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Integrated Financial and Operational Risk Management of Foreign Exchange Risk, Input Commodity Price Risk and Demand Uncertainty

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Abstract: In this paper, we study the risk management performance of a supply chain which is exposed to foreign exchange risk, commodity price risk and demand uncertainty. We develop an integrated risk management model which uses both financial derivatives and operational methods to hedge the supply chain risks. Findings are discussed for the cases of exchange rate risk with and without hedging.

Keywords: integrated risk management model, foreign exchange risk, commodity price risk, demand uncertainty, beer supply chain

1. INTRODUCTION

In this paper, we develop a model that incorporates an integrated financial/operational approach to risk management when managing risks along a supply chain. The risks of the supply chain consist of foreign exchange risk, uncertainty in the price of its input commodity and uncertainty in the demand for its output. The risk management methods used by the supply chain consist of financial derivatives and the use of operational hedging methods. We examine the performance of the supply chain's integrated risk management approach and focus on the impact of foreign exchange risk on this performance. We illustrate our model and its application by a study of a supply chain which consists of an aluminium can supplier, a brewery and a beer distributor. The domestic currency of the can supplier, brewery and beer distributor is the Canadian dollar (CAD). The input to the can supplier consists of aluminium sheets whose price is denominated in US dollars (USD). The volatility in the exchange rate between the USD and the CAD is the source of foreign exchange risk. The commodity price risk is due to fluctuation in the USD denominated price of the aluminium sheets. Demand uncertainty is due to variability in the demand for beer. Risk management is accomplished by controlling the inventory of aluminium sheets, aluminium cans and beer as well as by using options on aluminium futures, whose premiums as well as the underlying futures price are both denominated in CAD. The performance of the integrated risk management approach is quantified by the expected total opportunity cost of the supply chain.

Our paper adds to the existing literature on the benefits of integrating financial and operational methods in risk management. Operational approaches include real options such as switching production between plants located in different countries to supply different markets to protect against fluctuations in a currency exchange rate (Kogut and Kulatilaka 1994, Huchzermeier and Cohen 1996). The use of real options is integrated with the use of financial instruments in models developed by Mello et al. (1995), Chowdhry and Howe (1999) and Hommel (2003) to manage demand uncertainty and foreign exchange risk. Ding et al. (2007) use postponing of capacity allocation in addition to foreign currency options. Triantis (2000) notes that firms exposed to exchange rate risk can use financial derivatives to manage the short term impacts of transaction risk but cannot affect the long term effects of competitive risk. In their studies of multinational and non-financial firms, Allayannis et al. (2001), and Kim et al. (2006) find that geographical dispersion of a firm's activities is an operational hedging strategy that is complemented by the use of currency derivatives to hedge against foreign exchange risk. However, Aabo and Simkins (2005), who survey firms to determine their use of real options and financial instruments to manage foreign exchange risk, find that a majority of the firms would prefer to manage their exposure with real options.

Financial and operational risks faced by the beer supply chain studied are presented in Section 2. We describe in detail the integrated risk management model incorporating financial and operational hedging instruments in Section 3. Findings and concluding remarks are discussed in Section 4 and in Section 5, respectively.

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2. FINANCIAL AND OPERATIONAL RISKS FACED BY THE BEER SUPPLY CHAIN

A brewery purchases aluminium cans from a can supplier, produces canned beer and then transports it to a distribution centre which maintains an inventory of canned beer to meet retailers' demand. The supply chain faces risks which originate from both upstream and downstream. The can supplier, brewery and beer distributor are based in the domestic country, Canada. The can supplier buys aluminium sheets whose price is denominated in USD. The supply chain faces the joint effects of volatility in the USD denominated price of aluminium and volatility in the exchange rate between the USD and the CAD. The distribution centre faces uncertainty in beer demand causing either a stock-out or a surplus in beer inventory.

3. INTEGRATED RISK MANAGEMENT MODEL

Our model captures the benefits of integrating inventory management and the use of financial derivatives in managing the above risks. The model incorporates inventory levels of three items: canned beer at the distribution centre, empty aluminium cans at the brewery and aluminium sheets at the can supplier. The financial derivatives consist of over the counter (OTC) call and put options on aluminium futures which are purchased from a derivatives dealer. The option premiums and the underlying aluminium futures price are both denominated in CAD. The aluminium futures price thus incorporates fluctuations in the USD-denominated price of an aluminium futures contract as well as fluctuations in the exchange rate between the CAD and USD. The model minimizes the expected total opportunity cost, E(TOC), of the supply chain as a whole, while maintaining the value at risk (VaR) of this cost within a predefined limit. The VaR limit is incorporated in the model as a constraint and its value depends on the level of risk aversion of the supply chain.

3.1 Chronology of Supply Chain Risk Management Process

Figure 1 presents the chronology of the risk management process used by the supply chain. In the figure, 'w' is used to represent a week, 'T' is used to represent a time period that can span a number of weeks, and 't' represents a point in time, that is, the beginning of a week. All decision variables and some parameters in the model are associated with inventory type and/or a point in time. For these variables and parameters, we use two subscripts, *i* and *j*, where $i = \{a, b, c\}$ denotes **a**luminium sheets, canned **b**eer and empty **c**ans, respectively, and $j = \{0, 1, ..., 13\}$ represents a point in time.

3.2 Decision Variables and Cost

3.2.1 First Time Span (T_0)

Time t_0 represents the current point in time at which the can supplier places an order for aluminium sheets. The time period $T_1 = \{w_1 \dots w_{13}\}$ spans 13 weeks. The first five weeks of T_1 are reserved for the lead time L_c to produce empty cans (4 weeks) and the lead time L_b to produce beer (1 week). Faced with uncertainty in the USD-denominated aluminium price, the USD/CAD exchange rate and beer demand, the supply chain needs to make two strategic decisions on: i) the quantity of aluminium sheets to procure (Q_a) and ii) the number of OTC call and put options on aluminium futures to purchase.

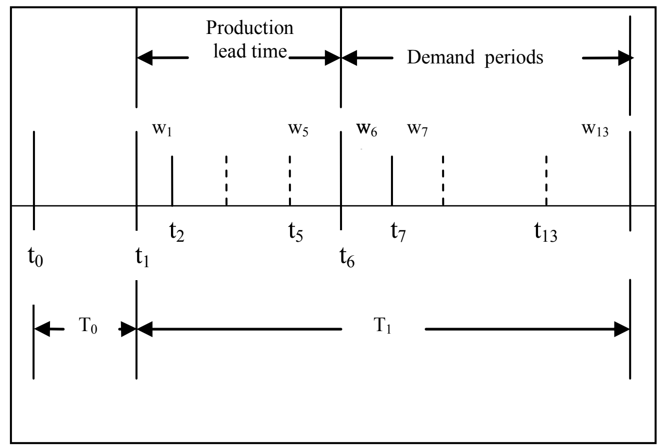

Fig.1. Chronology of the risk management process

Let S_0 and $\tilde{S}_1$ represent the USD-denominated spot price per ton of aluminium at times t_0 and t_1 respectively. Let F_0 and $\tilde{F}_1$ represent the USD-denominated futures price per ton of an aluminium futures contract with a delivery date at t_1, at times t_0 and t_1 respectively. Let E_0 and $\tilde{E}_1$ represent the exchange rate between the USD and CAD, in CAD/USD, at times t_0 and t_1 respectively. At time t_0, the can supplier purchases an initial quantity of aluminium Q_{a0} from the spot market at a CAD-denominated price of S_0E_0. This purchase is a hedge against future increases in the CAD-denominated aluminium price. At time t_1, the can supplier purchases a second quantity of aluminium Q_{a1} from the spot market at a price $\tilde{S}_1\tilde{E}_1$. The purchase of aluminium in two batches reduces the total costs of holding aluminium sheets in inventory and allows time for the buyer to respond to price changes that may occur after time t_0.

Considering the initial quantity of aluminium purchased at t_0, if the CAD-denominated aluminium price were to decline in the future, then the supply chain would incur an opportunity cost, since by waiting to purchase aluminium, it could have done so at a lower price. To offset this opportunity cost, the can supplier buys at t_0 a number N_p of European put options on the aluminium futures contract with a premium p_0, an exercise price K and expiration date t_1. The option's expiration date coincides with the delivery date of the futures contract. The put options' premium, the underlying aluminium futures price and the exercise price are all denominated in CAD. The put options are assumed to be at the money at purchase, thus $K=F_0E_0$. At time t_1, if the observed aluminium spot price in CAD, $\tilde{S}_1\tilde{E}_1$, is lower than S_0E_0, then the present value of the opportunity cost associated with the initial purchase of aluminium is $Q_{a0}(S_0E_0 - \tilde{S}_1\tilde{E}_1 e^{-rT0})$, where r represents the weekly risk free interest rate. The futures contract price in CAD on the option's expiration date equals $\tilde{F}_1\tilde{E}_1$. If $\tilde{F}_1\tilde{E}_1 \leq K$, the can supplier will exercise the put options, obtaining a payoff equal to $N_p(F_0E_0 - \tilde{F}_1\tilde{E}_1)$, which partially offsets the opportunity costs associated with the purchase of the initial quantity of aluminium. However, if $\tilde{F}_1\tilde{E}_1 > K$, the put options will be left to expire unexercised.

Considering the second quantity of aluminium sheets (Q_{a1}) purchased at time t_1, the supply chain would incur an opportunity cost should the CAD-denominated aluminium spot price, $\tilde{S}_1\tilde{E}_1$, increase. To offset this latter cost, at t_0, the supplier buys a number N_c of European call options on the aluminium futures contract at a premium c_0, an exercise price K, and expiration date t_1. The call options' premium, the underlying aluminium futures price and the exercise price are all denominated in CAD. As with the put options, the call options are assumed to be at the money so that $K=F_0E_0$. The option's expiration date coincides with the delivery date of the aluminium futures contract.

Associated with the decision to postpone a portion of the aluminium quantity purchase Q_{a1} to t_1, an opportunity cost is incurred if the CAD-denominated aluminium spot price, $\tilde{S}_1\tilde{E}_1$, is higher than its initial value S_0E_0. The present value of this cost is $Q_{a1}(\tilde{S}_1\tilde{E}_1 e^{-rT0} - S_0E_0)$. If $\tilde{F}_1\tilde{E}_1 \geq K$, the can supplier exercises the call options with a payoff equal to $N_c(\tilde{F}_1\tilde{E}_1 - F_0E_0)$, which partially offsets this opportunity cost. On the other hand, if $\tilde{F}_1\tilde{E}_1 < K$ the call options will be left unexercised.

The decision variables in the first time span, T_0, are the quantities of aluminium sheets to order (Q_{a0} and Q_{a1}) and the number of put and call options on aluminium futures to buy (N_p and N_c). The opportunity costs (gains) incurred over this time span are the costs (gains) of initial inventories and the costs (gains) of the call and put options.

The present value of the opportunity cost associated with purchase of aluminium at t_0 is:

$$Q_{a0}(S_0E_0 - \tilde{S}_1\tilde{E}_1 e^{-rT_0}) + fQ_{a0}h_{a0}T_0e^{-rT_0} \tag{1}$$

where f is an equivalence factor that converts tons of aluminium into millions of cans. In equation (1) and all formulations that follow, h_{i0} and h_{i1} are the weekly costs of carrying a quantity of inventory of type $i = \{a,b,c\}$, associated with aluminium sheet purchases at times t_0 and t_1 respectively. The first term in equation (1) represents the present value of the opportunity cost associated with the purchase of aluminium at time t_0. The second term captures the present value of the cost of carrying Q_{a0} over the time span from t_0 to t_1.

The present value of the opportunity cost (gain) associated with purchase of aluminium at t_1 is:

$$Q_{a1}(\tilde{S}_1\tilde{E}_1 e^{-rT_0} - S_0E_0) \tag{2}$$

The present value of the opportunity cost associated with the purchase of put options is:

$$N_p p_0 + N_p p_0\left(1 - e^{-rT_0}\right) - N_p e^{-rT_0} Max\{(F_0E_0 - \tilde{F}_1\tilde{E}_1), 0\} \tag{3}$$

The present value of the opportunity cost associated with the purchase of call options is:

$$N_c c_0 + N_c c_0\left(1 - e^{-rT_0}\right) - N_c e^{-rT_0} Max\{(\tilde{F}_1\tilde{E}_1 - F_0E_0), 0\} \tag{4}$$

The first term in each of equations (3) and (4) represents the premium paid for the options. The second term in each of equations (3) and (4) represent the present value of the interest incurred on the options' purchase price over the time period T_0. The third term in equations (3) and (4) represents the present value of the payoff on the expiration date from the put and call options, respectively.

3.2.2 Second Time Span (T_1)

To manage the demand occurring over time span T_1, the supply chain members maintain appropriate levels of the three inventory types in order to maximize the fill rate while minimizing holding costs. The lead times L_c and L_b are considered in scheduling production lots. Inventory flows are determined using pull logic with estimated beer demand as the starting point.

As an example, the following illustrates typical decision sequences corresponding to beer demand in week 6. The brewery estimates the demand $\tilde{d}_6$ that may be realized over week w_6 and accordingly ships a quantity of beer Q_{b6} to the distribution centre so as to have a beginning inventory B_{b6} ready to fill customers' orders over week 6. The brewery starts to fill and pack a corresponding quantity of beer cans P_{b5} at time $t_5 = t_6 - L_b$. Empty cans are transferred from the warehouse in which a beginning inventory level of empty cans B_{c5} is replenished by an incoming quantity of empty cans Q_{c5} from the can supplier. After transferring Q_{c5} to the canning process the warehouse's empty can inventory level drops to the ending value E_{c5}, to be transferred to the next week. To dispatch Q_{c5} on time, the first lot of can production P_{c1} at the can supplier starts at t_1, where $t_1 = t_5 - L_c$. The quantity of aluminium sheets required to produce P_{c1} is transferred from the beginning aluminium sheets inventory B_{a1} at the can supplier, which equals the sum of the aluminium quantities purchased at t_0 and t_1. Following the transfer, an inventory level E_{a1} remains on hand at the can supplier ready to be used during the following weeks.

At the start of week j, as the demand for canned beer $\tilde{d}_j$ starts being realized, the distribution centre satisfies this demand from available inventory B_{bj}, ending the week with remaining inventory E_{bj}. The total quantity of canned beer distributed during the week is M_{bj}. If $B_{bj} < \tilde{d}_j$, the supply chain incurs a stock-out cost. On the other hand, if $B_{bj} > \tilde{d}_j$ the surplus quantity is carried over to the next week, incurring a unit weekly holding cost.

Over the time period T_1, can production and beer filling and packing precede the realization of the weekly demands as lead times are involved in these actions. The values of Q_{bj} and Q_{cj} are to be decided before the corresponding weekly demands are realized. Following the realization of weekly demand ($\tilde{d}_j$) at the beginning of each week (w_j) starting from week 6, the quantity to be distributed to the market M_{bj} is set to satisfy demand as much as the beginning inventory allows.

The present value of the stock-out costs over an eight-week beer demand period is:

$$\sum_{j=6}^{13} Max\{(\tilde{d}_j - B_{bj})s, 0\}e^{-r(T_0+t_j)} \tag{5}$$

where s represents the unit stock-out cost per can of beer. The stock-out cost is incurred when the beginning inventory in the distribution centre (B_{bj}) is less than the realized weekly demand.

The following equations (6) through (8) determine the present value of the holding costs associated with the inventory of aluminium sheets, empty cans and canned beer, respectively.

$$\sum_{j=1}^{13} E_{aj}(u_0 h_{a0} + u_1 h_{a1})e^{-r(T_0+j)} \tag{6}$$

$$\sum_{j=1}^{8} E_{c(j+L_c)}(u_0 h_{c0} + u_1 h_{c1})L_c e^{-r(T_0+j)} + \sum_{j=5}^{13} E_{cj}(u_0 h'_{c0} + u_1 h'_{c1})e^{-r(T_0+j)} \tag{7}$$

$$\sum_{j=5}^{12} E_{b(j+L_b)}(u_0 h_{b0} + u_1 h_{b1})L_b e^{-r(T_0+j)} + \sum_{j=6}^{13} E_{bj}(u_0 h'_{b0} + u_1 h'_{b1})e^{-r(T_0+j)} \tag{8}$$

$$E_{aj} = E_{a8} \; for \; j = 9, \ldots, 13 \tag{9}$$

$$E_{c13} = E_{c12} \tag{10}$$

In equations (6) through (8), u_0 and u_1 are the proportions of aluminium sheet quantities purchased at time t_0 and t_1, respectively. The unit inventory holding cost has two components, h_{i0} and h_{i1}, that are proportional to the purchase price, S_0E_0 and $\tilde{S}_1\tilde{E}_1$, respectively. The contribution of each component is then weighted by u_0 and u_1. As units of empty cans and canned beer move downstream, warehousing requirements become more stringent and consequently unit holding costs increase. The model incorporates this increase in holding costs by setting $h'_{i0} > h_{i0}$ and $h'_{i1} > h_{i1}$. Equation (6) and the second term in each of equations (7) and (8) represent the present value of the cost of carrying a surplus quantity of the corresponding inventory type. This surplus is determined by the weekly ending inventory. This approach captures the concept of opportunity cost that is incorporated in our model. The first term in each of equations (7) and (8) represents the present value of the holding cost associated with carrying the surplus quantity during the production phase for the whole lead time period. Equations (9) and (10) ensure that the final ending inventory is carried over to the next planning period.

3.2.3 The Model

The integrated risk management model solves for the decision variables (Q_{a0}, Q_{a1}, N_c, N_p, Q_{bj} and Q_{cj}) in order to minimize the expected total opportunity cost *E(TOC)* along the supply chain, where the *TOC* is the summation of equations (1) through (8), while meeting, among others, the constraint related to the 95% value at risk (*VaR*) of the *TOC*. Thus, the objective function is given by:

$$Minimize \; E(TOC) \tag{11}$$

The following constraints are used in formulating the model.

$$B_{a1} = fQ_a \tag{12}$$

The constraint of equation (12) ensures that the beginning aluminium sheets inventory in the second time period T_1 equals the sum of the quantities of aluminium purchased at time t_0 and t_1.

$$Q_a = Q_{a0} + Q_{a1} \tag{13}$$

Equation (13) constrains the total quantity of aluminium sheets purchased to equal the sum of the purchases in the two points in time, t_0 and t_1.

$$M_{bj} = Min(B_{bj}, \tilde{d}_j) \; for \; j = \{6, \ldots, 13\} \tag{14}$$

The constraint of equation (14) ensures that, as long as there is sufficient inventory at the beginning of each week, all demand is to be satisfied. Having this constraint is important to avoid stock-out costs that are high compared to holding costs.

$$VaR \leq v \quad (15)$$

The constraint of equation (15) specifies the degree of risk aversion within the supply chain. The value of the upper bound *v* on the 95% value at risk of the total opportunity cost *TOC* is a function of the risk aversion level of the supply chain. A highly risk averse supply chain would choose a low value for *v*, while a less risk averse supply chain would choose a high value for *v*.

3.2.4 Applicability to Other Supply Chains

For purposes of providing an interesting and practical real-life application, we have formulated our model from the viewpoint of a supply chain which includes a can supplier, brewery and beer distributor. However, our model is applicable to other supply chains which include a supplier, manufacturer and distributor, in which the risks include foreign exchange risk, input commodity price risk and demand uncertainty. The financial derivative used in risk management consists of options, while the operational instrument used is inventory management.

4. FINDINGS WITH AND WITHOUT HEDGING OF FOREIGN EXCHANGE RATE RISK

A lognormal distribution is assumed for demand to simulate the weekly beer demand over the time period T_1. During the simulation runs, a random sample is obtained from this distribution for each iteration of the model. The model is solved for two levels of risk aversion along the supply chain, where maximum *VaR* (*v*) values are taken to be CAD 1.5 million and CAD 1.8 million for the less risk averse and more risk averse cases, respectively.

We use a simulation-based optimization tool (@RISK, part of the Decision Tools Suite provided by Palisade) to determine the values of the decision variables that minimize *E(TOC)* under relevant constraints. Starting with initial values of the decision variables, the optimization involves running a large number of simulations. Each simulation consists of 10,000 iterations. For each iteration, random values of the probabilistic inputs ($\tilde{S}_1, \tilde{F}_1, \tilde{E}_1$ and d_j) are generated and used in the calculation of the *E(TOC)*. The software uses genetic algorithms to find new solutions that improve the value of the objective function.

The results of the integrated risk management model with hedged and unhedged exchange rate risk are presented in Table 1, for the two different values of the maximum 95% *VaR* of the *TOC*, CAD 1.8 million (Panel A) and CAD 1.5 million (Panel B), respectively.

We first compare the results in Table 1, Panel A, for the integrated risk management model with hedging of foreign exchange risk and a maximum *VaR* of CAD 1.8 million, with the comparable model with no hedging of foreign exchange risk. We note that the performance of the model is better when foreign exchange risk is hedged. The value of *E(TOC)* when foreign exchange risk is unhedged is 20% higher than in the case when it is hedged. The total aluminium quantity purchased when foreign exchange risk is unhedged is not significantly different (0.56%) from the case when it is hedged. When foreign exchange risk is hedged, all of the aluminium quantity is purchased at t_1, while when foreign exchange risk is unhedged, 21.22% (37.8/178.1) of the aluminium is purchased at t_0, while the remaining portion is purchased at t_1. We cannot compare the numbers of put and call options purchased when foreign exchange risk is hedged with the corresponding numbers when foreign exchange risk is unhedged. This is because when foreign exchange risk is hedged, the options are options on aluminium futures with the futures price and the option premiums denominated in CAD, while when foreign exchange risk is unhedged, the options are options on aluminium futures with the futures price and the option premiums denominated in USD.

Table 1. Results of the integrated risk management model with foreign exchange risk hedged and unhedged for two different values of maximum *VaR*

Variable	Panel A. Maximum *VaR* CAD 1.8 million Foreign exchange risk		
	Hedged	**Unhedged**	**Diff. %**
***E(TOC)* in CAD**	495,182	619,664	20.09
Q_{a0} tons of aluminium	0.0	37.8	100.00
Q_{a1} tons of aluminium	177.1	140.3	-26.23
Q_a tons of aluminium	177.1	178.1	0.56
N_p tons of aluminium	939	3,395	-
N_c tons of aluminium	0	897	-

Variable	Panel B. Maximum *VaR* CAD 1.5 million Foreign exchange risk		
	Hedged	**Unhedged**	**Diff. %**
***E(TOC)* in CAD**	595,937	725,437	17.85
Q_{a0} tons of aluminium	19.8	60.5	67.27
Q_{a1} tons of aluminium	157.9	117.4	-34.50
Q_a tons of aluminium	177.7	177.9	0.11
N_p tons of aluminium	47	1,830	-
N_c tons of aluminium	330	695	-

We next compare the results in Table 1, Panel B, for the integrated risk management model with hedging of foreign exchange risk and a maximum *VaR* of CAD 1.5 million, with the comparable model with no hedging of foreign exchange risk. We note that, once again, the performance of the model is better when foreign exchange risk is hedged. The value of

E(TOC) when foreign exchange risk is unhedged is 18% higher than in the case when it is hedged. The total aluminium quantity purchased when foreign exchange risk is unhedged is not significantly different (0.11%) from the case when it is hedged. When foreign exchange risk is hedged, 11.4% (19.8/177.7) of the total aluminium quantity is purchased at t_0, while when foreign exchange risk is unhedged, 34.01% (60.5/177.9) of the aluminium is purchased at t_0, while the remaining portion is purchased at t_1. For the reason provided earlier, we cannot compare the numbers of put and call options purchased when foreign exchange risk is hedged with the corresponding numbers when foreign exchange risk is unhedged.

Next, we compare the results of the integrated risk management model, when foreign exchange risk is hedged, for the two different values of risk aversion, as captured by the maximum value of the 95% *VaR* of the *TOC*, CAD 1.8 million and CAD 1.5 million, in Table 1, Panels A and B. Note that when the maximum *VaR* is CAD 1.5 million, the supply chain exhibits a higher degree of risk aversion than in the case when the maximum *VaR* is CAD 1.8 million. There is not much difference between the total quantity of aluminium purchased in the two situations. The difference lies in the timing of the purchase. When the supply chain is less risk averse, all of the aluminium quantity is purchased in the future at t_1, while when it is more risk averse, a portion of the aluminium quantity is purchased at the current date t_0. The more risk averse supply chain uses both aluminium inventory and options to hedge its risks, while the less risk averse supply chain only uses options to hedge its risks.

5. CONCLUSION

In this paper, we study the performance of an integrated approach to risk management which is employed by a supply chain consisting of an aluminium can supplier, a brewery and a beer distributor, that is exposed to commodity price risk, demand uncertainty and foreign exchange risk. The commodity price risk arises from uncertainty in the input of aluminium sheets which are used to manufacture aluminium cans, demand uncertainty arises from uncertainty in the demand for the output, canned beer, and foreign exchange risk arises from uncertainty in the exchange rate between the CAD and the USD, since the aluminium sheets are priced in USD while the supply chain is located in Canada. Risk management is accomplished by using options on aluminium futures, as well by managing the inventory of aluminium sheets, cans and beer. The effectiveness of risk management is captured by the expected total opportunity cost of the supply chain. We find the optimal solutions for a less risk averse and a more risk averse supply chain, as represented by two different values for the maximum value of the 95% *VaR* of the total opportunity cost.

The results reveal that hedging foreign exchange risk is beneficial and that the supply chain can achieve a substantial reduction in its expected total opportunity cost as compared to the situation in which foreign exchange risk is unhedged. When foreign exchange risk is hedged, a supply chain does not purchase aluminium sheets at the current date, as it does in the case in which foreign exchange risk is unhedged, and opts to accomplish its risk management by the use of options on aluminium futures. An increase in the level of risk aversion of the supply chain, however, causes the supply chain to purchase aluminium sheets at the current date, even when foreign exchange risk is hedged.

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