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Karanjit Singh
University of Pennsylvania

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Disciplines

Business | Business Administration, Management, and Operations



Risk Management Hedging Commodity Exposure

By –Karanjit Singh
Advisor – Paul R. Kleindorfer
Wharton Undergraduate Research Scholars WH-299-301
April 2004

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This paper considers the optimization of a hedging portfolio subject to a Value-at-Risk (VaR) constraint (about corporate profits) that can be used by a company such as Anheuser-Busch to eliminate exposure to commodity prices. The model built along with this research study simulates hedging costs associated with various hedging portfolios consisting of financial derivatives on aluminum including options, futures, and futures and options. The results for an efficient hedging portfolio are then integrated with Anheuser-Busch's utility preferences to map out the optimal portfolio that the company can use to hedge its exposure. The simulation model built for this exercise also allows the hedger to simulate other strategies that may have a different objective than the one outlined in this study.

I. Introduction

Risk Management has become an important function at multinational corporations around the world. Incredible amounts of resources are allocated each year to make sure that firms are cognizant of their outstanding exposure and are able to best match supply and demand to minimize unpredictable losses. Recently, derivative contracts in business to business markets have become extremely popular. For example, real options on both capacity and output have helped integrate long-term and short-term contracting between buyers and sellers in capital intensive industries.¹ The flexibility that these contracts have brought to supply-chain decisions has created large economic benefits. Further, the existence of large exchanges on financial derivatives instruments such as futures and options are making it easier for corporations to hedge their exposure to input prices by taking the opposite position in a futures or options contract. The New York Mercantile Exchange, the world's largest commodity futures exchange, allows trading of derivative instruments on energy products such as oil and precious metals such as aluminum. The liquid market that this exchange provides allows large multinational companies to undertake hedging operations in-house by trading on contracts which are correlated to prices of their raw materials.

¹ Kleindorfer, P., Wu, D. J. 2002. Integrating Long-term and Short-term Contracting via Business-to-Business Exchanges for Capital-Intensive Industries. Philadelphia, PA.

Anheuser-Busch, a brewing company and one of the largest manufacturers of aluminum beverage containers, can participate in similar exchanges in order to carry out its risk management practices. Metal Container Corporation² (MCC), a subsidiary of Anheuser-Busch, produces more than 25 billion aluminum cans and 28 billion aluminum lids annually at its eight can and three lid manufacturing facilities. The subsidiary also supplies approximately 63 percent of Anheuser-Busch's can and 75 percent of Anheuser-Busch's lid requirements and is a significant supplier to the U.S. soft-drink container market. Given that aluminum is the primary raw material in what MCC manufactures and constitutes a large portion of the costs of each beer can that Anheuser-Busch produces, the firm's profitability is extremely dependent on aluminum prices. Given Anheuser-Busch's large size and its exposure to an extremely volatile commodity such as aluminum, the company can undertake its own risk management practices to hedge its exposure to the prices on the aluminum it receives at its plants.

II. Discussion of literature

A tremendous amount of literature, including research and textbooks, exists on the subject of risk management in general. One of the most fundamental yet comprehensive guides to risk management using derivatives contracts is John Hull's Options, Futures, and Other Derivatives. This book, prepared from the findings of many research efforts throughout the years, details many of the derivative instruments used today by practitioners in the field of risk management. Further, it provides a thorough discussion on the parameters such as volatility that will be key components in building the simulation model for Anheuser-Busch.

² <http://www.anheuser-busch.com/overview/package.html>

More specifically, academics have engaged in extensive research on the use of hedging contracts in specific industries. However, as pointed out by Kleindorfer and Wu (2002), the literature fails to integrate operations management issues with financial economics in order to provide a through analysis on the topic. The financial economic literature, including the famous paper by Black and Scholes (1971), provides pricing techniques for options that are traded in liquid markets in continuous form. In 1994, Dixit and Pindyck apply similar approaches to find the value of a real option which allowed for the postponement of an investment outlay for a capacity expansion until market demand is revealed. Birge (2000) uses the capacity planning context to further analyze the similarities and differences in operations risk management between real options and financial options. In particular, he shows that operating decisions, such as capacity expansions, are definitely affected by accounting for both real options associated with flexibility and by risk hedging from financial options. In 2002, Kleindorfer and Wu present a theoretical and practical survey of the use of options, on capacity and output, in integrating long-term and short-term contracting between buyers and sellers. Their study details the use of many different types of contracts in operations management in various B2B markets and through several mediums including the internet.

Perhaps the research that is most relevant to this study is conducted by Kleindorfer and Li in 2003 with special emphasis on applications in electric power industry. The research considers the optimization of portfolios of real and contractual assets, including derivative instruments similar to those used in this research, subject to a Value-at-Risk (VaR) constraint. The VaR constraint imposed by Kleindorfer and Li, however, is imposed on longer periods such as a year or a quarter but is affected by decisions made in the very short-run, say a week

or a month. They show that this problem can in fact be represented through available simulation and optimization methods which allow for management to implement VaR constraints while conducting hedging exercises. Simpler versions of this exercise were done by Marshall and Siegel (1997) and Coronado (2000) where all contingent claims and constraints on cash flows matured at the same end date.

III. Hedging

In risk management, the goal of hedging your cash flows can be thought of in one of two ways:

1. Reducing the underlying volatility of your cash flows.
2. Minimizing the probability of large losses.

Although both methods are correct in their own way, the second method of minimizing the probability of large losses is used more often in practice. This is because most corporations enjoy positive volatility because it allows them to earn extra profits. This second approach, which is only concerned with negative volatility, is used when calculating the Value at Risk (VaR) of a portfolio. Here the objective is to calculate the amount of money \$V that will represent the maximum loss that the company is allowed to sustain over a specified period of time with a certain degree of certainty. In other words, the company will only lose more than \$V over a certain time period with a specified probability.

Options Available for Hedging

Risk management at multinational corporations includes a lot more than financial derivatives contracts that this paper concentrates its efforts on. Some risks that Anheuser-

Busch faces maybe more optimally managed by operational decisions such as the division between “safe” projects or “risky” projects. Further, the capital structure that the company decides to use can also help the company avoid cash crunches and the costs of capital distress.³ In addition, real options on both capacity and price can help corporations integrate long-term and short-term contracting needs with its suppliers.

Arguments for Hedging

There is a tremendous amount of research in corporate finance and risk management outlining the arguments in favor of hedging by corporations. Most companies, including Anheuser-Busch, are in the business of manufacturing or providing a service to its clients. These companies are not particularly skilled at predicting variables such as exchange rates, interest rates, and in the case of this study, commodity prices. It makes sense for these companies to hedge their exposure to these variables and concentrate their efforts on their main business – in which they have particular skills and expertise. Hedging these risks can provide numerous benefits to the company including reducing the chances of a cash crunch and financial distress or even bankruptcy, making capital allocation more efficient, and allowing the company to provide consistent returns to the company’s shareholders.⁴ Further, hedging allows for easier and better performance evaluations of managers and business units since it allows the evaluator to strip the effects of price movements that are not controllable

³ Meulbroek, Lisa. 2001. *Risk Management at Apace*. Harvard Business School. Boston, MA

⁴ Hull, John C. 2003. Options, Futures, & Other Derivatives 5th Edition. Prentice Hall. Upper Saddle River, NJ.

by management. The company is also improves its ability to increase debt for rating agencies view hedging efforts in a positive manner.⁵

Nonetheless, an argument that is often presented against hedging by corporations is that shareholders can conduct risk management exercises themselves through diversification and purchasing hedging instruments. Thus, they do not need the company to manage risk for them. However, this argument ignores the problem of asymmetric information in that it assumes that the shareholders are just as knowledgeable about the company's risks as is the company's management. This is not often the case; thus, rendering this objection invalid. Further, it is often much cheaper in terms of transaction costs and commissions for the company to conduct its hedging in bulk rather than each shareholder having to manage all the company's outstanding risks.

IV. Simulation Exercise

To study the practices of risk management at Anheuser-Busch, this research exercise will consist of analyzing a simplified scenario where Anheuser-Busch will receive delivery of aluminum at its packaging division plant. Let us suppose that Anheuser-Busch needs to accept delivery of 880,000 pounds of aluminum at the spot price prevailing in the market in thirty days. The firm's costs for accepting this delivery are depicted in Exhibit 1 where the costs are directly dependent on the spot price of aluminum on the day that Anheuser-Busch accepts delivery.

⁵ Meulbroek, Lisa. 2001. *Risk Management at Apace*. Harvard Business School. Boston, MA

Exhibit 1

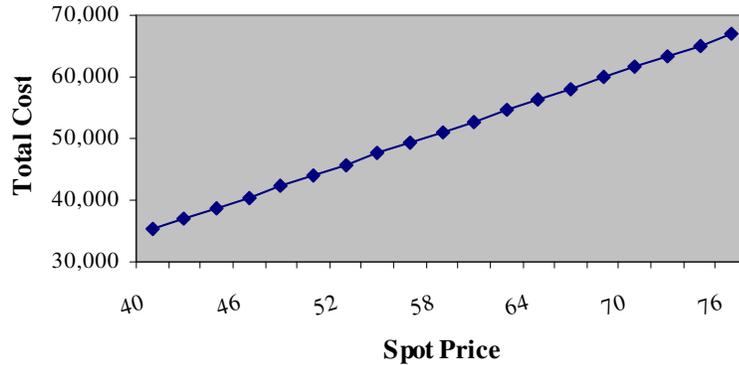
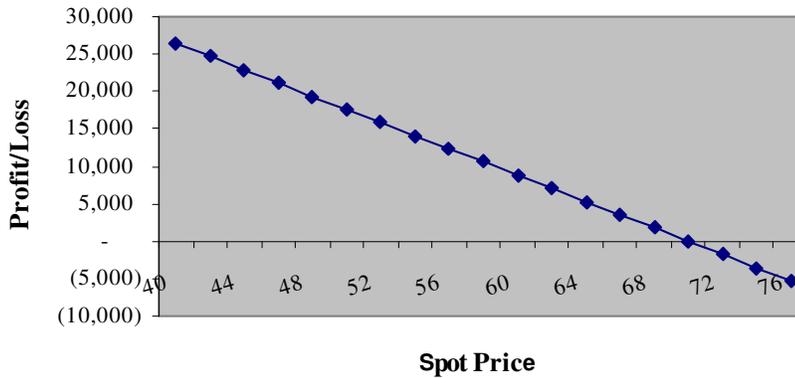


Exhibit 2 details the profit/loss based on a revenue rate of \$70 per pound of aluminum that Anheuser- Busch makes in association with each pound of aluminum.

Exhibit 2



As we can see, Anheuser- Busch is not at all hedged. Their profit/loss is completely dependent on the spot price of the aluminum on the date that the firm accepts delivery.

The goal of this project is to determine the efficient set of portfolios that Anheuser- Busch can use in order to hedge the aforementioned exposure to aluminum prices. The company's objective is to minimize their costs from hedging subject to a value at risk (VaR) constraint on the company's profits. Although VaR is criticized by many academics of

having potential shortfalls in measuring risk, it will be used in this study because of its popularity amongst hedging practitioners. The most accepted definition of VaR is the maximum loss that the portfolio is allowed to sustain over a specified period of time and at a specified level of probability. A VaR constraint is imposed by executives in order to limit the maximum loss that the company feels it can take over a defined period of time in order to avoid the problems of capital distress.

The costs of hedging are calculated to include all transaction costs and commissions associated with the trading of hedging instruments (T), all profits/losses on settlement of hedging instrument (Π), and any upfront costs to buy the hedging instruments in the case of options (C or P). For example, the total costs for hedging is determined as the sum of the three variables associated with the hedging portfolio summed across all instruments in the hedging portfolio.

$$\text{Total Costs} = \sum T_i + \sum \Pi_i + \sum C_i \text{ or } P_i.$$

The profit/loss from settlement of one hedging contract would be calculated as follows. For example, the profits from a European call option on aluminum futures would equal:

$$\Pi_i = \text{Max} [0, (F_T - K)]$$

where F_T is equal to the futures price upon expiration of the futures contract and K is equal to the exercise price on the call option.

The profits are calculated based on an assumed revenue of \$70 per pound of aluminum.

$$\text{Total profits} = [70 - \text{Effective Price}] * \text{Pounds of Aluminum purchased}$$

The effective price the firm pays for aluminum takes into consideration all profits/losses associated with hedging and thus is the post-hedging price that the firm pays for aluminum.

The objective of the simulation and Anheuser-Busch when conducting their hedging is to minimize C given a value at risk constraint about their profits which can be defined as follows:

$$\Pr \{ \text{Total Profits} \geq P' \} > 1 - \alpha$$

where total profits is calculated as described above. P' is an upper limit that the company imposes on the minimum profits that they would want to see serve as the protection level and $1 - \alpha$ could equal 0.95, 0.975, 0.99 based on the company's risk preference.

A critical assumption underlying VaR computations is that the underlying distribution is normal. While a normal distribution is extremely likely in financial markets, aluminum markets, similar to other commodities, are known to experience short-term price spikes that give rise to "fat-tails." This model will avoid this issue of normality because the P' (upper limit) will be read off of simulation results where it is guaranteed that profits fall below P' with a probability of $1 - \alpha$.

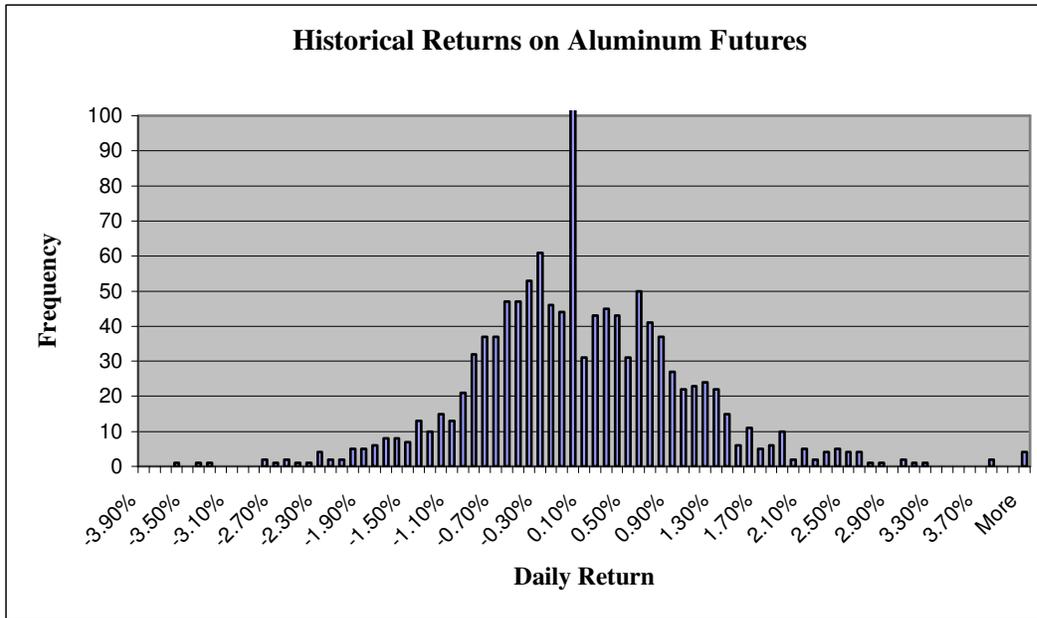
V. Assumptions and Description of Model

This simulation model allows Anheuser-Busch to focus on a portfolio of instruments which include futures on aluminum and options on aluminum futures contracts to hedge the firm's exposure to the prices it will have to pay for aluminum upon delivery. The model allows the company to hedge solely with one of these instruments or to use a combination of these instruments to carry out its hedging exercise.

In simulating aluminum prices, the model first needed to make an assumption about the distribution of aluminum prices going forward. After graphing the distribution of the daily

returns on aluminum futures over the last for year (Exhibit 3), it was determined that aluminum returns were approximately normally distributed with a mean daily return of 0.017% and a standard deviation of 0.963%. These parameters were then used in the model to simulate daily futures prices that Anheuser- Busch will encounter over the time horizon of their exposure.

Exhibit 3



A thorough description of the instruments offered to Anheuser-Busch in this simulation portfolio and the assumptions underlying these instruments in the simulation are now presented.

Futures Contracts

Futures contracts are standardized contracts that are traded on exchanges where illiquidity is seldom a problem. Exchange traded futures contracts make investors post margin which gets adjusted daily to reflect gains or losses incurred due to the change in settlement price of the contract. Futures contracts are usually closed out prior to maturity, thus the investor does not need to worry about physical delivery of the underlying asset.

Futures on aluminum are traded on the Commodity Exchange (COMEX), a division of the New York Mercantile Exchange. Each contract trades in denominations of 440,000 pounds of aluminum where the price of the future contract at settlement every day is quoted in cents per pound. Trading on a particular contract ends at the close of business on the third to last business day of the delivery month. The details of an aluminum futures contract traded on COMEX are presented in Appendix 1.

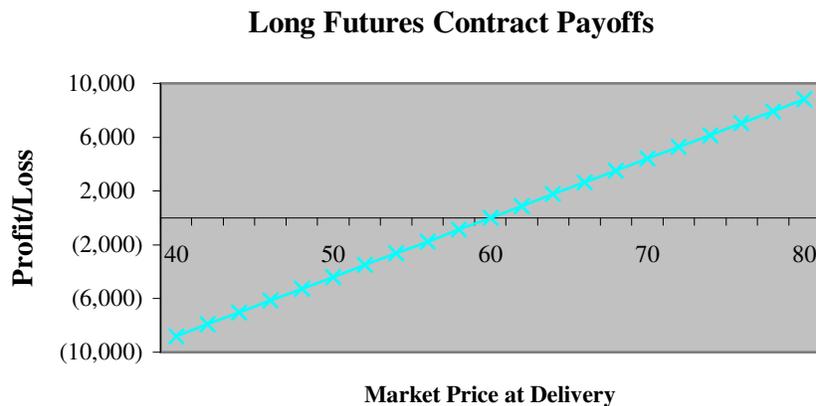
Example: Long Futures

As Anheuser Busch is short the exposure on aluminum since it needs to purchase 880,000 pounds of aluminum at the spot market, it can hedge its exposure by buying two futures contract for 440,000 pounds of aluminum at a strike price of \$60 per pound. This locks the firm to buy aluminum for \$60 per pound. For example, if the spot price of aluminum on the date of delivery is \$80 per pound, the firm will pay \$80 per pound for aluminum, but the gain from their futures position of $(S_T - K)$, where S_T = the spot price of aluminum on delivery and K = the strike price on the aluminum futures contract) $\$80 - \$60 = \$20$ per pound will offset the extra payment. Similarly, if the spot price of aluminum on the date of delivery is \$45 per pound, the firm will only pay \$45 per pound for aluminum.

However, the loss from their cash settlement of the futures position of $(K - S_T)$ $\$45 - \$60 = -\$15$ will offset the discount that they received on the spot transaction.

This allows the price that the firm pays for aluminum to be completely independent of the aluminum spot price on the day of delivery. Exhibit 4 illustrates the firm's position in one long futures contract. It is clear that this position, when combined with a short aluminum position, the appropriate number of long futures contracts will create a payoff position for the firm that is completely independent of the spot price.

Exhibit 4



In incorporating this hedging exercise into the simulation model, several assumptions were made regarding the maturity date of the futures contract and the underlying security of the futures contract. First and foremost, the assumption that the maturity of the futures contract matched the desired delivery date of aluminum eliminated any rollover risk that otherwise may have existed. If the desired delivery date of the aluminum exceeded the maturity on the forward contract, Anheuser Busch would have to close off its position in the

futures contract and enter into another futures contract to hedge its exposure. However, in doing this, there is the risk that the firm will not be able enter into a contract with the same strike price as they would desire.

Further, it was fortunate that there exists a futures market on the asset that Anheuser Busch is exposed to. This guarantees that the hedging instrument has a correlation of one to the exposure being hedged and thus, basis risk is eliminated. If a liquid aluminum futures market did not exist, Anheuser Busch would have to resort to another hedging instrument that perhaps does not covary perfectly with the price of aluminum, thus exposing the company to what is known as basis risk.

In the example above, it was also assumed that Anheuser Busch wanted to be perfectly hedged from movements in aluminum prices. This assumption however can be relaxed in the simulation model by changing the number of contracts that the company enters into in the futures market. For example, if the company was to accept delivery for 1,000,000 pounds of aluminum, going long two futures contract for 880,000 pounds of aluminum will allow the firm to be only 88% hedged to movements in aluminum prices.

Option Contracts on Aluminum Futures

Anheuser-Busch can also use call options on aluminum futures to place a ceiling on the cost of aluminum on the date of delivery. The benefit of an option over a forward contract is that the firm is not committed to settle its position. It will only exercise the option if it is desirable to do so, giving the contract a kinked payoff as described below. However, since an option contract allows the firm to have limited liability and at the same time provides a potential upside, the firm must pay for these options.

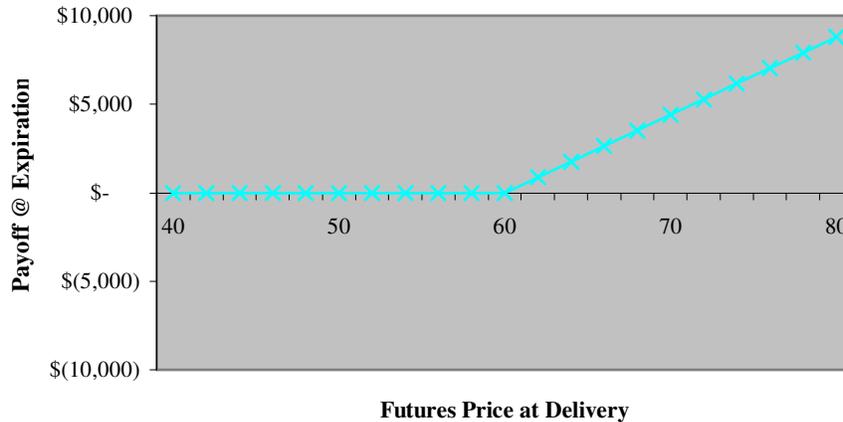
Options on aluminum futures are American-style options traded on the Commodity Exchange (COMEX), a division of the New York Mercantile Exchange. If a call futures option is exercised, the holder acquires a long position in the underlying futures contract plus a cash amount equal to the difference between the most recent settlement futures price and the strike price. If a put option is exercised, the holder acquires a short position in the underlying futures contract plus a cash amount equal to the difference between the strike price and the most recent settlement futures price. In effect, the actual payoff from a call futures option is the futures price at the time of exercise minus the strike price on the option. Further specifications of options traded on aluminum futures on COMEX are presented in Appendix 2.

Example: Call Option

Anheuser-Busch can purchase a call option on aluminum futures with an exercise price of \$60, allowing it to put a ceiling of \$60 per pound on the cost that it must pay upon delivery for aluminum. Thus, if the futures price on the date of delivery is below \$60, Anheuser-Busch will allow the option to expire without exercising it. However, if the futures price is above \$60, Anheuser-Busch will exercise the option and have a payoff of $F_T - K$. The total payoff to this contract is determined by the equation $\text{MAX} [0, F_T - K]$ giving rise to the following kinked payoff as shown in Exhibit 5.

Exhibit 5

Call Option Payoff

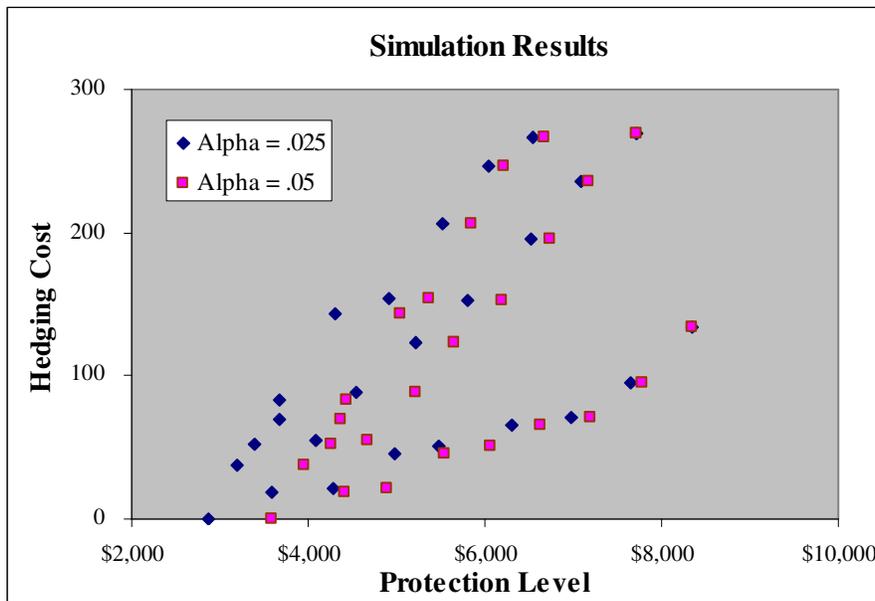


In incorporating this instrument into the simulation model, several assumptions were made in order to eliminate complications. First and foremost, the simulation uses only European options, meaning that the buyer of the options cannot exercise the option prior to maturity. The maturity of the option was also set equal to the maturity of the underlying futures contract and equal to the date of delivery of the aluminum that Anheuser-Busch will buy in the spot market. Options were valued in a closed form environment using the Black-Scholes methodology as described in their paper in 1973. Thus, the valuation of options makes all simplifying assumptions that Black and Scholes made including no transaction costs, no riskless arbitrage opportunities, continuous security trading, a constant risk-free rate, and all securities are perfectly divisible. A detailed description of the Black-Scholes equations used in valuing these options on aluminum futures can be found in Appendix 3.

VI. Results

In determining the efficient set of portfolios with respect to minimizing hedging cost, simulations were conducted on various portfolios consisting of futures, options, and options and futures. The hedging costs and the protection levels of these portfolios can be shown on the scatter plot below in Exhibit 6. The diamonds represent data points where the VaR protection level is based on an alpha of 2.5%. Respectively, the square data points represent data points where the VaR protection level is based on an alpha of 5.0%.

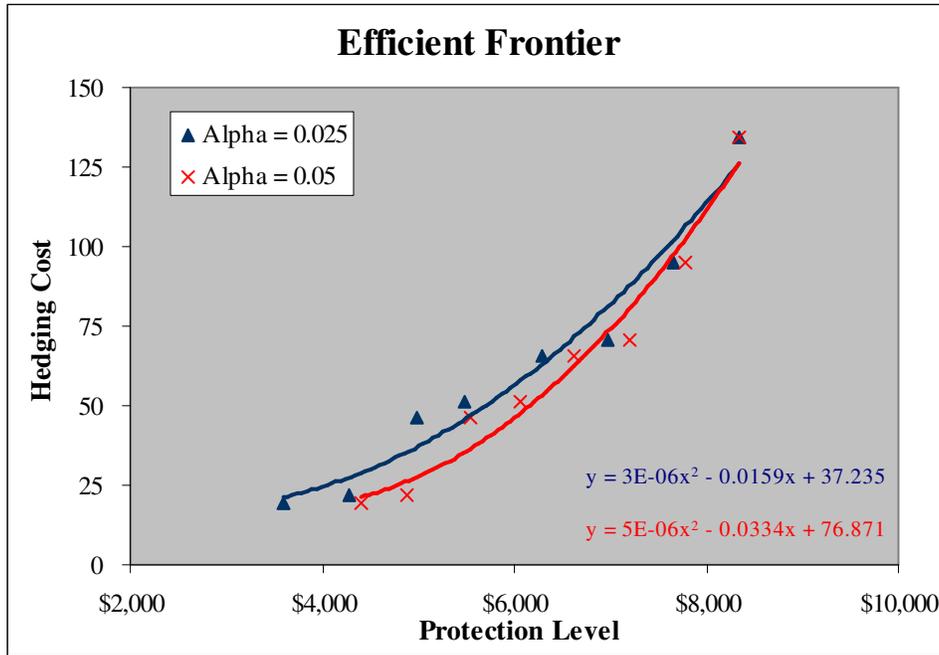
Exhibit 6



From all these data points, the efficient frontier can be mapped out by minimizing the hedging costs associated with various protection levels across all simulations conducted. Exhibit 7 depicts the efficient frontiers achieved from this optimization and displays the equation for each frontier. The blue line represents the efficient frontier where the VaR protection level is

based on an alpha of 2.5%. Respectively, the red line represents the efficient frontier where the VaR protection level is based on an alpha of 5.0%.

Exhibit 7



After achieving the efficient frontier, it was convenient to map out Anheuser-Busch’s certainty equivalent for various levels of protection to determine the optimal portfolio that Anheuser-Busch can choose in hedging its exposure to aluminum prices. In reaching the certainty equivalent, the expected utility (mean) for various simulations (various protection levels) was determined from the following utility function.

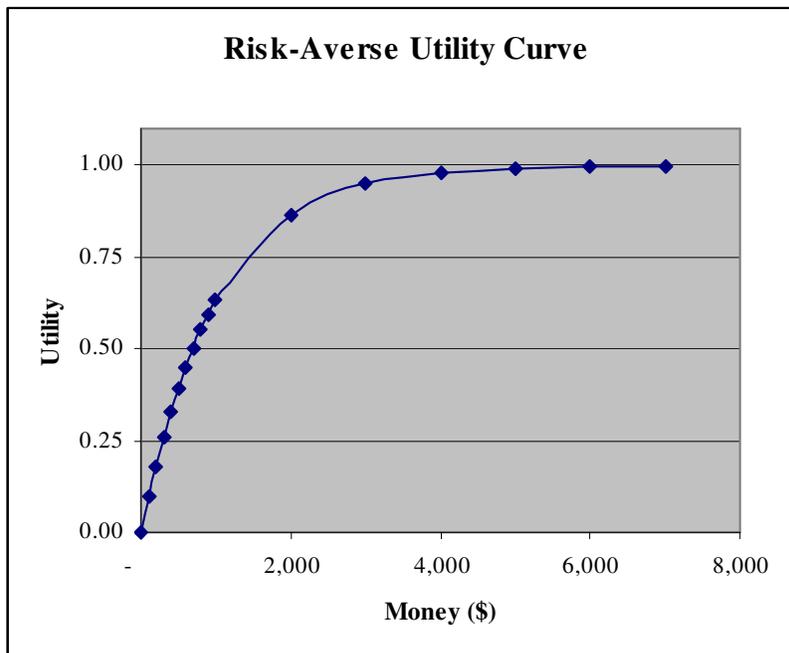
Utility Function: $U(x) = 1 - \exp(-x * \lambda)$

where λ is a risk-aversion coefficient, x is the amount of money, and $U(x)$ is the utility (or satisfaction) as a function of the money.

This utility function displays different properties for different levels of risk-aversion.

Risk-Averse Investor: For the risk-averse investor like Anheuser-Busch, the function increases in utility or satisfaction by more than \$A as x increases by \$A for relatively small values of x. However, once this investor has accumulated a certain amount of wealth, there is almost no increase in utility for each additional dollar increase in money. Overall, the utility of the investor for each additional dollar increases at a decreasing rate. The utility of the risk-averse investor is depicted in Exhibit 8.

Exhibit 8

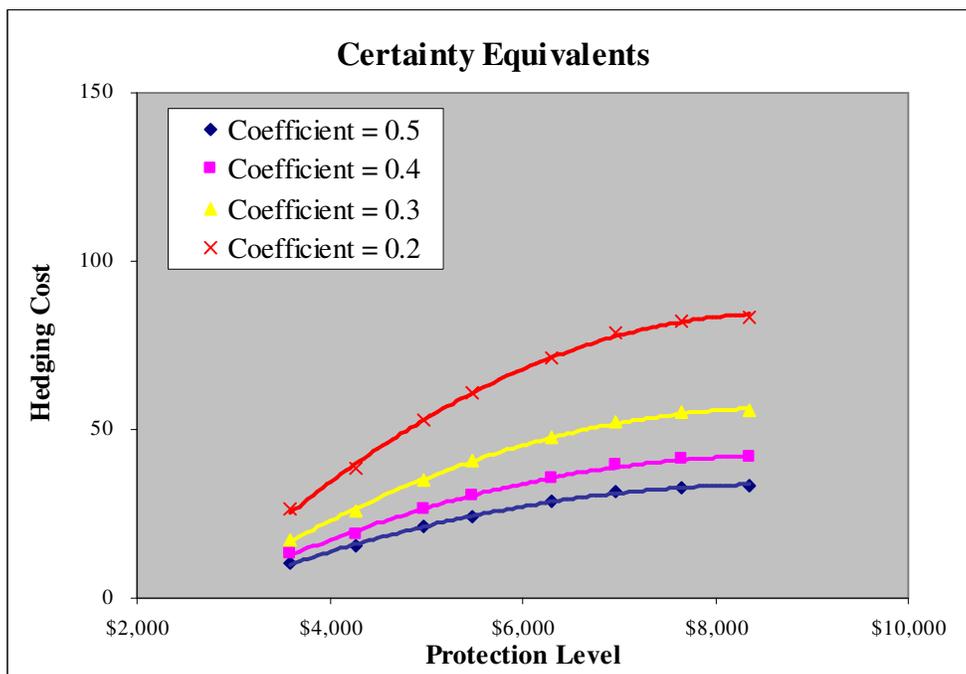


Each expected utility level obtained from each simulation was then used to compute the certainty equivalent that Anheuser-Busch would have for the protection level. The following function maps out the certainty equivalent.

Certainty Equivalent: $x = \ln[1 - U(x)] / \lambda$

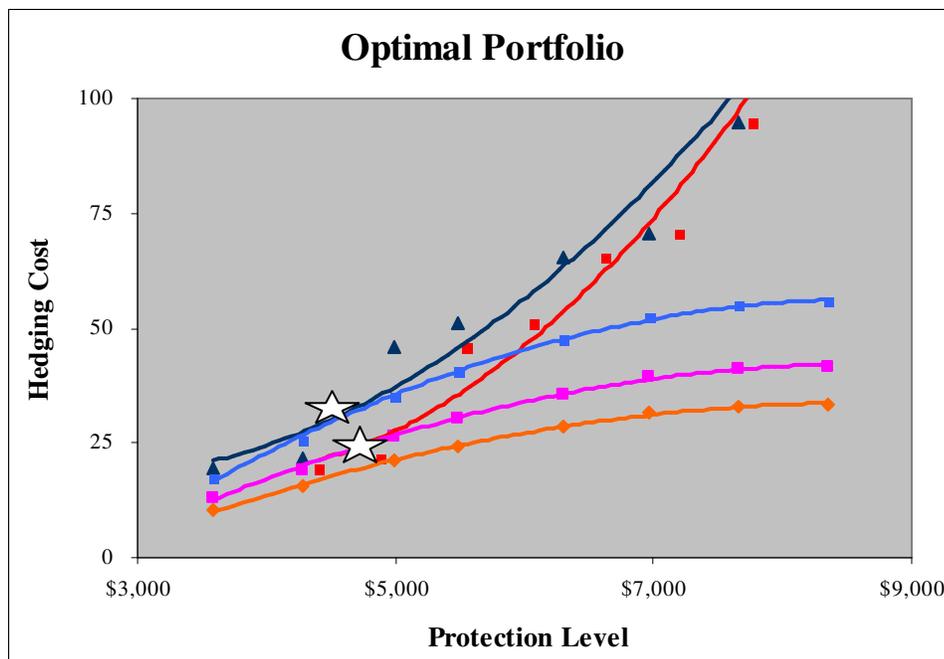
Exhibit 9 below displays the certainty equivalents obtained from the simulations for various different risk aversion coefficients where the greatest risk aversion coefficient represents the most risk-averse investor.

Exhibit 9



In order to determine the optimal portfolio along the efficient frontier that Anheuser-Busch should use in order to hedge their exposure to aluminum prices, it was useful to map out the efficient frontiers depicted above on the same graph as the certainty equivalents. According to the risk-aversion preference of the hedger, Anheuser-Busch, the optimal portfolio can be obtained by taking the tangency point of the efficient frontier and the proper certainty equivalent. Two optimal portfolios based on the two different alpha values specified above and based on two different risk coefficients are depicted by stars in Exhibit 10.

Exhibit 10



In terms of composition, the efficient frontier depicted in Exhibits 7 and 10 comprised only futures contracts. Intuitively, it makes sense that hedging with portfolios consisting of only futures is relatively cheaper than hedging with portfolios consisting of options or with portfolios consisting of options and futures. This is because options have an upfront premium cost that the hedger must assume since options give the investor a potential upside. Given that the objective of the simulation was to minimize C given a value at risk constraint about the company's profits which can be defined by: $\Pr \{ \text{Total Profits} \geq P' \} > 1 - \gamma$, the potential upside provided by options was completely ignored. If Anheuser-Busch wants to retain the potential upside that options provide, it may be more efficient to use portfolios consisting of options or portfolios consisting of both options and futures.

Nevertheless, the model allows Anheuser-Busch to simulate strategies where they may have a different objective than the one chosen in this study. For example, Anheuser-Busch can choose to hedge themselves of aluminum prices outside a certain price range and leave itself exposed within that price range. This may make sense if Anheuser-Busch believes that the volatility of aluminum prices will be extremely high and the company would like to save money on hedging. This strategy can be implemented through a collar option strategy where Anheuser-Busch would sell put options with low strike prices (i.e $X=56$) and buy call options with relatively higher strike prices (i.e. $X=62$). This also allows the company to save costs on the option premium since they will be receiving some money from selling the put options. By following this strategy, it can be seen through the simulation results below that Anheuser-Busch locks itself into profits between \$6,218.39 and \$11,630.39.

<u>Percentile</u>	<u>Profits</u>
0.0%	\$6,218.39
2.5%	\$6,218.39
5.0%	\$6,218.39
50.0%	\$7,681.13
95.0%	\$11,630.39
97.5%	\$11,630.39
100.0%	\$11,630.39

Although the company is protected against high aluminum prices, it has given up its potential upside in profits and limited its profit potential within a certain range. Similar to this, the model can help Anheuser-Busch simulate other strategies that it may wish to pursue in hedging their exposure to aluminum prices.

VIII. Conclusion and Further Questions

Although this research may be able to recommend a strategy to determine the optimal set of contracts and provide a simulation model for determining this portfolio, implementation of the strategy is always questionable. The first challenge is internal where it has been noted that it is extremely difficult to integrate operational decision-making with financial systems such as option pricing models. Further, results from the model may not be optimal as parameters used in the models are likely to change as the aluminum futures market evolves continuously over time. Such challenges can only be overcome with empirical evidence of the effectiveness of implementing these strategies.

The Value at Risk approach used in this simulation model has also received criticism for not being the optimal measure of downside risk for a corporation. Although it is accepted in practice, it may be more appropriate to use the “expected shortfall” alternative measure of risk supported by several researchers.⁶ Further, VaR constraints in practice are often applied to cash flows of a longer period of time, around a year, while they are affected by decisions made in the short-run, a week or a month. This model assumes that the constraint’s time-horizon equals that of the decision to hedge by Anheuser-Busch. In the future, the expected utility approach used in this model can also be substituted with other approaches that may be more practical including the expected value approach. Other assumptions made in this study that may be relaxed in future studies include the matching of Anheuser-Busch’s aluminum exposure to the maturity of the hedging instruments, using only European style options rather than using American-style options, and using cash settlement of derivatives position and not worrying about physical delivery of the underlying commodity.

⁶ Artzner, P., F. Delbaen, J-M. Eber, D. Heath and H. Ku. 2002. “Coherent Multiperiod Risk Management”, Working Paper, RiskLab, ETH, Zurich.

Further, for a complete analysis of risk management options available to Anheuser-Busch, additional topics of study may include the hedging of aluminum with derivatives on other commodities that are correlated to aluminum prices. One such commodity is electricity for it comprises a large portion of the costs of producing aluminum. Another area of study may include the hedging of aluminum prices using bi-lateral real option contracts between Anheuser-Busch and its suppliers.

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Appendix 1

Future Contract Specifications

Trading Unit

44,000 pounds of aluminum.

Price Quotation

Cents per pound.

Trading Hours

Open outcry trading is conducted from 7:50 A.M. until 1:10 P.M.

After hours futures trading is conducted via the NYMEX ACCESS® internet-based trading platform beginning at 3:15 P.M. Mondays through Thursdays and concluding at 7:40 A.M. the following day. On Sundays, the session begins at 7:00 P.M.

Trading Months

Trading is conducted for delivery during the current calendar month and the next 24 consecutive calendar months.

Delivery Location

Exchange-licensed warehouses in Kentucky and Tennessee.

Quality Specifications

Primary aluminum meeting all the requirements of the P1020A designation or primary aluminum of 99.7% purity with a maximum iron content of 0.20% and a maximum silicon content of 0.10%.

Shapes

Low-profile sows weighing 600 to 1,575 pounds. T-bars weighing 600 to 1,735 pounds.

Last Trading Day

Trading terminates at the close of business on the third to last business day of the delivery month.

Minimum Price Fluctuation

\$0.0005 (.05¢) per pound (\$22.00 per contract).

Maximum Daily Price Fluctuation

\$0.20 per pound above or below the previous day's settlement price, unless one of the two closest delivery month's trades at or is offered or bid for two minutes at the limit. In that case, after a 15-minute halt, the market will reopen with the limits expanded by \$0.20 on either side of the previous limit. This can happen no more than twice in a session for a maximum \$0.60 limit.

Trading Symbol

AL

Appendix 2

Options Contract Specifications

Trading Unit

One COMEX Division aluminum futures contract.

Price Quotation

Cents per pound.

Trading Hours

Open outcry trading is conducted from 8:00 A.M. until 1:10 P.M.

After hours futures trading is conducted via the NYMEX ACCESS® internet-based trading platform beginning at 3:15 P.M. Mondays through Thursdays and concluding at 8:00 A.M. the following day. On Sundays, the session begins at 7:00 P.M.

Trading Months

21 consecutive months

Delivery Location

Exchange-licensed warehouses in Kentucky and Tennessee.

Quality Specifications

Primary aluminum meeting all the requirements of the P1020A designation or primary aluminum of 99.7% purity with a maximum iron content of 0.20% and a maximum silicon content of 0.10%.

Shapes

Low-profile sows weighing 600 to 1,575 pounds. T-bars weighing 600 to 1,735 pounds.

Last Trading Day

Expiration occurs on the fourth business day prior to the delivery month of the underlying futures contract. If the expiration day falls on a Friday or immediately prior to an Exchange holiday, expiration will occur on the previous business day.

Minimum Price Fluctuation

\$0.0005 (0.05¢) per pound (\$22.00 per contract).

Maximum Daily Price Fluctuation

\$0.20 per pound above or below the previous day's settlement price, unless one of the two closest delivery month's trades at or is offered or bid for two minutes at the limit. In that case, after a 15-minute halt, the market will reopen with the limits expanded by \$0.20 on either side of the previous limit. This can happen no more than twice in a session for a maximum \$0.60 limit.

Options Strike Prices

A minimum of 13 strike prices, in increments of \$0.01 per pound for strike prices below \$0.40, \$0.02 per pound for strike prices between \$0.40 and \$1.20, and \$0.05 for strike prices above \$1.20.

Trading Symbol

OA

Appendix 3**The Black & Scholes Model**European Option Pricing**The Assumptions Underlying the Model**

1. No dividends are paid out on the underlying stock during the option life.
2. The option can only be exercised at expiry (European characteristics)
3. Efficient markets (Market movements cannot be predicted)
4. Commissions are non-existent
5. Interest rates do not change over the life of the option (and are known)
6. Stock returns follow a lognormal distribution

The Model (Non-Dividend)

The basic inputs to price a European option on a non-dividend paying stock is as follows:

S = Underlying futures price

X = Strike price

r = Risk free rate of interest

V = Volatility

T-t = Time to maturity

We can then apply these input variables into the following set of equations to derive the price for a European call option on a non-dividend stock:

$$c_t = SN(d_1) - Xe^{-r(T-t)}N(d_2)$$

And for a European put option on a non-dividend stock:

$$p_t = Xe^{-r(T-t)}N(-d_2) - SN(-d_1)$$

Where $N(d_1)$ and $N(d_2)$ are the cumulative normal distribution functions for d_1 and d_2 , which are defined as:

$$d_1 = \frac{\ln\left(\frac{S_t}{X}\right) + (r + 0.5\sigma^2)(T-t)}{\sigma\sqrt{T-t}}$$

$$d_2 = \frac{\ln\left(\frac{S_t}{X}\right) + (r - 0.5\sigma^2)(T-t)}{\sigma\sqrt{T-t}}$$

d_2 can be further simplified as:

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

In order to compute the cumulative normal distribution function, we can consider the partial derivative of $N(x)$.

$$N(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-\frac{z^2}{2}} dz$$