Does supply chain concentration improve sustainability performance: The role of operational slack and information transparency

Abstract

Purpose: Despite the increasing interest in the role of supply chain concentration (SCC) in improving performance, its influence on firms' sustainability performance remains unexplored, as do the underlying mechanisms of this relationship. Drawing on resource dependence theory, we investigate the relationship between SCC and manufacturing firms' sustainability performance and the moderating roles of operational slack and information transparency.

Design/methodology/approach: We use secondary data from 3,581 manufacturing firms listed on the Shanghai and Shenzhen A-share stock markets from 2006 to 2020 to conduct an empirical analysis using panel data regression models.

Findings: Manufacturing firms' SCC is negatively related to sustainability performance until it reaches a certain point, where SCC positively affects sustainability performance, presenting a U-shaped relationship. In addition, operational slack represented by a quick ratio moderates the relationship between SCC and sustainability performance by flattening the curve. Operational slack represented by receivable turnover ratio moderates the relationship between SCC and sustainability performance by steepening the curve and shifting the turning point left. Information transparency strengthens the effect of SCC on the sustainability performance by steepening the curve.

Originality/value: This investigation provides a comprehensive view of the SCC–sustainability performance relationship.

Keywords: Supply chain concentration; Sustainability performance; Operational slack; Information transparency; Resource dependence theory

Paper type: Research paper

1. Introduction

As concerns about forced labour, resource depletion and pollution are increasingly rising, the notion of the sustainable development of firms has come to the forefront (Jadhav *et al.*, 2019). Adopting sustainable strategies can address global environmental degradation, resource scarcity and potential health hazards linked to industrial activities. Supply chain operations play a pivotal role in achieving sustainability, fostering environmental quality, economic growth and social equity (Fahimnia and Jabbarzadeh, 2016). Moreover, mounting pressure from stakeholders, such as customers, investors and regulatory bodies, has underscored the need for firms to showcase their commitment to sustainability. As a single firm’s influence is often confined to production, distribution and consumption processes, enhancing sustainability performance across the supply chain has emerged as a critical imperative for firms aiming to retain competitiveness in the contemporary market.

In this regard, supply chain concentration (SCC) has emerged as a pivotal factor (Van der Vaart and van Donk, 2008). Supply chain concentration refers to a firm’s reliance on a concentrated supplier and customer base, implying interdependence with menbers in the supply chain up-and downstream (Lanier *et al.*, 2010). The pursuit of sustainable practices entails managing material, capital and information flows, necessitating cooperation among supply chain stakeholders to achieve economic, social and environmental goals (Tseng *et al.*, 2022). Notably, the CDP Global Supply Chain Report (2019) highlights that over 50% of suppliers have enhanced their sustainability performance through collaboration with firms. This partnership empowers firms to tailor strategies to meet specific customer requirements. Encouragingly, a significant 73% of customers are willing to transition away from existing suppliers based on their sustainability performance.

The sustainability performance of a firm is different from the linear economy, namely, the traditional way of producing, selling and disposing of goods, because it decouples economic growth from environmental and social impact (Fahimnia and Jabbarzadeh, 2016). From a traditional operations and supply chain perspective, by maintaining close ties with major suppliers and customers, focal firms gain enhanced control over their supply chains, enabling effective management of environmental and social impacts while fostering eco-conscious collaboration as a viable strategy for achieving environmental and productivity advancements (Zhu *et al.*, 2010). However, escalating supplier or customer concentration might strengthen firms' bargaining power, potentially complicating supply chain management and sustainability assurance because of heightened reliance on third-party suppliers and limitations in tracing lower-tier supply chain activities (Kim and Henderson, 2015; Li *et al.*, 2021; Zhu *et al.*, 2021). However, to date, there is no consensus on whether SCC increases or reduces a firm's sustainability performance.

To explore this under-researched issue, we use the resource dependence theory (RDT) as the theoretical underpinning of our framework. This theory stipulates that organisations strive to both secure vital resources (e.g. capital, raw materials, labour) for sustainable operations and minimise vulnerabilities to external forces (Pfeffer and Salancik, 1978). In the supply chain context, firms depend on trading partners for essential resources such as raw materials and components. Close collaboration with a limited number of suppliers/customers establishes strong interdependence (Casalin *et al.*, 2017). This dynamic can yield positive outcomes, enhancing sustainability performance. However, when a firm concentrates its supply chain by heavily relying on a few suppliers or customers, who tend to gain significant power in the relationship and might leverage the focal firm's dependency for their benefits (Kwak and Kim, 2020). This heightened dependency, while aiming to ensure resource access, can lead to negative consequences that hinder sustainability performance. Thus, the RDT provides an appropriate lens for us to explore the influence of operations management factors on the relationship between SCC and firm sustainability performance.

From the perspective of the RDT, corporate sustainability performance is heavily influenced by a firm's available resources, including its participation in sustainable activities (Omar *et al.*, 2022). Available resources for a firm can promote strategic behaviour, enabling firms to experiment with new strategies, such as engaging in corporate social responsibility endeavours, exploring new markets or introducing new products (Wiengarten *et al.*, 2017). Operational slack pertains to resources that are not fully utilized or committed, yet can be readily deployed to accomplish the organization's objectives and functions (Azadegan *et al.*, 2013). This may either result in costs and inefficiencies for firms (Tan and Peng, 2003) or launch novel strategies that venture into new markets (Wiengarten *et al.*, 2017). Information transparency refers to the extent of the visibility and accessibility of a firm's accounting information (Cho *et al.*, 2017). de Leeuw *et al.* (2013) contend that the more complex a system, the more information required to explain its current situation. Firms with transparent information have access to accurate and up to date information, and can make informed decisions based on data analysis. This enables them to implement changes that lead to increased efficiency and cost savings (Guenther *et al.*, 2017). By applying the RDT framework and considering the moderating influence of operational slack and information transparency, we can gain insights into how SCC impacts a firm's sustainability within the realm of operations and supply chain management. Considering the research background, we pose the following research questions:

> ***RQ1.*** *How does manufacturing firms' supply chain concentration affect their sustainability performance?*

> ***RQ2.*** *How do operational slack and information transparency affect the relationship between a manufacturing firm's supply chain concentration and its sustainability performance?*

Methodologically, we collect samples from Chinese manufacturing firms listed on the A-share markets of the Shanghai and Shenzhen Stock Exchanges in China from 2006 to 2020. Related data are collected from the China Stock Market and Accounting Research (CSMAR) database and the Chinese Research Data Services Platform (CNRDS) database. After excluding missing data and special treatment (ST) shares, the final sample included 3,581 observations. Then, we use panel data regression models to conduct our investigation.

Our study makes several contributions. First, to the best of our knowledge, this is the first study to empirically investigate the relationship between SCC and sustainability performance of manufacturing firms. Prior studies have demonstrated sustainability drivers (Blome *et al.*, 2023; Tseng *et al.*, 2022), which does not fully account for a firm's sustainable performance in the supply chain. Our study innovatively identifies the U-shaped relationship between SCC and sustainability performance. Second, we explore two operating characteristics—operational slack and information transparency—as factors affecting the U-shaped relationship between SCC and the sustainability performance. Third, we use secondary data to measure our research purpose, which provides objective empirical evidence for our conclusions. Our findings offer practical implications for managers concerning the business justification for restricting investments in SCC and the strategic rationale for shifting towards a more sustainable business operational model.

The rest of this paper is organized as follows: In Section 2, we examine existing literature and put forth our hypotheses. Section 3 outlines our data and sample, addressing methodological concerns. Our empirical findings are expounded upon in Section 4, while Section 5 showcases the implications drawn from our discoveries. The concluding section provides a summary of our study.

2. Literature and hypotheses

2.1 Resource dependence theory

The RDT is a useful framework to explain the relationship between SCC and sustainability performance because it sheds lights on how organisations rely on external resources and how these dependencies can influence their behaviour and outcomes (Pfeffer and Salancik, 1978). Initially, increased concentration might lead to dependency on a few partners, causing power imbalances and compromising environmental, social and governance (ESG) performance. However, after reaching an optimal concentration point, the firm reduces dependency risks, gains better bargaining power and deliver ESG commitments with partners. Shared resources and knowledge contribute to improved ESG performance (Kwak and Kim, 2020; Jiang *et al.*, 2023). This twofold possibility highlights that the impact of concentrated supply chain relationships on sustainability is contingent on factors such as the orientation of the concentrated partners and their motivation to collaborate towards shared sustainability objectives.

By utilising the RDT, firms can gain insights into how SCC affects their sustainability performance and identify strategies to address these challenges effectively. This may include fostering more transparent relationships with suppliers/customers, encouraging sustainable practices throughout the supply chain and diversifying supplier partnerships to enhance resilience and sustainability (Jiang *et al.*, 2023). In essence, the RDT provides a framework to understand the interplay between supply chain structure and sustainability performance, enabling firms to make informed decisions to improve their ESG outcomes.

2.2 Firm sustainability performance

Sustainability is a broad notion of fulfilling present requirements while safeguarding the potential of forthcoming generations to fulfil their own needs (Brundtland, 1987), which emphasises durable economic development, respect for nature and social equity (Boukherroub *et al.*, 2015). For firms, sustainability refers to integrating the value of economy, environment and society (triple bottom line), which is regarded as a long-term process to achieve performance outcomes (Omar *et al.*, 2022). Environmental sustainability aims to reduce the environmental burden, which is usually measured by greenhouse gas emissions and resource consumption (Fahimnia *et al.*, 2015). Social sustainability focuses on potential damage to human health and the entire community/society (Boukherroub *et al.*, 2015). Firms not only focus on creating profits for shareholders, but strive to satisfy stakeholders (including employees, customers, suppliers, communities and governments) to achieve the goal of multiple wins (Edmans, 2020), which is the fundamental purpose of sustainability performance.

Compared with the traditional linear model, which is a take–make–dispose process, sustainable performance focuses on the coordinated development of economics, environment and society while refusing to use quantities of non-renewable resources and protecting labour rights. Ahi and Searcy (2015) argue that sustainability is the integration of the triple bottom line, which effectively controls the procurement, manufacturing and value delivery of products/services to meet the requirements of stakeholders and improve the efficiency, resilience and competitiveness of the firm, both in the short and long term. Rajeev *et al.* (2017) suggest that sustainability requires collaboration and information exchange in supply chain networks to achieve higher organisational sustainability performance. Therefore, it is important for firms to incorporate the concept of sustainability into firm development strategy to gain a competitive advantage, especially in a supply chain management context.

2.3 Supply chain concentration

Supply chain concentration entails both supplier and customer concentration (Lanier *et al.*, 2010). Supplier concentration refers to both the count of suppliers providing a firm with raw materials and the concentration of procurement volume. A substantial supplier concentration signifies limited supplier engagement with the firm and a considerable share of purchase volume coming from primary suppliers (Kahkonen *et al.*, 2015). On the other hand, customer concentration encompasses both the count of customers and the concentration of the firm’s product sales volume. High customer concentration suggests a reduced number of firm customers, with a significant portion of sales revenue attributed to key customers within the total revenue (Hui *et al.*, 2019).

Research has looked at how SCC affects several factors such as operational efficiency, pricing, innovation, sustainability and risk management. Several findings have emerged from this literature. First, higher SCC is often associated with improved operational efficiency because dominant firms can benefit from economies of scale and streamlined coordination. However, excessive concentration may lead to reduced competition and potential negative effects on innovation and pricing (Carey *et al.*, 2011). Second, SCC can influence pricing dynamics. In some cases, concentrated supply chains may have more bargaining power and can negotiate lower prices with suppliers. However, concentration can also result in higher prices if dominant firms exploit their market power (Lanier *et al.*, 2010). Third, research has examined the relationship between SCC and innovation. While concentration can enable knowledge sharing and collaboration among dominant firms, it may also limit innovation by reducing competition and diversity in the supply chain (Delgado and Mills, 2020). Further, SCC may be more vulnerable to disruptions because the failure of a few key suppliers can have a significant impact on the entire chain. However, concentrated supply chains may also benefit from stronger relationships with suppliers, allowing for better risk mitigation and coordination (Hendricks and Singhal, 2014). However, there is a lack of empirical evidence on the impact of SCC on sustainability and further research is needed to deepen our understanding of the mechanisms and dynamics underlying SCC and its implications for supply chain management.

2.4 Hypothesis development

2.4.1 SCC and sustainability performance

With regard to sustainability, it is difficult to determine the impact of SCC on sustainability performance directly from empirical evidence. Referring to Haans *et al.* (2016), we explain the SCC– sustainability performance relationship from two opposing sides; that is, the benefit function and the cost function, as shown in Figure 1(a). The cost function indicates that sustainability performance decreases with an increase in SCC. This adverse correlation arises from several interrelated factors. First, a concentrated supply chain is more vulnerable to disruptions such as natural disasters, labour strikes, political instability or other unforeseen events (Hendricks *et al.*, 2009). Environmental risks may escalate because of a lack of diversification in sourcing hindering companies from adapting to changing sustainability demands (Whitney *et al.*, 2014). Additionally, the reduced number of suppliers or customers might limit employment opportunities and economic benefits for local communities. When firms depend heavily on a few suppliers, they might exert undue pressure on these partners, leading to potential labour rights violations, unsafe working conditions and compromised employee welfare (Porteous *et al.*, 2015). Moreover, concentrated supply chains can pose governance challenges. A strong dependency on a limited number of suppliers or customers can lead to power imbalances, creating opportunities for unethical practices, corruption and breaches of governance standards (Zhu *et al.*, 2021).

The benefit function means that sustainability performance increases thanks to the positive influence associated with SCC activities among supply chain partners. Sustainability performance cannot be achieved in isolation. Rather, focal firms need to cooperate with supply chain partners to maximise value (Jia *et al.*, 2020). Sustainable activities, such as circular economy activity in supply chains, involve interfirm trading linkages, considering how waste and byproducts are used as raw resources in subsequent production processes (Kristoffersen *et al.*, 2021). This may achieve cost efficiencies, reduced logistical complexities and better coordination with a limited number of suppliers or customers. In addition to typical product flows, supply networks that create new economic value through the constant interchange of resources, supported by innovative logistics and supply chain ecosystems, provide the supply chain with sustainable solutions (Batista *et al.*, 2018), which are easy to ignore when engaging in sustainable activities. Moreover, firms with stable relationship with suppliers and customers are associated with better long-term performance, which provides more resources to engage in sustainable activities (Zhu *et al.*, 2021).

Reconciling these arguments, the relationship between SCC and sustainability performance can be explained by the benefits and costs derived from different levels of concentration. At lower levels of concentration, firms may benefit from greater competition and diversification in their supply chains. These factors can lead to positive impacts on the environment, such as reduced carbon emissions and resource usage, improved labour conditions and strengthened corporate governance. However, as SCC increases, firms may have more control and leverage within their supply chains, leading to greater efficiency and coordination. At a certain point, however, the costs associated with high levels of concentration begin to outweigh the benefits. For example, high levels of concentration may lead to reduced competition and increased risk of supply chain disruption. This is where the costs associated with vulnerability and reduced resilience start to outweigh the advantages, ultimately harming a firm's sustainability. Additionally, as firms become more reliant on selected few supplier, they may be more vulnerable to environmental and social risks within those suppliers' operations. Therefore, the net effect of SCC on sustainability performance by combining these two potential functions is reflected as a U-shaped relationship. In such situations, we initially propose the following hypothesis:

H1: *The relationship between SCC and sustainability performance is U-shaped.*

2.4.2 Role of operational slack

Slack is regarded as an organisation's resource pool that exceeds the minimum resources required to produce a given output level. Thus, slack can provide opportunities for the organisation to develop new products and enter new markets, or it may indicate a financial burden and inefficiency (Wiengarten *et al.*, 2017). A prevalent debate in the research on slack has focused on operational slack and its potential double-edged sword. With more attention on sustainable operations, King and Lenox (2001) argue that reducing slack is related to the more efficient use of resources and less pollution. We thus enter this discourse from the perspective of firm operations management by discussing the moderating role of operational slack on the SCC–sustainability performance relationship.

Operational slack refers to the excess resources that a firm can freely use for a period of time to overcome risks or explore opportunities, which can take the form of spare physical inventory, surplus capacity, excess labour and time (Azadegan *et al.*, 2013). The common pursuit of resource utilisation in lean production is accompanied by potential operational risks (Holweg, 2007), which requires firms to pay attention to the comparison between resource frugality and redundancy. On the one hand, firms aim to reduce operational slack because this usually means redundancy and the inefficient use of resources (Wood *et al.*, 2017), in the pursuit of being more streamlined, efficient and profitable. Similarly, Lin *et al.* (2019) argue that a low level of slack indicates resource constraints and limited management discretion, in which a firm may focus on its main objectives and short-term performance, namely, profitability, rather than other performance priorities, such as the sustainability. On the other hand, operational slack is a buffer resource that can be used to support the operational activities of firms so that firms can better match changes between supply and demand. In this context, a low level of operational slack tends to result in reduced responsiveness and reliability to demand changes and product delivery (Kovach *et al.*, 2015). Marlin and Geiger (2015) argue that operational slack has a negative impact on firm performance by giving rise to low efficiency and limiting risk-taking behaviour. As such, we argue that slack may affect cooperation with supply chain partners because of a firm's excessive resources, further affecting joint sustainable activities, as well as operational slack, which affects the cost of sustainability performance.

Referring to the notion of L. Chen *et al.* (2022), we consider two categories of operational slack: financial slack and excess inventory. Financial slack represents resources that are not invested in a specific activity and can be used for other activities, such as cash and credit lines (M. Chen *et al.*, 2022; Guo *et al.*, 2020). We measure financial slack according to two types: the quick ratio and the receivables turnover ratio. The quick ratio represents the firm's liquidity, where quicker liquidity indicates greater financial slack, which is measured by quick assets divided by current liabilities (Azadegan *et al.*, 2013; Bortolotti *et al.*, 2015; L. Chen *et al.*, 2022; Kovach *et al.*, 2015; Wood *et al.*, 2017). Azadegan *et al.* (2013) suggest that this financial slack ensures the continuity of a firm's production. This provides a guarantee for profits and lays the foundation for sustainable activities. The receivables turnover ratio is measured by net sales divided by average accounts receivables (Chen *et al.*, 2022; Wood *et al.*, 2017).

A high turnover rate of accounts receivable indicates that the firm can rapidly redeploy or translate its operations into effective use because of cash abundance (Bates *et al.*, 2009). However, if a firm is focused on maximising its receivables turnover ratio, it may be less willing to invest in more advanced sustainable practices that could lead to longer-term benefits, which require upfront costs. In a concentrated supply chain, dominant firms may be able to exert pressure on their suppliers to prioritise short-term financial gains over longer-term sustainability, which could have negative long-term sustainability outcomes. In this regard, we assume that the quick ratio strengthens the benefit function of the influencing mechanism between SCC and sustainability performance. The receivable turnover ratio plays a moderating role in the relationship between SCC and sustainability performance by increasing the benefit function and cost function (as shown in Figure (b) and (c)).

Excess inventory proves valuable in adeptly tackling a diverse array of production-linked issues, spanning from deficits in raw materials to vacillations in demand. Unlike the end product, upholding the inventory of standardized subcomponents introduces extra adaptability in managing localized disruptions that impact specific product categories exclusively (Kovach 11 *et al.*, 2015). From the perspective of the RDT, excess inventory can reduce firms' dependence on resources. We take a firm's operating cycle and inventory turnover ratio as proxies of excess inventory (Gaur *et al.*, 2005; Rumyantsev and Netessine, 2007). The former is defined as the average length of time from acquiring inventory to receiving accounts receivable, whereas the latter is computed by dividing sales by average inventory (Azadegan *et al.*, 2018). Specifically, a longer operating cycle shows that the company needs more time to turn its inventory into cash. In this instance, we consider it as a favourable asset in the SCC–sustainability performance relationship because the firm may have a larger inventory to participate in sustainable activities. Kwak and Kim (2020) suggest that the operating cycle reduces operating expenses, which decrease with the number of supply chain partners.

Similarly, a higher inventory turnover ratio is usually related to better returns because firms can sell their inventory quickly. While a high inventory turnover ratio can indicate efficiency, relying solely on this metric may indicate ineffective inventory management, potentially leading to stockouts or shortages (Wan *et al.*, 2020). Further, Irvine *et al.* (2016) argue that concentrated supply chain relations reduce benefits by shifting demand shocks, delaying payment or delivery and switching to different trading partners who could offer more favourable contracts. Based on these arguments, we assume that the operating cycle weakens the cost function in the SCC–sustainability performance U-shaped relationship. We also assume that the inventory turnover ratio has a moderating effect on the relationship that we propose by decreasing the benefit function. Therefore, we extend H1 and hypothesise the following, as shown in Figure 1(b)–(e):

> ***H2a:*** *The quick ratio moderates the U-shaped relationship between SCC and sustainability performance by flattening the curve.*
>
> ***H2b:*** *The receivable turnover ratio moderates the U-shaped relationship between SCC and sustainability performance by shifting the turning point to the left and steepening the curve.*

H2c: *The operating cycle moderates the U-shaped relationship between SCC and sustainability performance by turning the point right.*

H2d: *The inventory turnover ratio moderates the U-shaped relationship between SCC and sustainability performance by steepening the curve.*

2.4.3 Role of information transparency

Information transparency is regarded as a wide range of firm-specific accounting information provided by listed firms to outsiders in the economy (Zhu *et al.*, 2021). The transparency of accounting information is important because less transparent accounting information weakens the mapping between income and cash flow, thereby increasing information risk (Hendricks and Singhal, 2014). Setia *et al.* (2013) highlight four characteristics of information transparency: integrity, which means that all the information that employees have when performing tasks needs to be offered; accuracy, which refers to the correctness of information; format, which refers to the display of information; and currency, which represents the extent to which the information provided is up to date. Therefore, high-quality information about a company provides investors and other external stakeholders with a more thorough picture of the company (Zhu *et al.*, 2021). For example, if a supplier discloses more information, its main customer can make corresponding decisions based on the information and reduce the relying on the signaling function of sustainability performance.

When the transparency of a firm is low, the firm may strategically adopt sustainable practices to shift stakeholders' focus and mask financial losses (Martínez-Ferrero *et al.*, 2016). Huang *et al.* (2022) argue that a manufacturer's information disclosure strategy may be affected by customers' expectations of product or service quality, which conversely affects customers' purchasing decisions. In the supply chain context, organisational information transparency may affect a firm's profits and relational performance (Cho *et al.*, 2017; Huang *et al.*, 2022). Eloranta and Turunen (2016) contend that customer service managers can better identify customer complex behaviour by collecting, combining and analysing information. In the context of sustainability, information transparency is important because it helps stakeholders to assess the ESG performance associated with a firm's business activities, which can affect their perception of the firm's sustainability performance. When firms are transparent about their sustainability practices, they are more likely to communicate with suppliers and engage in collaborative efforts to improve sustainability performance. Therefore, we argue that there is a considerable increase in sustainability performance related to benefits, which promotes the positive function of the proposed U-shaped relationship. We summarise these arguments and propose the following hypothesis (shown in Figure 1(f)):

> ***H3:*** *Information transparency moderates the U-shaped relationship between SCC and sustainability performance by steepening the curve.*

Figure 1 shows the hypotheses involved in the research and the overall model.

[Insert Figure 1(a–f) here]

3. Methodology

3.1 Data collection

Our study explores the effect of manufacturing firms' SCC on sustainability performance and the moderating effects of market munificence and financial slack on the proposed relationship. In this context, we first construct samples including Chinese manufacturing firms listed on the A-share markets of the Shanghai and Shenzhen Stock Exchanges from 2006 to 2020 from the CSMAR database. Based on this, we collect secondary data to calculate the proposed variables, including SCC, operational slack, financial slack and other control variables from the CSMAR database. The data on firms' sustainability performance are captured from the CNRDS database. We scan the list of manufacturing firms and eliminate the following types of firms:

(i) firms that are not A-share listed on the Shanghai Stock Exchange and Shenzhen Stock Exchange; (ii) firms that do not disclose sufficient financial data; and (iii) firms undergoing ST and delisting during the sample period. As a result, the final sample included 3,581 observations, which is unbalanced data including 653 different A-listed firms.

3.2 Variable measurements

3.2.1 Dependent variable

Sustainability performance. We measure firm sustainability performance using ESG scores that reflect the extent of the firm's involvement in sustainable activities. This measure is constructed based on the Hexun database, which has been used extensively in the prior ESG literature (Ahmed and Shafiq, 2022). The ESG scores are collected from public information, including financial reports, corporate social responsibility reports and other disclosure documents, government agency files such as industry plans, certifications and penalties, media reports on news and event investigations as well as data on green revenue and implied default rates of listed firms.

The ESG scores cover the three environmental, social and governance pillars. The environmental scores include five items: carbon emissions; energy efficiency; waste management; water use; and environmental management and policy. The social scores include five items: employee relations and labour rights and interests; supply chain responsibility and social impact; community investment and support; product and service quality and safety; and human rights and diversity. The governance scores include five items: board structure and independence; transparency and rationality of executive compensation; protection of shareholders' rights and interests; internal control and risk management; and anti-corruption policy and practice.

According to the *Industrial Classification for National Economic Activities* published by the National Bureau of Statistics of China, manufacturing can be divided into 21 sectors, such as the agricultural and sideline food processing industry, the tobacco products industry or the textile industry. Key ESG indicators for different sectors in the manufacturing industry are identified. Corresponding weights are assigned to each indicator based on its importance and the characteristics of different sectors. These weights are usually determined by professional research institutions and industry experts based on research and experience. This guarantees the accuracy and consistency of the scores when assessing various companies, and research has established that these ratings possess satisfactory measurement characteristics.

3.2.2 Independent variable

Supply chain concentration. The continuous connections and synergistic functions linking a firm's suppliers, customers, and the firm itself are recognized as the core of SCC (Flynn *et al.*, 2010). Previous research has depicted the upstream and downstream of the supply chain using the concepts of supplier and customer density (Xu *et al.*, 2023; Casalin *et al.*, 2017), which has been quantitatively labeled as ‘concentration’. Thus, we adopt the most prevalent concentration measure from past studies. Precisely, we formulate the aggregate of the percentage of sales to the top five customers as the gauge for customer concentration, and the aggregate of the percentage of purchases from the top five suppliers as the gauge for supplier concentration (Casalin *et al.*, 2017). Subsequently, we compute the average of customer concentration and supplier concentration to serve as the SCC measure. The specific formula is as follows:

$$SCC = \frac{1}{2}\left(\sum_{i=1}^{5}\frac{Purchasing_i}{Total\ Purchasing} + \sum_{i=1}^{5}\frac{Sales_i}{Total\ Sales}\right) \quad (2)$$

where *Total Purchasing* represents total firm buying from all its suppliers; $Purchasing_i$ denotes the firm’s purchasing quantity from major suppliers i ; $Total\ Sales$ represents the firm’s total sales; and $Sales_j$ represents the firm’s sales to major customer j .

3.2.3 Moderating variables

Operational slack. Referring to L. Chen *et al.* (2022), we consider four measurements to capture operational slack: quick ratio, receivable turnover ratio, operating cycle and inventory turnover ratio. The quick ratio (QR) is calculated as quick assets divided by current liabilities, where quick assets is measured by current assets minus net inventory balance (Bortolotti *et al.*, 2015; Campbell *et al.*, 2008; L. Chen *et al.*, 2022). The receivables turnover ratio (RTR), which is the net sales divided by the average accounts receivable, measures the firm’s efficiency in using its current assets and receiving its accounts receivable (L. Chen *et al.*, 2022; Wood *et al.*, 2017). The operating cycle (OC) refers to the average length of time from obtaining inventory to receiving accounts receivable (L. Chen *et al.*, 2022; Wood *et al.*, 2017). The inventory turnover ratio (ITR) is calculated as sales divided by average inventory (Azadegan *et al.*, 2013; L. Chen *et al.*, 2022). The specific measures are as follows:

$$QR \quad \frac{Quick\ Assets}{Current\ Liabilities} \quad (3)$$

$$RTR \quad \frac{Net\ Sales}{Average\ Accounts\ \mathrm{Re}\,ceivable} \quad (4)$$

$$ITR \quad \frac{Sales}{Average\ Inventory} \quad (5)$$

Information transparency. According to Hendricks and Singhal (2014), investors are concerned about the uncertainty of a firm's cash flow parameters, hence accruals quality is frequently used as a gauge of information quality. Accounting information quality maps between earnings and cash flows. (Dechow *et al.*, 1995). We apply the modified Jones model to calculate information quality because this can counteract the presumed inclination of the Jones model to miscalculate discretionary accruals when discretion is employed in relation to revenues (Dechow *et al.*, 1995). The measurement procedure is outlined as follows:

$$TA_{i,t} / A_{i,t\ 1} \quad {}_{i,1}\,(1 / A_{i,t\ 1}) \quad {}_{i,2}\,(REV_{i,t} / A_{i,t\ 1}) \quad {}_{i,3}\,(PPE_{i,t} / A_{i,t\ 1}) \quad {}_{i,t} \qquad (6)$$

$$NDA_{i,t} \quad {}_{i,1}\,(1 / A_{i,t\ 1}) \quad {}_{i,2}\,(REV_{i,t} \quad REC_{i,t} / A_{i,t\ 1}) \quad {}_{i,3}\,(PPE_{i,t} / A_{i,t\ 1}) \qquad (7)$$

$$DA_{i,t} \quad TA_{i,t} / A_{i,t\ 1} \quad NDA_{i,t} \qquad (8)$$

where $DA_{i,t}$ is the discretionary accruals of firm i at given year t, $TA_{i,t}$ is the total accruals of firm i at given year t, $NDA_{i,t}$ is the nondiscretionary accruals of firm i at given year t, $REV_{i,t}$ is the increment of the operating revenue of firm i in year t, $PPE_{i,t}$ is the fixed assets of firm i in year t, which is normalised by total assets at year $t\ 1$, $A_{i,t\ 1}$ is the total assets of firm i in year $t\ 1$, while $_{i,1}$, $_{i,2}$ and $_{i,3}$ are estimation of parameters.

Our study takes $|DA_{i,t}|$ as the index of firm information transparency. The smaller the value of $DA_{i,t}$, the more transparent the information.

3.2.4 Control variables

We incorporate four variables to account for additional factors that might impact the correlation between SCC and sustainability performance of manufacturing firms. These include one market-level factor and three company-level factors, as discussed below.

Market dynamism. Our study controls for this factor because a dynamic market measured by operating performance can be affected by sustainability practices and consumer demand for sustainable products and services (Keats and Hitt, 1988). Referring to Boyd (1995), market dynamism is measured with the standard error derived from the regression of the industry's annual sales over a 5-year period, which has been mentioned in the measure of munificence above.

Firm size. We use the natural logarithm of the firm's total assets as a measure to control the effect of its size. This is because firm size has been proven to affect a firm's sustainable or green strategies (Liu *et al.*, 2017).

Cash constraints. This factor is calculated by the ratio of cash balances over assets. We choose it because cash constraint can limit a company's performance (Balasubramanian *et al.*, 2021).

Book to market value. We control for book to market value by using the ratio of the book value and the market value of its equity because of the impact of the firm's growth prospects on its relevant performance (Derchi *et al.*, 2021). The concluded definitions of each variable are shown in Table Ⅰ.

[Insert Table Ⅰ here]

3.3 Models

We conduct the following panel data regression models to test our hypotheses. Model 1 is designed to test H1, which states that a firm's SCC affects its sustainability performance through a U-shaped curve (Equation (9)). Further, the moderating effects of operational slack and information transparency are expected to be included. We add the cross-terms of the independent and moderating variables to Model 2 and Model 3 (Equation (10)) to test H2 and H3, respectively. In addition, our study controlled for the fixed effects of *Firm* and *Year* to eliminate any heterogeneity from these factors. The specific models are shown below.

$$SUST_{i,t} \quad {}_{0}\,{}_{1}SCC_{i,t} \quad {}_{2}SCC_{i,t}^{2} \quad \overset{4}{\underset{k\,1}{}}{}_{k}Controls_{i,t} \quad Firm_{i,t} \quad Year_{i,t} \tag{9}$$

$$SUST_{i,t} \quad {}_{0} \quad {}_{1}SCC_{i,t} \quad {}_{2}SCC_{i,t}^{2} \quad {}_{3}M_{i,t} \quad {}_{4}SCC_{i,t}\,M_{i,t} \quad {}_{5}SCC_{i,t}^{2}\,M_{i,t} \quad \overset{4}{\underset{k\,1}{}}{}_{k}Controls_{i,t} \quad Firm_{i,t} \quad Year_{i,t} \tag{10}$$

where i and t denote the firm and year, respectively; M denotes the moderating variable, including operational slack and information transparency, respectively; $Controls_{i,t}$ represents all control variables, including MD, SIZE, CASH and BTM; and $Firm_{i,t}$ and $Year_{i,t}$ are dummy variables, which are included to explain time-invariant firm heterogeneity and time trends. To mitigate potential heteroscedasticity concerns, we employ robust standard errors clustered at the firm level within the regression model, where signifies stochastic residuals

4. Results

4.1 Descriptive statistics

Prior to regression analysis, our data are processed as follows: first, the 99% winsorisation is implemented to diminish the impact of potential erroneous outliers arising from extreme values present in the statistical dataset; second, to eliminate the potential influence of multicollinearity, we performed variance inflation factor tests on the variables (Weisberg, 2005). The results showed that the values for all predictors were < 5, which meant that multicollinearity was not a significant issue.

Table Ⅱ reports the means of the variables: SUST (0.306), SCC (0.306), QR (1.039), RTR (79.820), OC (72.004), ITR (5.307), IT (0.065), MD (1.027), SIZE (22.890), CASH (0.149) and BTM (0.633) and the standard deviation (SD) of variables: SUST (0.214), SCC (0.148), QR (0.650), RTR (673.134), OC (69.212), ITR (7.633), IT (0.132), MD (0.019), SIZE (1.349), CASH (0.110) and BTM (0.267). These results indicate that the variables of the sample firms are not very high and relatively stable.

Table Ⅲ presents the correlation matrix of the variables used in this study. Supply chain concentration is significantly and negatively related to sustainability performance, indicating that firms undertaking much SCC may weaken their sustainability performance. Other variables are generally significantly related to sustainability performance.

[Insert Table Ⅱ here]

[Insert Table Ⅲ here]

4.2 Regression results

Table Ⅳ summarises the regression results of SCC impact on sustainability performance and the moderating roles of operational slack and information transparency. The second column of Table Ⅳ shows the results of Model 1, testing the effects proposed in H1. Following Haans *et al.* (2016), we took three steps to test the regression result. First, the coefficient of SCC^2 is positive and significant ($_{SCC2}$ 0.435 , p 0.01). Second, the slope at the minimum SCC, which is $_{SCC}$ 2 $_{SCC2}$ $SCC_{\min}$ 0 , is negative and significant, while the slope at the maximum SCC, which is $_{SCC}$ 2 $_{SCC2}$ $SCC_{\max}$ 0 , is positive and significant. Third, the turning point, which is $_{SCC}$ / 2 $_{SCC2}$ 0.505 , is within the data range. These conclusions signify that when SCC is at a certain range, it undermines a firm's sustainability performance, while SCC beyond the critical boundary improves sustainability performance. Therefore, the relationship between SCC and sustainability performance shows a U-shaped curve, verifying H1.

The third column of Table Ⅳ corresponds to the results of testing the moderating role of QR. The coefficient of SCC is negative and significant ($_{SCC}$ 0.704 , p 0.001); the coefficient of SCC^2 is positive and significant ($_{SCC^2}0.853$, p 0.01), which verifies the presence of the original U-shaped curve. The coefficient of the SCC*QR interaction is positive but insignificant ($_{SCC\ QR}$ 0.264 , p 0.1), while the coefficient of SCC^2*QR is negative and statistically significant ($_{SCC_2\ QR}$ 0.394 , p 0.1). Referring to Haans *et al.* (2016), since $_{SCC}$ $_{SCC_2\ QR}$ $_{SCC_2}$ $_{SCC\ QR}$ 0 , the turning point of this curve moves to the right as QR increases and $_{SCC_2\ QR}$ 0 signifies that a flattening occurs for our U-shaped relationship.

Additionally, the precise value of QR at which the shape flip occurs is QR $_{SCC^2}$/ $_{SCC^2 QR}$ 2.165 . At this value, the SCC–sustainability performance relationship is linear and no turning point exists. Above the QR*-value, the curve takes an inverted U-shape; below the QR*-value, the curve takes on a U-shape. As such, the coefficient of SCC^2 is negative, but the turning point is beyond our data range. The moderating role of QR only flattens, not flips, the U-shaped relationship between SCC and sustainability performance. These findings verify H2a.

The fourth column of Table Ⅳ corresponds to the results of testing the moderating role of RTR. The coefficient of SCC is negative and significant ($_{SCC}$ 0.222 , p 0.1); the coefficient of

SCC^2 is positive and significant ($_{SCC^2}$ 0.094 , p 0.1), which verifies the presence of the original U-shaped curve. The coefficient of the SCC*RTR interaction is negative and significant ($_{SCC\ RTR}$ $1.358e$ ^{4} , p 0.1), while the coefficient of SCC^2*QR is positive and statistically significant ($_{SCC^2\ RTR}$ $2.618e$ ^{4} , p 0.1). Referring to Haans *et al.* (2016), since $_{SCC}$ $_{SCC^2\ RTR}$ $_{SCC^2}$ $_{SCC\ RTR}$ 0 , the turning point of this curve moves to the left as QR increases and $_{SCC^2\ RTR}$ 0 signifies that a steepening occurs for our U-shaped relationship. These findings verify H2b.

The fifth column of Table Ⅳ corresponds to the results of testing the moderating role of OC. The coefficient of SCC is negative and significant ($_{SCC}$ 0.444 , p 0.1); the coefficient of SCC^2 is positive and significant ($_{SCC^2}$ 0.450 , p 0.1), which verifies the presence of the original inverted U-shaped curve. However, the coefficient of OC*SCC and the coefficient of OC*SCC^2 are both insignificant. Therefore, OC does not play a moderating role in the U-shaped relationship between SCC and sustainability performance, which refutes H2c.

The second to last column of Table Ⅳ presents the results of testing the moderating role of ITR, which shows that the coefficient of SCC and the coefficient of SCC^2 are both insignificant. Therefore, there is not enough evidence to show that ITR plays a moderating role in the U-shaped relationship between SCC and sustainability performance, contradicting H2d.

The last column of Table Ⅳ presents the testing results of Model 3. The coefficient of SCC is negative and insignificant ($_{SCC}$ 0.127 , p 0.1); the coefficient of SCC^2 is negative and insignificant ($_{SCC^2}$ 0.040 , p 0.1). The coefficient of the SCC*IT interaction is negative and statistically significant ($_{SCC\ IT}$ 1.694 , p 0.1), while the coefficient of SCC^2*IT is positive and statistically significant ($_{SCC^2\ IT}$ 2.435 , p 0.1). Referring to Haans *et al.* (2016), since $_{SCC}$ $_{SCC^2\ IT}$ $_{SCC^2}$ $_{SCC\ IT}$ 0 but the coefficient of SCC is insignificant, there is not enough evidence to verify the turning point of this curve moving to the left as IT increases. $SCC2\ IT$ 0 signifies that a steepening occurs for our U-shaped relationship. Therefore, the moderating role of IT only steepens the U-shaped relationship between SCC and sustainability performance. These findings partly verify H3.

The control variables are not all statistically significant across our models. There is not enough evidence to link them to sustainability performance.

[Insert Table Ⅳ here]

4.3 Robustness test

To strengthen the empirical robustness results, we use another two measurements to calculate SCC. Following Ak and Patatoukas (2016), we use the Herfindahl–Hirschman Index (SCC–HHI) to calculate SCC. The specific measurement is shown in Equation (11). Table Ⅵ reports the results. We also use the average sum of the percentage of sale to the top customer and the percentage of purchasing from the top supplier (SCC–TOP) as the measurement instead (Zhu *et al.*, 2021). Equation (12) describes the measurement and the robustness results are shown in Table Ⅶ. The results in Table Ⅵ and Table Ⅶ show that the coefficients of the core explanatory variables and interaction terms are all significant and that the effects are consistent with all expectations. Given the conclusion in Table Ⅴ, it can be assumed that our findings are robust.

$$SCI\ HHI = \frac{1}{2}\left(\sum_{i\,1}^{5} \frac{Purchasing_i}{Total\ Purchasing}\right)^2 \left(\sum_{i\,1}^{5} \frac{Sales_i}{Total\ Sales}\right)^2 \quad (11)$$

$$SCI\ TOP = \frac{1}{2} \frac{Top\ Supplier}{Total\ Purchasing} \quad \frac{Top\ Customer}{Total\ Sales} \quad (12)$$

[Insert Table Ⅴ here]

[Insert Table Ⅵ here]

4.4 Endogeneity

To avoid potential endogeneity problems that may exist between SCC and sustainability performance, two-stage least squares (2SLS) is conducted. We adopt the logarithm of absolute inventory (INV) as an instrumental variable (Casalin *et al.*, 2017). During the first phase, we compute SCC by incorporating control variables and constants for firm-specific and yearly effects. Subsequently, in the second phase, we elucidate sustainability performance using the estimated SCC values. The outcomes presented in the initial column of Table VII illustrate a notable positive correlation between the instrumental variable and SCC. The outcomes of our investigation remain consistent, as demonstrated by the two-stage least regression results documented in Table VII.

[Insert Table VII here]

4.5 Post hoc analyses

According to Lanier *et al.*, (2010), it is possible that downstream customers and upstream suppliers have differing degrees of dependence or power over focal firms. Therefore, we test the respective effects of supplier concentration and customer concentration on sustainability performance. We find that the relationship between supplier concentration and sustainability performance shows a U-shaped curve, while the relationship between customer concentration and sustainability performance also shows a U-shaped curve. However, because of the limitations in separate testing, it is not possible to statistically confirm that operational slack and information quality significantly moderate the relationship between SCC and sustainability performance. While our results shown in Table VIII and Table IX are not statistically significant, we recognise the need for cautious interpretation of these non-significant findings. These outcomes underscore the complexity of the interaction between SCC, operational slack, information quality and sustainability performance within the distinct supplier and customer groups. Further exploration is required to understand the potential influence of joint participation by suppliers and customers on enhancing sustainable performance.

[Insert Table VIII here]

[Insert Table IX here]

5. Discussion

5.1 Theoretical implications

Our study contributes to the existing SCC–sustainability performance literature by adopting the RDT as a theoretical lens to build our models and considering the mechanism that affects this relation (i.e. the moderating role of financial slack and information transparency). First, we elaborate that the relationship between SCC and sustainability is a U-shaped one. By conducting an empirical analysis, to our knowledge, our research may be the first to reconcile the related arguments in the existing research on the positive effects of SCC (Zhu *et al.*, 2021) and the negative effects of SCC (Zhou *et al.*, 2019) on firm sustainability performance. Our study is also the first to propose a U-shaped relationship between SCC and sustainability performance. However, most studies on sustainability performance concentrate on the linear relations between its drivers, for example, a firm's digital transformation (Ahmed and Shafiq, 2022), which does not fully account for a firm's sustainable behaviour along the supply chain and sustainability performance. Our study extends this line of inquiry by offering empirical evidence that manufacturing firms' SCC is initially negatively related to sustainability performance, while beyond a certain level, SCC positively affects sustainability performance, presenting a generally U-shaped relationship.

Additionally, the relationship between supplier/customer concentration and sustainability performance is U-shaped. Suppliers/customers may have enough incentive or resources to invest in sustainability practices when concentration is low; however, when concentration is high, there may be reduced competition and less pressure to improve sustainability performance. This novel finding goes one step further than previous arguments, in which concentration plays a positive role in firm sustainability performance (Bressanelli *et al.*, 2019; Donkor *et al.*, 2021). In this way, it improves the theoretical understanding, that firms may need to carefully balance the benefits of concentration (e.g. reduced transaction costs) with the need for competition among suppliers/customers and incentives to invest in sustainability (Blome *et al.*, 2023).

Second, the study reveals the moderating effect of operational slack on the U-shaped relationship between SCC and sustainability performance. Our empirical evidence shows that operational slack represented by a quick ratio and receivable turnover ratio are significant to the SCC–sustainability performance relationship. Specifically, the quick ratio weakens the benefit function on the U-shaped curve of SCC–sustainability performance. This novel finding extends the literature on the role of financial slack on social responsibility (Lin *et al.*, 2019) and verifies the two-sided effect on firm performance. This is similar to the view of Paeleman and Vanacker (2015), according to which having too much financial slack leads to inefficient behaviour whereas having too little financial slack restricts decision-making.

The receivable turnover ratio, on the one hand, weakens the cost function and, on the other hand, strengthens the benefit function for the original U-shaped curve. This echoes the argument that the receivable turnover ratio decreases the operating cost with a reduction in the number of supply chain partners (Kwak and Kim, 2020). However, in our post hoc analysis, we find that the quick ratio and receivable turnover ratio both play a weak moderating role in the relationship between supplier/customer concentration and sustainability performance. This suggests that it is meaningful to consider the effects of SCC as a whole on sustainable performance.

Third, we test the moderating role of information transparency on the U-shaped relationship between SCC and sustainability performance. The finding shows that information transparency steepens the U-shaped curve; that is, information transparency enhances the positive function of the SCC–sustainability performance relationship, in line with previous studies that confirm the role of information transparency in improving relationship quality (Cho *et al.*, 2017). We posit that enhancing information transparency can benefit firms by providing more resources for sustainable activities. Our novel finding constructs a theoretical foundation of information transparency for sustainability performance, which contributes to subsequent research.

5.2 Practical implications

First, our study has direct implications for supply chain managers to participate in sustainable activities. Our findings show that the relationship between manufacturing SCC and sustainability performance displays a U-shaped curve. This suggests that SCC can be a potential means of increasing/decreasing sustainability performance. That is, SCC can serve as a differentiation strategy and enhance the acceptance of stakeholders. In addition, it furnishes a business rationale for constraining investments through the amalgamation of suppliers and customers. This study supplies strategic reasoning for the shift towards a more sustainable approach to business operations. This insight can prove particularly valuable to proactive managers and early adopters of sustainability performance who lack substantiated arguments or evidence to underpin a company's strategic shift.

Second, managers adopting an SCC strategy to improve performance should consider the possible effects of their other differentiation strategies. The moderating role of operational slack shows that the benefit and cost of SCC may be mitigated by other differentiation strategies. Companies need focus on the effect of financial slack on SCC and need to concentrate on either financial slack or SCC strategy. Further, managers should take the cost of SCC into account because it is another important mechanism of the U-shape.

Third, the moderating role of information transparency reveals that firms can improve the positive impact on sustainability performance by improving their capability to rationally use resources. The practical implication is that when there is greater transparency in the flow of information within the supply chain, it leads to better sustainability performance, especially in situations where the supply chain is highly concentrated. This suggests that businesses and policymakers should work towards enhancing transparency in the supply chain to improve sustainability performance, especially in industries where concentration is high. It also highlights the importance of collaboration and communication within the supply chain to ensure sustainability goals are met.

6. Conclusion

To solve the conundrum of the relationship between SCC and sustainability performance, we offer the moderating roles of operational slack and information transparency to illustrate the underlying mechanism based on Chinese listed manufacturing firms. Our empirical results show that the relationship between SCC and sustainability performance presents a U-shaped relationship. Moreover, operational slack represented by a quick ratio moderates the SCC–sustainability performance relationship by weakening the benefit function. Further, operational slack represented by a receivable turnover ratio moderates the U-shaped relationship between SCC and sustainability performance by steepening the curve and shifting the turning point left. Information transparency moderates the relationship by strengthening the benefit function.

This study has several limitations that suggest directions for further research. First, the RDT provides a possible explanation for the complicated relationship between SCC and sustainability performance. For future research, we recommend integrating the RDT with other theoretical perspectives, such as transaction cost theory. This would enable a more in-depth exploration of the underlying mechanisms of SCC. Second, this study's reliance on samples from Chinese publicly listed firms may restrict the broader applicability of the findings. It would be intriguing for future investigations to replicate this research in diverse international contexts. Third, this paper centers on operational slack and information transparency as mediators, and their partial mediation of the impact of SCC on sustainability performance is established. Other variables could potentially serve as mediators in the connection between SCC and sustainability performance. For forthcoming research, the acquisition of more detailed data and the exploration of alternative factors mediating the SCC-sustainability performance link could yield valuable insights.

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Table Ⅰ Variable definition

Variable	Measurements	Reference
Dependent Variable		
Sustainability performance (SUST)	Firm performance in terms of environment, society and governance from Hexun database	Ahmed and Shafiq (2022)
Independent variable		
Supply chain concentration (SCC)	The average of customer concentration and supplier concentration, whose data are from CSMAR database	Casalin et al. (2017)
Moderating variable		
Quick ratio (QR)	Quick assets divided by current liabilities, whose data are from CSMAR database	Chen et al. (2022)
Receivables turnover ratio (RTR)	Net sales divided by the average accounts receivable, whose data are from CSMAR database	Chen et al. (2022)
Operating cycle (OC)	The average length of time from obtaining inventory to receiving accounts receivable, whose data are from CSMAR database	Chen et al. (2022)
Inventory turnover ratio (ITR)	Sales divided by average inventory, whose data are from CSMAR database	Chen et al. (2022)
Information transparency (IT)	Jones model, whose data are from CSMAR database	Hendricks and Singhal (2014)
Control variable		
Market dynamism (MD)	The stand error derived from the regression of the industry's annual sales over a 5-year period, whose data are from CSMAR database	Boyd (1995)
Firm Size (SIZE)	The natural logarithm of the firm's total assets, whose data are from CSMAR database	Liu et al. (2017)
Cash Constrains (CASH)	The ratio of cash balances over assets, whose data are from CSMAR database	Balasubramanian et al. (2021)
Firm growth prospects (BTM)	The ratio of book value and market value of its equity from CSMAR database	Derchi et al. (2021)

Table Ⅱ Descriptive statistics

	Mean	S.D.	Max	Min
SUST	0.306	0.214	0.906	-0.081
SCC	0.284	0.148	0.935	0.032
QR	1.039	0.650	5.932	0.087
RTR	79.820	673.134	24920.160	0.660
OC	72.004	69.212	552.235	0.009
ITR	5.307	7.633	225.075	0.185
IT	0.062	0.128	2.299	-0.041
MD	1.027	0.019	1.160	1.013
SIZE	22.890	1.349	27.530	19.200
CASH	0.149	0.110	0.823	0.012
BTM	0.633	0.267	1.422	0.002

Table Ⅲ Correlation matrix statistics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
SUST	1.000										
SCC	-0.039^{b}	1.000									
QR	-0.072^{c}	0.172^{a}	1.000								
RTR	0.030^{c}	-0.002	-0.44	1.000							
OC	-0.115	0.063	0.608	-0.041	1.000						
ITR	0.048	0.184	-0.428	0.033	-0.295^{b}	1.000					

IT	0.069	-0.019	0.040^{b}	-0.009	0.089	-0.035^{c}	1.000				
MD	0.201^{a}	-0.009	0.029^{c}	0.028^{c}	-0.088	0.041	0.207^{a}	1.000			
SIZE	-0.036	-0.236^{a}	-0.256^{a}	0.004	-0.168	0.080	-0.110^{a}	-0.086^{a}	1.000		
CASH	0.118^{a}	0.138^{a}	0.277^{a}	-0.016^{b}	-0.027^{a}	-0.059^{a}	0.080	-0.047^{a}	-0.133^{a}	1.000	
BTM	-0.085^{a}	-0.142^{a}	-0.214^{a}	0.047^{b}	-0.085^{a}	0.131^{a}	0.021	0.070^{a}	0.437^{a}	-0.212^{a}	1.000

Notes: a, b, and c stand for significant at the level of 0.1%, 1%, and 10% respectively.

Table Ⅳ Regression results

	Model 1	Model 2				Model 3
SCC	-0.439***	-0.704**	-0.222**	-0.444*	-0.191	-0.127
	(0.125)	(0.222)	(0.081)	(0.175)	(0.147)	(0.094)
SCC^{2}	0.435**	0.853**	0.094*	0.450*	0.021	-0.040
	(0.162)	(0.293)	(0.018)	(0.235)	(0.198)	(0.125)
QR		-0.060*				
		(0.032)				
QR*SCC		0.264				
		(0.185)				
QR*SCC^{2}		-0.394*				
		(0.231)				
RTR			$1.805e^{-5}$			
			($1.141e^{-5}$)			
RTR*SCC			$-1.358e^{-4}$*			
			($7.994e^{-5}$)			
RTR*SCC^{2}			$2.618e^{-4}$*			
			($1.398e^{-4}$)			
OC				$-9.294e^{-5}$		
				($2.644e^{-4}$)		
OC*SCC				$3.964e^{-5}$		
				($1.609e^{-3}$)		
OC*SCC^{2}				$-1.200e^{-4}$		
				($2.052e^{-3}$)		
ITR					0.002	
					(0.002)	
ITR*SCC					-0.029**	
					(0.011)	
ITR*SCC^{2}					0.047***	
					(0.014)	
IT						0.374**
						(0.128)
IT*SCC						-1.694*
						(0.797)
IT* SCC^{2}						2.435*
						(1.164)
MD	2.568***	2.536***	2.110***	2.539***	2.564***	2.208***
	(0.276)	(0.275)	(0.185)	(0.278)	(0.274)	(0.185)
SIZE	0.013**	0.012**	0.013***	0.012**	0.012**	0.012***
	(0.004)	(0.004)	(0.003)	(0.005)	(0.004)	(0.003)
CASH	0.257***	0.308***	0.226***	0.256***	0.264***	0.225***
	(0.049)	(0.051)	(0.032)	(0.050)	(0.049)	(0.032)
BTM	-0.134***	-0.135***	-0.137***	-0.135***	-0.133***	-0.134***
	(0.022)	(0.022)	(0.015)	(0.022)	(0.022)	(0.015)
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.084	0.088	0.076	0.083	0.102	0.082
Observations	3581	3581	3581	3581	3581	3581

Note: *, **, and *** stand for significant at the level of 10%, 1%, and 0.1%, respectively.

Table V Robustness (a)

	Model 1	Model 2				Model 3
SCC	-0.443**	-0.709*	-0.458**	-0.639*	-0.387*	-0.439*
	(0.171)	(0.350)	(0.171)	(0.262)	(0.239)	(0.195)
SCC^2	0.745*	1.516*	0.627*	1.279*	0.366	0.589
	(0.447)	(1.030)	(0.449)	(0.752)	(0.579)	(0.507)
QR		-0.047***				
		(0.011)				
QR*SCC		0.245				
		(0.296)				
$QR*SCC^2$		-0.714*				
		(0.295)				
RTR			$2.024e^{-6}$			
			$(2.510e^{-6})$			
RTR*SCC			$-8.577e^{-5}$			
			$(8.446e^{-5})$			
$RTR*SCC^2$			$1.397e^{-3}$*			
			$(5.896e^{-4})$			
OC				$-3.697e^{-4}$***		
				$(9.387e^{-5})$		
OC*SCC				$2.662e^{-3}$		
				$(2.543e^{-3})$		
$OC*SCC^2$				$-6.614e^{-3}$		
				$(7.459e^{-3})$		
ITR					0.003*	
					(0.001)	
ITR*SCC					-0.020	
					(0.030)	
$ITR*SCC^2$					0.065	
					(0.072)	
IT						0.147**
						(0.052)
IT*SCC						-0.437
						(1.691)
$IT* SCC^2$						4.850*
						(2.905)
MD	2.440***	2.374***	2.386***	2.337***	2.388***	2.502***
	(0.247)	(0.246)	(0.247)	(0.248)	(0.247)	(0.247)
SIZE	0.006	0.004	6.124e-3	$2.659e^{-3}$	0.006	0.058
	(0.004)	(0.004)	(4.030e-3)	$(4.074e^{-3})$	(0.004)	(0.004)
CASH	0.210***	0.276***	0.217***	0.200***	0.220***	0.220***
	(0.043)	(0.045)	(0.043)	(0.043)	(0.043)	(0.043)
BTM	-0.085***	-0.090***	-0.085***	-0.086***	-0.090***	-0.082***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.064	0.076	0.067	0.073	0.069	0.070

Note: *, **, and *** stand for significant at the level of 10%, 1%, and 0.1%, respectively. The table shows the result, whose SCC measurement is replaced with SCC-HHI.

Table VI Robustness (b)

	Model 1	Model 2				Model 3
SCC	-0.335**	-0.624*	-0.328**	-0.435*	-0.085	-0.284*
	(0.126)	(0.244)	(0.126)	(0.187)	(0.184)	(0146)
SCC^2	0.380*	0.887*	0.318*	0.519*	-0.120	0.199*
	(0.235)	(0.482)	(0.242)	(0.376)	(0.325)	(0.217)
QR		-0.063***				

		(0.018)				
QR*SCC		0.279*				
		(0.204)				
QR*SCC^2		-0.476				
		(0.388)				
RTR			$1.494e^{-5}$*			
			($8.198e^{-6}$)			
RTR*SCC			$-2.157e^{-4}$*			
			($1.117e^{-4}$)			
RTR*SCC^2			$7.993e^{-4}$*			
			($3.841e^{-4}$)			
OC				-0.001**		
				(0.000)		
OC*SCC				0.002		
				(0.002)		
OC*SCC^2				-0.002		
				(0.004)		
ITR					0.006**	
					(0.002)	
ITR*SCC					-0.046*	
					(0.026)	
ITR*SCC^2					0.083*	
					(0.043)	
IT						0.190*
						(0.097)
IT*SCC						-1.044
						(1.345)
IT* SCC^2						3.928*
						(3.517)
MD	2.418***	2.357***	2.375***	2.316***	2.377***	2.479***
	(0.246)	(0.246)	(0.247)	(0.247)	(0.247)	(0.246)
SIZE	0.005	0.003	0.005	0.002	0.005	0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
CASH	0.211***	0.276***	0.215***	0.198***	0.219***	0.219***
	(0.324)	(0.044)	(0.043)	(0.043)	(0.043)	(0.043)
BTM	-0.086***	-0.090***	-0.085***	-0.086***	-0.089***	-0.082***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.066	0.078	0.068	0.074	0.071	0.072

Note: *, **, and *** stand for significant at the level of 10%, 1%, and 0.1%, respectively. The table shows the result, whose SCC measurement is replaced with SCC-TOP.

Table VII Endogeneity test

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Stage 1	Stage 2					
INV	0.014**						
	(0.005)						
SCC		-0.221**	-0.241*	-0.231**	-0.129*	-0.057	-0.111*
		(0.083)	(0.145)	(0.084)	(0.094)	(0.103)	(0.096)
SCC^2		0.092*	0.066	0.092*	0.075	0.114*	0.059
		(0.062)	(0.189)	(0.109)	(0.151)	(0.101)	(0.127)
QR			-0.043*				
			(0.021)				
QR*SCC			0.043				

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			(0.120)				
QR*SCC^2			-0.003				
			(0.154)				
RTR				$-4.100e^{-5}$*			
				($2.398e^{-5}$)			
RTR*SCC				$1.663e^{-4}$*			
				($1.460e^{-4}$)			
RTR*SCC^2				$-3.147e^{-5}$			
				($2.888e^{-4}$)			
OC					$-1.275e^{-4}$		
					($1.956e^{-4}$)		
OC*SCC					$-1.286e^{-3}$*		
					($1.016e^{-3}$)		
OC*SCC^2					0.002*		
					(0.001)		
ITR						0.004*	
						(0.002)	
ITR*SCC						-0.025**	
						(0.009)	
ITR*SCC^2						0.029**	
						(0.010)	
IT							0.394**
							(0.133)
IT*SCC							-1.785*
							(0.816)
IT* SCC^2							2.528*
							(1.174)
MD	0.017	2.153***	2.122***	2.150***	2.098***	2.151***	2.215***
	(0.029)	(0.185)	(0.185)	(0.185)	(0.186)	(0.186)	(0.185)
SIZE	$-4.835e^{-4}$*	0.012***	0.012***	0.012***	0.010**	0.012***	0.012***
	($2.696e^{-4}$)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
CASH	0.017**	0.218***	0.257***	0.221***	0.204***	0.225***	0.226***
	(0.005)	(0.032)	(0.033)	(0.032)	(0.032)	(0.032)	(0.032)
BTM	$-9.447e^{-4}$	-0.136***	-0.140***	-0.140***	-0.138***	-0.135***	-0.133***
	(0.002)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.090	0.075	0.083	0.077	0.082	0.077	0.82

Note: *, **, and *** stand for significant at the level of 10%, 1%, and 0.1%, respectively.

Table VIII A post-hoc of supplier concentration

	(1)	(2)	(3)	(4)	(5)	(6)
SC	-0.116*	-0.109*	-0.097*	-0.186*	-0.074	-0.049
	(0.071)	(0.023)	(0.018)	(0.097)	(0.089)	(0.084)
SC^2	0.034*	-0.020	0.003	0.087*	0.166*	-0.038
	(0.014)	(0.141)	(0.008)	(0.025)	(0.101)	(0.104)
QR		-0.036*				
		(0.018)				
QR*SC		-0.012				
		(0.100)				
QR*SC^2		0.051				
		(0.116)				
RTR			$-1.395e^{-5}$			
			($2.797e^{-5}$)			
RTR*SC			$3.604e^{-6}$			
			($1.341e^{-4}$)			

RTR*SC^2			$9.009e^{-5}$*			
			($1.260e^{-5}$)			
OC				$-4.000e^{-4}$*		
				($1.000e^{-4}$)		
OC*SC				0.001		
				(0.001)		
OC*SC^2				$-5.000e^{-4}$		
				(0.001)		
ITR					0.006**	
					(0.002)	
ITR*SC					-0.032***	
					(0.009)	
ITR*SC^2					0.032***	
					(0.009)	
IT						0.289*
						(0.119)
IT*SC						-1.021*
						(0.555)
IT* SC^2						1.175*
						(1.004)
MD	2.191***	2.153***	2.193***	2.107***	2.176***	2.255***
	(0.185)	(0.185)	(0.186)	(0.186)	(0.186)	(0.185)
SIZE	0.013***	0.011***	0.013***	0.010***	0.013***	0.014***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
CASH	0.204***	0.247***	0.206***	0.190***	0.211***	0.211***
	(0.032)	(0.033)	(0.032)	(0.031)	(0.032)	(0.032)
BTM	-0.135***	-0.139***	-0.135***	-0.136***	-0.134***	-0.132
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.070	0.073	0.071	0.075	0.073	0.075

Note: *, **, and *** stand for significant at the level of 10%, 1%, and 0.1%, respectively.

Table IX A post-hoc of customer concentration

	(1)	(2)	(3)	(4)	(5)	(6)
CC	-0.188**	-0.172*	-0.204***	-0.107*	-0.124*	-0.160*
	(0.061)	(0.013)	(0.062)	(0.045)	(0.074)	(0.072)
CC^2	0.100*	0.057	0.115*	-0.035	0.013	0.059
	(0.064)	(0.144)	(0.076)	(0.108)	(0.092)	(0.091)
QR		-0.034*				
		(0.015)				
QR*CC		0.019				
		(0.090)				
QR*CC^2		0.006				
		(0.109)				
RTR			$-7.568e^{-6}$			
			($2.167e^{-5}$)			
RTR*CC			$-2.316e^{-5}$			
			($1.999e^{-4}$)			
RTR*CC^2			$1.780e^{-4}$*			
			($2.961e^{-5}$)			
OC				$1.000e^{-4}$*		
				($3.470e^{-5}$)		
OC*CC				$-5.901e^{-4}$*		
				($3.867e^{-4}$)		

OC*CC^2				0.001*		
				(9.121e^{-4})		
ITR					0.001	
					(0.001)	
ITR*CC					-0.010*	
					(0.003)	
ITR*CC^2					0.013*	
					(0.007)	
IT						0.214*
						(0.107)
IT*CC						-0.626*
						(0.268)
IT* CC^2						0.888*
						(0.221)
MD	2.132***	2.105***	2.139***	2.088***	2.14***	2.194***
	(0.186)	(0.185)	(0.185)	(0.186)	(0.185)	(0.185)
SIZE	0.014***	0.012***	0.013***	0.012***	0.013***	0.014***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
CASH	0.220***	0.255***	0.219***	0.209***	0.223***	0.226***
	(0.032)	(0.033)	(0.032)	(0.032)	(0.032)	(0.032)
BTM	-0.137***	-0.141***	-0.136***	-0.139***	-0.136***	-0.133***
	(0.015)	(0.015)	(0.015)	(0.014)	(0.015)	(0.015)
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.075	0.079	0.074	0.079	0.075	0.077

Note: *, **, and *** stand for significant at the level of 10%, 1%, and 0.1%, respectively.

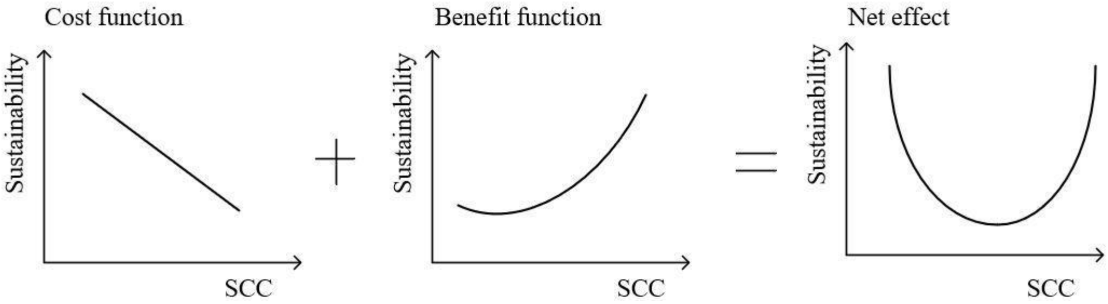

Figure 1(a). Latent mechanism of U-shaped relationship

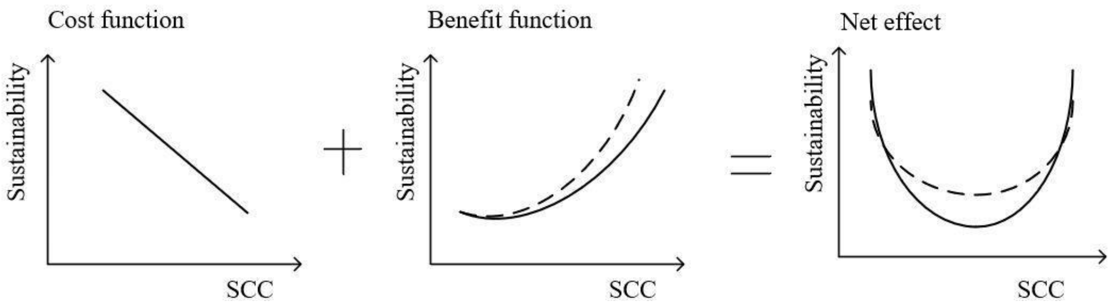

Figure 1(b) Moderator QR strengthens the benefit function

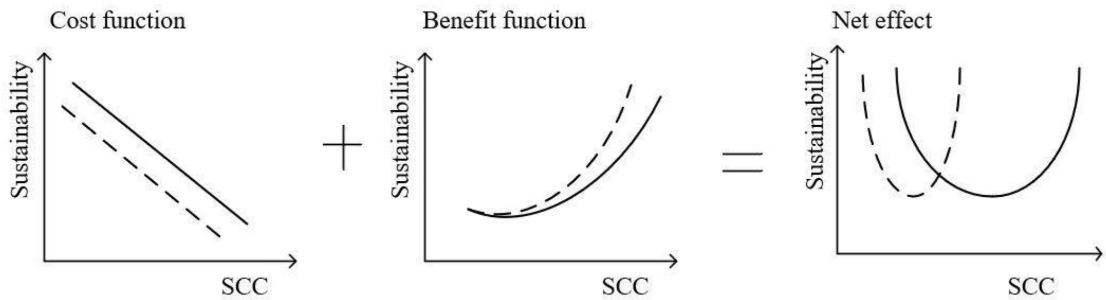

Figure 1(c) Moderator RTR weakens the cost function and strengthens the benefit function

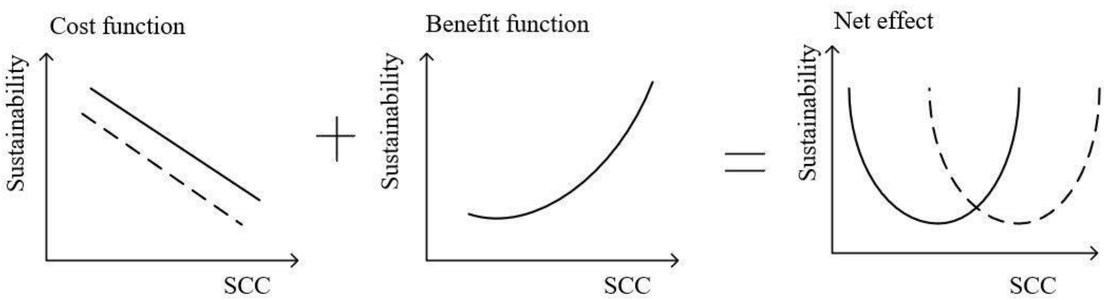

Figure 1(d) Moderator OC weakens the cost function