# Does R&D intensity promote the adoption of circular supply chain management? Evidence from China

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Acknowledgement:
All authors contribute equally to the paper and are shown in alphabetical order. The authors gratefully acknowledge the financial support by Natural Science Foundation of China Young Scientist Fund (No. 71991460, 71902159), and China-UK Innovation and Development Association (Grant No. RF350137).

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**Abstract**

This paper explores the relationship between research and development (R&D) intensity and circular supply chain management (CSCM) adoption of high-tech manufacturing companies in China to deepen our understanding of how to improve CSCM adoption in emerging economies. In particular, we examine the moderating effect of three kinds of institutional pressures (i.e., regulatory pressure from governmental regulations, mimetic pressure from industry competition, and normative pressure from overseas customer demand) from the perspective of institutional theory. Based on the panel data of 310 Chinese listed companies from 2006 to 2019, we find that R&D intensity positively affects firms' CSCM adoption. We further observe that this positive effect is strengthened when the ratio of state-owned shares or the degree of industry competition is higher. However, overseas operating income does not affect the impact of R&D intensity on CSCM adoption. Our study contributes to the literature on the innovation – circular economy debate, confirming the positive effect of R&D intensity on firms' CSCM adoption, and provides insights into moderating effects on this relationship in an emerging economy context.

Keywords: CSCM, R&D intensity, circular economy, innovation, institutional theory

## 1. Introduction

The continuous increase in population, consumption and production activities has led to an upsurge in human demand for natural resources, putting pressure on the environment. It is predicted that by the end of 2050, the global demand for natural resources will further increase to double the current level (International Resource Panel, 2017). If we do not change current production, consumption and trade patterns, many natural resources will be exhausted in the foreseeable future and the UN Sustainable Development Goals may not succeed. In particular, developing countries face more severe environmental pressures than developed countries; by 2050, more than 90% of the world's population may live in developing countries, posing major environmental challenges that require systematic intervention (Mangla et al., 2018).

Meanwhile, some developing countries, such as China, are experiencing rapid economic development and industrialisation. Demand for natural resources in these so-called 'emerging economics' is thereby continually increasing, and the international community has expressed concerns, accusing such countries of disregarding environmental issues in favour of economic development. Therefore, it is necessary to improve current resource management practices in emerging economics to promote opportunities for economic growth while maintaining environmentally friendly practices (Shi et al., 2017).

Recently, scholars have turned their attention to the circular economy (CE) concept, which is increasingly considered an important means to reduce the environmental impact while promoting economic growth (Stahel, 2016). The CE is a strategy to transform the traditional consumption system into a circular system (Mangla et al., 2018), based on the 6Rs—reuse, reduce, recycle, redesign, remanufacture and repair—applied to all products, by-products and services (Lüdeke-Freund et al., 2019). By advocating green initiatives and minimising resource inputs, waste, emissions and energy leakage, a CE reduces the environmental impacts of production activities without endangering economic growth and prosperity (Evans, 2009). According to McKinsey, the economic potential of the CE may reach the trillions of dollars (McKinsey Quarterly, 2017), and in line with this, the CE is seen as an important means of achieving sustainable goals, especially for emerging countries facing both environmental and economic pressures. To empower CE principles in firm-level organisations, scholars have viewed the supply chain as the basic unit for CE adoption (Ripanti & Tjahjonon, 2019), and set out the advanced concept of circular supply chain management (CSCM) (Farooque et al., 2019). Traditional linear supply chains deplete available natural resources, leading to scarcity of natural resources and serious environmental pollution (Genovese et al., 2017). In contrast, CSCM tends to form a restorative production system. Across the product life cycle, resources are reused, remanufactured and recycled in an infinite loop to optimise the utilisation of resources (Mangla et al., 2018).

The existing literature has summarised several drivers of CSCM adoption by an organisation, including innovation (e.g., Agyemang et al., 2019; Govindan & Hasanagic, 2018; Lahane et al., 2020). As international corporate activity in emerging economies has experienced significant growth over the past few years (Guillén & Garcia-Canal, 2009), the global innovation landscape has also changed significantly. Traditionally, emerging economies served only as low-cost manufacturing bases for developed economies' low-end value chain; however, emerging economies have witnessed substantial growth in research & development (R&D) investment by multinationals (J. Li & Kozhikode, 2009). For example, as one of the fastest-growing production centres globally, China has adopted several policies to actively encourage companies to implement innovation, such as the 'Innovation-Driven Development Strategy' in the 13th Five-Year Plan released in 2016 (The State Council, 2016). As a result, annual Chinese R&D expenditure had risen to 2.4 trillion RMB by the end of 2020—the highest in history (National Bureau of Statistics, 2021).

However, there is controversy regarding the effect of innovation on CSCM adoption in recent literature. Some scholars believe that innovation is a key enabler of successful CSCM. For example, Ozkan-Ozen et al. (2020) pointed out that companies may face challenges implementing CSCM without relevant information technologies and systems to manage CE involvement and objectives. Therefore, firms with higher innovation capabilities can reduce the technical barriers to applying information technologies related to CSCM, such as the Internet of Things (IoT), Big Data and blockchain techniques (Chen, Jiang et al., 2021; Farooque, 2019). On the contrary, Bressanelli et al. (2019) indicated that product technology improvement might hamper circularity since a product designed to be durable may not participate in a continuous process of technical improvement, undermining the achievement of sustainable improvement (Bakker et al., 2014; Kumar & Putnam, 2008). Meanwhile, information security also raises concerns about adopting advanced information technology in supply chains (Saidani et al., 2018).

To the best of our knowledge, no study provides empirical evidence describing how a firm's innovation inputs, especially R&D intensity, affect the adoption of CSCM. Past empirical research focusing on the sustainability effects of R&D intensity has also concentrated on developed economies (e.g., Wang et al., 2021). Given the huge differences in cultural and political structures between emerging economies and the developed world, experience and knowledge derived in Western countries may not be applicable to the emerging context. Moreover, although the CE principle behind CSCM shares a similar vision as sustainability, there are some essential differences between the two concepts. For example, sustainability focuses on the coordination of interests among stakeholders to achieve sustainable development, while the CE prioritises the financial health of enterprises and reduces resource consumption and environmental pollution (Geissdoerfer et al., 2017). Therefore, previous literature on the impact of R&D intensity on sustainability may not apply to the current CSCM research context. Further, under the current business-to-business (B2B) context, manufacturers face acute pressure to 'green' their supply chains because supply chain sustainability has become a critical factor for customers in selecting suppliers (Cui et al., 2021; Mariadoss et al., 2011; Vesal et al., 2021). This shift has already been seen in some B2B markets. For example, online material and waste exchanges have emerged to effectively reuse industrial surplus materials and provide substantial environmental advantages (Dhanorkar et al., 2020).

In summary, no previous study provides empirical evidence of the R&D intensity – CSCM adoption relationship, which represents a huge gap in the literature. Therefore, we believe that it is necessary to explore R&D intensity as a potential driver of CSCM adoption to provide guidance for managers in emerging economies facing economic development and environmental protection pressures (Yang et al., 2021). This paper contributes to the debate on the role of technological innovation in CSCM by analysing the impact of R&D intensity on CSCM adoption in the context of Chinese high-tech industries. Further, since external institutional drivers generally affect firms' internal strategy adoption (Zailani et al., 2012), we also explore potential moderators of the R&D intensity – CSCM adoption relationship by adopting institutional theory. In particular, our research aims to address the following two research questions:

*1. How does R&D intensity affect the CSCM adoption of Chinese firms?*

*2. What are the factors that affect this relationship?*

The remainder of this paper is structured as follows. Section 2 provides a literature review on the critical constructs, the theoretical background to institutional theory, and the development of relevant hypotheses. Section 3 describes the research design, including the justification of sample selection, data collection, variables and model specification. The results are presented in Section 4, followed by a discussion in Section 5, including the contributions and limitations of the study and proposed future research directions.

## 2. Literature review and hypothesis

### 2.1 Circular supply chain management

The CE has recently emerged in the literature as a powerful driver of sustainable development, and is now seen as an effective means of achieving the Sustainable Development Goals. The Ellen MacArthur Foundation (2013) defines a CE as an industrial economy that is restored or regenerated through intent and design. In the past ten years, the number of articles and journals dealing with this topic has increased dramatically (Farooque et al., 2019). A large body of literature has explored the potential advantages of a CE, such as maintaining the highest utility of products and materials in the biological and technological cycle, eliminating waste, minimising the harm to the environment from human production and consumption activities, and creating more wealth opportunities (Barros et al., 2021). In considering the adoption of CE principles at the firm level to realise the CE vision, scholars have viewed the supply chain as the basic unit (Ripanti & Tjahjonon, 2019). Although CSCM research is still at an early stage, a comprehensive definition of CSCM has appeared in the literature. As defined by Farooque et al. (2019, p. 884), CSCM comprises:

> the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically re-stores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholders in a product/service lifecycle including parts/product manufacturers, service providers, consumers, and users.

Though ideal circular supply chains with zero-waste do not exist, CSCM aims to reduce the environmental impact to a minimal level by optimising resource utilisation throughout the product life cycle (Genovese et al., 2017). In summary, CSCM is seen as an important means of achieving sustainable goals, particularly for emerging economies facing economic and environmental pressures.

## 2.2 Innovation and R&D intensity

Innovation is a critical resource for companies to survive in the face of fierce competition (Coombs & Bierly, 2006; Tsinopolous et al., 2019). In addition, a consensus has been reached that more innovative companies are likely to be more successful than those that are less innovative because innovation enables enterprises to create breakthroughs, consolidate their brand reputation and improve their market position, thus attracting more customers (Coombs & Bierly, 2006; Reichert et al., 2011).

As an index widely used in innovation literature to measure a firm's innovation capacity, R&D intensity has been applied in empirical studies to explore the antecedents or consequences of firm-level innovation. R&D intensity is considered a form of investment in technology capital, the result of which is the improvement of innovation capabilities, in both product and process (Padgett & Galan, 2010; Tsinopolous et al., 2018). As a form of technical investment, R&D activities improve a firm's performance by helping them to come up with new ideas and discover new solutions through experimentation (Ho et al., 2005; Yan et al., 2021). Recently, the focus on R&D and innovation has stemmed from exploring ways to achieve better environmental outcomes without harming business interests (Alam et al., 2019). In the CSCM literature, innovation is also a key driver for enterprises to implement CSCM (Agyemang et al., 2019; Govindan & Hasanagic, 2018; Lahane et al., 2020). However, after reviewing the innovation and CSCM literatures, we find no empirical evidence on the relationship between R&D intensity and CSCM adoption. For example, Wang et al. (2021) argued that corporate R&D activities increase labour production efficiency to reduce the energy consumption of the production activities, while Ardito and Dangelico (2018) and González-Blanco et al. (2018) pointed out that a firm's environmental impact is unrelated to its R&D investment since all company strategies must meet the survival premise.

Such controversies and the lack of empirical evidence are regarded as gaps in the literature. To fill such gaps, we empirically explore the relationship between R&D intensity and CSCM adoption and consider potential moderators on this relationship. In the next section, we introduce the institutional theory and three institutional pressures as potential moderators.

### 2.3 Institutional theory and institutional pressures

External factors, including institutional factors, often influence the internal strategy of a company. In management disciplines, scholars apply institutional theory to analyse the influence of external institutional factors on the implementation of corporate decisions, and CSCM research is no exception (Lahane et al., 2020). Institutional theory holds that an institution is a governance structure based on rules, norms, values and cultural significance (Scott, 1987). Organisational behaviour must be explained in the business world on a contextual basis, as each context is different (Scott, 1995); therefore, business choice is not only a rational economic decision but also one influenced by external norms, values and traditions (Chu et al., 2018).

As discussed in the previous section, although R&D investment has been identified as a driver of CSCM adoption, not all studies agree with this perspective (e.g., Ardito & Dangelico, 2018; González-Blanco et al., 2018). These differences in findings may be caused by the heterogeneity of firms and industries. Such heterogeneity is also manifested in an organisation's institutional pressures (González-Benito & González-Benito, 2006). Therefore, scholars have adopted institutional theory to explain the heterogeneities in a firm's outcomes (e.g., Chen et al., 2015; Handelman & Arnold, 1999; Scott, 1995; Shou et al., 2020).

According to institutional theory, firm decisions may be affected by three kinds of institutional pressures: normative, coercive and imitative (DiMaggio & Powell, 1983). First, coercive pressure refers to pressure from political sources to align the firm's procedures or structures with best practices, which derives from the firm's demand for resource-dependent actors. For example, government agencies may affect a firm's actions through regulations and policies (Berrone et al., 2013; L. Li et al., 2020). Second, mimetic pressure aims to reduce uncertainty for a company since imitating successful peers is regarded as a safe action to reduce risk under uncertainty. Last, normative pressure comes from professionalisation. It enables people within the company to recognise that certain types of structures and processes are legitimate. As a result, customer demand is considered a core normative pressure for a firm's decision-making because the firm tends to meet customer needs. For example, a company's environmental practices may be a response to green consumerism (Bansal & Roth, 2000).

In summary, although there is no study providing empirical evidence for the effect of the above three institutional pressures on firms' CSCM adoption, several studies have revealed the moderating effect of institutional pressures on the relationship between innovation and firm-level environmental practices (e.g., Chu et al., 2018; Zhu & Sarkis, 2007). Therefore, we believe it is worthwhile to explore how institutional pressures (i.e., normative, coercive and imitative pressures) affect the R&D intensity – CSCM adoption relationship since CSCM adoption involves a wide range of environmental practices. In the following sections, we explore the role of R&D intensity in CSCM adoption and adopt institutional theory to analyse how these three institutional pressures affect the relationship between R&D intensity and CSCM adoption.

## 2.4 R&D intensity and CSCM adoption

As Farooque et al. (2019) defined, CSCM aims to integrate the CE principle into supply chain management to achieve zero-waste by continually improving production efficiency and reducing waste and emissions. At the firm level, CSCM adoption mainly involves eco-design, cleaner production, energy conservation and waste management (Ghisellini et al., 2016). Although there is little literature on the relationship between R&D intensity and CSCM, some studies have revealed the positive effects of R&D on several key practices of CSCM adoption. For example, King and Lenox (2002) argued that a firm's R&D intensity might lead to an improved production rate; Jiang et al. (2014) found that R&D intensity significantly reduces soot emissions by manufacturing enterprises; and Fei et al. (2014) pointed out that technological progress may promote renewable energy and carbon emission reductions, implying that R&D investment promotes the adoption of clean energy. Further, waste management, as a critical CSCM practice in the production back end (Yang et al., 2019), also benefits from R&D intensity as advanced technology helps prevent waste generation (Voulvoulis & Burgman, 2019). These findings make intuitive sense as R&D increases the unique knowledge and technologies of a firm, which may then be effectively deployed in activities related to CSCM adoption.

Meanwhile, the existing CSCM literature has emphasised the crucial role of understanding how advanced technologies can directly support the adoption of CSCM. For example, Farooque et al. (2019) and Saberi et al. (2019) claimed that companies could improve supply chain transparency and traceability via advanced digital technology, such as IoT and blockchain technology, which are critical enablers of CSCM adoption. Specifically, in the current Industry 4.0 transition, lack of technology availability is regarded as a critical barrier to adopting CSCM (Bressanelli et al., 2019; Farooque et al., 2019; Govindan & Hasanagic, 2018; Mangla et al., 2018), and hence

R&D is argued to be crucial for organisations to overcome technical barriers related to CSCM adoption.

Finally, there has been controversy in academic circles about whether the efforts of enterprises to improve the environment (including CSCM adoption) will damage their performance (Eiadat et al., 2008; Klassen & McLaughlin, 1996; Melnyk et al., 2003), raising concerns regarding the motivation of firms to adopt CSCM. Conventional economic wisdom holds that any effort to improve the environment represents an external cost (Ambec & Lanoie, 2008). Therefore, the adoption of CSCM at the firm level may lead to an increase in operational costs, in turn harming their long-term financial performance. In addition, as a critical practice in the production front end of CSCM, eco-design involves green innovation, such as green product and process development (Lahane et al., 2020; Yang et al., 2019). Therefore, knowledge spillovers and public benefit attributes may reduce the motivation of a firm to adopt eco-design because it involves higher uncertainties and expensive innovation costs, while the firm cannot obtain a return in the short run and fails to reap all innovation benefits (Aghion & Jaravel, 2015; Ahuja et al., 2008). To overcome the impediment effect of knowledge spillovers and public benefit attributes on innovation activities (i.e., eco-design), scholars have considered absorptive capacity, defined as the ability to understand, modify and assimilate the knowledge generated by scientific progress to commercialise products (Ahuja et al., 2008; Cohen & Levinthal, 1990). In other words, firms with stronger absorptive capacity may generate more profits from eco-design, reducing the cost of CSCM adoption. Previous literature has confirmed that a firm's absorptive capacity is positively related to R&D intensity (Aldieri et al., 2018; Leahy & Neary, 2007). Therefore, firms with higher R&D intensity will have a stronger absorptive capacity to reduce the cost of and reap more profit from CSCM adoption, further increasing their motivation to adopt CSCM.

In summary, corporate R&D activities promote critical CSCM practices (i.e., eco-design, cleaner production, energy conservation and waste management), reduce technical barriers to advanced technologies application, and improve firms' absorptive capacity to promote CSCM adoption. Based on the above discussion, we propose that:

*H1. A company's R&D intensity has a positive impact on its CSCM adoption.*

2.5 Coercive pressure from government regulation

Coercive pressure from government regulations has generally been seen as a driver of CSCM adoption (Govindan & Hasanagic, 2018). Several studies have discussed the positive effect of government regulations on CSCM adoption practices. For example, Xue et al. (2010) emphasised the vital role of laws formulated by the government in forcing a company to implement a CE strategy since many companies are solely driven by profit. Park et al. (2010) argued that policies and regulations to promote CSCM practices, including cleaner production, consumption and waste management, are mandatory drivers for many developing economy context organisations. In particular, China has introduced the 'Circular Economy Promotion Law of the People's Republic of China' as early as 2009 (Lieder & Rashid, 2016). In China, the central government sees the CE as a top-down political objective at the national level, while in developed countries and areas such as the US and the European Union, it is seen as a means to develop bottom-up policies for environment protection (Ghisellini et al., 2016). Therefore, we believe that government regulations act as a coercive pressure to promote firms to deploy R&D resources to environmentally friendly initiatives, such as eco-design and waste management, to improve their CSCM adoption.

Based on this perspective, we further propose that the coercive pressure from government regulations facing Chinese firms is related to their state ownership structure. Governments in emerging regions, especially China, may have more power than those in developed countries since they are primarily responsible for resource allocation and formulating national macroeconomic control policies (Goldman et al., 2013; Haveman et al., 2017). Therefore, to maintain control over the development of strategic industries and protect key resources, China has established many state-owned enterprises (SOEs) in energy, manufacturing and other industries and provided direct capital for investment (Chan & Rosenbloom, 2009). Unlike private-owned enterprises (POEs), which are more concerned with survival and profit, SOEs are more likely to engage in corporate social responsibility (CSR). According to the CSR report released by the Chinese Academy of Social Sciences (2020), SOEs' CSR index is far ahead of that of private enterprises.

Further, as China attaches greater importance to environmental protection, SOEs are also facing environmental pressure. In the 13th Five-Year Comprehensive Work Plan for Energy Conservation and Emission Reduction released in 2016, the central government stressed that SOEs should actively undertake the work of pollution reduction and asked the State-owned Assets Supervision and Administration Commission of the State Council to effectively strengthen supervision and assessment of SOEs' energy conservation and emission reduction. Therefore, we believe that state ownership structure is positively related to coercive pressure from government policy and regulations. Under greater coercive pressure, SOEs are more likely to adopt CSCM and improve their environmental performance than POEs.

Moreover, in China, access to sensitive resources related to R&D is strictly controlled by government agencies. Since Chinese SOEs are viewed as government agents (Yi et al., 2017), managers of SOEs often find it easier to cultivate personal relationships with government officials, which gives companies access to more resources related to R&D (Shou et al., 2020). Compared with POEs, SOEs usually find it easier to establish good relations with the government and receive preferential treatment. For example, SOEs can easily obtain large loans from banks and subsidies from the government (Zhou et al., 2017), enabling them to deploy more critical resources for R&D activities.

In summary, we believe that coercive pressure from government regulations positively moderates the relationship between R&D intensity and CSCM adoption. Specifically, this coercive pressure is related to a firm's state ownership structure. Compared with POEs, SOEs face greater coercive pressure since they are forced to take more responsibility for environmental protection. Therefore, SOEs are more inclined to deploy R&D towards practices related to CSCM adoption than POEs. In particular, we extend the traditional dual measurement of state ownership (i.e., 1 for SOEs and 0 for POEs) and use the ratio of state-owned shares to measure state ownership structure (Qiang, 2003). For listed companies, the higher the state-owned share, the deeper state-owned control is, implying they will face greater coercive pressure. Based on the discussion above, we propose that:

*H2. The ratio of state-owned shares positively moderates the relationship between R&D intensity and CSCM adoption.*

2.6 Mimetic pressure from industry competition

Much of the literature views competitive pressure as a kind of mimetic pressure (e.g., Chu et al., 2018; Zhu & Sarkis, 2007), as imitation is a standard corporate response to uncertainty when firms face stiff competition (DiMaggio & Powell, 1983). Since R&D is an activity with a high degree of uncertainty regarding outcomes and risks, firms may study how their competitors conduct these activities and how this affects them (Dai et al., 2015). DiMaggio and Powell (1983) claimed that enterprises might adopt the same approach to imitate successful enterprises after observing competitors' success. Therefore, we believe that firms in more competitive industries face greater imitative pressure than those in less competitive industries.

Competitive pressure might play a prevalent role in corporate environmental responsibility. For example, for the manufacturing sector to remain competitive in today's era of sustainable development, companies are forced to reduce resource consumption in the production process (Ridaura et al., 2018). In addition, globalisation has increased multinational corporations' investment in China. As a result, organisations with international experience, such as those in the electronics industry, experience greater pressure from competitors to adopt practices that protect the environment with positive economic outcomes (Hui et al., 2003).

In terms of CSCM, firms in a more competitive industry may deploy greater R&D resources to CSCM adoption to improve their environmental performance and gain competitive advantages. Previous studies have also acknowledged that competitive pressure can increase a firm's investment in innovation activities (i.e., R&D) for environment protection (Hofer et al., 2012; Sarkis et al., 2011). Moreover, such competitive pressure may force other firms to imitate the CSCM adoption of those firms with superior environmental performance. Therefore, we believe that a firm in a more competitive industry may face greater mimetic pressure, and hence deploy more R&D

resources to CSCM adoption. Therefore, from the discussion above, we put forward H3:

*H3: The level of industry competition positively moderates the relationship between R&D intensity and CSCM adoption.*

2.7 Normative pressure from overseas customer demand

In previous literature, pressures related to customer and market demands have been treated as normative pressures to improve environmental performance (Chu et al., 2018; González-Benito & González-Benito, 2006; Sarkis et al., 2010). Zhu and Sarkis (2007) pointed out that customer pressure derives from customers' requirements and expectations regarding environmental issues. Zailani et al. (2012) concurred, and proposed that educating customers can improve manufacturers' environmental awareness, while customer pressure may also influence regulatory policies through lobby groups and even the news media. Such pressure related to consumers' environmental awareness can also be regarded as a CSCM adoption driver (Govindan & Hasanagic, 2018). For example, Ilić and Nikolić (2016) indicated that consumers are starting to understand the impact of industrial production on the ecological environment and pressuring manufacturers to develop a CE strategy. Consumers' environmental awareness is not limited to the traditional B2C context but is increasingly applicable to larger B2B transactions. Both end consumers and upstream customers are demanding sustainable products from suppliers and are more likely to partner with companies that adopt sustainable supply chain practices (i.e., CSCM adoption) (Hoejmose et al., 2012; Lopes de Sousa Jabbour et al., 2018; Mariadoss et al., 2011; Vesal et al., 2021). Therefore, we believe that customer pressure is a normative pressure that promotes the adoption of CSCM by firms to satisfy customers' requirements for environmentally friendly products.

China has been the world's largest exporter of goods since 2009 and is currently the largest import source for 65 countries (McKinsey Global Institute, 2019). Consistent with the views of Zhu and Sarkis (2007), we argue that overseas customers bring normative pressure for companies to improve their environmental performance. Therefore, CSCM adoption may be a valuable practice for those companies with more overseas customers to achieve better environmental performance without harming financial performance. Moreover, overseas countries, especially developed countries, have more stringent environmental certification systems and environmental protection standards. Therefore, Chinese manufacturers are more likely to implement CSCM to improve their environmental performance to protect themselves from trade barriers, while overseas consumers are willing to provide implicit and explicit help. As a result, we believe that overseas customer demand may prompt enterprises to deploy R&D in more environmentally friendly ways, such as CSCM adoption. We further propose that companies with a higher share of overseas operating income will come under greater normative pressure to be green than firms with a lower such share. Accordingly, we propose:

*H4. Overseas operating income positively moderates the relationship between R&D intensity and CSCM adoption.*

Based on our hypothesis development, we present our overall research model, as shown in Figure 1.

Insert Figure 1 above here

**3. Methodology**

3.1 Justification of the empirical context

As one of the fastest-growing production centres globally, China has adopted several policies to actively encourage companies to implement innovation. For example, the central government emphasised its ‘Innovation-Driven Development Strategy’ in the 13th Five-Year Plan released in 2016 (The State Council, 2016). As a result, in 2020, total Chinese investment in R&D activities increased by 10.3% to 2.4 trillion RMB, which is the highest level in history (National Bureau of Statistics, 2021). However, as the biggest emerging economy, China has also become the ‘largest carbon emitter’ and ‘largest energy consumer’ (Chinese Academy of Sciences, 2012). In the past, China has been criticised by the international community for its environmental problems. For example, Beijing has been hit by several severe smog episodes since 2013 and has issued several red alerts for heavy air pollution since 2015 (Hunt & Lu, 2015). Therefore, exploring the relationship between R&D intensity 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.

### 3.2 Sample and data

We collected data from multiple sources. First, we obtained Chinese listed companies' CSCM adoption data from the Chinese Research Data Services Platform (CNRDS). After that, we collected firms' R&D intensity data and other relevant data from the China Stock Market and Accounting Research (CSMAR) database, which provides financial and governance data. Both CNRDS and CSMAR have been widely used by prior firm-level secondary studies (e.g., Hsu, 2009; Z. Li et al., 2021; Sun et al., 2018).

Our sample contains companies listed on the A-share markets of the Shanghai and Shenzhen Stock Exchanges in China over 2006–2019. The CNRDS database's CSCM adoption data are available from 2006; thus, we chose 2006 as the starting year. Following previous R&D intensity research (e.g., Hong et al., 2016; Shou et al., 2020), we focus on China's high-tech companies because they have extensively conducted R&D investment. According to the industry segmentation guide and digital codes issued by the National Bureau of Statistics (2017) and China Securities Regulatory Commission (2012), we identify China's high-tech enterprises in manufacturing industry. After removing special treatment firms and firms with missing performance data, we obtained 1,879 firm-year observations, comprising 310 firms over 2006–2019. Table I shows our classification of the high-tech manufacturing industry and the relevant distribution of sample firms by industry in China.

Insert Table I above here.

### 3.3 Measures

#### 3.3.1 Dependent variable

To construct the measurement of CSCM adoption by Chinese listed manufacturers, we obtained firm-level environmental activity data from the Chinese Corporate Social Responsibilities (CCSR) database of CNRDS. The CCSR database incorporates six aspects of CSR: charity, corporate governance, diversity, employee relations, the environment and products. Prior literature has summarised key indicators to measure the CE and CSCM adoption of a firm (Farooque et al., 2019; Govindan & Hasanagic, 2018; Jain et al., 2018; Lahane et al., 2020; Sassanelli et al., 2019). Following their work, we selected eight indicators from the environmental dimension of the CCSR database to measure listed manufacturers' CSCM adoption: *environmentally friendly products*, *measures to reduce three types of waste*, *circular economy strategy*, *energy conservation*, *a green office*, *ISO14001 certification*, *environmental recognition* and *other strengths*.

First, the CE is regarded as the philosophy behind CSCM (Farooque et al., 2019). Management's sustainability awareness and understanding of CE insights are considered keys to successful CSCM adoption (Batista et al., 2018; Hussain & Malik, 2020). Therefore, we adopt *circular economy strategy* as our first indicator of the dependent variable. The term *circular economy strategy* refers to the policies and measures adopted by a company to use renewable energy or engage in the CE. Next, various research has emphasised the importance of durable and recyclable products in CSCM (e.g., Ghisellini et al., 2016; Ness, 2008). Moreover, Jain et al. (2018) and Bakker et al. (2014) argued that product design, especially eco-design, is an important indicator for CSCM adoption. Hence, we include the indicator *environmentally friendly products* as our second indicator to measure a firm's CSCM adoption. The term *environmentally friendly products* refers to whether a company has developed or applied innovative products, equipment or technologies that benefit the environment. Third, the indicator *measures to reduce three types of waste* refers to a company's policies, practices or technologies to reduce emissions of waste gas, waste water and waste residue. As suggested by prior research, CSCM adoption leads to effective waste management that includes but is not limited to the reduction of waste gas (Pan et al., 2015), waste water (Gherghel et al., 2019) and waste residue (Huysman et al., 2017; Malinauskaite et al., 2017). Fourth, we adopt the indicator *energy conservation*, described as whether a company has policies, measures or technologies to save energy, consistent with Shaw et al. (2010) and Jadhav et al. (2019). Further, ISO 14001 is considered the premier business tool integrated with CE principles to guide a firm on how to mitigate its environmental impact (Kristensen et al., 2021; Liu et al., 2018). Both CE principles and ISO 14001 are based on the concepts of reducing waste and taking action to reduce the risk of a firm's impact on the greater environment (Stichting Coördinatie Certificatie Management, 2019; Ying & Li-jun, 2012). Therefore, we include the indicator *ISO 14001 certification* to construct the overall CSCM adoption measurement. The indicator *green office*, referring to whether a company has a green office policy or measures, is also included in our measurement system, as suggested by Hanulakova and Dano (2018). To measure if the adopted CSCM practices improve the firm's overall environmental performance, we add the seventh indicator, *environmental recognition*, described as whether the company has received environmental recognition or other positive evaluations. Finally, we include *other advantages*, defined as other advantages in the company's environment that are not included in the above indicators. Each item is coded 1 if the firm has demonstrated this initiative and 0 otherwise. We add the score of each item to obtain a total score as the measure of CSCM adoption.

#### 3.3.2 Independent variable

R&D intensity is our key independent variable. We measure the R&D intensity of listed companies using the ratio of R&D expenditure to the year's total sales. As suggested by previous innovation studies, we assign 0 to those firms with missing R&D expenditure data (e.g., Kim & Zhu, 2018; Shou et al., 2020).

#### 3.3.3 Moderating variables

According to our previous discussion regarding institutional theory, we identify three institutional pressures that may moderate the relationship between R&D intensity and

CSCM performance:

(1) A firm with a higher ratio of state-owned shares may face greater coercive pressure to improve its environmental performance; hence, this firm is more likely to adopt a CE strategy in its supply chain. We measure state ownership by the ratio of state-owned shares to total share capital, expanding previous research, which only considers state ownership as a binary dummy variable (i.e., 1 for SOEs and 0 for POEs).

(2) Competitive pressure in an industry is regarded as mimetic pressure that moderates the relationship between R&D intensity and CSCM adoption. Therefore, we use 1 minus the industry Herfindahl index (Sun et al., 2018) to measure industry competition. The Herfindahl index was calculated by adding up the square of the market shares of all firms with the same industry code.

(3) Normative pressure from overseas customers may moderate the R&D intensity – CSCM adoption relationship. We believe that firms with a higher ratio of overseas operating income face more normative pressure. Therefore, we measure the ratio of overseas operating income to the year's total sales as overseas customer demand.

### 3.3.4 Control variables

We control for different factors that may affect CSCM adoption for listed companies to ensure the rigour of our developed model. First, we control firm size as a control variable, as previous literature has recognised that firm size is positively associated with a firm's sustainable practices adoption (Wang et al., 2021; Zhu & Sarkis, 2007). We measure firm size as the natural logarithm of a firm's total assets. Second, as financial performance may affect a firm's environmental activities (e.g., Clarkson et al., 2008), we control return on assets (ROA), measured as operating income / total assets. We also use leverage to control a firm's financial risk proxy, defined as long-term debt as a percentage of total assets. It has been argued that firms facing higher financial risk might pay less attention to environmental pressures (Bhattacharya et al., 2020). Moreover, the independent director ratio, measured as the number of independent directors to the total number of directors, may also affect a firm's CSR activities (McGuinness et al., 2017). Further, we control CEO duality, as Zou et al. (2015)

suggested that firms with CEO duality are more sensitive to environmental issues. We introduce a dummy variable to measure CEO duality, which equals 1 if the CEO and the firm's chairperson is the same person, and 0 otherwise. Finally, firms with high growth capacity may participate in more environmental activities to meet stakeholders' needs and gain public legitimacy (D. Y. Li et al., 2017). Hence, we control for growth ability measured as the operating income growth rate of the firm.

### 3.4 Model specification

Firm-level performance, including financial and environmental performance, often persists, such that current corporate performance is highly correlated with past corporate performance (Yiu et al., 2020). Previous studies have also highlighted that it is necessary to control firm performance in the past, especially for research that takes current firm performance as the dependent variable (e.g., Suarez et al., 2013; Vandaie & Zaheer, 2014). Therefore, to ensure more robust estimates of the impact of enterprise-level variables on CSCM adoption, we control for the performance of past CSCM adoption in our analysis. Moreover, the panel data approach is adopted for model estimation, as our dataset comprises panel data containing 1,879 firm-year observations of 310 firms. Therefore, the Hausman test is performed to check the applicability of the fixed-effect model and random-effect model. The result indicates the applicability of the fixed-effect regression model ($\chi^2$ (21) = 576.97, $p < 0.01$), which is hence adopted in our regression models. Further, we develop the following regression models to test our hypotheses. In model 1, we aim to explore the effect of R&D intensity on a listed firm's CSCM adoption. In model 2, we add an interaction term between R&D intensity and our moderators to explore the potential moderating effect.

$$CSCM\ adoption = \beta_0 + \beta_1 R\&D\ intensity + \sum_{k=2}^{8} \beta_k Controls_k + YearDummy + \varepsilon \quad (1)$$

$$CSCM\ adoption = \beta_0 + \beta_1 R\&D\ intensity + \beta_2 R\&D\ intensity * State\ ownership + \beta_3 R\&D\ intensity * Industry\ competition +$$

$\beta_4 R\&D\ intensity * Overseas\ operating\ income + \sum_{k=5}^{11} \beta_k Controls_k + YearDummy + \varepsilon$ (2)

## 4. Results

4.1 Descriptive statistics

Table II presents the descriptive statistics and correlation matrix of the variables used in the regression analyses. To mitigate the possible influence of outliers on the regression results, we apply a winsorisation process to all the continuous variables. Winsorisation is a data cleaning method that has been widely used in regression analysis (Lien & Balakrishnan, 2005). It can reduce the effect of potential outliers by limiting extreme values in datasets and improving the regression's goodness of fit. Specifically, the operator sets outliers to a certain percentile of the data; for example, winsorisation performed in the 5th percentile and 95th percentiles will set all data below the 5th and above the 95th percentiles of the distribution to the values of the 5th and 95th percentiles. In this study, we apply a winsorisation process at the 1st and 99th percentiles to all the continuous variables, transforming data below the bottom 1% and above the top 1% to the values of the 1st and 99th percentiles.

Moreover, we conduct variance inflation factor tests for potential multicollinearity among the variables. Our tests indicate that multicollinearity is not a concern in our model as the values of the variance inflation factors for all variables are less than the threshold ($3.78 < 10$) (Kennedy, 1998).

Insert Table II above here

4.2 Regression results

Table III presents the regression results for our models. In the first model, which explores the main effect, the coefficient of R&D intensity is significantly positive ($\beta = 4.417$, $p < 0.05$), suggesting that R&D intensity has a positive effect on a firm's CSCM adoption. Therefore, Hypothesis 1 is supported.

Insert Table III above here

In model 2, the coefficient of the interaction term between R&D intensity and state ownership is significantly positive ($\beta = 15.440$, $p < 0.1$), suggesting that state ownership positively moderates the relationship between R&D intensity and a firm's CSCM adoption, supporting Hypothesis 2. In addition, we plot the effects of low (one standard deviation below the mean) and high (one standard deviation above the mean) ratios of state-owned shares on the relationship between R&D intensity and CSCM adoption. Figure 2 shows that when the proportion of state-owned shares is high, the slope of the relationship between R&D intensity and CSCM adoption is higher than when the proportion of state-owned shares is low, confirming Hypothesis 2.

Insert Figure 2 above here

The coefficient of the interaction term between R&D intensity and industry competition is significantly positive ($\beta = 10.964$, $p < 0.1$), which implies that state industry competition positively moderates the relationship between R&D intensity and CSCM adoption. Therefore, Hypothesis 3 is supported. As shown in Figure 3, when industry competition is high, the slope of the relationship between R&D intensity and CSCM adoption is steeper than when industry competition is low, consistent with Hypothesis 3.

Insert Figure 3 above here

The coefficient of the interaction term between R&D intensity and overseas operating income is negative and insignificant ($\beta = -5.051$, $p > 0.1$). Therefore, Hypothesis 4 is not supported.

### 4.3 Additional robustness checks

We next perform two checks to confirm the robustness of our results. First, we modify the measurement of firm size to check sensitivity to this variable, adopting the natural logarithm of a firm's total operating income. Second, we consider the potential effect of outliers on our model by applying a winsorisation process on the continuous variable at the 5% level rather than the original 1% level. The results indicate that our models are rational and robust (see Table IV).

Insert Table IV above here

## 5. Discussion

### 5.1 R&D intensity as a driver of CSCM adoption

Few studies have explored the relationship between R&D intensity and CSCM adoption, and ambiguous results have been obtained (e.g., Ardito & Dangelico, 2018; Bressanelli, 2019). Moreover, no study provides empirical evidence from firm-level secondary data on the potential positive effect of R&D intensity on CSCM adoption in the emerging context. Potential moderators affecting the relationship between R&D intensity and CSCM adoption in emerging economies has also received insufficient attention. Our study addresses this research gap and provides empirical evidence to show that a firm's R&D intensity positively affects its CSCM adoption. First, enterprise R&D helps to realise technology development and increase production efficiency. For example, corporate R&D outputs often involve the invention of better equipment and machinery, which increases production efficiency with minimum energy consumption (Alam et al., 2019), consistent with the CSCM vision. Second, enterprise R&D helps enterprises to apply modern information technology to improve their CSCM adoption. For example, blockchain, Big Data and RFID technology have become key for enterprises to develop circular supply chains and reverse supply chains. R&D can help enterprises overcome potential technical bottlenecks to achieve better CSCM adoption (e.g., Farooque, 2019; Jia, Yin et al., 2020; Ozkan-Ozen et al., 2020). Further, corporate R&D promotes the development and deployment of renewable energy, which plays a central role in the transition to clean energy (Fei et al., 2014). Other critical practices related to CSCM adoption, such as eco-design and waste management in production, will also benefit from a firm's R&D investment (e.g., Bressanelli et al., 2019; Gohlke & Martin, 2007). Finally, corporate R&D improves a firm's absorptive capacity, helping to overcome the externality caused by knowledge spillovers and public benefit attributes. Therefore, corporate R&D activities can be an important tool for promoting CSCM adoption in emerging economics.

5.2 Moderating effects of institutional pressures

In addition, the positive effect of R&D intensity on a firm's CSCM adoption is enhanced when the proportion of state-owned shares or the level of industry competition is higher. In China, SOEs tend to take on more CSR (Chinese Academy of Social Sciences, 2020); the higher the proportion of state-owned shares in an enterprise, the greater the environmental pressure it faces from the government and regulatory authorities. Moreover, SOEs have better access to the resources needed for R&D activities. Therefore, state ownership positively moderates the relationship between R&D intensity and CSCM adoption. Industry competition is another moderating variable that affects the relationship between R&D intensity and CSCM adoption. In the current policy context, firms tend to improve their environmental performance by adopting sustainable practices (i.e., CSCM adoption) to gain more competitive advantages (Alam, et al., 2019). Our results confirm that firms in industries with a higher level of competition are more likely to adopt CSCM.

Moreover, our results indicate that overseas customer demand has no significant influence on the relationship between R&D intensity and CSCM. This is an interesting finding since past literature has suggested that foreign consumers are more environmentally conscious. In addition, in the current B2B context, foreign customers continue to increase environmental standards on domestic manufacturers to avoid potential risks from stricter environmental regulations (Zhang & Yang, 2016). Therefore, conventional wisdom holds that companies with more overseas turnover face greater pressure to become green, and are hence more likely to deploy R&D resources towards environmental improvement efforts, such as CSCM adoption. However, this view may be biased. First, China is the third country to develop a CE policy at the national level. In 2009, China introduced the CE framework 'Circular Economy Promotion Law of the People's Republic of China' to solidify its vision to develop a CE (Lieder & Rashid, 2016). In addition, the 13th Five-year Plan (2016–2020) for the nation's economic and social development highlighted the Chinese government's efforts to improve environmental standards and its willingness to continue to develop a CE (The State Council, 2016). Therefore, in the face of increasing environmental pressure, domestic customers in the B2B market keep increasing their suppliers' environmental standards to avoid potential penalties from the government.

The green consumption behaviour of consumers is positively correlated with educational level and household income (Zhu et al., 2013). With the continuous development of China's economy, per capita income and education level are increasing, contributing to consumers' awareness of green consumption. All up, with the continuous improvement in China's environmental protection regulations and consumers' awareness of green consumption, the gap between domestic and foreign environmental pressure faced by Chinese manufacturers has narrowed. As a result, the demand of overseas customers does not have a significant moderating effect on the main relationship. Overall, our findings shed new light on the contingent impact of three important factors (i.e., firm ownership, industry competition and overseas customer demand) on the link between R&D intensity and CSCM adoption.

## 6. Conclusion

This paper is the first to provide empirical evidence on the relationship between R&D intensity and CSCM adoption. In the investigation, we adopt panel data of 310 China's high-tech manufacturing enterprises listed in the A-share markets of the Shanghai and Shenzhen Stock Exchanges over 2006–2019. The results of our regression model validate the positive effect of R&D intensity on firms' CSCM adoption. Additionally, by adopting institutional theory, we further examine the moderating effect of three kinds of institutional pressure: regulatory pressure from governmental regulations, mimetic pressure from industry competition and normative pressure from overseas customer demand. The regression results indicate that regulatory pressure, measured as the ratio of the state-owned shares, positively moderates the R&D intensity – CSCM adoption relationship. We also observe that mimetic pressure, measured as the degree of industry competition, positively moderates the main relationship. However, normative pressure, measured as overseas operating income, does not affect the impact of R&D intensity on CSCM adoption. We believe that this interesting finding is caused by the increasing awareness of green consumption in China and stricter environmental regulations put in place by the Chinese government.

## 6.1 Theoretical contributions

Our empirical study makes several contributions. First, it provides insights into the relationship between R&D intensity and firm CSCM adoption and the contingencies on this relationship. Although the literature on innovation and CSCM is overwhelming, no research has provided empirical evidence to discuss the role of R&D intensity in achieving effective CSCM. For example, while Wang et al. (2021) provided empirical evidence to support the positive role of R&D intensity in a firm's environmental performance, they adopted $CO_2$ emission reduction as a measurement of firm-level environmental performance, which limited the comprehensiveness of their work, as they ignored other aspects of environmental performance and CE strategies, such as eco-design and waste management. To fill this research gap, we clarify the positive effect of R&D intensity on CSCM adoption. Further, we obtained firm-level data on environmental activities to construct the measurement of CSCM adoption to test our hypotheses. As a result, we reveal the positive effect of R&D intensity in CSCM adoption, which enriches the CSCM literature.

In addition, in line with the lack of company-level data (Alam et al., 2019; Wang et al., 2021), we know very little about the factors that influence this relationship. Our study responds to the call to explore the background conditions that influence the relationship between R&D and CSCM adoption and confirms the positive moderating effect of state-owned ownership and industry competition on this relationship. In contrast, the moderating effect of overseas customer demand is not significant. Therefore, this paper contributes to the literature by defining boundary conditions for the R&D intensity – CSCM adoption relationship; that is, environmental benefits from R&D investment may differ according to the specific situation.

Second, we apply institutional theory to explain possible moderating effects facing the relationship between R&D intensity and CSCM adoption. Past research has utilised institutional theory to explore variables affecting firm outcomes (e.g., Chen et al., 2015; Handelman & Arnold, 1999; Scott, 1995; Shou et al., 2020; Zailani et al., 2012). Although the impact of institutional pressures on environmental practices has been discussed in several studies (e.g., Chu et al., 2018; Zhu & Sarkis, 2007), little is known about how institutional pressures affect CSCM adoption, leaving a research gap in the CSCM literature. In this study, institutional theory provides a useful theoretical perspective on how a corporation satisfies stakeholders to gain competitive advantages, and explores potential moderators affecting the relationship between a firm's R&D intensity and CSCM adoption. In particular, we consider three moderators that may affect this relationship: state ownership, industry competition and overseas customer demand. Although overseas customer demand fails to moderate the relationship, the constraining effects of state ownership and industry competition are validated. Therefore, this study improves our understanding of a firm's motivations to obtain environmental benefits from R&D activities and how strong these motivations are. Overall, this article contributes to the literature by introducing institutional pressures to deepen our understanding of the effect of R&D intensity on CSCM adoption.

Third, our research contributes to the innovation and CSCM literature by exploring the moderating effects of three critical factors on the R&D intensity – CSCM adoption relationship in the Chinese context. The existing literature provides little empirical evidence on how potential moderators affect the R&D intensity – environmental practices relationship, especially in the emerging context. It has been pointed out in the literature that, because of their population density, emerging economies face more severe resource crises and environmental challenges than developed countries, while the concept of a CE is still relatively new to developing countries (Goyal et al., 2016; Mangla et al., 2018). The great differences between emerging and developed economies in innovation development and environmental awareness further emphasise the necessity of further research on the theory and practice of innovation management and CSCM in emerging economies. Therefore, our research provides timely insights into the role of R&D intensity on CSCM adoption and the moderating effects of a firm's ownership structure, industry competition and overseas customer demand in the Chinese context.

### 6.2 Managerial implications

Our research offers several implications for managers. First, our research confirms the positive effect of R&D activity in achieving effective CSCM. While R&D may improve environmental practices related to the CE, such as production efficiency, thus reducing energy consumption and emissions, it can also help overcome the technical barriers that enterprises face in applying information technology to improve their CSCM adoption; for example, information technology to adopt a CE strategy, blockchain and IoT technology requires enterprises to master the corresponding knowledge. Therefore, investment in relevant R&D activities can be a significant enabler of CSCM adoption, which may inspire managers who are eager to improve their firm's adoption.

Second, our study demonstrates that overseas demand does not significantly affect the relationship between R&D intensity and CSCM adoption, possibly because domestic consumers have begun to accept green consumerism and the CE principle. Therefore, for manufacturers whose main customers are domestic consumers and enterprises, it remains necessary to adopt CSCM to continuously improve environmental performance to meet the higher environmental needs of domestic stakeholders and avoid possible punishment.

Finally, our findings provide policymakers with a deeper insight into the effect of R&D intensity on CSCM adoption. Considering that sustainability issues remain a common challenge for all of humanity (United Nations, 2015), our results suggest that policymakers in emerging economies should continually promote firms' investment in R&D activities by formulating appropriate policies because R&D intensity can improve CSCM adoption, which further improves environmental performance without harming financial performance.

### 6.3 Limitations and future directions

Our study has several limitations, which indicate opportunities for future research. First, this paper takes high-tech manufactures as the research object. While this helps ensure high internal effectiveness, the insights generated in this article may not apply to other contexts, such as the supply chains in other industries (Chen, Jia et al., 2021). Therefore, it is necessary to study how R&D intensity affects firm CSCM adoption in other manufacturing industries. Second, this paper explores the role of several moderators on the R&D intensity – CSCM adoption relationship. However, other contingent factors (such as political linkages, financial slack and government subsidies) may also have moderating effects. Therefore, future studies should further explore other possible moderators to deepen our understanding of the R&D intensity – CSCM adoption relationship. Third, this paper focuses on Chinese enterprises, which limits the generality of our results. Politics, culture and institutions may differ across different countries, hindering the universality of this study. Future research could expand on this paper by examining the impact of R&D intensity on CSCM adoption in other emerging countries or developing regions. Finally, we only consider R&D intensity as a driver of CSCM adoption. It is necessary to examine other factors that promote CSCM adoption in the current B2B context, such as supply chain finance (Jia, Zhang et al., 2020) or supply chain collaboration (De Angelis et al., 2018), to deepen our understanding of CSCM.

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