European Journal of Operational Research 277 (2019) 1010–1026

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Decision Support

When to increase firms' sustainable operations for efficiency? A data envelopment analysis in the retailing industry

Yeming Gong[a], Jiawen Liu[b], Joe Zhu[c,*]

[a] EMLYON Business School, 23 avenue Guy de Collongue, Ecully Cedex 69134, France
[b] School of Management, Huazhong University of Science and Technology, Wuhan 430074, China
[c] School of Business, Worcester Polytechnic Institute, MA, USA

ARTICLE INFO

Article history:
Received 25 January 2018
Accepted 13 March 2019
Available online 28 March 2019

Keywords:
Data envelopment analysis
Sustainable supply chain
Sustainable operations
Efficiency
Creating shared value

ABSTRACT

Retailers increasingly incorporate sustainable operations to improve their efficiency, which raises questions: Is it always beneficial to increase firms' sustainable operations for operational efficiency? Under which conditions should a retailer increase its socially-responsible and environmentally-friendly operations to improve efficiency? Our research addresses inconsistent viewpoints in relation to sustainable activities and performance at an operational level, and fills in research gaps in measuring the efficiency of, and identifying the operational mechanisms active in, sustainable retail operations. By collecting data from 124 retailers, we integrate the DEA (data envelopment analysis) model with empirical methods. We first apply DEA models to evaluate the efficiency of retailers. Using efficiency values provided by DEA, we conduct hierarchical regression analysis to examine the influence of socially-responsible and environmentally-friendly operations, and understand the role of sustainable operations in the supply chain. Finally, we use nonlinear analysis to identify the conditions required to increase the efficiency of sustainable operations. Supply chain integration can improve efficiency with higher levels of socio-economic integration and environmental-economic integration. Firms in an internal operational environment with a higher level of financial flow integration and a lower level of physical flow integration are more likely to achieve high retail efficiency. We find two conditions for implementation with managerial insights. When these conditions, characterized by financial flow and physical flow integration, are satisfied, a retailer can increase sustainable operations to increase efficiency. We have a surprising but reasonable finding: the interaction of sustainable operations and physical flow integration is negatively correlated to efficiency.

© 2019 Elsevier B.V. All rights reserved.

1. Introduction

An increasing number of retailers have invested in sustainability by integrating environmental and social objectives into their operations management (Eccles, Ioannou, & Serafeim, 2014), and the growing concern over socially-responsible and environmentally-friendly operations has led to attempts to integrate economic, environmental and social values (Tang, Lai, & Cheng, 2016). However, while sustainable operations, as key elements in supply chains, have been regarded as operational drivers of performance in academia (Klassen & Whybark, 1999; Kleindorfer, Singhal, & Wassenhove, 2005; Vachon & Klassen, 2008), the viewpoints of practitioners in relation to sustainable operations are inconsistent. A joint survey by the Boston Consulting Group (BCG) and MIT's Sloan Management Review (SMR) found that only 37% of businesses reported that sustainability measures had increased profitability, which meant that over half of businesses did not see significant profits from the input of sustainable operations (Kiron, Kruschwitz, Haanæs, Reeves, & Goh, 2013). "Nonetheless, plenty of companies still struggle to view sustainability as an opportunity. Almost half the survey respondents find it difficult to quantify the intangible effects of sustainability, and 37% say it conflicts with other priorities" (Kiron et al., 2013, p. 5). For example, Bloomberg Businessweek reported that Nike had launched its first line of environmentally friendly shoes, "Considered", made with brown hemp fibers, in 2005 (Reena, 2009). However, the shoes had an earthy appearance, and did not achieve success with Nike's customers, who preferred Nike's high-tech image. This led to inferior business performance and the boots being taken off the shelves. This interesting evidence partially motivated our research.

* Corresponding author.
E-mail addresses: GONG@em-lyon.com (Y. Gong), jiawen_liu@hust.edu.cn (J. Liu), jzhu@wpi.edu (J. Zhu).

https://doi.org/10.1016/j.ejor.2019.03.019
0377-2217/© 2019 Elsevier B.V. All rights reserved.

From a theoretical perspective, we also find relevant debate and discussion. Since Porter and Kramer (2011) proposed the theory of CSV (creating shared value) which argued that, different from traditional CSR (corporate social responsibility) with a value of just "doing good" (Porter & Kramer, 2011, p. 76), an organization can also create economic value with socially-responsible activities, supporters of both sides (CSR and CSV) have aired contradictory opinions regarding whether the inputs of sustainable activities can always efficiently improve business performance. Taking cost efficiency as an example, in the survey by BCG and SMR, "forty percent report that higher operational costs take away from profit, and 33% cite increased administrative costs connected with sustainability programs as another profit drain" (Kiron et al., 2013, p. 5). Particularly, using data from S&P 500 firms, (Hillman & Keim, 2001, p. 125) found that "social issue participation is negatively associated with shareholder value". This famous finding, published in a rigorous outlet, disappointed many supporters of environmentalism and led to heated debates in academia and society. It seems that, without considering further operational details and implementation conditions, it is not that easy to achieve the beautiful picture of CSV proposed in Porter and Kramer (2011).

At the operational level, it is unclear whether it is always beneficial for firms to increase supply chain integration and sustainability integration. Although the link between sustainable operations and operational efficiency has been discussed (Blass, Corbett, Delmas, & Muthulingam, 2014; Muthulingam, Corbett, Benartzi, & Oppenheim, 2013), the results are inconsistent in the literature, which contains the following divergent viewpoints (Derwall, Guenster, Bauer, & Koedijk, 2005; Russo & Fouts, 1997): (1) adopting sustainable operations can help retailers improve their operational efficiency when social and environmental excellence drives operational excellence (Corbett & Klassen, 2006). Social and environmental objectives encourage firms to use resources more efficiently, and sustainable operation strategies can improve overall competitiveness (Porter & van der Linde, 1995). A focus on the performance of sustainability can be a competitive asset for firms (Hart, 1997). After adopting sustainable operations, firms become more entrepreneurial and more motivated to discover new goods and services (Larson, Teisberg, & Johnson, 2000). (2) Although managers may benefit operationally from improved environmental and social practices, doing so may entail a higher cost for retailers. Sustainable operations may affect products and service levels by improving customer satisfaction and loyalty (Klassen & Vachon, 2003; Pil & Rothenberg, 2009), but, as a type of agency cost, may also influence, and even decrease, a firm's efficiency. The traditional economic view suggests that any environmental improvement made by a firm transfers costs previously incurred by society back to the firm (McGuire, Sundgren, & Schneeweis, 1988). Hence, sustainable operations can be expected to be negatively linked to operational performance. The additional environmental constraints may make optimizing a firm's operational efficiency more difficult and may increase the cost of operations such as ordering, inventory and delivery in the retail industry. One result of the tendency towards environmental or social operational measures is that firms often associate environmental regulation with higher costs (Rajaram & Corbett, 2002). When firms seek environmental certification (e.g. ISO 14001), their decision to do so tends to be less economically driven than that of firms that decide against certification (Melnyk, Sroufe, & Calantone, 2003). Therefore, these debates and discussions in relation to the various theories and evidence raise Research Question 1: *"Is it always beneficial for retailers to increase sustainable operations for efficiency? Can the integration of environmental and social objectives into operations management bring superior efficiency to the retail industry? "*

Corporate sustainability performance measurement is important research foundation (Pryshlakivsky & Searcy, 2017; Searcy, 2012) for sustainable supply chain management. Sustainability, defined as meeting the needs of a firm's direct and indirect stakeholders without compromising its ability to meet the needs of future stakeholders as well (Dyllick & Kai, 2002), calls on organizations to view their responsibility in terms of the "triple-bottom-line (TBL)" (Gong, 2013; Kleindorfer et al., 2005). TBL theory deeply influences global retailing operations by proposing three bottom lines: profit, people and planet, for the firms' economic, social and environmental values (Elkington, 1998). Increasingly, sustainability concerns are being considered an integral part of retailing operations, rather than a separate set of issues (Fabbe-Costes, Roussat, Taylor, & Taylor, 2014; Longoni & Cagliano, 2015). The pressures for improved environmental performance and social responsibility must be integrated with other key aspects of operations and process excellence if retailers are to successfully balance their environmental, social and economic challenges (Corbett & Kleindorfer, 2003; Servaes & Tamayo, 2013).

Since traditional business performance measures (e.g., profit and sales) have been studied in the existing literature on sustainable supply chains, we considered a new performance measure of efficiency, as the measurement and comparison of the achievement of operations objectives, to evaluate the performance of operations across organizations in the retailing industry. Since efficiency is an important consideration in sustainability strategies, one of the motivations of CSV is to go beyond the "trade-offs between economic efficiency and social progress that have been institutionalized in decades of policy choice" (Porter & Kramer, 2011, p. 64). Understanding the role of sustainable operations and the impact of environmental investment on retailing operations requires an appropriate definition of the concept of efficiency. Operational efficiency in this paper is defined in accordance with a well-constructed definition in the literature on data envelopment analysis (DEA). Färe, Grosskopf, Lovell, and York (1985) proposed that efficiency could be measured as the distance between an observation and an estimated ideal, referred to as the efficient frontier. The efficient frontier, or the production possibility frontier, which envelops on top of the production possibility set, guarantees at least the outputs of firms in all components while proportionally reducing the inputs to the smallest possible value. In the DEA literature, efficiency is measured with an output-to-input ratio related to productivity. This efficiency evaluation method has been widely applied in various industries, and has been shown to be a reliable and persuasive method.

Despite the economic significance of sustainable operations, the relationships between sustainability and supply chain operations is not straightforward (Kretschmer, Spinler, & Wassenhove, 2014). There may be either direct or indirect relationships among sustainability management, supply chain management and organizational performance (Zhang, van Donk, & van der Vaart, 2011). The mechanisms governing the manner in which supply chain operations can support the effectiveness of sustainable operations are unclear to both academics and practitioners. While recent research has considered people, planet and profit by reviewing the social consequences of supply chain operations (Vachon & Klassen, 2008; Zhu & Sarkis, 2004), little research has been done in relation to the ideal conditions under which to employ sustainability practices in supply chain operations processes for efficiency. Therefore, we paid particular attention to the effects of socio-economic integration (SEI) and environmental-economic integration (EEI) on the relationships between supply chain operations and business activities. To facilitate the practical implementation, we need to identify the ideal conditions under which to increase sustainable operations in order to improve operational efficiency. Our paper is at the level of operations strategy, not corporate strategy. Thus, our focus is on internal operational conditions. On this basis, we raise Research Question 2: *"When (under which internal operational*

conditions) should a retailer increase sustainable operations in order to improve operational efficiency?"

To answer the research questions, we considered sustainable operations in an environment of retailing supply chain management, and attempted to find an accurate quantitative research method considering multiple input and output measures and optimal operational efficiency. By collecting data from 124 retailers, we integrated the DEA models with empirical methods. We first established DEA models to evaluate the efficiency of retailers in relation to sustainability, operational, and business decisions. Our model captures the relationship between sustainable activities and the efficiency of different Decision Making Units (DMUs) based on multiple input-output data. The DEA models provided in this research can be appropriate tools to obtain an accurate understanding of the performance of firms with sustainable retailing operations. Using efficiency values provided by DEA, we then conducted hierarchical regression analysis to examine the influence of socially-responsible and environmentally-friendly operations on, and understand the role of sustainable operations in, the supply chain considering the interaction effect between supply chain integration and sustainable operations. Finally, we used nonlinear analysis to identify the ideal conditions under which to increase sustainable operations for efficiency.

The benefits of our proposed DEA models are as follows: first, the use of single measures for assessing sustainable operations ignores the potential interactions that may exist among various firm performance measures. In this respect, DEA has been shown to be an effective tool to assess performance when multiple measures are considered (Zhu, 2003). Second, DEA does not require a priori information about the relationship between multiple performance measures, as it estimates the empirical efficient trade-off curve or best-practice frontier from the observations (Cooper et al., 2007). Third, DEA provides an optimal and more accurate model to measure operational efficiency. As such, in order to better understand the sustainable operations, it is required to designate the optimal performance and assess all other performances by deviations from the frontier line, which is feasible with a DEA framework. Fourth, DEA assesses a firm's performance by calculating it and comparing it with the efficiency frontier without assuming any random parameter values. The inputs and outputs of all firms form a production possibility set where the observed firm activities are used to construct a production function. The efficient frontier, or the production possibility frontier, which floats (or envelops) on top of the production possibility set, guarantees at least the outputs of firms in all components while reducing the inputs proportionally to a value as small as possible. Finally, independent measurement methods of individual firms may lead to erroneous interpretations. To avoid such interpretational errors, DEA (a) uses data from multiple firms to calculate the distance to the efficiency frontier, (b) estimates different ratios for these firms, and (c) provides a more accurate and rigorous view of the role of sustainable operations in organizational performance. Therefore, the DEA models provided in this research can be appropriate tools to obtain an accurate understanding of the performance of firms with sustainable retailing operations. Using efficiency values provided by DEA, we then conducted hierarchical regression analysis to examine the influence of socially-responsible and environmentally-friendly operations on, and understand the role of sustainable operations in, the supply chain considering the interaction effect between supply chain integration and sustainable operations.

Our study makes the following theoretical contributions. (1) This research contributes to theories of CSV and CSR (Porter & Kramer, 2011) by delving into operational details, and presenting implementable conditions for sustainable operations to increase efficiency. (2) The findings contribute to theories in supply chain management by identifying a new capability of supply chain process integration in interacting with sustainable operations to increase efficiency. (3) This paper provides implications for, and contributions to the literature on, retailing by identifying the role of sustainable operations in the retailing and by indicating the manner in which improved operational efficiency is achieved in the supply chain through the adoption of sustainable retailing operations. (4) This paper contributes to the literature on sustainable operations by discovering a mechanism by which to increase the efficiency of sustainable supply chains: high levels of SEI and EEI result in high operational efficiency when physical flow and financial flow integration are appropriately involved in these supply chain operations. (5) Our research enriches the theory of internal fit. We have a surprising but plausible finding: the interaction of sustainable operations and physical flow integration are negatively correlated with efficiency. This partially explains why some retailers for whom physical flow integration is critical are unable to increase efficiency after putting in place sustainable operations.

Our practical contributions are: (1) although sustainable operations are relevant to efficiency, without appropriate supply chain integration (e.g., if financial flow integration is very low), they cannot always lead to high efficiency. This answers Research Question 1 and proves that it is indeed essential to identify an implementation condition. (2) We identify two conditions for implementation with managerial insights. When these conditions, characterized by financial flow and physical flow integration, are satisfied, a retailer can increase sustainable operations in order to increase efficiency. This answers Research Question 2.

In the following, we review the literature in Section 2. Then we propose a research design integrating DEA-based framework with empirical analysis to assess and analyze sustainable supply chains in the retailing industry in Section 3. Section 3 also presents constructs, measures, and DEA models. Section 4 then shows the collection and assessment of data set. In Section 5, we apply DEA models to evaluate the efficiency of retailers, conduct hierarchical regression analysis to examine the results using the operational efficiencies provided by DEA, and use nonlinear analysis to identify the conditions required to increase sustainable operations for efficiency. Section 6 presents the implications for theories and practice. Conclusions are drawn in Section 7.

2. Literature review

2.1. Supply chain operations and operational efficiency

The potential for improved supply chain performance through various forms of integration and coordination has been demonstrated extensively in recent literature and management practices (Corbett & Decroix, 2001). Supply chain integration, as the extent of operational, tactical, and strategic sharing that occurs between a retailer and its supply chain partners, describes the degree to which a retailer uses process optimization with its partners to handle the stocking and flow of materials and finished goods (Rai, Patnayakuni, & Seth, 2006). Supply chain integration can improve cost efficiency by reducing the costs of production, warehousing, transportation and logistics (Lei & Goldhar, 1991). It can enable firms to optimize order frequency, reduce purchasing costs, optimize lot sizes, and improve material handling (Patnayakuni, Rai, & Seth, 2006). Supply chain integration supports routines and activities to collect supply information and accurately forecast demand, which are essential for the coordination of routine tasks (Patnayakuni et al., 2006), and helps reduce inventory cost, and resolve conflicting objectives in the supply chain.

Since supply chain integration breaks down functional barriers to meeting the requirements of organizational operations, enables retailers to create greater value, and detects demand changes more quickly, it is expected to be related to operational

competency(Avci, Girotra, & Netessine, 2014; Matos & Hall, 2007; Porter & Kramer, 2006), including cost competency and flexibility competency (Neely, Gregory, & Platts, 1995; Rantasila & Ojala, 2012; Wiengarten, Fan, Lo, & Pagell, 2016). A close relationship between the upstream and downstream of supply chain offers opportunities for improving the accuracy of information, which reduces design and planning time and inventory cost. Supply chain integration improves operational competency by allowing supply chain partners to better anticipate and coordinate supply and demand (Ettlie & Reza, 1992). They are essential inputs for retailers who need to respond to changing markets quickly and provide innovative solutions (Terwiesch & Xu, 2008) and further facilitate joint efforts in cost and inventory reduction. With a low level of supply chain integration, a retailer is more likely to receive inaccurate or distorted supply and demand information, which results in poor production plans, high levels of inventory and poor delivery reliability.

2.2. Sustainable operations in the retail industry

A theoretical foundation of this section is CSV theory (Porter & Kramer, 2011), different from traditional CSR, which argues that an organization can create economic value while also creating social value. This theory is also applied to sustainable supply chains in order to move beyond the trade-off between efficiency and social objectives. For example, in Africa, Nestlé established a sustainable supply chain by working with small milk farmers, which improved operational efficiency and enabled Nestlé to "obtain a stable supply of high-quality commodities without paying middlemen" (Porter & Kramer, 2006, p. 90).

Retailers now have to integrate their sustainable operations to obtain both economic profits and social impacts, which is referred to as Social-Economic Integration (SEI) (Gong, 2013; Linton, Klassen, & Jayaraman, 2007; Rondinelli, 2007). SEI can address the sustainable use of resources and local community development programs for improving a firm's social performance (Avci et al., 2014; Cachon, 2014; Gong, 2013; Linton et al., 2007). SEI has the potential to improve social performance in terms of jobs created (Matos & Hall, 2007), employee health (Porter & Kramer, 2011, p. 28; Matos & Hall, 2007), worker safety (Porter & Kramer, 2011, p. 28; Matos & Hall, 2007), employee skills (Porter & Kramer, 2006), work standards and welfare (Rondinelli, 2007), supplier access and viability (Porter & Kramer, 2011, p. 28), knowledge enhanced and transferred to local communities, health and safety for local communities, equal opportunities and diversity, and stakeholder engagement satisfaction (Matos & Hall, 2007).

Retailers also use sustainable operations to achieve both environmental and economic objectives (Agrawal, Atasu, & Ittersum, 2015; Matos & Hall, 2007; Unruh & Ettenson, 2010), and Environmental-Economic Integration (EEI) refers to the efforts that firms put into the environmental perspective in relation to the lifecycle of products, the transportation sector's carbon footprint, facility layout and renewable resources (Avci et al., 2014; Cachon, 2014; Linton et al., 2007). EEI has the potential to improve sustainability competency by, for example, inducing firms to focus on recycling waste or use collaboration tools such as, telecommunication and video conferences to reduce travel costs.

SEI and EEI can help retailers achieve same results with fewer resources and greater efficiency (Gholami, Sulaiman, Ramayah, & Molla, 2013). Sustainability calls for retailers to meet the needs of the present without compromising the ability of future generations to meet their own needs, which forces retailers to simultaneously consider economic growth, environmental protection, and social equity in their business planning and decision-making (Mejias, Paz, & Pardo, 2016; Rondinelli, 2007). Retailers who invest in integration between environmental, social and economic activities may not only operate as environmentally-friendly retailers and socially-responsible organizations but also earn reasonable profits and provide fair returns to supply chain performance. For example, retailers that address community concerns, such as the protection of employees, safety issues, and fair compensation for the local community, would obtain greater benefits to their supply chain operations. SEI and EEI have generally been regarded as holding the potential to move supply chain operations toward higher efficiency.

2.3. The moderating effects of sustainable operations on the supply chain

Recent research cites multiple instances of environmental or social awards positively affecting supply chain competency and environmental crises negatively affecting business performance (Hart, 1997; Klassen & McLaughlin, 1996; Roehrich, Grosvold, & Hoejmose, 2014; Zhu & Sarkis, 2004). The role of sustainable operations in the supply chain has received significant academic attention and existing research emphasize the importance of developing sustainable strategies for effective supply chain practices in various industries (Agrawal et al., 2015; Angell & Klassen, 1999; Atasu & Cetinkaya, 2006; Atasu, Guide, & Wassenhove, 2008; Klassen & Whybark, 1999). Considering the effects of supply chain operations and sustainable operations on operational efficiency, one of the principal concerns in the retailing is the impact of the integrations of environmental and social operations on supply chain performance.

Cooperation with suppliers, customers, and the local community may facilitate fulfilling the demands of supply chain operations through efficient production and logistics processes. Porter and Kramer (2006) argue that the more closely a social and environmental issue is tied to a firm's operations, the greater the opportunity to leverage the firm's resources to benefit society.

Another theory relevant to the retailing context is the commitment-trust theory. In regard to stakeholder management, prior literature has suggested that sustainability has a positive influence on operational efficiency by helping firms develop mutual trust with their suppliers and customers in the form of strong long-term relationships (Hillman & Keim, 2001). With cross-value integration, firms tend to trust each other and curb opportunistic behavior (Cheng, Ioannou, & Serafeim, 2014; Foo, 2007). Supply chain integration creates a commitment to supply chain partners that is based on mutual trust and a longer-term orientation. Therefore, firms that are embedded, through mutual trust and the building of long-term relationships, with relevant stakeholders by means of the integration of social and environmental issues in their operational models and strategies will be better placed to address the effects of supply chain capabilities, such as the reduction of agency and transaction costs, and mount quick responses to changing market needs through supply chain integration.

More retailers, such as Whole Foods Market and 7-Eleven, now offer consumers organic and healthy food products, which benefit the health of the local community and bring profits to rural areas. In cases such as these, the interactions between sustainability and supply chain operations can be seen to affect operational efficiency. High levels of sustainability strengthen the effects of supply chain integration on operational efficiency, while low levels weaken such effects.

2.4. DEA

DEA can be often combined with various regression analyses to identify the significant factors contributing to superior performance of the DMUs on the efficient frontier (Kolodny, Jardine, & Tsang, 1999). The procedure has been used to compare operational

performance among airlines (Zhu, 2011), banks (Cook, Seiford, & Zhu, 2004; Sherman & Zhu, 2006), hospitals (Du, Wang, Chen, Chou, & Zhu, 2014), information technology (Chen, Liang, Yang, & Zhu, 2006; Chen & Zhu, 2004), the manufacturing industry (Park, Lee, & Zhu, 2014) and sustainable product design (Chen, Zhu, Yu, & Noori, 2012). A review of the various basic DEA models and their extensions to deal with complications such as multi-stage network process or inputs and outputs that have categorical values can be found in Zhu (2003). Compared with previous researches, our framework based on DEA models and considering multiple inputs and outputs and productive effects, can explain the nonlinear relationship between supply chain operations, sustainable operations, and operational efficiency. In our models for the efficiency in the retailing supply chains, we consider different types of inputs and outputs from supply chain decisions, sustainability decisions and business decisions.

3. Models and methodology

3.1. Research design

We design a research process integrating DEA-based framework with empirical analysis to assess and analyze sustainable supply chains in the retailing industry, including six steps.

In Step 1 (measure identification), we identify key constructs in the research model and develop a survey instrument with items adapted from the convincing literature.

In Step 2 (data collection), we collect data regarding operational information in the retailing industry. We interview and visit retailers to understand decision structure in the retail industry. Then we use approaches to confirm the validity and reliability of the quantitative data. In addition, we test for non-response bias and common method bias.

In Step 3 (model building), we build DEA models with multiple inputs and outputs to describe the decision structures of sustainable supply chains in the retailing industry.

In Step 4 (DEA analysis), we solve and analyze DEA models, calculate efficiency measuring, and assess the organizations' performance in terms of efficiency.

In Step 5 (hierarchical regression analysis), we conduct the hierarchical regression analysis based on the DEA results. We evaluate the main effects of the independent variables and the moderating effects of SEI and EEI. The results are mainly used to answer Research Question 1.

In Step 6 (nonlinear analysis), we use nonlinear analysis, an empirical analytical technique, to further analyze the results based on the DEA models and finally identify conditions required to increase firms' sustainable operations for operational efficiency, answering Research Question 2.

3.2. Constructs and variables

The constructs and variables in this research were adapted from prior literature. We avoid the mixed usage of volume measures and percentage measures (Dyson et al., 2001) in DEA modeling, and the inputs and outputs in DEA models are percentage measures. Table 1 summarizes all the constructs and measures.

3.2.1. Variables in supply chain

For supply chain decisions, retailers use supply chain coordination to improve operational performance. Supply chain coordination measures the degree to which a retailer plays an active role in developing innovative business practices and implementing incentives with suppliers and customers (Hill & Scudder, 2002). Supply chain coordination helps retailers to exchange information about products, processes, schedules and capabilities and to develop a strong strategic partnership which will facilitate suppliers' understanding and anticipation of customers' needs. Supply chain coordination recognizes the importance of establishing interactive close relationships with customers and suppliers.

3.2.2. Variables of sustainable operations

Existing literature (e.g. Nicolas, Pocheta, & Poimboeuf, 2003; Quak & De Koster, 2007; Richardson, 2005) distinguishes three values: social, economic and environmental values. Sustainability level measures the degree to which retailers improves their compliance, environmental sustainability and created sharing values. Sustainability level contributes to social and environmental competency in sustainability decisions. Social competency measures the performance of retailers in relation to jobs created, the health and safety of local communities, employee skills, work standards and welfare, knowledge enhanced and transferred to local communities, and stakeholders engagement satisfaction (Gong, 2013; Matos & Hall, 2007; Porter & Kramer, 2006; Rondinelli, 2007). Environmental competency measures the performance of retailers in relation to waste management, land disturbance, reclamation diversity, and the reduction of energy, greenhouse gas emissions, and water consumption. (Avci et al., 2014; Cachon, 2014; Matos & Hall, 2007; Porter & Kramer, 2006).

3.2.3. Variables of operational competency

Cost competency refers to the competency in function-related cost (e.g., transportation, warehousing, cargo handling, packaging and administration) and overhead costs (e.g., inventory carrying, value of time, lost sales, customer service level, non-marketable goods) (Neely et al., 1995; Rantasila & Ojala, 2012), while flexibility competency refers to the competency in product customization ability, and volume and mix flexibility (Neely et al., 1995; Wiengarten et al., 2016). Cost competency and flexibility competency are the two dimensions of operational competency.

3.2.4. Variables of business performance

For business decisions, financial performance should be the main measure of outputs in the retail supply chain because of the shareholder profit motive (Chen & Paulraj, 2004). Based on Flynn, Huo, and Zhao (2010) and PlanetRetail (2017), we consider growth in sales, growth in profit, growth in market share, return on investment in business performance. Cost, flexibility, environmental, and social competency in business decisions all contribute to the performance of firms.

3.3. Decision structure from the perspective of DEA

In DEA, a DMU is regarded as the entity that is responsible for converting inputs into outputs and whose performance is to be evaluated. A group of DMUs is used to evaluate each other with each DMU having a certain degree of managerial freedom in decision-making. The conventional DEA considers a set of DMUs indexed by K. For all $k \epsilon K$, DMU_k uses inputs $X_k = [x_{ik}]_{i=1}^{|I|} \epsilon \Re_+^{|I|}$ to obtain the output $Y_k = [y_{jk}]_{j=1}^{|J|} \epsilon \Re_+^{|J|}$ where I and J are the index sets for inputs and outputs. $\Re_+^{|n|}$ represents the n-dimensional positive real space. All inputs used are assumed to have a *contemporaneous correspondence* to outputs, meaning that inputs contribute only to the outputs that occur at the same time. The decision structure, described in Fig. A.1 in Appendix, includes three DMUs:DMU of operational decision, DMU of sustainability decision, and DMU of business decision.

3.3.1. DMU of operational decision

In the DMU of operational decision, a retailer inputs supply chain coordination, leading to outputs in cost competency and flexibility competency. Thus, inputs X for supply chain decisions are

Table 1
Constructs and measures.

	Construct	Item	Measures	Load	References
Inputs for Stage 1	Supply chain coordination ($\alpha = 0.85, CR = 0.85, AVE = 0.60$)	SCC1	Our company strives to be the preferred supplier (customers) to our customers (supplier).	0.85	Hill and Scudder (2002)
		SCC2	Our company plays an active role in developing innovative business practices between our suppliers and customers.	0.79	
		SCC3	We consider our suppliers and customers to be our partners.	0.88	
		SCC4	Our company is taking an active role in the implementation of ECR incentives with our suppliers and customers.	0.86	
	Sustainability level ($\alpha = 0.95, CR = 0.95, AVE = 0.81$)	SL1	Compliance. Our company implements a sustainability strategy for the commitment to act with honesty and respect for laws and regulation.	0.95	Porter and Kramer (2011), Gong (2013)
		SL2	Environmental sustainability. Our company implements a sustainability strategy, with using natural resources, promoting the use of sustainably managed renewable resources, and achieving zero waste.	0.91	
		SL3	Created Sharing Values. Our company shares values for both company and society, implements a sustainability strategy not separated from but integrated with profit maximization, and expands the overall amount of social and economic values beyond the trade-off.	0.86	
Outputs for Stage 1 and inputs for Stage 2	Cost competency ($\alpha = 0.87, CR = 0.87, AVE = 0.63$)	CC1	Our company has a low direct function related cost (e.g. transportation, warehousing, cargo handling)	0.86	Rantasila and Ojala (2012), Neely et al. (1995)
		CC2	Our company has a low indirect function related cost (e.g. packaging, administration cost)	0.91	
		CC3	Our company has a low direct overhead cost (inventory carrying, value of time)	0.76	
		CC4	Our company has a low indirect overhead cost (cost of lost sales, cost of customer service level, non-marketable goods)	0.82	
	Flexibility competency ($\alpha = 0.81, CR = 0.80, AVE = 0.58$)	FC1	Our company has a good performance in volume flexibility	0.84	Wiengarten et al. (2016), Neely et al. (1995)
		FC2	Our company has a good performance in mix flexibility	0.81	
		FC3	Our company has a good performance in product customization ability	0.92	
	Social competency ($\alpha = 0.95, CR = 0.94, AVE = 0.81$)	SC1	Our company has a good performance in jobs created, health and safety for local communities	0.91	Porter and Kramer (2006), Matos and Hall (2007), Gong (2013), Rondinelli (2007)
		SC2	Our company has a good performance in employee skills and work standards/welfare	0.94	
		SC3	Our company has a good performance in knowledge enhanced/transferred to local communities	0.87	
		SC4	Our company has a good performance in stakeholders engagement satisfaction	0.89	
	Environmental competency ($\alpha = 0.92, CR = 0.92, AVE = 0.75$)	EC1	Our company has a good performance in green gas emission and water consumption reduction	0.88	Cachon (2014), Avci et al. (2014), Porter and Kramer (2006), Matos and Hall (2007)
		EC2	Our company has a good performance in energy reduction	0.90	
		EC3	Our company has a good performance in waste management	0.85	
		EC4	Our company has a good performance in land disturbance and reclamation diversity	0.83	

(*continued on next page*)

Table 1 (*continued*)

	Construct	Item	Measures	Load	References
Outputs for Stage 2	Business performance ($\alpha = 0.94, CR = 0.90, AVE = 0.69$)	BP1	Growth in sales.	0.84	Flynn et al. 2010
		BP2	Growth in profit.	0.83	
		BP3	Growth in market share.	0.82	
		BP4	Return on investment.	0.84	
Other variables	Supply Chain Integration ($\alpha = 0.95, CR = 0.95, AVE = 0.81$)	SCI1	Our company uses data and enterprise application integration among internal functions.	0.95	Rai et al. (2006)
		SCI2	Our company uses cross functional teams in process improvement and new product development.	0.91	
		SCI3	Our company uses real-time integration and connection among internal functions from raw material management through production, shipping, and sales.	0.86	
		SCI4	Our company uses periodic interdepartmental meetings among internal functions.	0.89	
Social-Economic Integration ($\alpha = 0.94, CR = 0.94, AVE = 0.79$)	SEI1	Our company uses technology to address sustainability or use resources to improve social performance	0.88	Linton et al. (2007), Gong (2013), Rondinelli (2007)	
		SEI2	Our company uses market forces to drive sustainability	0.79	
		SEI3	Our company uses education program to improve social performance	0.88	
		SEI4	Our company uses philanthropy/charity to improve social performance	0.86	
	Environmental-Economic Integration ($\alpha = 0.91, CR = 0.91, AVE = 0.72$)	EEI1	Our company uses sustainable product and environmental impact perspective for life-cycle product to consider both environmental and economic impact.	0.89	Avci et al. (2014), Cachon (2014), Agrawal and Thomas (2012)
		EEI2	Our company improves transportation sector's carbon footprint and dependence on oil.	0.80	
		EEI3	Our company improves facility layout and planning for both environmental and economic objectives.	0.86	
		EEI4	Our company uses renewable resources (e.g. energy, materials).	0.86	
	Financial flow integration ($\alpha = 0.93, CR = 0.93, AVE = 0.88$)	FFI1	Account receivables processes are automatically triggered when we ship to customers.	0.92	Rai et al. (2006)
		FFI2	Account payable processes are automatically triggered when we receive supplies from suppliers.	0.96	
	Physical flow integration ($\alpha = 0.94, CR = 0.94, AVE = 0.81$)	PFI1	Inventory holdings are minimized across the supply chain.	0.91	Rai et al. (2006)
		PFI2	Supply chain-wide inventory is jointly managed with suppliers and logistics partners(e.g., UPS, FedEx).	0.88	
		PFI3	Suppliers and logistics partners deliver products and materials just in time.	0.90	
		PFI4	Distribution networks are configured to minimize total supply chain-wide inventory costs.	0.91	
	Information flow integration ($\alpha = 0.95, CR = 0.95, AVE = 0.82$)	IFI1	Production, delivery schedules and performance metrics are shared across the supply chain.	0.94	Rai et al. (2006), Patnayakuni et al. (2006)
		IFI2	Supply chain members collaborate in arriving at demand forecasts	0.91	
		IFI3	Our stream partners(e.g., distributors, wholesalers, retailers) share their actual sales data with our company.	0.89	
		IFI4	Inventory data are visible at all steps across the supply chain.	0.86	

supply chain coordination (Hill & Scudder, 2002). Operational competencies U are outputs for retail supply chain decisions which include two variables: cost competency and flexibility competency.

3.3.2. DMU of sustainability decision

In the DMU of sustainability decision, inputs W for retail sustainability decisions are sustainability level. Investment on sustainability level improves a retailer's sustainability competency. Input W leads to the sustainability competency V which contains two variables: social competency and environmental competency in sustainability decisions.

3.3.3. DMU of business decision

In the DMU of business decision, retailers use cost competency, flexibility competency, environmental competency, and social competency to achieve business performance measured by output Y. Operation management research suggests that these operational competencies are relevant to business performance (Lambert & Pohlen, 2001). Operational competency helps to improve the efficiency of supply chains and the functioning of related infrastructure, services, procedures and regulations which in turn benefit business performance. Furthermore, there is evidence that firms with better sustainability also achieve better market performance (Derwall et al., 2005; Klassen & McLaughlin, 1996). Driven by current legislation, public interest and competitive opportunity (Linton et al., 2007), social competency and environmental competency enable retailers to utilize external factors and achieve better business performance.

3.4. DEA models for sustainability decisions in the retailing industry

Based on the decision structures of the three DMUs in the retailing industry, we introduce DEA models to calculate the efficiency of retailers. Our two-stage DEA model, which is a modification of the CCR model, measures the efficiency of each retailer in the sample—that is, it seeks to find the efficiency, θ_k, by which the kth retailer can shrink its input vectors. First, we present the conventional CCR model in the following multiplier format.

$$\max_{\mu,\nu} \quad \theta = \mu y_k \tag{CCR}$$

subject to:

$$\begin{aligned} \nu x_k &= 1 \\ \mu y_i \leqslant \nu x_i &\quad (i = 1, 2, \ldots, n) \\ \mu, \nu &\geqslant 0 \end{aligned}$$

As we discussed above, the decision structure in the retailing industry was found to mainly include two stages. The first stage involves two parallel processes, one for the DMU of operational decision and the other for DMU of sustainability decision. Then the DMU of business decision is in the second stage. Cook, Liang, and Zhu (2010) and Aviles-Sacoto, Cook, Imanirad, and Zhu (2015) show that the performance improvement of one decision affects the efficiency status of the other. Therefore, in order to deal with multi-stage efficiency in a single implementation, we present the following formulation:

$$\max_{\theta,\mu} \quad \theta_k = \sum_{p=1}^{P} \mu_{up} u_{pk} + \sum_{q=1}^{Q} \mu_{vq} v_{qk} + \sum_{j=1}^{J} \mu_{yj} y_{jk} \tag{I}$$

subject to:

$$\sum_{i=1}^{I} \mu_{xi} x_{ik} + \sum_{l=1}^{L} \mu_{wl} w_{lk} + \sum_{p=1}^{P} \mu_{up} u_{pk} + \sum_{q=1}^{Q} \mu_{vq} v_{qk} = 1$$

(Operational Decision)

$$\sum_{p=1}^{P} \mu_{up} u_{pk} \leqslant \sum_{i=1}^{I} \mu_{xi} x_{ik}$$

(Sustainability Decision)

$$\sum_{q=1}^{Q} \mu_{vq} v_{qk} \leqslant \sum_{l=1}^{L} \mu_{wl} w_{lk}$$

(Business Decision)

$$\mu_{yk} y_{jk} \leqslant \sum_{p=1}^{P} \mu_{up} u_{pk} + \sum_{q=1}^{Q} \mu_{vq} v_{qk}$$

$$\mu_x, \mu_w, \mu_u, \mu_v, \mu_y \geqslant 0,$$

where $\theta_k \epsilon [0, 1]$ is the input-orientated efficiency measurement for DMU$_k$, μ_x, μ_w, μ_u, μ_v, and μ_y are the multiplier weights assigned to inputs and outputs for the firm k. $X = [x_{ik}]_{i=1}^{|I|}$, $W = [w_{lk}]_{l=1}^{|L|}$, $U = [u_{pk}]_{p=1}^{|P|}$, $V = [v_{qk}]_{q=1}^{|Q|}$, $Y = [y_{jk}]_{j=1}^{|J|}$ are the $I \times K$, $L \times K$, $P \times K$, $Q \times K$, $J \times K$ matrix of observed input or output quantities. The vectors x_k, w_k, u_k, v_k are the inputs and y_k are the outputs of retailer k.

In this model, the efficiency measurement θ_k and the multiplier vectors μ_x, μ_w, μ_u, μ_v, μ_y are decision variables. Given the technology defined by the DEA frontier. If a retailer is efficient in its inputs, then each stage represents non-dominated performance given a set of optimized measures determined by Model (I). This model can also provide optimal values on the measures with which all stages are efficient.

We calculate the efficiency score of the kth retailer as the ratio of the optimal inputs to the observed inputs. In particular, if $\theta_k = 1$, then $\theta_k x_{ik} = x_{ik}$, which means that the current discretionary input x_k has reached optimality and the efficiency of the retailer has achieved its optimal value in relation to its competitive environment factors, consistent with the efficiency measurement $\theta_k = 1$. Model (I) correctly defines the efficient frontier of a multi-decision process and can further characterize the role of sustainability decision in the overall decision-making of firms and calculate the impact of sustainability inputs on business performance. In the sustainability decision, we consider the effects of SEI and EEI on sustainability competency by using the multiplier vector μ_{wk} and μ_{vk} for the retailer k. In the operational decision, we consider the effects of supply chain performance on operational competency by using the multiplier vector μ_{xk} and μ_{uk} for the retailer k. In the business decision, we consider the relationship of operational and sustainability competency to business performance by using the multiplier vector μ_{uk}, μ_{vk} and μ_{yk} for the retailer k. This can further help to correctly characterize the indirect impact of sustainability on firm performance. Thus, we have: retailers with the highest efficiency in the whole industry are at the optimal DEA efficiency frontier in all the decisions with $\theta_k^* = 1$, where $(*)$ represents optimal values in Model (I).

The above discussion indicates that, if a retailer is efficient in its use of sustainability inputs, then each stage represents non-dominated performance given a set of optimized measures determined by Model (I). Model (I) provides not only an efficiency index, but also the optimal value which makes all decisions efficient through their inputs and outputs. Model (I) provides directions for achieving the DEA frontier of this process. Consequently, we can analyze the impact of sustainable operations on operational efficiency. We demonstrate this in our empirical studies.

4. Data

We obtained a mailing list of the world's retail organizations from PlanetRetail.com, a leading provider of global retail intelligence covering retailers all over the world, whose database is

widely used in the literature (Gielens & Dekimpe, 2007; Oh, Sohl, & Rugman, 2015; Reardon, Timmer, & Minten, 2012). We obtained background information about the targeted organizations.

We then collected first-hand data by means of a survey with a set of questionnaires using the scale set out in Table 1. To ensure the ease of use and clarity of the questionnaire, we pretested it among managers from France and China with extensive experience in sustainable operations, which led us to modify some of the wording based on their feedback. We distributed 220 sets of questionnaires to executives and managers at these retailers who possessed a full understanding of supply chain and sustainable operations. After receiving the questionnaires, the managers were asked to ensure that senior executives, operations managers and sustainability executives responded to parts A, B, and C of questionnaires concerning organizational performance, supply chain operations, and sustainability issues, respectively. Respondents frequently participated in sustainability meetings and had an understanding of the operational plans and actions of other stakeholders in the organization. These respondents had access to information from supply chain management and could appropriately evaluate each item related to the supply chain, sustainable operations, and business performance. The respondents were also contacted to ensure that they reported on each item reliably and had not encountered any problems.

We received 124 valid responses. The response rate was 56.4%, which is comparable to that of prior similar studies (Ray, Muhanna, & Barney, 2005; Wong, Lai, Shang, Lu, & Leung, 2012). The senior executives and operational managers had an average of 7.8 years of managerial experience (standard deviation = 6.4 years) and 6.7 years of managerial experience (standard deviation = 5.1 years)in the current organization (they may have worked in other organizations before). Sustainability managers (they may have worked in other organizations before) had an average of 5.6 working years in the current organizations(standard deviation = 4.1 years), which enabled us to obtain accurate and reliable data. Table A.1 in Appendix displays the sample profile of the organizations.

The measure items used for each construct were adapted from previous instruments. We adapted a seven-point reflective Likert-type scale, ranging from “strongly disagree” to “strongly agree” from existing scales. Each construct in the model consists of three or more measurement items. Table 1 sets out the measures and shows the data description of these inputs and outputs in our DEA model.

4.1. Data assessment

We collected quantitative data through a matched-pair survey of 124 organizations in the retail industry in North America, Europe, and Asia. Retailers worldwide operate their international business and communication with global data rather than data from a one single region. Hence, it is necessary to collect data from different countries and regions when considering global operations in the supply chains of retailers. In order to examine the impact of cultural differences in our global data collection, we considered Hofstede’s cultural dimensions (power distance, individualism, uncertainty avoidance, and masculinity) to address systematic differences between national cultures (Lee, Trimi, & Kim, 2013). Power distance represents the degree to which the less powerful members of society accept and expect that power is distributed unequally. Individualism represents the extent to which people in a society are integrated into groups. Uncertainty avoidance shows the culture’s tolerance for ambiguity and masculinity presents the preference for achievement and material rewards for success in different countries and regions. We divided our samples into two categories according to differences in the power distance index (high and low) and conducted Kruskal–Wallis tests to determine whether there were any differences between these two categories. We also conducted Kruskal–Wallis tests for high and low categories of individualism, uncertainty avoidance, and masculinity, and found the test results to be consistent. The differences between the high and low levels of these four cultural dimensions are insignificant, indicating that the influence of cultural differences on our sample is insignificant in the retailing industry.

We used Harmon’s single-factor test to examine common method bias (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). The exploratory factor analysis set out in Table 1 shows no single variable taking up the majority of covariance (all the rotation sums of squared loadings are $< 29\%$). Therefore, common method bias is not a problem in our sample. We also evaluated non-response bias to detect external validity. We compared the questionnaires from the earlier phase with those from the latter phase. The *t*-tests show that the significance levels of business performance, supply chain coordination, sustainability level, SEI, and EEI are $p = 0.45$, 0.29, 0.53, 0.13 and 0.18, respectively. No significant differences were detected. Thus, our study was not compromised by common method bias or non-response bias.

Internal consistency and convergent validity tests were conducted to detect measurement validity. Table 1 presents the factor loadings. The minimum factor loading in Table 1 is 0.72, higher than the commonly accepted level of 0.707 (Dijkstra & Henseler, 2015), and all loadings are significant ($p < 0.000$). The loadings between each item and the other constructs are much lower than that between each item and its principal construct. Table 1 presents the descriptive statistics, Cronbach’s alpha (α), composite reliabilities (CR), and average variance extracted (AVE) for all constructs and Table A.2 presents the correlations for all constructs. Cronbach’s alpha and composite reliabilities for all the variables are higher than 0.76 (Wiengarten et al., 2016). All AVEs are higher than 0.5, and the square root of each AVE is greater than the correlations between a pair of latent variables (Simonin, 2015), suggesting internal consistency, discriminant validity, and convergent validity.

4.2. Control variables

We considered four environmental factors as control variables: firm size, firm region, firm age, and product sectors. Business scale tends to be systematically linked to operational performance, and larger and older firms usually have more internal operations for supply chain management. Given that firm size, firm region, and firm age exhibit considerable complexity and are competitive assets in the success of a retailer, operational performance may differ between large and small businesses. Investigation of the effects of firm size, firm region, and firm age on operational performance is therefore important. Product sectors exhibit variations in consumer demand in market uncertainty and thus influence operational performance. Product sectors, as strategic factors, are important resources in the link to consumer demand in the retail industry (Wong, Boon-Itt, & Wong, 2011). The effects of product forecasts on the operational performance of retailers should be examined. Thereby, we controlled for the effects of firm size, firm region, firm age, and product sectors on operational efficiency. “Product sectors” was measured by the main business or main product description, which belonged to different product sectors such as fast-moving consumer, fashion, leisure, and diversified goods. Firm size was measured as the firm’s total assets.

In addition, we used AMOS 21.0 to perform confirmatory factor analysis of all independent variables to evaluate unidimensionality. The root mean square error of approximation is 0.046, which is lower than 0.05, and χ^2/df is 1.26, with a degree of freedom (df) of 142, which is lower than 3. The chi-square statistic (χ^2) is 179.19 ($p = 0.019$), indicating an appropriate fit index between the

Table 2
Results of hierarchical regression analysis.

	Efficiency measurement θ	
	Model 1	Model 2
Independent variables:		
Supply chain integration	0.23**	0.28***
SEI	0.22**	0.27***
EEI	0.17*	0.17*
Interaction terms:		
SEI × supply chain integration		0.14*
EEI × supply chain integration		0.16*
Control variables:		
Firm size	0.02	0.03
Firm region	0.01	0.02
Firm age	0.04	0.05
Product sectors	0.02	0.03
Intercept	0.17**	0.05
Residual standard error	0.21	0.18
Adjusted *R*-squared	0.43	0.48
F-statistic	20.81***	25.78***

Note: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.
Number of observations (n) is 124 and no missing item scores were observed in the analysis.
Each path coefficient is standardized.

Table 3
Results of hierarchical regression analysis.

	Efficiency measurement θ		
	Model 3	Model 4	Model 5
Independent variables:			
SEI	0.28***	0.24**	0.24**
EEI	0.29***	0.24**	0.21**
Information flow integration	0.11	0.12	0.13
Financial flow integration	0.25**	0.29***	0.24**
Physical flow integration	0.29***	0.22**	0.21**
Interaction terms:			
SEI × Information flow integration		−0.10	
SEI × Financial flow integration		0.28***	
SEI × Physical flow integration		−0.26***	
EEI × Information flow integration			−0.11
EEI × Financial flow integration			0.27***
EEI × Physical flow integration			−0.24***
Control variables:			
Firm size	0.07	0.05	0.06
Firm region	0.04	0.05	0.03
Firm age	0.01	0.01	0.01
Product sectors	−0.03	−0.02	−0.03
Intercept	0.22**	0.04	0.03
Residual standard error	0.15	0.13	0.13
Adjusted *R*-squared	0.35	0.46	0.47
F-statistic	28.34***	31.66***	33.49***

Note: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

data and the measurement model (Hoehle & Venkatesh, 2015). The other model fits, including the comparative fit index (0.98), incremental fit index (0.98), normed fit index (0.92), and Tucker-Lewis index (0.98), also suggest that an adequate fit exists between the data and the measurement model (Hulland, 2015). Therefore, our measurement model exhibits satisfactory properties.

5. Analysis and results

5.1. DEA analysis and results of operational efficiency

We applied DEA Model (I) to compute the efficiencies of all sampled firms and report the results of the analysis of efficiency measures. The statistics of the dataset and the efficiency scores for all firms are tabulated in Table A.3. θ_k represents the different efficiency measurement for DMU_k. The mean, standard deviation, maximum and minimum of different DMU decisions are displayed in Table A.3. Specifically, after applying the Wilcoxon signed-ranks test to paired efficiency results of DMUs for operational, sustainability, and business decisions, we did not find a significant discrepancy between the scores obtained from the three DMUs and the overall efficiency measurements for all firms. Therefore, we used overall efficiency measurements to analyze the influence of different supply chain decisions and sustainability decisions on operational performance.

5.2. Hierarchical regression analysis

Using hierarchical regression analysis (Hsieh, Rai, & Keil, 2008), we tested latent variables step-by-step to determine the explanation for these variances in the dependent variable. To demonstrate robustness, we built and examined two models (see Table 2), with both models including a different set of variables. We analyzed the main effects of the independent variables and examined the interaction effects between the independent variables. We computed the incremental explained variance and *F* hierarchical value of different models to validate the significance level.

Table 2 indicates the results of the hierarchical regression analysis, including standardized path coefficients, explained construct variances, and *F* hierarchical values. We compared the changes in R^2 between two adjacent models to obtain the *F* hierarchical values. Significant relationships between the independent variables and operational efficiency were identified in Model 1. All the independent variables in Model 1 have significant and positive effects on the dependent variable. Supply chain integration, SEI and EEI significantly and positively influence operational efficiency.

The interaction effects between SEI and supply chain integration, and EEI and supply chain integration, on operational efficiency in Model 2 are significant and positive. The significance level of the *F* hierarchical value in each model is verified by these results. The path coefficients of SEI and EEI against operational efficiency increase with supply chain integration, which indicates the stronger effectiveness of these two sustainable operations in the presence of supply chain integration. Adding the interaction terms further increased the predictive power of the regression model, which was statistically significant.

To further analyze the influence of supply chain integration on the relationship between sustainability inputs and operational efficiency, we considered a construct introduced by Rai et al. (2006), supply chain process integration, which includes physical flow integration, financial flow integration and information flow integration. From the perspective of process integration, physical flow integration represents the degree to which a firm uses process optimization with its supply chain partners to manage the stocking and flow of materials and finished goods. Financial flow integration represents the degree to which exchange of financial resources between a focal firm and its supply chain partners is driven by workflow events. Information flow integration represents the extent of operational, tactical, and strategic information sharing that occurs between a retailer and its supply chain partners (Rai et al., 2006). The cost that retailers incur in relation to these integrations can improve operational competency by reducing the costs of production, transportation, warehousing, and logistics (Lei & Goldhar, 1991). These integrations could enable firms to improve material handling and resolve conflicting objectives. We explore the respective impacts of financial flow integration, physical flow integration and information flow integration on operational efficiency. Table 3 presents the estimation results of hierarchical regression.

Table 3 presents the results of the influence of sustainability and supply chain process integration on different retailers' efficiency. From Table 3, We find: (1) for all retailers, the coefficient of the SEI and EEI for the efficiency is positive and highly

Table 4
Sustainability analysis in perspective of SEI.

Different level of FFI				Different level of PFI			
FFI	Coef. SEI[b]	Standard Error 1[c]	*t*-value	PFI	Coef. SEI[b]	Standard Error 2[d]	*t*-value
0.1	0.10	0.10	0.96	0.1	0.64	0.10	5.91
0.3	0.19	0.19	0.97	0.3	0.54	0.22	2.79
0.5	0.25	0.23	1.13	0.5	0.40	0.27	1.37
0.65[a]	0.33	0.31	1.09	0.68[a]	0.30	0.30	1.00
0.8	0.36	0.33	1.19	0.8	0.24	0.36	0.75
1	0.43	0.40	1.17	1	0.16	0.44	0.41

[a] *Note*: FFI, PFI and SEI denote financial flow integration, physical flow integration and SEI. Mean value in the study.
[b] Coef. SEI = 0.24 + 0.28 FFI - 0.26 PFI. (with FFI and PFI mean-centered).
[c] Standard Error 1 (Coef. SEI)^2 = (Var(β_{SEI}) + FFI^2 × Var($\beta_{FFI\times SEI}$))^2 + 2 FFI × COV(β_{SEI}, $\beta_{SEI\times FFI}$).
[d] Standard Error 2 (Coef. SEI)^2 = (Var(β_{SEI}) + PFI^2 × Var($\beta_{PFI\times SEI}$))^2 + 2 PFI × COV(β_{SEI}, $\beta_{SEI\times PFI}$).

significant, which is consistent with the results from Table 2; (2) the interaction coefficient between SEI and financial flow integration is positive and highly significant, showing complementarity between these constructs, and that between SEI and physical flow integration is negative and also highly significant, indicating substitutability between these constructs; (3) the interaction coefficient between EEI and financial flow integration is positive and significant, and that between EEI and physical flow integration is negative and also significant. Adding the interactions between SEI or EEI and physical or financial flow integration further increased the predictive power of the regression model which was statistically significant. However, the interactions between SEI or EEI and information flow integration were not statistically significant. We therefore find evidence that retailers incurring a greater advantage from a high degree of interaction between sustainability integration and financial flow integration are more likely to operate efficiently, while those experiencing greater pressure from a high degree of interaction between sustainability integration and physical flow integration are more likely to operate inefficiently.

The *R*-squared values of all the models, including main effects, were above 0.35, indicating that our model was a good fit. It is worth noting that the four interaction terms increased the explained variance in operational efficiency when comparing Model 2 with Model 1, and Models 4 and 5 with Model 3. The F statistics of the changed *R*-squared of all the models were also significant.

5.3. Nonlinear analysis and conditions under which to increase sustainable operations for efficiency

We observe a complementary relationship within sustainability decisions between supply chain process integration and sustainable operations. According to the results set out in Table 3, the combined effects of SEI and financial flow integration, EEI and financial flow integration, SEI and physical flow integration, and EEI and physical flow integration, are significant and superior to their separate effects. In particular, SEI and EEI are more effective when associated with high levels of financial flow integration and low levels of physical flow integration. To interpret the variable interactions, we used a technique from Ping (2002), Titah and Barki (2009) to analyze the nonlinear relationship between sustainable operations and supply chain process integration in the retail industry. From Model 4 in Table 3, we find:

Operational efficiency = 0.24 Socio economic integration + 0.28 Socio economic integration × Financial flow integration − 0.26 Socio economic integration × Physical flow integration + others

Thus, a higher level of financial flow integration and a lower level of physical flow integration ensures flexible SEI, resulting in higher operational efficiency. These effects vary at different levels of financial and physical flow integration, as shown in Table 4. Table 4 demonstrates complementarity between SEI and financial flow integration, and substitutability between SEI and physical flow integration.

From Table 4, we find that the effect of SEI is strong and positive when the level of financial flow integration is high. When the level of financial flow integration decreases, the positive coefficient of SEI on operational efficiency decreases and becomes insignificant. When physical flow integration decreases, SEI also shows a positive effect on operational efficiency. These findings show the importance of sustainable operations on supply chain process integration, which implies that financial and physical flow integration moderate the effects of SEI on operational efficiency. Then we have the following Proposition 1, Condition 1, and Theorem 1:

Proposition 1. *SEI and financial flow integration show complementarity, while SEI and financial flow integration show substitutability.*

Condition 1. *Coefficient of SEI* (0.24 + 0.28 Financial flow integration −0.26 Physical flow integration) > 0, then we have:

Theorem 1. *If a retailer satisfies Condition 1, the increase in SEI can improve operational efficiency. If a retailer does not satisfy Condition 1, to achieve a higher level of operational efficiency, the retailer should reduce its SEI.*

We can obtain similar results in the interaction between supply chain integration and EEI. From Model 5 in Table 3, we find:

Operational efficiency = 0.21 EEI + 0.27 EEI × Financial flow integration − 0.24 EEI × Physical flow integration + others

Table 5 shows that EEI effects vary at different levels of financial flow integration and physical flow integration.

We find substitutability between supply chain integration and EEI. Specifically, EEI is more effective alongside high financial flow integration and low physical flow integration. At a high level of financial flow integration, the relationship between EEI and operational efficiency becomes stronger according to Table 5. When the level of physical flow integration is high enough, the influence of EEI becomes less significant. The substitution relationship between EEI and supply chain integration provides a clear picture of these two constructs and their effects on operational efficiency. Then we have the following Proposition 2, Condition 2 and Theorem 2:

Proposition 2. *EEI and financial flow integration shows complementarity, while EEI and financial flow integration shows substitutability.*

Condition 2. *Coefficient of EEI* (0.21 + 0.27 Financial flow integration −0.24 Physical flow integration) > 0.

Theorem 2. *If a retailer satisfies Condition 2, the increase in EEI can improve operational efficiency. If a retailer does not satisfy Condition 2, to achieve a higher level of operational efficiency, the retailer should reduce its EEI.*

Table 5
Sustainability analysis from the perspective of EEI.

Different level of FFI				Different level of PFI			
FFI	Coef. EEI[b]	Standard Error 1[c]	*t*-value	PFI	Coef. EEI[b]	Standard Error 2[d]	*t*-value
0.1	0.18	0.06	2.84	0.1	0.70	0.16	4.56
0.3	0.21	0.07	2.92	0.3	0.54	0.22	2.37
0.5	0.26	0.09	3.13	0.5	0.45	0.32	1.40
0.65[a]	0.31	0.10	3.67	0.68[a]	0.31	0.42	0.83
0.8	0.39	0.12	3.69	0.8	0.26	0.47	0.57
1	0.40	0.12	3.77	1	0.13	0.58	0.24

[a] *Note*: FFI, PFI and SEI denote financial flow integration, physical flow integration and SEI. Mean value in the study.
[b] Coef. EEI = 0.21 + 0.27 FFI − 0.24 PFI. (with FFI and PFI mean-centered).
[c] Standard Error 1 (Coef. EEI)^2 = (Var(β_{EEI}) + FFI^2 × Var($\beta_{FFI\times EEI}$))^2 + 2 FFI × COV(β_{EEI}, $\beta_{EEI\times FFI}$).
[d] Standard Error 2 (Coef. EEI)^2 = (Var(β_{EEI}) + PFI^2 × Var($\beta_{PFI\times EEI}$))^2 + 2 PFI × COV(β_{EEI}, $\beta_{EEI\times PFI}$).

Theorems 1 and 2 can help managers solve the question of how to adjust their SEI and EEI to achieve optimal operational efficiency. The complementary relationship provides a clearer picture of how supply chains leverage sustainability for operational efficiency. These findings highlight the importance of supply chain integration and sustainable operations and their interaction in operational efficiency.

6. Discussion

This study not only provides new theoretical implications for sustainability and supply chain management but also generates practical implications to help managers effectively implement improvements in supply chains and sustainable operations in the retail industry.

6.1. Implications for theories

6.1.1. New development of CSV and CSR theories

This research contributes to the theories of CSV and CSR in three respects (Porter & Kramer, 2011). First, while CSV theory has not previously provided suggestions at the operational level, this paper enriches CSV theory by delving into operational details, which were formerly considered black boxes in corporate strategy. Second, the existing literature on CSV explores the possibility of creating shared value, without specifying the conditions, pathways, or approaches required to achieve CSV. Our research partially fills this gap by presenting an implementable approach for sustainable operations to increase efficiency. Third, we confirm the difficulty of implementing CSV by "going beyond trade-off". For example, while retailers (e.g., Walmart) tend to focus on increasing physical flow integration, this does not always benefit sustainable operations. Thus, the study of CSV only at the level of corporate strategy is not enough for corporations.

6.1.2. New capability of supply chain process integration

The findings of this paper provide implications for and contributions to theories in supply chain management. This paper addresses a research gap in the supply chain literature by identifying a new capability of supply chain process integration which can have a positive impact on the effect of sustainable operations on efficiency. We also found the effect of sustainability on operational efficiency to increase in the presence of physical flow integration and financial flow integration.

6.1.3. Role of sustainable operations in the retailing

This paper also provides implications for and contributions to the literature in the retailing. We found the role of sustainable operations to be complex. Our research indicates that the effect of supply chain integration on operational efficiency increases in the presence of high SEI and high EEI. Our findings highlight the positive role of sustainability in supply chain operations and reveal how SEI and EEI significantly moderate the effects of supply chain integration on operational efficiency. This research further contributes to the retailing literature by indicating how high operational efficiency can be achieved in the supply chain through the adoption of sustainable retailing operations.

6.1.4. Mechanism to increase the efficiency of sustainable supply chain

In advancing the view that sustainability has a moderating role in the implementation of supply chain practices, we identify a mechanism for how sustainable operations can support the effectiveness of supply chain process integration. The mechanism is as follows: as indicated in Table 3, high levels of financial flow integration and low levels of physical flow integration result in high operational efficiency when SEI and EEI are effectively involved in these supply chain operations.

6.1.5. Enriching the theory of internal fit

Strategic internal fit theory (Miller, 1992) can influence operations strategy. Strategic fit can be classified into environmental fit and internal fit (Miller, 1992), and this paper provides new implications for internal fit. While the research on environmental fit is rich in CSV theory, Bozarth and McDermott (1998, p. 438) suggested that future research place "more emphasis on internal fit." Therefore, this paper provides insights into the internal fit between supply chain integration and sustainable operations, finding that the effect of sustainability on operational efficiency increases only under conditions with appropriate physical flow integration and financial flow integration. Our finding is surprising: the interaction of sustainable operations and physical flow integration (PFI) is negatively correlated with efficiency. We demonstrate the plausibility of this finding through an analysis using the following measure items of PFI designed by Rai et al. (2006). (1) While "inventory holdings are minimized across the supply chain"(Rai et al., 2006) with a high value of PFI, social programs may increase inventory cost. For example, Nestlé's "Fairtrade Sourcing Program" will increase holding inventory to receive goods from Fairtrade farmers widely dispersed in remote regions. (2) With a high value of PFI, supply chain–wide inventory is jointly managed with suppliers and logistics partners (Rai et al., 2006). However, smaller suppliers and local farmers hardly have the capacity (e.g., logistics, facilities and information systems) to join in supply chain management. (3) "Suppliers and logistics partners deliver products and materials just in time" with a high value of PFI (Rai et al., 2006). However, green goods may require more time to produce and deliver. For example, for organic goods, the prohibition on chemicals and pesticides means that pest reduction is more time intensive. The

shipping of ethical products, when compared to standard goods in large supply chains like that of Walmart, requires more time spent on smaller loads. (4) "Distribution networks are configured to minimize total supply chain–wide inventory costs" (Rai et al., 2006) with a high value of PFI. Unfortunately, sustainable activities may influence the configuration of distribution networks. For example, Walmart applied its "direct farm" program in a number of developing countries, which led to decentralized regional distribution networks linking local farms, reducing cost efficiency (Gong, 2013).

PFI is part of supply chain process integration. SEI and EEI are mainly about the processes used in sustainable operations. Internal fit is the third type of fit "among variables of process" proposed by Miller (1992, p. 163). Considering the emphasis placed by retailers like Walmart and Tesco on physical flow integration, this partially explains why some retailers are unable to increase efficiency after adopting sustainable operations. Our research enriches the theory of internal fit by providing operational details.

6.2. Implications for practice

6.2.1. Practical Research Question 1

Although sustainable operations are indeed relevant to efficiency, they cannot always lead to high efficiency due to their interaction with supply chain integration. If supply chain integration is low, efficiency may remain low even given more sustainable operations. For example, a measure item of supply chain integration is "our company uses cross functional teams in process improvement and new product development" (Patnayakuni et al., 2006; Rai et al., 2006). In the case of Nike, when the sustainability and new product development department proposed the environmentally friendly "Considered" shoes, they had not built an effective cross-functional organization with the customers relationship management (CRM) team (Reena, 2009). Thus, this sustainable operation, without an internal fit with supply chain integration, failed to achieve excellence in performance. This answers Research Question 1 and indicates that it is indeed necessary to identify an implementation condition.

6.2.2. Practical Research Question 2

For practical Research Question 2, we find that: SEI and EEI have more pronounced effects on operational efficiency with high levels of financial flow integration and low levels of physical flow integration. We identify two implementable conditions for SEI and EEI: information flow integration, and financial flow integration. These provide insight into managerial practice. When these conditions are satisfied, a retailer should increase its sustainable operations for optimal operational efficiency. This answers Research Question 2. Theorems 1 and 2 can help managers adjust their SEI and EEI for increase efficiency. This complementary relationship provides a clearer picture of how supply chains leverage sustainability to achieve operational efficiency. These findings highlight the importance of supply chain integration and sustainable operations, and their interaction in relation to operational efficiency.

6.2.3. Implications for the retailing practice

For the retailing practice, our findings offer guidelines for retailers to align sustainable operations with operational competencies. First, to improve operational competencies, organizations should develop sustainable operations capabilities. Managers should combine sustainable operations and supply chain operations in order to achieve operational efficiencies. Second, building supply chain capabilities is also not sufficient for an organization to achieve operational competencies. Retailers must build cross-value integration to ensure that supply chain, financial, and physical flows are integrated. Managers may adjust retailers' SEI and EEI in accordance with financial and physical flow integration to achieve optimal efficiency.

7. Concluding remarks

This study developed a methodological framework based on DEA, considering multiple inputs and outputs, to study and understand the role of sustainable operations in the retail industry. Our methods considered the advantages of DEA models in performance evaluation and efficiency measurement, and their disadvantages in further mechanism discovery. Without assuming parameter values, DEA assesses the performance of an organization by calculating and comparing it with the efficiency frontier, which is a function that indicates the minimum attainable level of inputs corresponding to a given quantity of outputs. Using a sample of 124 retailers, we proposed a DEA model that integrates sustainability and supply chain operations into the theoretical framework of a sustainable supply chain. Compared with previous studies, our model, by considering multiple-source data and sustainability decision impacts, can explain the non-linear relationship between operational activities, sustainability impacts, and efficiency. We applied DEA method to provide a rigorous efficiency measurement for sustainable supply chains, and integrated it with other quantitative methods, including hierarchical regression analysis and nonlinear analysis, to explain the results of DEA models and provide new findings in relation to the research question.

This study had some limitations and may need future research. We discovered a mechanism governing the interaction of supply chain integration with sustainable operations to increase efficiency, but it is unclear whether other mechanisms exist. Our target audience is in the field of operations management and operations strategy. Thus, our implementation condition is "internal operational conditions". It is unclear whether other conditions at the level of corporate strategy need to be satisfied. Our findings are also limited by sample size and data collection time. Our findings are based on evidence from the retailing industry, and we do not know whether similar results can be found in other industries.

Acknowledgments

We gratefully acknowledge the editor and three referees for their valuable comments. This research is supported by NSFC (Nos. 71828101; 71620107002) and NSSFC (No. 16ZDA013).

Appendix

A.1. Bootstrap procedure

One technique applicable to DEA efficiency is proceeded in two stages. First, we use DEA models to calculate the efficiency scores, and then the efficiency scores obtained by DEA models can be used in regress analysis as a dependent variable. This approach is applied by Chortareas et al. (2013), Curi et al. (2015), Wanke (2016), and Simar and Wilson (2007), among others. Although it is commonly used, there is discussion in the literature whether this characteristic makes the efficiency scores truncated or fractional (McDonald, 2009). Simar and Wilson (2007) have argued that DEA efficiency estimates lacking a sound statistical foundation are somehow censored. However, Banker and Natarajan (2008) show that the two-stage approach for DEA can yield statistically consistent coefficient estimators under certain general distributional assumptions. Johnsonab (2012) further show that the estimators remain statistically consistent even when the first-stage input and output variables in DEA are correlated with the second-stage variables in the regression model. Recent researches (Simar and Wilson, 2007; Wanke, 2016; Curi et al., 2015; Chortareas et al., 2013)

suggest that bootstrap appears to offer the way to approximate asymptotic distribution of the distance function estimators in multivariate settings.

Therefore, we apply the following bootstrap procedure based on Algorithm 1 in Simar and Wilson (2007), using 2000 bootstrap replications for the confidence intervals of the estimated coefficients. See Table A.4 in Appendix.

Step 1. Using the original data of inputs and outputs, we compute the efficiency score θ_k for DMU_k.

Step 2. We estimate with the following equation to re-identify the efficiency score $\theta_k = Z_k\beta + u_k$, where θ_k is the efficiency score for DMU_k. X_k is a vector of explanatory variables, including a constant term. u_k is an error term with a standard error of σ_u. Since efficiency scores θ_k are truncated below from zero and above from unity, u_k is an error term with double truncation. Use the method of maximum likelihood to obtain an estimate β and an estimate σ_ε in the truncated regression of θ_k on Z_k.

Step 3. For each $k = 1, \ldots, n$, we draw ε_k from the $N(0, \sigma_\varepsilon^2)$ distribution with truncation at $(1 - Z_k\beta)$, then compute $\theta_k^* = Z_k\beta^* + \varepsilon_k$ and estimate the truncated regression of θ_k^* on Z_k, yielding estimates $(\beta^*, \sigma_\varepsilon^*)$.

Step 4. Loop over Step 3 for 2000 times to obtain a set of bootstrap estimates $\{\beta_t^*, \sigma_{\varepsilon,t}^*\}_{t=1}^{2000}$.

Step 5. Use the bootstrap values in $\{\beta_t^*, \sigma_{\varepsilon,t}^*\}_{t=1}^{2000}$ for each element of β and for σ_ε.

Table A.4 reports the results of parameter estimates in truncated regression and their bootstrapped confidence intervals. We also present the mean and standard deviation for lower and upper bounds of the efficiency measures based on a bootstrapping method at a confidence level of 95%. The truncated regression analysis in Table A.4 offers a robust check and verifies our results from the regression model.

A.2. Tables and figure

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ejor.2019.03.019.

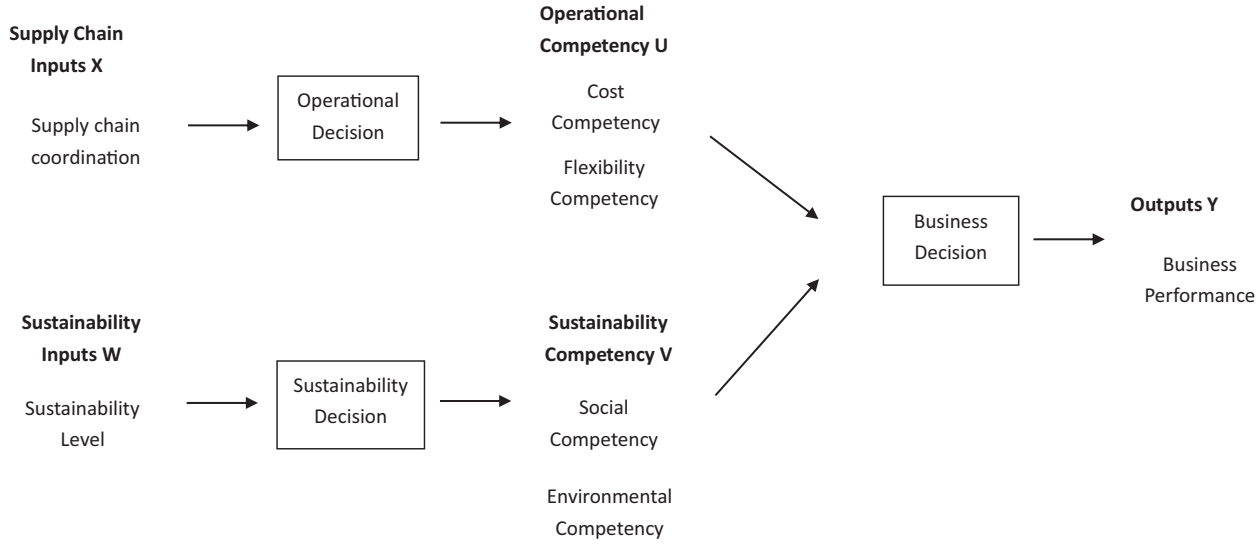

Fig. A.1. Decision structure in the perspective of DEA.

Table A.1
Sample profile of 124 organizations.

		Range	Observations	%
Firm size	1	< USD 10 billion	10	8.06
	2	USD 10 to 100 billion	36	29.03
	3	> USD 100 billion	78	62.90
Firm region	1	Asia	51	41.13
	2	Europe	41	33.06
	3	North America	22	17.74
	4	Others	10	8.06
Firm age	1	< 10 years	26	20.96
	2	10–20 years	65	52.42
	3	> 20 years	33	26.61
Product sectors	1	Fast-moving consumer	75	60.48
	2	Fashion	8	6.45
	3	Hardlines and Leisure	7	5.65
	4	Diversified	34	27.42

Table A.2
The correlations of construct measurement.

	SL	SCC	SEI	EEI	SC	EC	CC	FC	FFI	PFI	IFI	SCI	BP
SL	1.00												
SCC	0.11	1.00											
SEI	0.13	0.14	1.00										
EEI	0.11	0.21	0.27	1.00									
SC	0.12	0.17	0.23	0.17	1.00								
EC	0.21	0.27	0.17	0.19	0.31	1.00							
CC	0.19	0.25	0.29	0.28	0.13	0.17	1.00						
FC	−0.12	0.32	−0.22	0.04	−0.11	0.13	−0.11	1.00					
FFI	0.13	−0.07	0.16	0.14	0.19	0.13	0.16	−0.12	1.00				
PFI	0.16	0.15	0.18	0.20	0.10	0.01	0.17	−0.20	0.22	1.00			
IFI	0.13	0.13	0.11	0.10	0.07	0.14	0.14	−0.03	0.21	0.17	1.00		
SCI	0.15	0.10	0.18	0.19	0.06	0.07	0.08	0.01	0.22	0.19	0.17	1.00	
BP	0.12	0.13	0.20	0.14	0.16	0.15	0.20	−0.10	0.12	0.17	0.15	0.11	1.00

Table A.3
Data description of efficiency measures calculated by DEA model.

θ	Operational DMU	Sustainability DMU	Business DMU	Overall efficiency measures
Mean	0.64	0.66	0.63	0.61
S.D.	0.30	0.30	0.34	0.35
Max	1	1	1	1
Min	0.01	0.02	0.02	0.01

Note: Data are from 124 firms.

Table A.4
Truncated regression analysis.

	Efficiency measurement θ	
	Model 6	Model 7
Independent variables:		
Supply chain integration	0.187*	0.277***
SEI	0.224**	0.192**
EEI	0.266**	0.163*
Interaction terms:		
SEI × supply chain integration		0.124*
EEI × supply chain integration		0.159*
Control variables:		
Firm size	0.101	0.023
Firm region	0.067	0.014
Firm age	0.021	0.026
Product sectors	0.129	0.044
Intercept	−0.167*	0.047
95%C.I. lower bound Mean	0.51	0.39
95%C.I. upper bound Mean	0.69	0.70

Note: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.
The coefficient estimates are transformed to represent the marginal effects evaluated at the means of the independent variables. Each path coefficient is standardized.

References

Agrawal, V. V., Atasu, A., & Ittersum, K. V. (2015). Remanufacturing, third-party competition, and consumers' perceived value of new products. *Management Science, 61*(1), 60–72.

Agrawal, V. V., & Thomas, V. M. (2012). Is leasing greener than selling? *Management Science, 58*(3), 523–533.

Angell, L. C., & Klassen, R. D. (1999). Integrating environmental issues into the mainstream: An agenda for research in operations management. *Journal of Operations Management, 17*(5), 575–598.

Atasu, A., & Cetinkaya, S. (2006). Lot sizing for optimal collection and use of remanufacturable returns over a finite life-cycle. *Production & Operations Management, 15*(4), 473–487.

Atasu, A., Guide, V. D. R., & Wassenhove, L. N. (2008). Product reuse economics in closed-loop supply chain research. *Production & Operations Management, 17*(5), 483–496.

Avci, B., Girotra, K., & Netessine, S. (2014). Electric vehicles with a battery switching station: Adoption and environmental impact. *Management Science, 61*(4), 772–794.

Aviles-Sacoto, S., Cook, W. D., Imanirad, R., & Zhu, J. (2015). Two-stage network DEA: When intermediate measures can be treated as outputs from the second stage. *Journal of Operational Research Society, 66*(11), 1868–1877.

Banker, R. D., & Natarajan, R. (2008). Evaluating contextual variables affecting productivity using data envelopment analysis. *Operations Research, 56*(1), 48–58.

Blass, V., Corbett, C. J., Delmas, M. A., & Muthulingam, S. (2014). Top management and the adoption of energy efficiency practices: Evidence from small and medium-sized manufacturing firms in the US. *Energy, 65*(2), 560–571.

Bozarth, C., & McDermott, C. (1998). Configurations in manufacturing strategy: A review and directions for future research. *Journal of Operations Management, 16*(4), 427–439.

Cachon, G. P. (2014). Retail store density and the cost of greenhouse gas emissions. *Management Science, 60*(8), 1907–1925.

Chen, C. L., Zhu, J., Yu, J. Y., & Noori, H. (2012). A new methodology for evaluating sustainable product design performance with two-stage network data envelopment analysis. *European Journal of Operational Research, 221*(2), 348–359.

Chen, I. J., & Paulraj, A. (2004). Towards a theory of supply chain management: The constructs and measurements. *Journal of Operations Management, 22*(2), 119–150.

Chen, Y., Liang, L., Yang, F., & Zhu, J. (2006). Evaluation of information technology investment: A data envelopment analysis approach. *Computers & Operations Research, 33*(5), 1368–1379.

Chen, Y., & Zhu, J. (2004). Measuring information technology's indirect impact on firm performance. *Information Technology & Management Journal, 5*(1–2), 9–22.

Cheng, B., Ioannou, I., & Serafeim, G. (2014). Corporate social responsibility and access to finance. *Strategic Management Journal, 35*(1), 1–23.

Chortareas, G. E., Girardone, C., & Ventouri, A. (2013). Financial freedom and bank efficiency: evidence from the european union. *Journal of Banking & Finance, 37*(4), 1223–1231.

Cook, W. D., Liang, L., & Zhu, J. (2010). Measuring performance of two-stage network structures by DEA: A review and future perspective. *OMEGA, 38*(2010), 423–430.

Cook, W. D., Seiford, L. M., & Zhu, J. (2004). Models for performance benchmarking: Measuring the effect of e-business activities on banking performance. *OMEGA, 32*(4), 313–322.

Cooper, W. W., & Ruizb, J. L. (2007). Choosing weights from alternative optimal solutions of dual multiplier models in dea. *European Journal of Operational Research, 180*(1), 443–458.

Corbett, C. J., & Decroix, G. A. (2001). Shared-savings contracts for indirect materials in supply chains: Channel profits and environmental impacts. *Management Science, 47*(7), 881–893.

Corbett, C. J., & Klassen, R. D. (2006). Extending the horizons: Environmental excellence as key to improving operations. *Manufacturing & Service Operations Management, 8*(1), 5–22.

Corbett, C. J., & Kleindorfer, P. R. (2003). Environmental management and operations management: Introduction to the third special issue. *Production & Operations Management, 12*(12), 287–289.

Curi, C., Lozano-Vivas, A., & Zelenyuk, V. (2015). Foreign bank diversification and efficiency prior to and during the financial crisis: does one business model fit all? *Journal of Banking & Finance, 61*, S22–S35.

Derwall, J., Guenster, N., Bauer, R., & Koedijk, K. (2005). The eco-efficiency premium puzzle. *Financial Analysts Journal, 61*(2), 51–63.

Dijkstra, T. K., & Henseler, J. (2015). Consistent partial least squares path modeling. *MIS Quarterly, 39*(2), 297–316.

Du, J., Wang, J., Chen, Y., Chou, S. Y., & Zhu, J. (2014). Incorporating health outcomes in pennsylvania hospital efficiency: An additive super-efficiency DEA approach. *Annals of Operations Research, 221*(1), 161–172.

Dyllick, T., & Kai, H. (2002). Beyond the business case for corporate sustainability. *Business Strategy & the Environment, 11*(2), 130–141.

Dyson, R. G., Allen, R., Camanho, A. S., Podinovski, V. V., Sarrico, C. S., & Shale, E. A. (2001). Pitfalls and protocols in DEA. *European Journal of Operational Research, 132*(2), 245–259.

Eccles, R. G., Ioannou, I., & Serafeim, G. (2014). The impact of corporate sustainability on organizational processes and performance. *Management Science, 60*(11), 2835–2857.

Elkington, J. (1998). *Cannibals with forks: The triple bottom line of 21st century business*. Gabriola Island, BC: New Society Publishers.

Ettlie, J. E., & Reza, E. (1992). Organizational integration and process innovation. *Academy of Management Journal, 35*(4), 795–827.

Fabbe-Costes, N., Roussat, C., Taylor, M., & Taylor, A. (2014). Sustainable supply chains: A framework for environmental scanning practices. *International Journal of Operations & Production Management, 34*(5), 664–694.

Färe, R., Grosskopf, S., Lovell, C. A., & York, N. (1985). *Measurement of efficiency of production*. Springer.

Flynn, B. B., Huo, B., & Zhao, X. (2010). The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of Operations Management, 28*(1), 58–71.

Foo, L. M. (2007). Stakeholder engagement in emerging economies: Considering the strategic benefits of stakeholder engagement in a cross-cultural and geopolitical context. *Corporate Governance, 7*(4), 379–387.

Gholami, R., Sulaiman, A., Ramayah, T., & Molla, A. (2013). Senior managers perception on green information system (IS) adoption and environmental performance: Results from a field survey. *Information & Management, 50*(7), 431–438.

Gielens, K., & Dekimpe, M. G. (2007). The entry strategy of retail firms into transition economies. *Journal of Marketing, 71*(2), 196–212.

Gong, Y. (2013). *Global operations strategy: Fundamentals and practice*. Berlin: Springer.

Hart, S. L. (1997). Beyond greening: Strategies for a sustainable world. *Harvard Business Review, 75*(1), 66–76.

Hill, C. A., & Scudder, G. D. (2002). The use of electronic data interchange for supply chain coordination in the food industry. *Journal of Operations Management, 20*(4), 375–387.

Hillman, A. J., & Keim, G. D. (2001). Shareholder value, stakeholder management, and social issues: What's the bottom line? *Strategic Management Journal, 22*(2), 125–139.

Hoehle, H., & Venkatesh, V. (2015). Mobile application usability: Conceptualization and instrument development. *MIS Quarterly, 39*(2), 435–472.

Hsieh, J., Rai, A., & Keil, M. (2008). Understanding digital inequality: Comparing continued use behavioral models of the socio-economically advantaged and disadvantaged. *MIS Quarterly, 32*(1), 97–126.

Hulland, J. (2015). Use of partial least squares (PLS) in strategic management research: A review of four recent studies. *Strategic Management Journal, 20*(2), 195–204.

Johnsonab, A. L. (2012). One-stage and two-stage dea estimation of the effects of contextual variables. *European Journal of Operational Research, 220*(2), 559–570.

Kiron, D., Kruschwitz, N., Haanæs, K., Reeves, M., & Goh, E. (2013). *The innovation bottom line* (pp. 1–20). MIT Sloan Management Review, Research Report, Winter 2013.

Klassen, R. D., & McLaughlin, C. P. (1996). The impact of environmental management on firm performance. *Management Science, 42*(8), 1199–1214.

Klassen, R. D., & Vachon, S. (2003). Collaboration and evaluation in the supply chain: The impact on plant-level environmental investment. *Production & Operations Management, 12*(3), 336–352.

Klassen, R. D., & Whybark, D. C. (1999). The impact of environmental technologies on manufacturing performance. *Academy of Management Journal, 42*(6), 599–615.

Kleindorfer, P. R., Singhal, K., & Wassenhove, L. N. V. (2005). Sustainable operations management. *Production and Operations Management, 14*(4), 482–492.

Kolodny, H., Jardine, A. K. S., & Tsang, A. H. C. (1999). Measuring maintenance performance: A holistic approach. *International Journal of Operations & Production Management, 19*(7), 691–715.

Kretschmer, A., Spinler, S., & Wassenhove, L. N. V. (2014). A school feeding supply chain framework: Critical factors for sustainable program design. *Production and Operations Management, 23*(6), 990–1001.

Lambert, D. M., & Pohlen, T. L. (2001). Supply chain metrics. *International Journal of Logistics Management, 12*(1), 1–19.

Larson, A. L., Teisberg, E. O., & Johnson, R. R. (2000). Sustainable business: Opportunity and value creation. *Interfaces, 30*(3), 1–12.

Lee, S. G., Trimi, S., & Kim, C. (2013). The impact of cultural differences on technology adoption. *Journal of World Business, 48*(1), 20–29.

Lei, D., & Goldhar, J. D. (1991). Computer-integrated manufacturing (CIM): Redefining the manufacturing firm into a global service business. *International Journal of Operations & Production Management, 11*(10), 5–18.

Linton, J. D., Klassen, R., & Jayaraman, V. (2007). Sustainable supply chains: An introduction. *Journal of Operations Management, 25*(6), 1075–1082.

Longoni, A., & Cagliano, R. (2015). Environmental and social sustainability priorities: Their integration in operations strategies. *International Journal of Operations & Production Management, 35*(2), 216–245.

Matos, S., & Hall, J. (2007). Integrating sustainable development in the supply chain: The case of life cycle assessment in oil and gas and agricultural biotechnology. *Journal of Operations Management, 25*(6), 1083–1102.

Mcdonald, J. (2009). Using least squares and tobit in second stage dea efficiency analyses. *European Journal of Operational Research, 197*(2), 792–798.

McGuire, J. B., Sundgren, A., & Schneeweis, T. (1988). Corporate social responsibility and firm financial performance. *Academy of Management Journal, 31*(4), 854–872.

Mejias, A. M., Paz, E., & Pardo, J. E. (2016). Efficiency and sustainability through the best practices in the logistics social responsibility framework. *International Journal of Operations & Production Management, 36*(2), 164–199.

Melnyk, S. A., Sroufe, R. P., & Calantone, R. J. (2003). A model of site-specific antecedents of ISO 14001 certification. *Production & Operations Management, 12*(12), 369–385.

Miller, D. (1992). Environmental fit versus internal fit. *Organization Science, 3*(2), 159–178.

Muthulingam, S., Corbett, C., Benartzi, S., & Oppenheim, B. (2013). Energy efficiency in small and medium-sized manufacturing firms: Order effects and the adoption of process improvement recommendations. *Manufacturing & Service Operations Management, 15*(4), 596–615.

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. *International Journal of Operations & Production Management, 15*(4), 80–116.

Nicolas, J. P., Pocheta, P., & Poimboeuf, H. (2003). Towards sustainable mobility indicators: Application to the lyons conurbation. *Transport Policy, 10*(3), 197–208.

Oh, C. H., Sohl, T., & Rugman, A. M. (2015). Regional and product diversification and the performance of retail multinationals. *Journal of International Management, 21*(3), 220–234.

Park, J., Lee, D., & Zhu, J. (2014). An integrated approach for ship block manufacturing process performance evaluation: Case from a korean shipbuilding company. *International Journal of Production Economics, 156*(156), 214–222.

Patnayakuni, R., Rai, A., & Seth, N. (2006). Relational antecedents of information flow integration for supply chain coordination. *Journal of Management Information Systems, 23*(1), 13–49.

Pil, F. K., & Rothenberg, S. (2009). Environmental performance as a driver of superior quality. *Production & Operations Management, 12*(3), 404–415.

Ping, R. A. (2002). Interpreting latent variable interactions. In *Proceedings of the 2002 American marketing association (winter) educators conference* (pp. 213–220). Austin, TX. February 22–25

PlanetRetail (2017). http://www.planetretail.net.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology, 88*(5), 879.

Porter, M., & Kramer, M. (2006). Strategy & society: The link between competitive advantage and corporate social responsibility. *Harvard Business Review, 84*(12), 78–92.

Porter, M., & Kramer, M. (2011). Creating shared value: How to reinvent capitalism and unleash a wave of innovation and growth. *Harvard Business Review, 84*, 62–77.

Porter, M. E., & van der Linde, C. (1995). Green and competitive: Ending the stalemate. *Harvard Business Review, 73*(5), 120–134.

Pryshlakivsky, J., & Searcy, C. (2017). A heuristic model for establishing trade-offs in corporate sustainability performance measurement systems. *Journal of Business Ethics, 144*(2), 323–342.

Quak, H. J., & De Koster, M. B. M. (2007). Exploring retailers' sensitivity to local sustainability policies. *Journal of Operations Management, 25*(6), 1103–1122.

Rai, A., Patnayakuni, R., & Seth, N. (2006). Firm performance impacts of digitally enabled supply chain integration capabilities. *MIS Quarterly, 30*(2), 225–246.

Rajaram, K., & Corbett, C. J. (2002). Achieving environmental and productivity improvements through model-based process redesign. *Operations Research, 50*(5), 751–763.

Rantasila, K., & Ojala, L. (2012). Measurement of national-level logistics costs and performance. In *Proceedings of the 2012 international transport forum on seamless transport: Making connections*. Leipzig, Germany.

Ray, G., Muhanna, W., & Barney, J. B. (2005). Information technology and the performance of the customer service process: A resource-based analysis. *MIS Quarterly, 29*(4), 625–651.

Reardon, T., Timmer, C. P., & Minten, B. (2012). Supermarket revolution in asia and emerging development strategies to include small farmers. *Proceedings of the National Academy of Sciences, 109*(31), 12332–12337.

Reena, J. (2009). *Nike quietly goes green*. Bloomberg Businessweek. 11 June

Richardson, B. C. (2005). Sustainable transport: Analysis frameworks. *Journal of Transport Geography, 13*(1), 29–39.

Roehrich, K., Grosvold, J. J., & Hoejmose, U. S. (2014). Reputational risks and sustainable supply chain management: Decision making under bounded rationality. *International Journal of Operations & Production Management, 34*(5), 695–719.

Rondinelli, D. A. (2007). Globalization of sustainable development: Principles and practices in transnational corporations. *Multinational Business Review, 15*(1), 1–24.

Russo, M. V., & Fouts, P. A. (1997). A resource-based perspective on corporate environmental performance and profitability. *Academy of Management Journal, 40*(3), 534–559.

Searcy, C. (2012). Corporate sustainability performance measurement systems: A review and research agenda. *Journal of Business Ethics, 107*(3), 239–253.

Servaes, H., & Tamayo, A. (2013). The impact of corporate social responsibility on firm value: The role of customer awareness. *Management Science, 59*(5), 1045–1061.
Sherman, D. H., & Zhu, J. (2006). Benchmarking with quality-adjusted DEA (q-DEA) to seek lower-cost high-quality service: Evidence from a U.S. bank application. *Annals of Operations Research, 145*(1), 301–319.
Simar, L., & Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics, 136*(1), 31–64.
Simonin, B. L. (2015). Ambiguity and the process of knowledge transfer in strategic alliances. *Strategic Management Journal, 20*(7), 595–623.
Tang, A. K. Y., Lai, K., & Cheng, T. C. E. (2016). A multi-research-method approach to studying environmental sustainability in retail operations. *International Journal of Production Economics, 171*(3), 394–404.
Terwiesch, C., & Xu, Y. (2008). Innovation contests, open innovation, and multiagent problem solving. *Management Science, 54*(9), 1529–1543.
Titah, R., & Barki, H. (2009). Nonlinearities between attitude and subjective norms in information technology acceptance: A negative synergy? *MIS Quarterly, 33*(4), 827–844.
Unruh, G., & Ettenson, R. (2010). Growing green: Three smart paths to developing sustainable products. *Harvard Business Review, 88*(6), 94.
Vachon, S., & Klassen, R. D. (2008). Environmental management and manufacturing performance: The role of collaboration in the supply chain. *International Journal of Production Economics, 111*(2), 299–315.
Wanke, P., Azad, M. A. K., & Barros, C. P. (2016). Financial distress and the malaysian dual baking system: a dynamic slacks approach. *Journal of Banking & Finance, 66*, 1–18.
Wiengarten, F., Fan, D., Lo, C. K. Y., & Pagell, M. (2016). The differing impacts of operational and financial slack on occupational safety in varying market conditions. *Journal of Operations Management, 52*(1), 30–45.
Wong, C. W., Lai, K. H., Shang, K. C., Lu, C. S., & Leung, T. K. P. (2012). Green operations and the moderating role of environmental management capability of suppliers on manufacturing firm performance. *International Journal of Production Economics, 140*(1), 283–294.
Wong, C. Y., Boon-Itt, S., & Wong, C. W. (2011). The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance. *Journal of Operations Management, 29*(6), 604–615.
Zhang, X., van Donk, D. P., & van der Vaart, T. (2011). Does ICT influence supply chain management and performance? A review of survey-based research. *International Journal of Operations & Production Management, 31*(11), 1215–1247.
Zhu, J. (2003). Imprecise data envelopment analysis (IDEA): A review and improvement with an application. *European Journal of Operational Research, 144*(3), 513–529.
Zhu, J. (2011). Airlines performance via two-stage network DEA approach. *The Business and Economics Research Journal, 4*(2), 260–269.
Zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in chinese manufacturing enterprises. *Journal of Operations Management, 22*(3), 265–289.