Measuring the financial effects of mitigating commodity price volatility in supply chains

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Abstract

Purpose – Firms can choose from an array of approaches for reducing the detrimental financial effects caused by unfavorable fluctuations in commodity prices. The purpose of this paper is to provide guidance for effectively estimating the financial effects of mitigating commodity price risk volatility (CPV) in supply chain management decisions.

Design/methodology/approach – This paper adopts two prominent and complementary methodologies, namely, total cost of ownership (TCO and real options valuation (ROV), to illustrate how commodity price risk mitigation strategies can be analyzed with respect to their effect on costs and performance. The paper provides insights through a case study to demonstrate the application of these methods together and establish the benefits and challenges associated with their implementation.

Findings – The paper illustrates advantages and disadvantages of TCO and ROV and how these approaches can be adopted together to contribute to effective purchasing decisions. Supply chain flexibility is a key capability but requires investments. Holistically measuring the financial effects of flexibility investments is imperative for gaining executive management support in mitigating commodity price volatility.

Research limitations/implications – This study can provide supply chain professionals with useful guidance for measuring the costs and benefits related to developing strategies for mitigating commodity price volatility. TCO provides a focus on the costs associated with the commodity purchasing process, and ROV enables the aggregation of all the costs and benefits associated with the use of the strategy and synthesizes them into the net value estimate.

Originality/value – The paper provides a comparison of different but complementary approaches, specifically TCO and ROV, for analyzing the effectiveness of CPV risk mitigation decisions. In addition, these two methods allow supply chain professionals to evaluate and control the financial effects of CPV risk, particularly the impact of mitigation on firm's cash flows.

Keywords Purchasing, Supply chain risk, Commodity price volatility, Risk mitigation, Total cost of ownership, Real options valuation, Risk management, Supply risk, Commodities

Paper type Research paper

1. Introduction

Most organizations purchase commodities in some form as part of its firm's operations. Commodities, such as metals (e.g. steel, aluminum, copper, silver, gold), energy (e.g. natural gas, oil) and agricultural products (e.g. wheat, corn, soybeans) can be acquired directly as raw material inputs to a firm's products, indirectly as components of purchased items from a firm's suppliers, and/or as part of a firm's operations and overhead expenses (Zsidisin *et al.*, 2013). Commodities are a significant input affecting many industries: steel for automotive or electronics companies, lead for battery manufacturing, agricultural commodities for food companies and jet fuel in the airline industry are just a few examples. When an extensive portion of the firm's overall purchases consists of price-volatile commodities, a key concern is commodity prices changing sharply, putting the company's economic viability at risk (Fischl *et al.*, 2014; Bandaly *et al.*, 2014). If not effectively managed, commodity price volatility (CPV) may severely undermine the ability to meet customer requirements, creating challenges for product pricing decisions, budget planning and

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net cash flow management (Kaufmann *et al.*, 2017; Finley and Pettit, 2011; Matook *et al.*, 2009).

From a supply chain risk management (SCRM) perspective, CPV has been considered as a subcategory of supply chain risk (Fischl *et al.*, 2014). During the past years, different approaches have been discussed for mitigating CPV. In particular, Bandaly *et al.* (2014) highlighted the key role of cross-functional collaboration between operations and finance to minimize the expected total opportunity cost related to upstream commodity price fluctuations and downstream demand variability. Several risk mitigation strategies have been identified from the financial perspective, namely, financial hedging (Sun *et al.*, 2017; Caniato *et al.*, 2016), and from the SCRM perspective, specifically sourcing approaches (forward buying, switching supplier, substituting commodities, vertical integration) (Manikas and Kroes, 2016) and contracting strategies (escalator clauses, staggering contracts, passing price increase to customers) (Gaudenzi *et al.*, 2018; Zsidisin *et al.*, 2013; Wakolbinger and Cruz, 2011). All of these strategies are characterized by different thresholds between costs and benefits, which need to be carefully evaluated by supply management professionals before implementing measures to mitigate this form of risk. Hence, companies should calculate how risk mitigation strategies reduce the negative effects of CPV. Despite this practical need, the existing SCRM literature on CPV and its mitigation has mainly focused on analyzing how firms perceive CPV and how CPV affects profitability along its supply chain (Zsidisin and Hartley, 2012). Others have analyzed the range of possible mitigation strategies available to supply chain managers for mitigating CPV (Liu and Wang, 2019; Zsidisin *et al.*, 2015), which are the main factors influencing the choice of CPV mitigation strategies (Gaudenzi *et al.*, 2018) and how the concept of flexibility may be leveraged for building the mitigation capability of specific SCRM strategies in dealing with CPV (Pellegrino *et al.*, 2019; Costantino *et al.*, 2016).

There is a lack of structured tools benchmarking commodity price risk mitigation strategies for understanding which approaches are more effective and efficient in mitigating commodity price risk and the conditions under which some strategies perform better than others. In addition, both practitioners and academics highlight the need to further investigate how to mitigate emerging risks, such as CPV, affecting supply chains (Kumar and Park, 2019; Manikas and Kroes, 2016; Bandaly *et al.*, 2014). This paper aims to fill the abovementioned gaps, from both practical and theoretical perspectives, and develops an approach for better measuring the financial and operational performance effects from implementing risk mitigation strategies. The measures are based upon two prominent approaches, namely, total cost of ownership (TCO) and real options valuation (ROV). The rationale for using these two approaches is twofold. First, they both assess the financial effects of mitigating CPV, namely, the impact that strategy adoption has on firm cash flows (Carmichael, 2016). The different risk mitigation strategies (financial hedging, sourcing approaches and contracting strategies) have different features which often are non-comparable. TCO can potentially support decision-makers through the monetary quantification and aggregation of these features. Specifically, features that are not naturally expressed as a financial unit of measure are "translated" into financial numbers (Morssinkhof *et al.*, 2011). Further, several CPV mitigation strategies build their mitigation capability on creating flexibility, whose value may be well captured in financial terms by ROV approach rather than pure discounted cash flow (DCF)-based tools (Pellegrino *et al.*, 2019; Carmichael, 2016; Carmichael, 2015). The second reason for combining these two approaches is their practicality, which fits to the aim of the paper to provide guidance for effectively estimating the financial effects of mitigating CPV in supply chain management decisions, as discussed in the following sections.

2. Total cost of ownership

2.1 Overview

TCO is a methodology and philosophy which goes beyond the purchase price to include several other purchase-related costs (Bhutta and Huq, 2002). It is the term used to describe costs associated with the acquisition, use and maintenance of a good or service (Ellram and Siferd, 1993). TCO examines the cost associated with purchased goods and services throughout the entire supply chain, including the costs from the idea of the product/service (e.g. cost of working with a supplier to develop a new or improved part, in relationship with production and/or assembly systems) (Brad *et al.*, 2018; Heilala *et al.*, 2006), through warranty claims because of that part once the final product is used by the customer (Ellram, 1993).

According to the TCO approach, the buying firm needs to base sourcing decisions not just on adopting a "price only" focus, as found in the traditional approaches to supplier selection under supply chain risk conditions (Dupont *et al.*, 2018; Yoon *et al.*, 2018). Rather, firms need to determine which costs they consider most important or significant in the acquisition, possession, use and subsequent disposition of a good or service. Hence, in addition to the price paid for the item, a TCO approach may include other elements such as order placement, research and qualification of suppliers, transportation, receiving, inspection, rejection, replacement, downtime caused by failure and disposal costs, among many others (Ferrin and Plank, 2002).

The two primary conceptual insights provided by a TCO approach can be summarized as follows:

1. the evaluation of a broader spectrum of all the costs related to a 'TCO' perspective, considering acquisition costs, all the costs related to suppliers, and generally all internal costs; and
2. the evaluation of life cycle costs, which consider all the costs associated with using a given item from a given supplier during the entire life of the item, including costs incurred when the item is in use.

2.2 Total cost of ownership for measuring commodity price risk mitigation

Several models have been suggested for understanding TCO associated with purchasing a product or service. Ellram and Siferd (1993) suggest grouping purchasing activities into six categories: quality, management, delivery, service, communications and price. Another approach consists in looking at costs based upon the order in which the cost elements are incurred, following the transaction sequence: *pre-transaction*, *transaction* and *post-transaction* (LaLonde and Zinszer, 1976).

In TCO, the quoted price of the commodity is the starting point. Then, other factors considered important in the

purchasing of a commodity are considered and replaced by a cost factor. Each issue is translated into a cost component that is added into a price adder formula (Bhutta and Huq, 2002). Finally, the total cost of each purchasing option is calculated: the best option is the one with the lowest total cost. Following the TCO approach, Table 1 reports some costs elements associated with the commodity purchase under different commodity price risk mitigation strategies, classified as pre-transaction, transaction and post-transaction.

The analysis of the cost components related to the risk mitigation strategies – conducted through a TCO approach of commodity purchases – reveals many additional costs arise beyond the purchase price. These cost elements highlight the need to carefully revise the decision-making processes regarding risk mitigation strategies based on purchase price.

When organizations create their commodity purchasing strategy, there is a risk of paying limited attention to a detailed ex ante analysis of the consequences and benefits stemming after its implementation. A purchase price comparison is often the key criteria driving the purchasing strategy, although the practice may highlight additional expenses might occur, such as negotiating price adjustments, qualifying new suppliers and personnel travelling costs, for example. Furthermore, uncertainties and risks might increase, such as the risk of supply chain disruptions because of suppliers cancelling orders because they cannot offset price increases from their commodity purchases. For these reasons, the commodity purchasing strategy should holistically consider the costs related to the purchasing process, the risks generated by CPV and the total costs related to implementing commodity price risk mitigation strategies. Table 1 highlights examples of possible cost elements in a TCO model when selecting a commodity price risk mitigation strategy.

3. Real options valuation

3.1 Overview

ROV has been introduced in the literature as an approach that overcomes the limits of traditional methodologies for evaluating investment opportunities under uncertain environments. Traditional methods, such as those based on DCF – net present value, internal rate of return and discounted pay back period – implicitly assume investment benefits and, therefore, the "expected scenario" of cash flows are known and presume management's passive commitment to a certain operating strategy (Zhao *et al.*, 2015; Wei and Tang, 2015; Boute *et al.*, 2004). During project management and operations, especially in highly uncertain and dynamic environments, managers may make different choices about operating actions when new information from the market is available. The right, but not the obligation, to do something in the future represents a (real) option (Dixit and Pindyck, 1995). This concept emphasizes the manner in which investments create economic value through operating flexibility. Having a real option in a project means being able to react to unexpected market changes, assuring the capability to mitigate project risk, therefore improving project value (Chiara *et al.*, 2007). This possible additional value needs to be considered during the decision-making process. A broad variety of real options have been studied in the literature including – for example – the option to defer production, temporarily shut down production, hold or abandon a project, decide the timing of investment, choose the production technology, inputs and outputs and to change a project's output mix (Amram and Kulatilaka, 1999; Trigeorgis, 1998; Majd and Pindyck, 1987; McDonald and Siegel, 1986).

Two key insights underlie the application of ROV. First, ROV builds upon the assumption that opportunity costs are associated with irreversible investments under uncertainty. This implies the possibility to defer committing resources under uncertainty is worthwhile (Trigeorgis, 1998). Second, ROV recognizes many investments create valuable follow-on investment opportunities (Amram and Kulatilaka, 1999). These insights suggest that certain up-front investments enable management to capitalize on favorable opportunities and mitigate negative events by proactively managing uncertainty over time in a flexible way (Kogut, 1991) rather than by attempting to avoid uncertainty. This managerial flexibility may be exploited, for example, when new information regarding market demand, competitive conditions or the viability of new processes technologies is available (Leiblein, 2003).

3.2 Real options valuation for commodity price risk mitigation approaches

Among different risk treatment strategies, risk transfer means passing the financial consequences of a risk to a third party (supplier, subcontractor, service, distributor, customer, etc.), whereas risk sharing means dividing it among different actors. Conversely, risk taking is a single-handed strategy that is characterized by the use of only internal risk management techniques (Lavastre *et al.*, 2012; Hallikas *et al.*, 2004; Harland *et al.*, 2003). While risk transfer and risk sharing consist of passing some parts of risks and sharing it with others, risk taking is a decision made within the organization, thereby requiring the identification of appropriate and feasible approaches for its management.

The literature on SCRM has recognized the combination of redundancy and operational and strategic flexibility as effective practices for mitigating supply chain risk (Namdar *et al.*, 2018; Daultani *et al.*, 2015; Ho *et al.*, 2015; Yu *et al.*, 2015). Strategies that prioritize their mitigation capability on redundancy essentially maintain excess resources such as inventory and capacity. Among commodity price risk mitigation approaches, this is the case of forward buying and vertically integrating. Investments in creating supply chain flexibility can serve as an approach for mitigating the detrimental effects of commodity price volatility. We define flexibility in terms of the firm's ability to proactively react to environmental changes with little or negligible penalty and sacrifice in terms of time, operational efforts, cost or performance (Lu *et al.*, 2017; Pérez *et al.*, 2016; Upton, 1994). The choice of the mitigation strategies requires not only a deep understanding of all the costs associated with the strategies itself, beyond the purchase price, but also the assessment of the value created by the flexibility itself.

Firms can also create operational and strategic flexibility for mitigating CPV risk (Pellegrino *et al.*, 2019). For instance, among flexible sourcing approaches, *Switching Suppliers* and *Substituting Commodities* are two flexibility-based commodity

Table 1 Cost elements associated with commodity purchases using various commodity price risk mitigation approaches

Strategy	Sourcing approaches			Contracting approaches				Financing approaches	
Cost component	Forward buying	Switching supplier	Substituting commodity	Vertically integrating	Inserting escalation clauses	Staggering contracts	Passing price increase to customers	Financial hedging	Cross-hedging
Pre-transaction components	Assessing the feasibility of using the commodity (e.g. perishability)	Supplier search	Innovative design with multiple materials (R&D involvement)	Assessing vertical integration alternatives	Negotiating the contractual terms (e.g. frequency of price adjustment, base cost/price, price corridor)	Negotiating the (multiple) contract terms	Customer approval for using a different commodity	Maintaining margin in account	Maintaining margin in account
	Continuous price monitoring	Supplier evaluation	Testing facilities	Integrating the distribution channel (i.e. relationship-specific investments)		(Multiple) contracting	Negotiating the contract terms	Monitoring	Monitoring
	Build up (extra) storage capacity and handling capability	Supplier qualification	Commodity (long-term) validation	Obtaining customer approval for using different commodity	Adding new supplier to internal systems (e.g. ERP platform)				
		Educating new supplier in firm's strategies and operations							
Transaction components	Purchase price	Purchase price	Purchase price		Purchase price	Purchase price	Purchase price	Purchase price	Purchase price
	Order placement	Order placement	Order placement		Order placement	Order placement	Order placement	Short term cash outlay	Short- term cash outlay
	Delivery/ transportation	Delivery/ transportation	Delivery/ transportation		Delivery/transportation	Delivery/ transportation	Delivery/ transportation	Broker fees	Broker fees
	Tariffs/duties	Tariffs/duties	Tariffs/duties		Tariffs/duties	Tariffs/duties	Tariffs/duties		
	Inspection	Inspection	Inspection		Inspection	Inspection	Inspection	Inspection	
	Return of non-compliant materials	Return of non-compliant materials	Return of non-compliant materials		Return of non-compliant materials	Return of non-compliant materials	Return of non-compliant material *s*	Follow-up and corrections	Follow-up and corrections
	Follow-up and corrections	Supplier switching (change management): (1) set up adjustments for the production equipment (2) handling costs to operate and clean equipment and load the new material	Commodity switching (change management): (1) set up adjustments for the production equipment (2) handling costs to operate and clean equipment and load the new material		Follow-up and corrections	Follow-up and corrections	Follow-up and corrections		

(*continued*)

Table 1

Strategy	Sourcing approaches				Contracting approaches			Financing approaches	
Cost component	Forward buying	Switching supplier	Substituting commodity	Vertically integrating	Inserting escalation clauses	Staggering contracts	Passing price increase to customers	Financial hedging	Cross-hedging
		(3) extra warehousing space to store the second material	(3) extra warehousing space to store the second material						
Post-transaction components	Monitoring increased inventory levels	Damages to supplier relationships	Customer goodwill/ reputation of firm	Managing the integrated channel	Administrative activities of maki ng price changes	(Multiple) contract management	Administrative activities of making price changes	Foregone profit from favorable price fluctuations	Foregone profit from favorable price fluctuations
	Inventory capital costs	Communication/ maintaining a (long term) relationship with suppliers					Damage to customer relationships and reputation of firm	Monitoring	Monitoring
	Risk/cost of scrap (obsolescence)						Contract management		

price risk mitigation approaches: the decision-maker will decide whether substituting commodities or switching suppliers is appropriate on the basis of the commodity prices and the cost of enabling such flexibilities. *Inserting escalation clauses* or *financial hedging* are examples of flexibility-based commodity price risk mitigation approaches among contracting and financial ones. Operationalizing and assessing these mitigation strategies requires modeling the managerial flexibility of the decision-maker, considering both the price of commodities and the cost of flexibility itself. Any attempt to quantify this flexibility leads almost naturally to the concept of options. Hence, these approaches are analyzed in this paper by operationalizing them from an ROV perspective.

Although most of the commodity price risk mitigation approaches summarized in Table 1 provide firms flexibility in responding to commodity price changes, the four we will highlight with respect to ROV are *switching suppliers* and *substituting commodities* among the sourcing approaches, *inserting escalation clauses* among the contracting ones and *financial hedging* among the financial ones. *Switching Suppliers* provides a firm the ability, but not the obligation, to reconsider its cost structure in response to commodity price changes. The company will switch suppliers when the cost efficiency gains outweigh the aggregate transaction costs of setting up operational flexibility. Similarly, *substituting commodities* gives a firm an option to react to CPV by making the commodity substitution when there are favorable conditions, such as when the financial benefits gained through the substitution are greater than its costs. At the same time, however, to open an option, such as making a substitution technically and commercially viable, there is the need for upfront investments in R&D, market research and material/supplier qualification, as well as the need for sustaining on-going supply chain costs to manage such flexibility. *Inserting escalation clauses* in contractual agreements with commodity suppliers allows the organization to define how often the commodity prices are reviewed and changed, the base "price" from which adjustments will be made, and if past or future prices will be changed. The company has the right, but not the obligation, to demand price adjustment when the actual prevailing price in spot market is above a base (predefined) target price. To have such a flexibility, administrative costs which depend on the frequency of review (monitoring) and price adjustment have to be sustained. Financial hedging gives companies needing to buy significant quantities of commodity the possibility to hedge against rising commodity price by taking up a position in the commodity futures market. In this way, the company secures a purchase price for a supply of commodity that it will require sometime in the future. If the commodity price increases, the company has the possibility to offset it by the gains in the futures market (i.e. the difference between the actual price of commodity and the price locked with the futures). To build this mitigation ability, the company has to pay the cost for entering into future contracts and monitoring the commodity spot price.

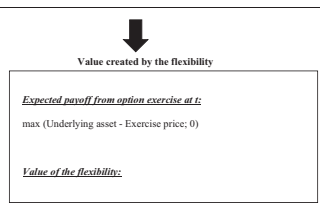
Figure 1 describes the discussed strategies from the perspective of ROV. It shows how an ROV model provides an approach for integrating and comparing seemingly incomparable issues (either qualitative or quantitative, either cost- or benefit-related), thus guiding the purchasing manager to select the commodity price risk mitigation strategy which ensures the required trade-off among such issues.

4. Advantages and disadvantages of total cost of ownership and real options valuation

TCO and ROV have their respective advantages and disadvantages with regard to measuring the financial effects from implementing commodity price risk mitigation strategies.

Figure 1 Flexibility-driven commodity price risk mitigation strategies from a real options valuation perspective

Real Option modelling \ Strategy		Sourcing approaches		Contracting approaches	Financing approaches
		Switching supplier	Substituting commodity	Inserting escalation clauses	Financial hedging
Real Option parameters	*Option Cost*	The cost of acquiring flexibility: Multiple sourcing arrangements involve higher costs than those of single sourcing (due to the need for managing more than one contract/supplier and the loss of scale economies).	It is the (sunk) cost needed to "implement the flexible system", namely, the upfront investment in R&D, market research and material qualification for having flexible products or processes and being able to change commodity. It is given by the sum of: (1) cost to produce test products with the alternative material (mainly personnel cost for people that work on the qualification), and (2) the cost of the material itself for the test."	Administrative costs which depend on the frequency of price review and adjustment.	The sunk cost needed to enter into the contract and to monitor the commodity price.
	Exercise Price	Transaction costs when exercising the switching option.	Cost of making the switch from one commodity to the other one and vice versa (e.g., tooling, process modifications, inventory costs): (1) set up adjustments for the production equipment (2) handling costs to operate and clean equipment and load the new material (3) extra warehousing space to store the second material since the two commodities cannot be physically mixed	Targeted commodity price: Base price of the commodity, from which adjustments are made.	It is the price of commodity futures: To hedge against a rise in commodity price, the company has to lock in a future purchase price by taking a long position in an appropriate number of futures contracts (in order to cover the commodity quantity needed by the company).
	Underlying asset	Expected cost efficiency gains from flexibility: savings from switching the	Expected cost efficiency gains from flexibility: savings from switching the commodity source	Actual commodity price paid for the supply	The prevailing spot price for commodity.
Source of managerial flexibility	*Decision at each t*	At t, the company will switch the commodity supplier whether the savings gained by purchasing from the alternative supplier charcing a lowest price are higher than the cost of making the switch.	At t, the company will substitue the commodity whether the savings gained by the alternative commodity with lowest price are higher than the cost of making the switch.	At t, the company will demand commodity price adjustment only if the actual commodity price is above the base (predefined) price (exercise price), otherwise the option will be worthless.	At t, with the increase in commodity price, the company will offset the increased purchase price by the gains in the futures market; with the prevailing spot price of commodity having fallen, the company will offset the loss in the commodity futures market by the savings realised from the reduced purchase price for the commodity.



A summary of these advantages/disadvantages is proposed in Table 2 and is discussed below.

4.1 Total cost of ownership advantages and disadvantages

One advantage of the TCO approach concerns the potential thoroughness of incorporating many different cost elements associated with implementing a commodity price risk mitigation strategy. These can include, for example, investment (pre-transaction) costs in qualifying alternate supply sources, costs in creating flexibility in product design to facilitate substituting commodities, negotiating contracts with suppliers and/or customers for inserting escalation clauses and building inventory capacity in preparing for forward buys, among others. Further, additional cost elements (transaction costs) can likewise be incorporated, such as switching supply sources, changing production processes to use different commodities, adjusting payment amounts at specific time intervals from escalation clause agreements and transporting larger quantities from forward buys, for example. Other potential future (post-transaction) costs from implementing commodity price risk mitigation strategies can also be incorporated such as carrying additional inventory, losing customer confidence and goodwill from changing product materials, creating additional scrap and waste and experiencing unforeseen product failures and quality issues. These costs elements can be aggregated for better gauging the actual cost of implementing these strategies, beyond solely looking at the potential commodity price savings accruing from mitigating commodity price risk. However, some of these costs, especially post-transaction costs, can be very difficult to accurately assess.

Using TCO as a measurement approach provides supply management professionals, as well as other key organizational stakeholders, greater insight to supply chain processes, including those of their suppliers (Ellram, 1993). This information is critical for better preparing negotiations with suppliers (and even sometimes customers) in determining how best to address "what if" scenarios of significant commodity price movements, both in the short as well as long term. By understanding costs beyond those associated with the commodity prices themselves, such as its effects on supplier performance and internal costs, purchasing professionals can be better prepared to negotiate with suppliers, both for those with direct spend on commodities, as well as "value chain" purchases of suppliers acquiring commodities and the potential "cascading" effects of those commodity prices in the supply chain.

Although there are many reported benefits of TCO (Bhutta and Huq, 2002; Ellram, 1995), there are also various drawbacks associated with implementing this measurement approach for assessing commodity price risk mitigation strategies. The first consists of its complexity to implement and time it takes to collect the data and derive calculations, many of which are difficult to estimate and understand. Second, it is a static approach, where changes in the internal/external environment, such as changes in technology affecting cost structures and additional maintenance and operating costs, can influence the outcomes of the model. Being a deterministic model, TCO relies mostly on uncertain data, making it difficult to forecast the future expense or income for a specific purchase.

Another challenge with TCO models is potentially ignoring cost elements beyond mathematical measurement. For instance, in case of forward buying strategy, the model ignores the intrinsic value of the strategy that consists in eliminating the price volatility at an unknown cost, because there is no way to account for the risk of fixed prices being higher or lower than the fluctuating price. The essential TCO metric focuses only on cost, and because of this insight might select a mitigation strategy minimizing expenditures, rather than a strategy maximizing the return for the company. Finally, TCO ignores the benefits of flexibility in the supply chain because it is a static model.

4.2 Real options valuation advantages and disadvantages

The ROV as an analytic tool for measuring the effects of implementing a commodity price risk mitigation strategy has several benefits. First, an ROV model assesses the value created

Table 2 TCO and ROV advantages and disadvantages

	Advantages	Disadvantages
TCO	Incorporates numerous cost elements associated with a given strategy into consideration	Complex and time consuming
	Considers costs beyond acquisition price (purchase price comparison)	Static system
	Allows for the identification of costs that otherwise may remain hidden	Deterministic model relying mostly on uncertain data
	Provides a tool for negotiating with suppliers	Great effort in tracking and maintaining cost data
		Often focuses on costs and not revenues
		Often situation-specific
		Ignores flexibility benefits
ROV	Assesses the value created by the flexibility embedded in some strategies	Need for estimating uncertain elements
	Ability to model the decision-making process of the manager, even when quantitative and qualitative factors need to be considered	Computational complexity
	Focuses on cash flow and profit, not just cost minimization	Non-standardized calculation methods for option values
	Helps in comparing strategy performance (benchmark) against other approaches and self over time	
	Opportunity to understand the impact of changes in the environment	

from the flexibility embedded in a strategy by estimating the potential benefits of investing in specific approaches for mitigating commodity price risk given changing valuations. Further, these models provide managers insights to the decision-making process for adopting and implementing a given strategy, going beyond the cost elements themselves. Therefore, this approach can lead to a more holistic understanding of the strategy, considering both the costs (as TCO does), as well as its associated risks.

Another advantage of the ROV model is its analysis measuring the effectiveness of commodity risk mitigation strategies on maximizing cash flow and profit rather than minimizing cost. While a TCO model can provide significant insights on the cost of the approach, the ROV model will also analyze those costs, but as well provide estimates how the price of the commodity influences cash flow expenditures and profits from considering investments *a priori*. This analysis provides an opportunity to understand the impact of changes in both the internal and external environment on the effectiveness of the selected strategy.

However, the ROV also has several drawbacks associated with its use. Similar to TCO models, and maybe even more significant, there is computational complexity in deriving these models. This is because of the challenges of framing inputs to the model, as well as the mathematics involved. ROV requires using software programs such as Oracle Crystal Ball Decision Optimizer and Real Option SLS, which are often beyond the training of many purchasing professionals. An additional drawback is the lack of standardized models. There are different calculation methods for option values and their necessary assumptions and simplifications. The lack of standardization can yield significantly different results, depending on the calculation methods.

Although TCO and ROV have their respective advantages and disadvantages, they are complementary tools, which are able – respectively – to fill the gaps and limitations of each other, contributing to a holistic management of cost, risk and mitigation strategies, as summarized in Table 3. The adoption of both the tools can provide insight to the effectiveness of implementing flexibility strategies for mitigating the detrimental financial effects of commodity price volatility. The next section provides a grounded example of how these approaches are applied.

5. Measuring the cost of mitigating commodity price risk: a case example

An aim of this paper is to provide insights through a case example to demonstrate the application of TCO and ROV and establish the benefits and challenges associated with their implementation. To provide a practical example, we selected a company listed in the Fortune ranking of the 100 best companies, which is one of the leaders in the fast-moving consumer goods industry. It is a multinational company offering a broad range of products across the world. The identity of this firm is concealed for confidentiality reasons. In this example, the company was exposed to commodity price volatility in the region including Europe, Middle East and Africa, where the company buys surfactants used in personal care and detergent, cosmetics, cleaning agents and detergents. In this example we considered realistic operational conditions and market values, adjusted by a specific coefficient for reason of confidentiality.

For mitigating commodity price risk, the company is interested in exploring the opportunity for substituting the commodity by using a natural surfactant – Commodity A (i.e. made with organic ingredients) or a synthetic one – Commodity B (i.e. petroleum derived raw materials). The base case considers a total volume of 10 K tons of surfactants, a total investment of $0.1m (option cost) to implement the flexible system for switching from one material to the other and a switching cost (exercise price) from natural surfactant to synthetic one and vice versa of $0.2m. After applying TCO and ROV approaches to the case, we revised the results with one of the managers involved in the case to get his perspective about the two approaches.

5.1 Applying the total cost of ownership approach

The analysis of the costs adopting the *substituting commodity* strategy according to the TCO approach has been carried out following Table 1. First, the possibility to switch the commodity depends on the ability of the final products/materials to be obtained by using a different mix of commodities without changing its quality requirements. In other words, switching commodities is possible when a flexible formulation of the final product/material exists. To build such a flexible formulation, the R&D department needs to search for the proper mix of commodities which produces commercially acceptable outputs. Hence, the company has to invest in the R&D activity to create a flexible formulation using different commodities. In this case, because such flexibility produces commercially acceptable outputs (with the same requirements), it is not required to obtain customer approval for using a different commodity. However, there are costs for testing alternative materials and validating the new commodity. The sum of all these (pre-transaction) cost elements to

Table 3 How total cost ownership and real options valuation contribute to effective purchasing decisions

Key elements of effective purchasing decisions	Contribution of the tools	
	TCO	ROV
Holistic cost structure assessment (Purchasing price & total cost consideration)	x	x
Assessment of risk dimensions	x	
Cash flow, revenue and profit considerations		x
Support the decision-making process	x	x
Optimize flexibility		x
Aid in negotiating with suppliers	x	
Measurement of commodity risk mitigation strategy effectiveness	x	x

implement the flexible system able to switch from one material to the other is the material qualification cost and accounts for $0.1m (option cost).

Once the flexibility has been enabled in the system, the buyer will compare the purchase price of the alternative commodities A and B, which have been estimated averaging the historical data of commodity prices paid by the company for the two sources. Contrary to what could be concluded with a rough assessment, the choice of the commodity to be used will not be based only on the lowest price, but will necessarily have to take into account if the lowest price commodity is not being currently used, the company will incur additional switching costs because of set up adjustments for the production equipment and handling costs to operate and clean the equipment, for example. In our specific case, these are the switching costs (exercise price) from a natural surfactant to a synthetic one and vice versa, which account for $0.2m.

The transportation cost also needs to be considered as an additional transaction cost. In this scenario, because the commodities are purchased from the same country and have similar physical characteristics, the transportation cost is the same and does not affect the price comparison. Finally, there are some post-transaction cost components associated to *substituting commodity* strategy, which are the loss of economies of scale incurred because very often contracts have a minimum volume, thus causing a loss of some discounts as company leverages a different commodity; higher scrap rate and market share loss because of different performance of the new commodity versus the other. Table 4 reports the main cost elements associated with the *substituting commodity* strategy.

Three main insights may be drawn from the TCO application for commodity price risk mitigation strategies. First, as shown in Table 4, the TCO approach provides a more holistic understanding of the costs associated with adopting the *substituting commodity* strategy, beyond the pure purchase price. In the specific case, this analysis is useful because it improves the buyer's understanding of the purchasing process and the related cost structure and therefore provides an excellent data source for negotiations. This is particularly valuable because it allows us to understand that an assessment based purely on the purchase price would be misleading for two reasons. On one hand, a choice based on the mere comparison of the average purchase price would lead to the conclusion that the substituting

Table 4 Simplified total cost ownership model for substituting commodity

Strategy / Cost component	Substituting commodity
Pre-transaction components	A.
Innovative design with multiple materials (R&D involvement) = 55.000$	
	B
Testing facilities = 30.000 $	
	C
Commodity (long-term) validation = 15.000 $	
	Total material qualitification cost (A + B + C) = 100.000 $
Transaction components	D If company purchases commodity A:
Purchase price of commodity A = 1.105,82 $/unit (Tot. Volume 10.000 units)	
Transportation cost (land freight) = 150 $/ton	
	If company purchases commodity B:
Purchase price of commodity B = 1.384,40 $/unit (Total volume 10.000 units)	
Transportation cost (land freight) = 150 $/ton	
	E
Commodity switching (change management):	
	(1) Set up adjustments for the production equipment (2) Handling costs to operate and clean equipment and load the new material (3) Extra warehousing space to store the second material
	Commodity switching (change management) = 200.000 $
Post-transaction components	F
Loss of economies of scale (if one contract has a minimum volume, you may lose some discounts as you leverage a different commodity)	
	G
Higher scrap rate (i.e. if the new commodity has different performance vs the other)	
	H
Market share loss (e.g. if the new commodity offers low performance vs the other)	
	TCO = A + B + C + D + E + F + G + H

commodity strategy is not appropriate because the commodity has a lower price (in this case Commodity A having a lower price than Commodity B). On the other hand, if instead we consider the real uncertainty of prices, we would choose the lowest-priced commodity from time to time, thus defining for the company a purchase cost given, time by time, by the lower price commodity (Figure 2). This would be a deceptive conclusion if we do not consider this choice having other costs. A more holistic evaluation of all cost components makes it possible to understand that switching costs arise beyond those under the direct purview of the purchasing department. The flexibility of the substituting commodity strategy involves business functions including, but going beyond, the purchasing department and therefore entails additional costs that must be considered. The perspective is that organizations need to align TCO as the KPI across all the functions involved in the sourcing process.

As a second insight, as other costs associated with the strategy are considered and assessed, the total cost of the strategy cannot be calculated by simply summing up all the cost elements associated with the strategy itself, as shown in the Table 4. Looking at each cost element, we can conclude they are not homogeneous. Specifically, the pre-transaction component represents a sunk cost (*one-off* cost for implementing the flexible system), while, contrarily, the transaction component is actually recurrent (this cost is charged anytime there is a commodity substitution). From additional discussions with this firm's management, more complex analyses require the need for the involvement of the finance function in determining how exactly these models should look like, which costs/benefits have to be included and how the cost elements should be calculated. This is a call to action for companies to involve the finance function to a greater extent in creating these models and validating measures and calculations.

Third, the TCO approach does not provide any information about the benefits created by using the *substituting commodity* strategy for the company. The TCO approach shows its limits in assessing the net value of flexibility-driven strategies, such as the commodity substitution strategy provided in this example. In this sense, TCO provides a full understanding of costs and benefits (in terms of saving opportunities) associated to the single purchasing option rather than a full assessment of the strategy as a commodity price risk mitigation approach.

The ROV model provides some solutions to these limitations. While TCO is still the primary approach at this firm, it requires a calculation of all costs involved. The challenge becomes that when there is uncertainty, such as including volatility commodity prices into the equation, the "risk" needs to be added as a cost in the TCO model. ROV is a way to quantify and embed those uncertainties into TCO.

5.2 Application of real options valuation in the case study

Using an ROV, we simulated the forecasted values of the two commodities prices (Commodity A and B) for a timeframe of 12 months based on the historical data of commodity prices paid by the company. In running this simulation, coherently with the literature (Pellegrino *et al.*, 2019), we assume price to vary stochastically in time following a mean reverting process. In particular, the key parameters related to long run mean, annual volatility, mean reversion rate and the initial values are reported in Table 5. The outcome of the mathematical model in terms of total value of the flexibility, computed as the sum of expected payoffs over the strategy lifetime – option cost as described in Figure 1 – is shown in Figure 3. Because the model inputs are uncertain, specifically the price of the two commodities, and because the decision taken at each time t is dependent on the evolution of such values along the strategy lifetime, the value created by the flexibility is not a determinist value, but rather a probability distribution. Looking at the statistics of the distribution, it is possible to observe that the value created by the flexibility ranges between a negative value equal to –$0.138m up to a positive value equal to

Figure 2 Historical data on commodities prices: Commodity A, Commodity B and lowest price between A and B

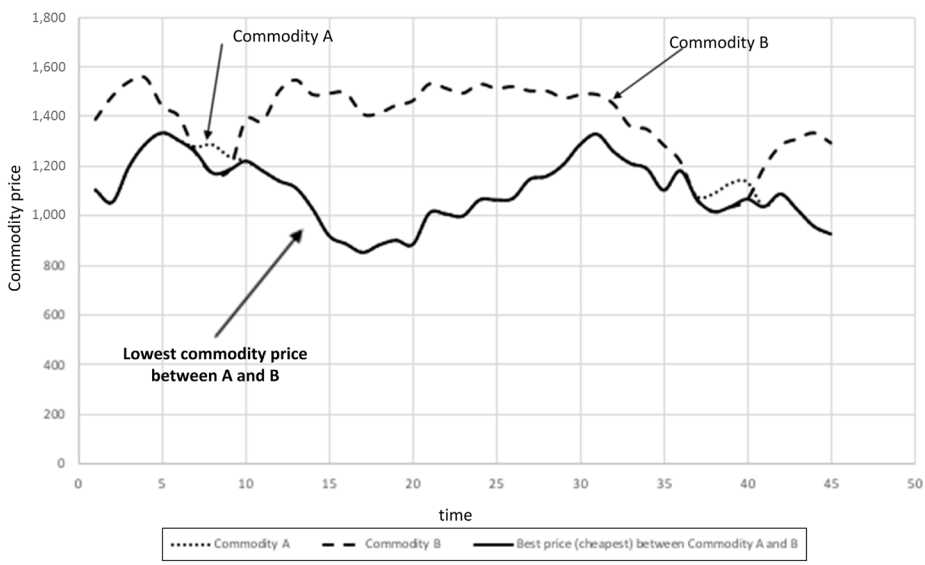
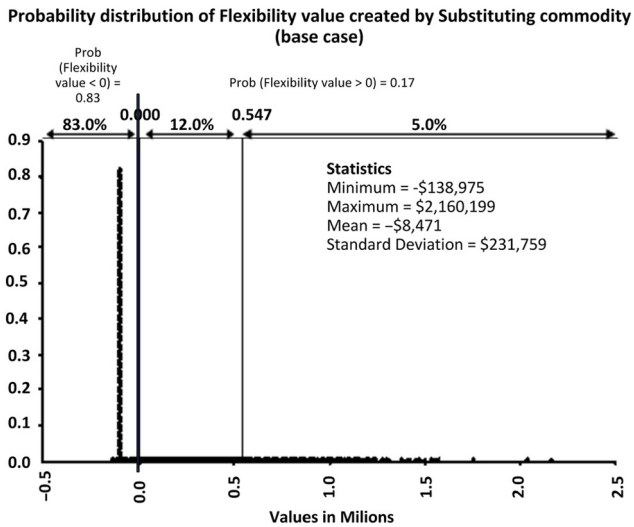


Table 5 Parameters of commodities prices

	Long run mean	Annual volatility	Mean reversion rate (in %)	Initial value S_0
Commodity A	$1,021.88	0.0555	7.17	$923.54
Commodity B	$1,171.58	0.0513	3.06	$1,094.21

Figure 3 Probability distribution of the value of flexibility



$2.160m. This means that against the initial price to develop the flexible system, the net benefits associated with the *substituting commodity* strategy are positive with a certain risk level (measured by the probability that the value of the flexibility is lower than 0). In particular, given the initial parameters considered as inputs of the model, we found that there is a chance of about 17% that this strategy positively impacts on the firm's profit delivering a value up to $2.160m. In the remaining 83% of cases, the strategy produces a loss for the firm up to –$0.138m.

We also carried out a sensitivity analysis on the switching cost (i.e. the exercise price of the option). The findings are depicted in Figure 4 which shows the probability distributions of the value of flexibility when switching costs change, whereas the statistics of the distributions are summarized in Table 6.

As the findings highlight, the mean value of the flexibility passes from being negative (a loss of $0.0085m when Switching costs are $0.2m) to positive (a gain of $0.19m when switching costs are $0.05m). This implies that the *substituting commodity* strategy becomes more effective in mitigating CPV (i.e. it delivers higher value), as expected, when the switching cost decreases. In other words, the impact of the strategy adoption on the firm's profit becomes more positive when the switching cost is lower. At the same time, the risk that the *substituting commodity* strategy results in a loss for the company, decreases from 83% to 43%.

Three main insights may be drawn from the ROV application for commodity price risk mitigation strategies. First, it is interesting to observe the net benefit associated with these strategies (NPV of the flexibility) is positive with a certain risk level (measured by the probability that the value of flexibility is lower than 0). Beyond the specific numbers found for the value of flexibility in the discussed case, the findings show flexibility-driven strategies may be effective in mitigating CPV because they positively contribute to the firm's cash flow and profits.

Second, the findings highlight that it is crucial for companies to carefully assess the value of these strategies before their implementation, because they are characterized by high implementation costs that need to be justified by the materialized cost savings. In fact, there is still a chance the value of the flexibility is less than 0. It is essential to consider the value of the managerial flexibility to decide whether it is logical to pursue switch sourcing option when properly assessing their value. This shows the importance of adopting ROV to model such managerial flexibility and account for its value.

Finally, the sensitivity analysis of the value of flexibility to the variation of the switching costs shows how the value of such strategies is not just dependent on the CPV but also on the structural characteristics of such strategies and on the costs needed to develop flexibility. The effectiveness of the strategy in mitigating CPV increases when the switching cost decreases.

Figure 4 Results of sensitivity analysis: probability distribution of the value of flexibility when Switching costs change

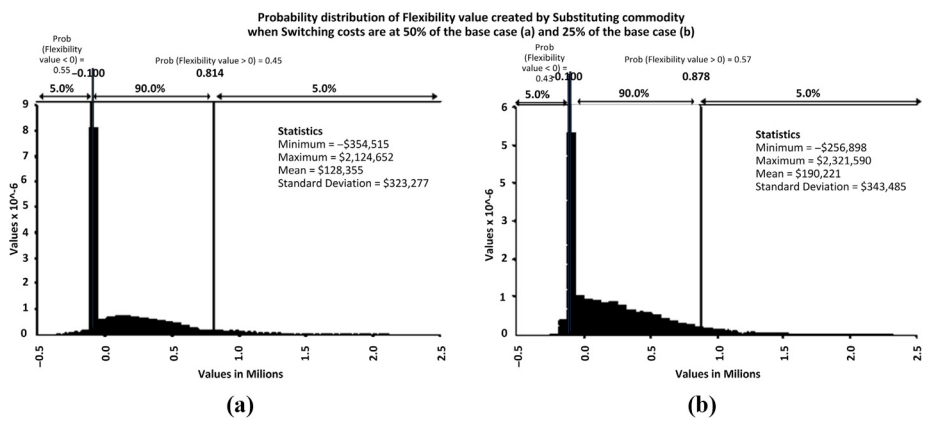


Table 6 Results of sensitivity analysis: summary of statistics

	Base case	Switching – 50%	Switching – 25%
Investment MM$	0.1	0.1	0.1
Switching MM$	0.2	0.1	0.05
Volume kt	10	10	10
Mean value of the flexibility:	−$0.0085MM	$0.128MM	$0.19MM
Prob (Flexibility Value > 0)	0.17	0.45	0.57
Range of flexibility value (Min–Max)	− 0.138 MM$ 2.160 MM$	− 0.354 MM$ 2.124 MM$	− 0.256 MM$ 2.320 MM$

Reviewing the application of ROV to the case with management from the case company, the main insight we discovered was that there is not a general framework that can simplify these decisions: inputs need to be collected (hence, the importance of a cross-functional approach, with multiple inputs required from multiple functions) and a specific person or business function needs to own these calculations (which can be the finance function, purchasing, or another function determined by the firm).

6. Implications and conclusions

Creating a portfolio of flexible commodity price risk mitigation strategies may provide supply management professionals the capability to select the most effective option given CPV financial and operational risk exposure. This paper analyzes commodity price risk mitigation strategies under the perspective of their costs and performance by adopting two measurement approaches: the TCO and ROV. The case provides an example of the analysis by showing how such approaches can be used to address the effective and efficient selection of commodity price risk mitigation strategies. The findings and their discussion highlight how the two approaches do not seem to be alternative or mutually exclusive, but instead we discovered that ROV can serve as an extension of TCO because of its ability to calculate the net value of the strategy and its impact on the firm's bottom line. ROV considers not only costs associated with the strategy at various times in its life cycle and with different recurrence but also its benefits.

Findings from this paper provides contributions to both the business and academic literatures. With regard to contributions to practice, we believe this study can provide supply chain professionals useful guidance for measuring the costs and benefits related to developing strategies for mitigating commodity price volatility. Supply chain flexibility is a key organizational and supply chain capability but requires investment. Holistically measuring the financial effects of flexibility investments is imperative for gaining executive management support in mitigating commodity price volatility. Using TCO and ROV for measuring the effectiveness of commodity price risk mitigation approaches ex ante is a step toward this direction. The application to the case and the discussion of findings show that TCO provides a focus on the costs associated with the commodity purchasing process, sets priorities regarding the areas in which it is needed to intervene to obtain benefits (i.e. saving opportunities) and provides excellent data for negotiations with suppliers. However, TCO does not provide a full assessment of the strategy itself and its mitigation capability. On the other side, ROV enables the aggregation of all the costs and benefits associated with the use of the strategy, including the value of flexibility as a mitigation capability, and synthesizes them into a single (economic) value which is the net value of the strategy. This helps in comparing strategy performance (benchmark) against other approaches and itself over time. Such characteristics makes ROV a powerful tool that can be used by purchasing managers not only to understand the effectiveness of the selected strategy in terms of its impact on firm's profit, but also to understand the impact of changes in both the internal and external environment on the effectiveness of the selected strategy (as the sensitivity analysis demonstrates). This will guide the manager in the selection of the appropriate strategy given actual conditions and future expectations.

The review of the case results with the company management also highlight interesting insights of what managers perceive about the two approaches:

- the importance of cross-functional collaboration for obtaining all the inputs needed for a proper application of TCO and ROV approaches;
- the need for scorecards to be aligned/synchronized across functions;
- the need for finance to have greater involvement;
- the ROV as a complement to TCO to embed risk into the equation;
- the need to understand who owns and leads the implementation of these capabilities in a company; and
- the need to run these analyses on a case-by-case basis because of the need to incorporate many factors, making it difficult to generalize the effectiveness of a certain strategy.

Finally, according to their management, the value of this approach is for sourcing organizations to be smarter on how to embed risk into calculations so that the correct resource allocations are made.

As for contributions to the academic community, this work begins to address an existing gap regarding the use of structured tools for analyzing the effectiveness of commodity price risk mitigation approaches. Prior research provides insight for comparing the benefits and drawbacks of TCO in the supply chain as a whole (Brad *et al.*, 2018; Heilala *et al.*, 2006) and in relation with other measurement approaches such as the analytic hierarchy process (Bhutta and Huq, 2002; Ramanathan, 2007) and data envelopment analysis (Garfamy, 2006; Ramanathan, 2007). TCO models have often been used

for improving decisions associated with evaluating and selecting suppliers (Bhutta and Huq, 2002; Wouters *et al.*, 2005), outsourcing (Ellram and Maltz, 1995), purchasing processes (Degraeve and Roodhooft, 1999) and more recently with specific services such as cloud computing (Han, 2011; Martens *et al.*, 2012) and data centers (Koomey *et al.*, 2007). We believe our paper extends current understanding of the benefits and drawbacks of TCO, and how other measurement approaches such as ROV can be used to complement the analysis of purchasing processes, especially those associated with creating flexibility in the supply chain.

Commodity price volatility directly affects the financial performance of organizations. Creating supply chain flexibility can be a strategic enabler for reducing the detrimental effects of significant commodity price shifts. Analyzing the effects on commodity prices alone, however, only provides a limited, and sometimes deceptive perspective on the "true cost" associated with mitigating this form of risk. TCO and ROV can provide firms a more holistic insight into how the use of flexible supply chain strategies can improve financial performance, and more specifically, which forms of supply chain flexibility may yield the greatest benefits.

The study has several limitations, which also offers potential directions for future research. One limitation is that the two approaches have been applied to only one specific case example. However, given the novelty of the methods adopted, the case example serves to highlight, beyond the specific numbers, interesting managerial insights from the use of the two approaches. Second, this study did not examine how TCO and ROV can be used in all of the CPV risk mitigation strategies presented in the literature, and instead only focused on the strategies used by the case study company (supplier switching and substitution). Future research may want to investigate how the effectiveness of other commodity price risk mitigation strategies are calculated using TCO and ROV. Such a study can draw out additional characteristics and cost and uncertainty elements for assessing the viability of other CPV mitigation approaches. Further, the application of the approaches to a higher number of and more complex cases may provide other useful insights. For instance, it could be used to understand if there are preferences about the use of the two approaches depending on the characteristics of context in which the firm operates, and the types of mitigation strategies adopted. In addition, the two methods can be applied in different industries to analyze whether and how different types of CPV, supply chain characteristics and risk mitigation strategies might lead to different results.

Commodity price volatility and risk have and will continue to present challenges to supply chain management professionals – as well as opportunities. Mitigating this form of risk through creating supply chain flexibility may provide financial benefits for firms in the long run. This paper provided insight as to how TCO and ROV can be implemented as decision analytic approaches for determining how organizations can make investments for better mitigating this form of risk in the supply chain and contribute to firm success.

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