operational and financial resources. In such an unstable environment, firms may focus more on their basic businesses and invest less in the adoption of GI and CSCM (Boso et al., 2017). Finally, according to the order qualifiers and winners model proposed by Bowman and Faulkner (1997), current order winners become order qualifiers in the future because competitors may imitate them. Order qualifiers can be defined as necessary attributes that a product must possess for it to be entered into competition in today's market, while order winners are described as attributes that lead to customers buying a product. As the third country to formulate CE policies at the national level, China is one of the pioneers in the development of CE (Lieder and Rashid, 2016). Therefore, in the Chinese context, GI and CSCM practices have been considered as order qualifiers rather than order winners. In other words, Chinese listed companies, especially those with good financial performance, may have already started to adopt CSCM. In contrast, companies with poor financial performance are in urgent need of building a sustainable competitive advantage. They tend to actively invest in GI to improve CSCM adoption to avoid potential punishment from environmental regulators and build a competitive advantage. Therefore, higher ROE, to some extent, may not accelerate the positive effect of GI on CSCM adoption.

The results of this study also indicate that the positive effect of GI on CSCM adoption is enhanced by a high level of R&D, which is consistent with Hypothesis 3. As a by-product of R&D actives, absorptive capability makes a firm effectively absorb external knowledge spillovers (Lim, 2009) and alleviates the negative effects of internal knowledge spillovers and public benefit attributes of its own GI (Chen et al., 2021c). Therefore, firms with a higher level of R&D can reduce the cost of GI for CSCM adoption through stronger absorptive capability. Moreover, R&D promotes the application of GI, such as using renewable energies, developing recycled products, and improving waste management (Voulvoulis and Burgman, 2019; Yang et al., 2019). As a result, R&D is another route that promotes GI to benefit CSCM adoption at the firm level.

5.6. Conclusion

The present research explores the relationship between GI and CSCM adoption at the firm level. We adopt secondary data of 284 Chinese manufacturing firms listed on the A-shares markets of both the Shanghai and Shenzhen Stock Exchanges in China during 2008–2020. By applying a panel data regression analysis, this research reveals that GI measured as green patent acquisition positively affects CSCM adoption at the firm level. Based on the RBV, we further explore the potential moderating effects of two firm-level variables: financial performance and R&D level. The results indicate that financial performance measured as ROE does not positively moderate the relationship between GI and CSCM adoption, while R&D level measured as RDPR positively moderates this central relationship.

5.6.1 Theoretical contribution

Our empirical study makes three contributions to the R&D/innovation stream of the operations and supply chain management literature. First, this study is the first to provide empirical evidence on the relationship between GI and CSCM adoption at the firm level. Although scholars have highlighted the positive role of technical innovation in CE (e.g., Lopes de Sousa Jabbour et al., 2018; Dubey et al., 2019b), there is a lack of focus on GI and empirical evidence on the relationship between GI and CSCM adoption. For example, Takalo and Tooranloo (2021) found that few studies revealed the relationship between supply chain management and GI, and most of the scientific and technological innovations in the literature related to CSCM implementation referred to innovation across all fields rather than focusing on GI. Therefore, exploring how GI affects CSCM adoption is necessary to reveal a new route for stainability. Our research answers the call for more empirical analysis of the innovation - CSCM relationship (Chen et al., 2022a; Chauhan, Parida and Dhir, 2022; Barbieri et al., 2021). We obtained firm-level data on green patent acquisitions and ESG to measure GI and CSCM adoption. The regression results confirm the positive effect of GI on CSCM adoption, enriching both the innovation and supply chain management literature.

Second, we adopt the RBV to explore why GI affects different firms. According to the RBV, the contingencies of firms' internal resources and capabilities may explain the heterogeneity of firm-level outputs (Barney, 1991). In the CSCM context, there is no empirical study exploring the potential moderating effect of GI on CSCM adoption, representing a research gap. We address this gap and answer the call to investigate the effect of the heterogeneity of internal resources and capabilities on CSCM (Lopes de Sousa Jabbour et al., 2018). Based on the RBV, our study explores how two potential firm-level moderators affect the primary relationship: financial performance and R&D level.

We confirm the positive moderating effect of the R&D level on the central relationship. However, financial performance has a negative moderating effect, contrary to our hypothesis. This is counterintuitive but interesting. We provided three possible explanations. First, firms with higher financial performance can directly purchase technologies developed by other firms or institutions, which limit the number of green patent acquisitions. Second, the higher ROE caused by an average shareholder equity decrease can increase the firm's financial leverage, which reduces the firm's incentive to invest in GI and CSCM. Last, companies with poor financial performance are in urgent need of building a sustainable competitive advantage. Therefore, compared with high ROE firms, they tend to actively invest in GI to improve CSCM adoption. Overall, our findings provide inspiration for the role of financial performance in firms' sustainable practices.

Finally, this research enriches the sustainability and CE literature by revealing GI - CSCM adoption at the firm level in the context of emerging economics (i.e., China) and the factors influencing this relationship. Since emerging economies have higher population density and stricter resource constraints, they face pressures regarding both economic development and environmental protection (Chen et al., 2021b; Mangla et al., 2018). Given the enormous differences between emerging and developed economies in economic development, environmental pressures, and policy implementation, it is necessary to conduct in-depth research on how to promote CSCM adoption in emerging economies. Our research sheds light on the positive role of GI on CSCM adoption in a Chinese context, which provides timely insights into CSCM adoption in an emerging economic context and inspires other emerging economies, such as Brazil and India, to promote their CSCM adoption and achieve sustainability.

5.6.2 Practical implications

This study has three practical implications. First, we confirm the positive effect of GI on CSCM adoption at the firm level. GI can improve green practices by adopting renewable energy, recycled products, and advanced green technology, thereby improving a firm's CSCM adoption. Moreover, GI accumulates corporate knowledge reserves to reduce the cost of introducing external green technologies or practices. Our study highlights the positive role of GI in improving company CSCM adoption to achieve sustainable development, suggesting that managers who want to gain a competitive advantage by improving CSCM adoption should increase their investment in GI.

Second, our study indicates that the R&D level positively moderates the primary relationship by promoting the application of green technologies and practices and improving the firm's absorptive capability. Specifically, stronger absorptive capacity may generate more profits from GI, reducing the cost of CSCM adoption. Therefore, investing in R&D is also important for a company to better adopt CSCM to achieve competitive advantages in the sustainability area.

Finally, our findings give policy-makers a greater understanding of how GI influences CSCM adoption. Sustainable development is a challenge common to all of humanity. To further improve the environment without compromising financial performance, we suggest that policy-makers continue promoting corporate GI and R&D levels by developing appropriate policies.

5.6.3 Limitations

Although this research makes significant contributions, some limitations suggest areas for further research. First, the research sample only contains the manufacturing industry to ensure a high internal effectiveness level. However, the regression analysis results may not apply to other industries. Therefore, exploring the relationship between GI and CSCM adoption in other industries, such as retail, is necessary. Moreover, since we could not obtain enough data, we did not conduct a subgroup analysis to test the heterogeneity of sublevel manufacturing industries. Therefore, it is also necessary to explore the differential effects of industries on the central relationship if more data can be collected.

For example, future research can compare the GI - CSCM adoption relationships in traditional and high-tech manufacturing industries.

Second, our research explores potential moderating effects, including financial performance and R&D level. However, other firm-level factors, such as political connection, firm ownership, and organisational learning capability, may have moderating effects. Moreover, institutional factors may play vital roles in the main relationship because institutional pressures may be critical enablers in CSCM adoption in the Chinese context (Chen et al, 2022a; Chen et al., 2022b). Therefore, researchers could explore the potential moderating effects of other factors to gain a deeper understanding of the relationship between GI and CSCM adoption.

Finally, the fact that our results are restricted to Chinese businesses further limits the applicability of this study. Given the variations in politics, culture, and institutions, this study could not be applicable to all situations. Future studies might investigate if GI influences the adoption of CSCM and the moderating effects that may exist in other developing nations or rising economies.

Chapter 6. Conclusion

The four pertinent studies discussed in this thesis were all motivated by a mix of industrial and scholarly interests. From a business standpoint, the CE is becoming more popular in China. The adoption of formal practices and formal manifestations of CE, and in particular the pathways for its future diffusion, are of great critical value in guiding the development of the industry and the market in the future due to the strong demand for sustainable growth in the Chinese manufacturing market, as well as frequent market and policy changes.

A small number of studies have examined the connection between CE practices and firm performance from an academic perspective, but most of the prior research on CE adoption has concentrated on particular technological developments in the engineering field (Baars et al., 2021, Shanmugam et al., 2021). Additionally, a single-case analysis methodology has been adopted in most empirical investigations in this field (Bjørnbet et al., 2021; Jia et al., 2020). A key contribution of this research is that it adds to the body of knowledge building the connection between CE adoption and the performance of Chinese manufacturing enterprises based on the literature and fills the major gaps mentioned in the two empirical studies focusing on the antecedents of the circular economy.

This thesis begins with an extensive overview of the literature on CE in the textile and apparel industry (Essay 1), which amplifies this theme by focusing on a specific industry and provides insights. The idea of Essay 1 is inspired by the comprehensive literature analysis and the four themes identified when adopting the circular economy in the textile and apparel industry: drivers, impediments, practices, and measures of sustainable performance. Essay 2 (*Circular economy practices and sustainable performance: A meta-analysis*) uses a meta-analysis methodology based on current empirical research to investigate the association between circular economy practices and firm performance. This thesis performs two empirical studies (Essays 3 and Essay 4) focusing on the link between digital transformation/green innovation and CE performance after noting the significance of technological innovation on CE performance based on the findings of Essays 1 and 2. Essay 3 (*Does Digital Transformation Improve Circular Economy Performance?*) uses panel data from 2006 to 2019 of 238 Chinese listed high-tech manufacturing companies, and regression analysis is conducted. The results show that DT has a positive impact on CE performance at the firm level. Additionally, Essay 3 discovers that this link is positively moderated by regional institutional development and industry competition. However, a firm's political connection does not affect the DT - CE performance relationship. The topic of Essay 4 (*Green innovation and circular supply chain management adoption*), which examines another antecedent, green innovation's effect on circular supply chain management adoption, introduces two moderators of financial performance and the research and development (R&D) level based on panel data regression analysis of secondary data of 284 Chinese manufacturing firms listed on the A-shares markets of both the Shanghai and Shenzhen Stock Exchanges in China from 2008 to 2020.

6.1 Summary of key findings

The main findings of the four studies are list as follows:

First, a systematic literature review of the circular economy is conducted. In Essay 1, four themes—drivers, obstacles, practices, and sustainable performance indicators—are identified for adopting a circular economy in the textile and clothing industry, one of the most polluting industrial sectors. A conceptual model is developed based on these four themes to show the connections between them. This study outlines two major obstacles to the adoption of CE and provides corresponding guidance for managers in the textile and apparel industry.

Second, issues related to CE are receiving more attention from businesses, academia, policy-makers, and consumers (Bag et al., 2021a; Youn et al., 2013). In particular, whether corporate performance activities result in desirable firm performance clearly requires academic research (Kuei et al., 2013; Bag et al., 2021a). Additionally, empirical research on the impact of corporate CE practices on firm performance has drawn contradictory findings. The results of the meta-analysis are presented in Essay 2 as convincing evidence that adopting CE methods has a considerable positive effect on firm performance. Despite mixed results in the literature, the research in this essay reveals that sample size, economic nation, industry type, and company size may be to blame for the variations in the studies. In this research, CE implementation has a minimal impact on firm performance in non-manufacturing sectors, but a large impact on that in manufacturing sectors. In contrast to industrialised regions, the impact of economic performance is minimal in impoverished nations. The outcomes of Essay 2 inspire the research choice to gather information on China's manufacturing industry for a more thorough empirical examination.

Third, while academics have offered instances of DT-enabled circularity, the DT-based circularity method now discussed in the literature is more of a possibility than a reality (Nobre and Tavares, 2019; Rosa et al., 2019). A significant gap in the literature is the dearth of empirical studies on the conceptual elements of DT - CE interactions (Alcayaga, Wiener and Hansen, 2019; Rosa et al., 2019; Uçar, Dain and Joly, 2020). Therefore, Essay 3 gathers panel data of 238 Chinese listed companies in the high-tech manufacturing industry from 2006 to 2019, in order to evaluate this association. The study proposes a research methodology and hypothesis based on institutional theory, taking into account the moderating effect of three variables: political relationships, regional institutional development, and industrial competition. Through regression analysis, it is found that DT can improve CE performance at the firm level. Moreover, this research also discovers that this association is strengthened in regions with a high level of institutional development and industrial competition. While, the DT - CE performance link is not affected by the firm's political allegiance.

Fourth, this thesis discovers that few empirical studies at the supply chain level consider the circular economy and green innovation (Khanra et al., 2022). According to Albort-Morant et al. (2017), only 14 empirical studies that employ GI as a study framework are included in the Web of Science database, Additionally, although certain research (e.g., Karimi-Takalo et al., 2021) views green innovation as a requirement for more circular systems, no studies have shown empirical support for how green innovation influences the circular economy or CSCM. Furthermore, there is a lack of research on CE adoption in developing nations given the huge variations in economic development, environmental issues, and policy execution between emerging and industrialised economies. The adoption of CSCM at the firm level is shown to be positively impacted by GI in a panel data regression study of secondary data from 2008 to 2020 on 284 Chinese manufacturing businesses listed on the Shanghai and Shenzhen A-shares. In addition, I find that, in contrast to my expectations, financial success as assessed by return on equity (ROE) does not positively moderate the association between GI and CSCM adoption, although R&D level as measured by R&D personnel (RDPR) positively moderates this core relationship. This study offers the first empirical proof of a link between firm-level GI - CSCM adoption. Thus, the results of this study have significance for both theory and practice and are instructive for further study.

6.2. Theoretical Contributions

Based on the findings of the four studies, this thesis contributes to the emerging topic of the circular supply chain management stream of the operations supply chain management literature from the following aspects.

First, Essay 1 develops a conceptual framework, which provides an integrated and deeper understanding of the CE in the textile and apparel industry based on the findings of the topic in this study. There are four main themes in Essay 1, i.e., drivers, barriers, practices, and sustainable performance indicators, for the implementation of CE in the textile and garment business. Based on these four themes, I create a conceptual model that shows how they relate to one another. The essay identifies two key obstacles, first one is circular supply chain execution in the T&A industry and the second one is the relationship management with suppliers and stakeholders—that are related to implementation of practices in building SSCM towards a CE. According to a survey of the chosen publications, most studies solely consider economic and environmental performance when evaluating CE practices that measure progress after implementation. These performance evaluation indicators might also serve as a guideline for the adoption of more thorough and organised procedures, which would benefit the improvement of long-term performance.

Second, the findings of the meta-analysis offer convincing proof that CE practices have a considerable and beneficial influence on company performance. This study reveals that the sample size, economy of the nation, industry, and firm size may all have a role in the contradictions in the study, even though there are negative or contentious links in the current literature. Because of the nature of CE practices, a meta-analysis study supports the idea that they have a more favourable effect on business performance than nonbusiness performance for enterprises. CE practices are a practical means for manufacturing companies to acquire a competitive edge in environmentally friendly production and provide intangible gains, such as boosting consumer loyalty and enhancing buyer–seller relationships (Franco, 2017; Baxter et al., 2018). Hence, CE techniques must be implemented. While, doing so involves major resources and expenditures that might not be immediately profitable. The intricate link between CE practices and corporate success is clarified by this research.

In Essay 2, the findings reveal that compared with the research that only collects information from companies in just one industry, those gathering information from companies in different industries discover a stronger correlation between CE practices and performance. It may be worthwhile to investigate the reasons why certain industries find it simpler to apply CE practices to make money than other industries. The findings of this meta-analysis further imply that the relationship between CE practices and firm performance is different for SMEs compared to large businesses. Differences in the association between CE practice and performance may also be explained by moderating factors. Contextual factors such as industry and country have frequently been used as controls in earlier research (Svensson, 2007; van Raaij and Schepers, 2008). The findings of this essay indicate that, in terms of industry, CE implementation in nonmanufacturing industries has no appreciable impact on firm performance, but CE implementation in manufacturing industries significantly improves firm performance. According to the findings of the meta-analysis, different types of countries have different effects on how CE practices affect company performance. Performance affects underdeveloped nations greatly while having little effect on developed areas. This result does not totally agree with earlier research.

Third, Essay 3 offers empirical support for the causality of the association between DT and CE performance. According to the examination of the literature, there are no thorough empirical studies that offer definitive proof of the beneficial effect of DT on CE performance. This empirical study adds two significant contributions to DT - CE connection flows in literatures about operational and supply chain management. It offers empirical proof of the link between DT and CE performance as well as the cause-and-effect of this impact. No robust empirical studies have been found to provide firm-level proof of the beneficial effects of DT on CE performance, according to the literature review in this research. When predicting how certain digital technologies may assist CE behaviours, for instance, Bai, Orzes and Sarkis (2022) employed a case study but did not show or establish a direct link between DT, CE, and sustainable development goals. The results of DT and CE do not chime with one another simultaneously. Although DT is mostly seen as an antecedent of CE techniques, several academics dispute this idea. For instance, Cohen (2018) claimed that DT will lower CE performance and improve energy usage and, consequently, carbon emissions. Therefore, it is essential to investigate how DT affects CE performance. The further secondary data analysis on this subject is addressed by this work (Chen et al., 2022a; Chauhan, Parida and Dhir, 2022; Barbieri et al., 2021). Essay 3 collects information on environmental actions at the firm level and created independent metrics of CE and DT by using numerical methodologies. The findings in Essay 3 add to the body of knowledge about DT and CE and concur the favourable effect of DT on CE performance. In order to understand the diversity of DT's effects on corporate administrative performance, Essay 3 applies institutional theory, which defined that external factors from the institutional setting exert pressure on businesses' decisions and actions in addition to economic and technical drives (Scott, 1987). The possible moderating impact of institutional forces on the link between DT and CE performance has been neglected in the previous studies, despite the fact that institutional pressures may affect the adoption of DT and CE practices (Bag et al., 2021c). Therefore, in order to account for the three institutional pressures—coercive pressure, normative pressure, and mimetic pressure—that have an impact on the primary connection, the author chose three variables, including political connection, institutional development, industry competition. The regression findings support the beneficial moderating effects of industrial rivalry and institutional development, yet political connection is to find to have little impact on the key associations. This study investigates the function of institutional elements in the DT - CE relationship by presenting contextual conditions that may impact on the link between DT and CE performance (Bag et al., 2021c; Chauhan, Parida and Dhir, 2022).

Fourth, although academics have emphasised the beneficial impact of technological innovation in CE (e.g., Lopes de Sousa Jabbour et al., 2018; Dubey et al., 2019a), there is a dearth of empirical data on the emphasis on GI and the connection between GI and CSCM adoption. Takalo and Tooranloo (2021), for instance, discovered that few studies indicated the connection between supply chain management and GIS and that most STI in the literature pertaining to the implementation of CSCM refers to innovation across all domains rather than concentrating on GIS. This research supports calls for more secondary data analysis on this subject (Chen et al., 2022b; Chauhan, Parida and Dhir, 2022; Barbieri et al., 2021). Using numerical approaches, I collected information on corporate environmental efforts and created independent metrics of CE and GI. The findings add to the body of knowledge on technology innovation and CE by confirming the beneficial effects of GI on CSCM adoption. The RBV contends that a firm's performance is mostly attributed to the diversity of its resources and competencies (Barney, 1991). As a result, the variable nature of business resources and competencies may account for why GI's influence differs among organisations. However, there is a research gap since, to our knowledge, there are no empirical studies investigating the possible moderating influence of GI on the CSCM performance connection. The research in Essay 4 closes this gap and satisfies the request for research on the business resources and competencies necessary to enable the deployment of the CE based on green technology innovation (Lopes de Sousa Jabbour et al., 2018). The data analysis results in Essay 4 also point to a lack of significance for the major effect of financial performance. Thus, by presenting background factors that might have an impact on the link between GI and CSCM adoption performance, this study adds to the body of knowledge (e.g., Chauhan, Parida and Dhir, 2022).

A research vacuum exists since there are no empirical studies investigating the possible moderating impact of GI on the adoption of CSCM in the setting of CSCM. I fill this gap and take up the request to examine how internal resource and capacity heterogeneity affects CSCM (Lopes de Sousa Jabbour et al., 2018). Essay 4 examines, using the RBV, how two putative firm-level moderators—financial performance and R&D level—affect the main link. The analysis results confirm that R&D level has a beneficial moderating effect on the main relationship. Contrary to what I predicted, financial performance has a negative moderating effect. This is an intriguing finding, as it is not intuitive. I provide three potential justifications. The number of green patent purchases is first constrained by improved financial performance, which enables companies to directly buy technology created by other companies or organisations. Second, increased financial leverage from higher ROE brought on by lower average shareholder equity lessens the motivation for enterprises to engage in GI and CSCM. Finally, it is critical for businesses with subpar financial performance to create a long-lasting competitive edge. In contrast to companies with high ROE, low ROE companies tend to actively engage in GI to increase CSCM usage. Overall, this research offers encouragement for the part that financial success may play in business sustainability initiatives.

Fifth, by illuminating the link between DT - CE performance and GI - CSCM adoption at the firm level in an emerging economy environment (China), the body of information on sustainable company performance is enriched by this study. The simultaneous demand for economic expansion and environmental conservation is greater in emerging nations, which are both more densely populated and subject to tougher resource limits (Chen et al., 2021b; Mangla et al., 2018). There is a need for a thorough investigation of how developing economies influence CE given the significant variations between emerging and industrialised nations with regard to economic development, environmental constraints, and policy execution. This study sheds light into the adoption of circular economy in an emerging economy and provides some inspirations to other emerging economies (e.g., Brazil and India) in promoting circular economy for sustainable development. However, it is possible that the findings in the context of China may not be applicable to other emerging economies due to disparities in politics, institutions, economies, and other aspects. This is also a direction for in-depth analysis. Moreover, it also reveals the positive effects of DT on CE performance and the positive effects of GI on CSCM adoption in the context of Chinese.

6.3 Practical implications

This study poses practical significance for the manufacturing industry.

First, this study offers crucial empirical proof that CE practices may affect firm performance independent of firm size, industry, or location. The results indicate that manufacturers may increase performance in terms of sales, revenue, and market share when they take ecological aspects into account while managing their supply chains, in addition to achieving energy savings, waste reduction, and pollution reduction. Additionally, a business's operational efficiency (such as scrap rates, lead times for delivery, inventory, and capacity utilisation) is likely to increase. Considering CE as a business strategy to improve firm performance may be encouraged by the favourable association between the adoption of CE practices and ecological and financial success. Sustainable supply chain efforts, according to Golicic and Smith (2013), can enhance several facets of corporate performance. Given that many outcomes originate from organisations that have previously adopted these methods, confidence in their adoption should be boosted. For instance, many industries have quickly embraced green manufacturing practices such as total quality management and ISO 9000 certification (Diabat, Kannan and Mathiyazhagan, 2014), which seem to have produced comparable good results in addressing ecological issues such as lowering waste, reducing and adjusting lead times, and enhancing the quality of goods and services.

Second, this research sheds light on the many performance enhancements that result from each CE practice for managers in the manufacturing sector. As a result, businesses can appreciate how crucial government funding and regulation are to achieving the benefits of CE implementation. Additionally, policy-makers should actively participate in the creation of environmental regulations and laws to persuade manufacturers to follow environmental guidelines since they favour ecological operations that adhere to proper standards and principles (Zhu, Sarkis and Lai, 2012). As a result, policy-makers might employ a "carrot and stick" approach to encourage manufacturers to implement CE practices (Zailani et al., 2012b).

Third, the findings of the meta-analysis offer a variety of performance indicators that managers may use to more readily explain the advantages of using CE. Manufacturers are starting to pay attention to striking a balance between commercial improvement and ecological protection as a result of stakeholder demand for eco-friendly goods and services. According to Jawaad and Zafar (2019), businesses are becoming better at determining the costs and benefits of integrating with supplier and consumer partners. They would probably examine comparable possibilities with respect to prospective outcomes for ecological sustainability and business success using the methods they now use to plan and manage transactions with supply chain partners. Despite the obviousness of this, many businesses have been slow to implement sustainable practices (Huang and Yang, 2014). Inconsistent academic study findings worsen the situation. The findings of the meta-analysis provide a more complete picture of the additional business benefits that businesses will experience as a result of their efforts to develop circular supply chains. This analysis should motivate manufacturing companies to implement CE practices to maximise resource efficiency.

Fourth, Essay 3 has established that DT has a favourable effect on CE performance at the firm level. By optimising resource inputs, waste management, and reverse supply chain management, DT may help businesses monitor their production processes and the entire supply chain. Additionally, DT offers businesses the foundation they need to implement cutting-edge data analysis technologies such as cloud computing and AI. As a result, DT also assists businesses in overcoming technological obstacles to the adoption of CE norms. According to this research, to achieve a competitive advantage through enhanced CE performance, managers should raise their investment in DT, which demonstrates the beneficial impact of DT in helping organisations increase their CE performance towards sustainable development.

The analysis results of Essay 3 also help policy-makers understand how DT affects CE performance. The difficulties of sustainable development have been puzzling all mankind. Given the fact that Essay 3 has shown the empirical evidence of the beneficial impact of DT on corporate CE performance, the author advises policy-makers to further promote corporate DT by enacting appropriate legislation, so as to enhance the environment without compromising financial success.

Fifth, Essay 4 establishes that the adoption of CSCM at the company level has benefited from green innovation. By utilising recyclable materials, renewable energy, and cutting-edge green technology, GI can enhance its green practices and boost the uptake of CSCM by businesses. Green innovation also increases a company's knowledge base and lowers the cost of implementing outside green technology or practices. To gain a competitive edge, managers should raise their investment in green innovation, which also underlines the beneficial effect of green innovation in encouraging corporate CSCM adoption for sustainable growth.

Research has demonstrated that by promoting the adoption of green innovation and practices and boosting the absorptive capacity of businesses, the amount of R&D investment positively moderates this fundamental link. More specifically, increased absorptive capacity increases GI profit, which lowers the cost of CSCM adoption. Therefore, spending money on R&D will help a business use CSCM more effectively and obtain a competitive edge in a sustainable market. The findings provide decision-makers with better knowledge of how SCM adoption might be influenced by green innovation. It is a common struggle for humanity to achieve sustainable development. Therefore, I advise policy-makers to encourage green innovation and R&D levels in businesses through the adoption of suitable legislation to further enhance the environment without compromising financial success.

6.4 Limitations and future research directions

This section presents the limitation in this thesis, and some future research directions are proposed.

The first limitation is the meta-built-in analysis. For instance, several studies use data from various sources at various times and arrive at numerous subjective findings. There has not been many empirical studies of CE so far. To the best of my knowledge, I have examined all relevant research in the literature that has already been published. The sample size might be increased in the future as the amount of empirical research on the circular economy grows, and the validity of the hypotheses could be retested. Additionally, only a few of the numerous background questions were examined in this study. Future research should incorporate elements such as product features. Moreover, the meta-analysis can only evaluate the linear link between firm performance and the circular economy. The nonlinear effect of CE practices on performance cannot be examined using this method; therefore, additional approaches (such as surveys) must be used. Finally, scholars are advised to provide precise measures of CE practices and business performance in subsequent empirical studies on the relationship between CE practices and firm performance. This will support upcoming, more thorough meta-analyses, which will further the CE idea. Another limitation in Essay 2 is the lack of related keywords in the search string, such as “environmental performance” and “ecological performance”.

These keywords should be added in the literature research to make it more comprehensive. Moreover, misuse of the terms "sustainable performance" and "sustainability performance" when searching for articles is also one of the shortcomings of this article

Second, the summary of keyword synopsis in Essay 1 is not comprehensive. The keywords in Essay 1 could be divided into three categories: supply chain, circular economy/sustainable development and textiles. The keywords within each category were identified based on a review of the existing literature. As I browsed through the existing literature to identify and collect related keywords, some infrequently relevant keywords may have been overlooked, such as 'network' or 'system' or 'ecosystem'. This is a limitation of this thesis and could be included more fully in future research. Another limitation of Essay 1 is that Figure 2.5 is a succinct figure depicting the manufacturing and circularity processes of the whole textile industry supply chain. The recycle and reuse of purchased goods are the primary examples of recycling and sustainability. It only shows the primary "R" strategy in each phase of production in this figure, but does not represent the circular economy of the textile sector in a closed-loop manner. A complete, detailed diagram of the circular economy in the textile industry can be provided in future research. The same goes for Figure 2.7. Figure 2.7 did not cover the detailed and comprehensive closed-loop of textile supply chain. More details need to be added to make it more comprehensive in the future research. Another limitation of the thesis is that the selection of environmental and economic performance indicators is different and inconsistent. Essay 1 focuses on the textile and apparel business, and Essay2 is a study of diverse industries. That is why different indicators are used in the two papers. Owing to the differed samples for Essay1 and Essay 2 as the basis for the indicators' summary, separate indicators were selected. This could be enhanced in further studies.

Third, it is evident from the review findings of Essay 1 that the single case study is the methodology that is most frequently utilised in this research field. However, they do not represent all typical apparel companies, so their findings cannot be applied to the T&A industry as a whole. They do, while, offer a unique perspective on the effective application of circular supply chains and the roles played by tactical capital and shareholder relations. As a result, more case studies of more businesses employing CLSC to meet sustainability goals are to be expected, which will increase the amount of information on CLSC practices in other businesses and industries. Future studies might analyse participants in the CE using many case studies to obtain additional data and reflective knowledge. Alternatively, such studies could be expanded to compare multicultural instances or include cases from various institutional contexts.

Fourth, the analysis of the literature reveals that while few studies examine the connection between social sustainability and CE, many articles concentrate on the relationship between environmental sustainability and CE. Therefore, a potential area for future study is to examine how social variables affect the use and effectiveness of CE by businesses. A systematic or fuzzy hierarchical procedure might be utilised in future correlation analysis to rank the components, and the ranked components could then be used to gauge the social performance in CE. Some studies have deliberately focused on the dynamics of projects and goods while disregarding the organisational obstacles that prevent the use of CE models. Future CE research may thus take a different approach by focusing on organisational obstacles and investigating how internal corporate structures and duties might be rearranged or redesigned to facilitate the adoption of CE. The dependence of conventional businesses on their supplier networks for innovation is the third and last issue in Essay 1 for further study.

Fifth, Essay 3 investigates the association between DT and CE performance by using a secondary data analysis methodology. However, the mechanisms by which various digital technologies impact CE performance in detail have not been detailed. As a result, additional approaches (such as case studies) are required to fully comprehend the link between DT and CE performance at the organisational level. Additionally, this study measures the DT level of the sample businesses by using the natural logarithm of total amount of words containing DT-related terms in each company's annual report. The difference between what a firm announces and what it actually can be huge. Therefore, it is necessary to create a more reliable approach to gauge the amount of DT in businesses. Moreover, it is assumed in Essay3 that if the moderating variables are the same, then all sorts of businesses would have a similar extent of pressures and "motivations". This is also one limitation in this research. Institutional theory could be applied in future study to discover and categorise motives and pressure from different aspects. Another drawback of Essay 3 is that owing to data availability, institutional related variables are created by using political interactions, institutional development, and industrial competitiveness, whereas other institutional elements, such local government regulations and customer pressure, are disregarded. The possible moderating impact of institutional variables on the link between the DT and CE warrants exceptional investigation. On the basis the resource-based approach, a firm's distinctive resources or talents are unquestionably crucial to its success (Grant, 1996). This presents another constraint in Essay 3. As a result, it is crucial to investigate how resources and abilities, like financial resources, IT resources, and innovative skills, impact the link between DT and CE performance. Moreover, to achieve a high level of internal validity, Essay 3 takes into account the high-tech industrial sector. However, the conclusion of the current study might not apply for other businesses, such as conventional manufacturing or retailing. These sectors should not be disregarded because they account for a sizable share of China's manufacturing businesses. Future research may thus examine the DT - CE performance link in more scenarios to draw a broader conclusion. The generalisability of this study is limited because the findings are restricted in the samples of Chinese enterprises. This study may not be generalisable given the political, cultural, and institutional variances. The limitation is the same for Essay4. The upcoming study might look at how DT impacts the CE performance of other emerging or developing nations and how GI impacts CSCM adoption in other emerging economies. In addition the different emerging economies, the other interesting area of this research is how circular economy practices (such as DT and GI) differ in countries with different political systems, for example, between a top-down country (e.g., China) and bottom-up countries (e.g., the USA). It is previously suggested that countries with different political systems and cultural contexts may adopt different emphases in the practice of circular economy. Therefore, the political logic may play a vital role in promoting the implementation of circular economy, and it is an intriguing topic for future research to study the motives why different companies and different actors choose to implement the circular economy with different political logics.

Sixth, a high degree of internal validity is ensured by the research sample, which exclusively covers companies in the manufacturing industry. However, it is possible that other industries will not be able to use the findings of the regression analyses. Therefore, it is essential to investigate how supply chain management and green innovation relate to other sectors, including retail. Additionally, due to a lack of appropriate data, I did not perform subgroup analyses to check for variability in sublevel production. Therefore, if more data could be gathered, it would also be important to investigate the diverse consequences of industry-to-centre linkages. For instance, future studies can analyse the link between GI and CSCM uptake in conventional manufacturing and high-tech manufacturing.

Last but not least, Essay 4 investigates possible moderating influences, such as levels of R&D and financial success. However, additional company-level variables may also function as moderators, such as business ownership, and organisational learning capacity. Institutional pressures may be a major element in the adoption of CSCM in the Chinese environment. Hence, institutional considerations may also be significant in the primary connection (Chen et al., 2022b). As a result, to comprehend the association between GI and CSCM adoption more thoroughly, researchers can investigate the possible moderating influence of other parameters. What's more, the findings are limited to Chinese companies, which further limits the generalisability of the study. Given the political, cultural and institutional differences, this study may not be generalisable. Future research may examine whether GI affects the adoption of CSCM and the potential moderating effect on this relationship in other developing countries or emerging economies.

Appendices

Appendix A: Formulae used to convert data

Statistics to be transformed	Formula to calculate correlation	Note
Student's t	$r=\sqrt{(t^2)/(t^2+\text{df})}$	Can be used for either paired or unpaired t test
F-ratios	$r=\sqrt{(F)/(F+\text{df(error)})}$	Can only be used for one-way ANOVA
χ^2	$r=\sqrt{\chi^2/n}$	χ^2 is the chi-square value and n is the sample size Can be used when df = 1
d	$r=(d)/(\sqrt{d^2+4})$	d = Cohen's d
β	$r=0.98\times\beta+0.05$, if $\beta\geqslant 0$; $r=0.98\times\beta$, if $\beta<0$	β is the beta coefficient of the regression results, $\beta\in(-0.5, 0.5)$

Note: r denotes the correlation between an independent variable and a dependent one

Appendix B: Keywords related to DT for content analysis of the company's financial report (CSMAR, 2022)

Indicator types	Related keywords
AI technology	Artificial intelligence, business intelligence, image recognition, decision support system, intelligent data analysis, intelligent robotics, machine learning, deep learning, semantic search, biometrics, face recognition, speech recognition, authentication, autonomous driving, natural language processing.
Blockchain technology	Digital currency, smart contracts, distributed computing, decentralization, Bitcoin, alliance chain, differential privacy technology, consensus mechanism.
Cloud computing technology	In-memory computing, cloud computing, stream computing, graph computing, Internet of Things, multi-party secure computing, Brain-inspired Computing, green computing, cognitive computing, fusion architecture, concurrent computing, Exabyte (EB)-level storage, Cyber-Physical Systems (CPS).
Big data technology	Big data, data mining, text mining, data visualization, disparate data, credit investigation, augmented reality, mixed reality, virtual reality.
Digital technology application	Mobile Internet, industrial Internet, digital health, e-commerce, mobile payment, third party payment, NFC payment, B2B, B2C, C2B, C2C, O2O, NetsUnion Clearing, wearable smart devices, Smart Agriculture, Intelligent Traffic System (ITS), smart healthcare, intelligent contact center, smart home, robo-advisor, intelligent cultural travel, smart environmental protection, smart grid, smart energy, intelligent marketing, digital marketing, unmanned retail, Internet finance, digital finance, Fintech, quantitative finance, open banking.

Abbreviation

AI	Artificial intelligence
CBM	Circular business models (
CCSR	Chinese Corporate Social Responsibilities
CE	Circular Economy
CLCSRR	China Listed Company Social Responsibility Research
CLSC	Closed-loop supply chain
CMA	Comprehensive meta-analysis
CNRDS	Chinese Research Data Services
CSC	Circular supply chains
CSCM	Circular supply chain management
CSMAR	Chinese Stock Market and Accounting Research
CSR	Corporate social responsibility
CSRC	China Securities Regulatory Commission
DfE	Design for the environment
DT	Digital transformation
EMF	Ellen MacArthur Foundation
ESG	Environmental, social and governance
GI	Green innovation
GPRD	Green Patent Research Database
GSCM	Green supply chain management
GRI	Global Reporting Initiative
I4.0	Industry 4.0
IoT	Internet of Things
NERI	National Economic Research Institute
NRBV	Natural-Source-Based View
NDRC	National Development and Reform Commission
SCC	Supply Chain Council
SCM	Supply chain management
RBV	Resource based view
R&D	Research and development
RDPR	R&D personnel

ROA	Return on assets
ROE	Return on equity
RL	Reverse logistics
SEPA	State Environmental Protection Administration of China
SSCM	Sustainable supply chain management
SMEs	Small and medium-sized enterprises
T&A	Textile and apparel
NERI	National Economic Research Institute
VIF	Variance inflation factor

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