# CHAPTER THIRTEEN

## Managing Risks: Airline Fuel and Currency Hedging

*The airline business is fast-paced, high risk, and highly leveraged. It puts a premium on things I like to do. I think I communicate well. And I am very good at detail. I love detail.*

*— Robert L. Crandall, CEO and President*

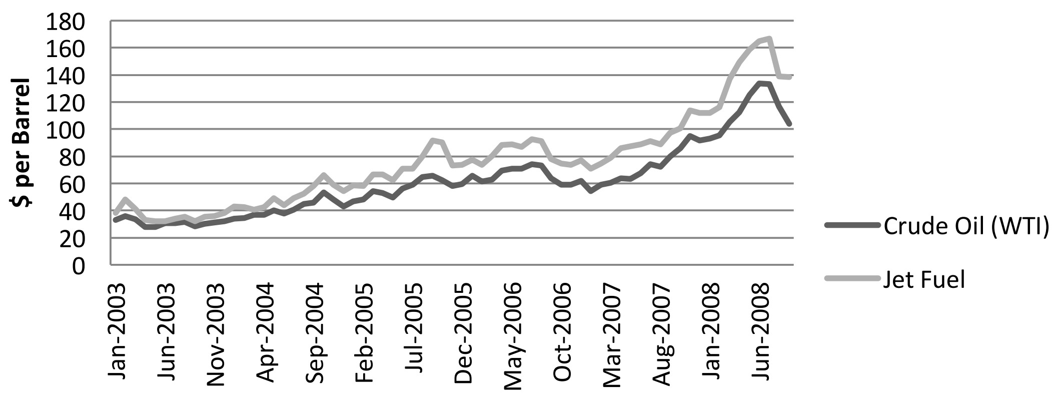
*American Airlines.*

As highlighted in chapter thirteen, the airline industry is filled with risks. One of the largest risks to the airline industry is the price of jet fuel. Fuel hedging can help reduce the risk, and, in order to understand how fuel hedging works, the concepts of future and forward contracts are required. The process of hedging involves offsetting the risk of a possible future event by betting on the opposite of that event. A variety of examples illustrate how call options contracts can be used to manage fuel cost. The chapter explains collars and future contracts and presents information about the role of fuel hedging in airline industry.

- Financial Derivatives and Options
- Hedging
    - Should an airline hedge?
    - Financial Derivatives
        - Swaps
        - Call Options
        - Collars
        - Future Contracts
    - How much should an airline hedge?
- Appendix: Black-Scholes Option Pricing Model

One of the most recent shifts in the airline industry has been the increasing proportion of jet fuel costs to an airline's cost structure. Previously, wages, salaries, and benefits represented the greatest expense to airlines; however, as the price of crude oil has continued steadily rising airlines have been subjected to a cost that has increased nearly sevenfold in just five years (IATA, 2008). For example, Southwest Airlines fuel expenses in 2007 were $2.5 billion, more than double their fuel costs in 2005 (Southwest Airlines, 2008). Figure 13.1 depicts the soaring cost of fuel from January 2003 to September 2008.

**Figure 13.1 Jet Fuel and Crude Oil Prices**




Source: Data compiled by authors from Energy Information Administration

The major problem concerning fuel for airlines is that, unlike some other costs, jet fuel prices are largely out of an airline's control. The reason for this is the simple fact that the price of jet fuel is ultimately the result of a market clearing price. An airline's inability to have control over its largest cost is the source of an immense amount of risk. In fact, jet fuel in the airline industry is probably one of the largest costs that any firm has no direct control over. However, airlines do have ways of controlling the amount they pay for jet fuel since they can hedge against the soaring costs of oil. Hedging is a strategy that involves taking an opposite position in a security (sell vs. buy) in order to minimize risk. Ultimately, hedging is performed to minimize the volatility and risk of a major input or cost to a firm. While jet fuel represents the largest hedging opportunity to airlines, currency hedging is also routinely performed to minimize the volatility in world currency prices. For airlines operating to a multitude of countries, currency hedging can help separate a good business decision from a disastrous one. Fuel and currency hedging are types of financial options and, in order to understand them, we must first understand options.

**Financial Derivatives:**

Options, futures and forwards are financial derivatives. They are called derivatives because their value is derived from an underlying security. An option is a contract which gives the holder the right, but not the obligation, to buy or sell an asset at a given price during a given period of time. There are two different options: a call option and a put option.

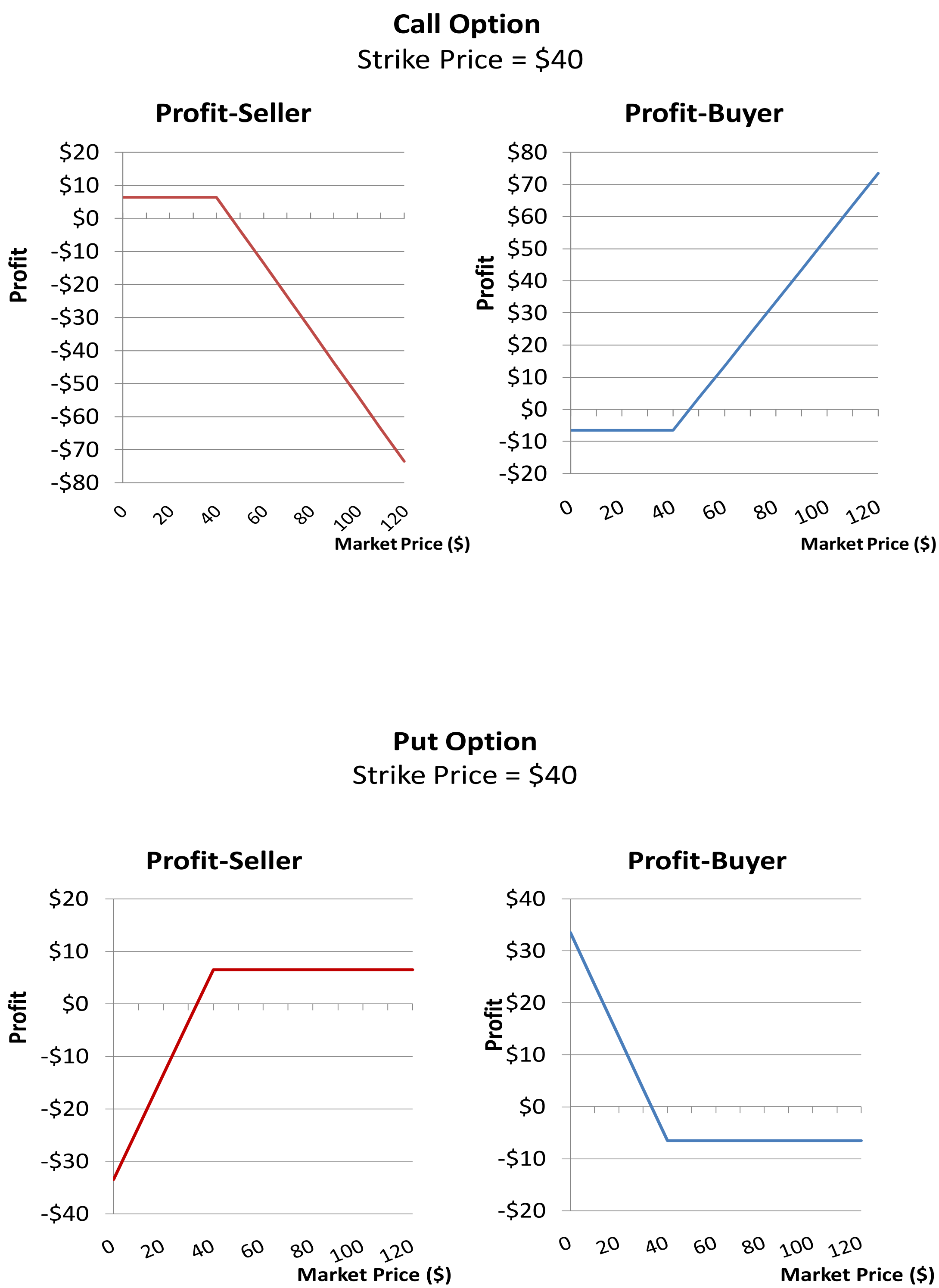
- **Call option** is the right, but not the requirement, to buy a particular asset at a predetermined fixed price (strike price) at a time up until the maturity (expiration) date of the option.

Buyers of call options pay a premium for the right to buy the commodity at the specified price (Hull, 2008). Call options act as caps on the price of a commodity (such as jet fuel). If the market price of the commodity is less than the strike price, the holder of the call option will not exercise his option and will simply buy the commodity at market price. However, if the market price of the commodity is above the strike price the holder of the call option will utilize his call option in order to buy at the lower strike price. The opposite of call options are put options.

- **Put options** are the right, but not the requirement, to sell a particular asset at a predetermined fixed price (strike price) at a time up until the maturity date of the option.

Put options protect the seller of a commodity by placing a floor on the price they will be able to sell the commodity for; a put option will only be exercised if the market price falls below the strike price. There are always two parties involved in the purchase of an option. There is the writer (seller) and the buyer. The buyer pays the writer a premium for the contract to compensate the writer for the risk that the option may be exercised. The amount of this premium depends on the value of the underlying commodity, the volatility of its price, and the time to maturity of the option. In the figure below we show the profit and loss potential for the buyer and the seller of call and put options.

**Figure 13.2 Profitability of Call and Put Options**

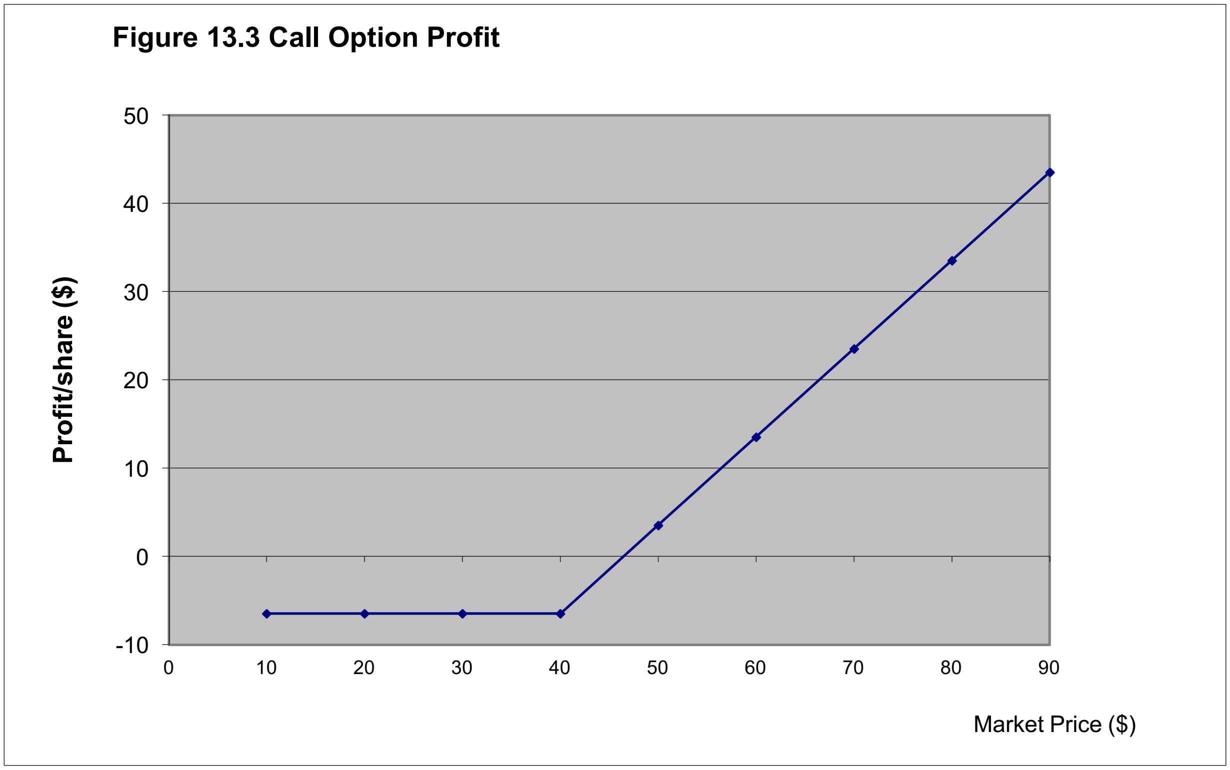


In order to better understand the value of options, let us examine the following example. Suppose you were to buy 10 April call contracts for DirectJet stock with a strike price of $40 and $6.50 premium for this call option.[1] Each call option contract is for the purchase of 100 shares of DirectJet stock. The option is quoted at a premium of $6.50 per share, so the contracts cost $650 each. You would spend a total of 10 x $650= $6,500. You wait until the expiration date (EXP); the following table tells you the option value and profit per share for exercising the call option:

| Table 13.1 | DirectJet stock- Call Option values/share ($) | | |
|---|---|---|---|
| Stock Price | Option Value | Premium | Profit |
| 10 | 0 | -6.5 | -6.5 |
| 20 | 0 | -6.5 | -6.5 |
| 30 | 0 | -6.5 | -6.5 |
| 40 | 0 | -6.5 | -6.5 |
| 50 | 10 | -6.5 | 3.5 |
| 60 | 20 | -6.5 | 13.5 |
| 70 | 30 | -6.5 | 23.5 |
| 80 | 40 | -6.5 | 33.5 |
| 90 | 50 | -6.5 | 43.5 |
| 100 | 60 | -6.5 | 53.5 |
| 110 | 70 | -6.5 | 63.5 |
| 120 | 80 | -6.5 | 73.5 |

Consider the payoffs graphically. As can be seen from the following figure, the payoffs are one to one after the asset rises above the exercise price. In this case, when the price is less than the exercise price ($40) the call option is referred to as out of the money, and the option would expire as worthless. In this case your loss is limited to the premium paid to purchase the contract.

[1] Options expire on a specific date and the time to expiration is known as its maturity.




Here's what happens. Remember, you bought the DirectJet April $40 call. On expiration Friday, assume DirectJet is at $50 per share. You have a Call option, which can be exercised to purchase 100 shares of DirectJet Stock at $40 per share (Chance, 2003). Conversely, if the share price goes up, your return on investment is much greater for the option than for the share. If you do that, you can then sell that stock back in the market and make a $10 return per share, or $1000. Since your initial Call premium was $650, your net profit is $350. You could simply sell the option back in the market, at any time before expiration, and take the profit on the option itself. Figure 13.3 plots the profit of a call option at expiration against the stock price. Hence, a call option has value to its owner only if the price of the underlying asset is above the strike price. If the value of the asset is below the strike price, the owner of the option simply lets it expire unexercised.[2] The primary advantage of buying options is that the investor cannot lose more than the premium of $6.50 per share. If you buy the shares and the price goes down below $40, you are exposed to the full amount of the loss.

[2] The option value would be negative

**Hedging**

Now that we understand how financial options work, we can look at how the hedging of fuel prices and foreign currencies works. Hedging is similar to buying and selling options since the objective is to reduce risk.

In order to understand hedging, three critical questions must be answered:

- Should the firm hedge?
- If so, how to hedge?
- How much to hedge?

***<u>Should the firm hedge?</u>***

*Its operation in a world beset by fuel and energy crises makes no sense at all.*

*Senator Cranston of California, regarding the Concorde, 1974*

Senator Cranston's comments regarding the Concorde could apply to some of the fuel inefficient aircraft of today. American still operates a very large MD-80 fleet and the newly combined Delta/Northwest still operate large MD-80 and DC-9 fleets.[3] It may not be feasible, operationally or financially, to replace a large number of airplanes at once; therefore, airlines with older, less fuel-efficient planes are going to be more heavily impacted by rising fuel prices. In order to protect against rising fuel prices airlines, even those with newer fleets, may enter into fuel hedging contracts. Similar to an insurance policy, the sole purpose of hedging is to minimize risk. Therefore, any cost that might fluctuate widely, and over which an airline has no control, represents a cost for which hedging should be analyzed. Ultimately, hedging is a mechanism used to reduce or eliminate the fluctuations in costs, providing an airline with a more assured cost structure, thereby reducing an airline's risk exposure. Fuel costs represent the greatest opportunity for hedging in the airline industry, since the price of jet fuel is largely out of an airline's control and it also fluctuates widely. While currency does not represent as significant a

[3] Sources: www.delta.com, www.aa.com

risk exposure to airlines, currency is routinely hedged as exchange rates can fluctuate significantly.

Once financial risks have been identified, a decision needs to be made as to whether or not the airline should hedge. There is no universally correct answer on whether an airline should hedge jet fuel and/or currencies. Historically, airlines have both prospered (i.e. Southwest Airlines) and been hurt through hedging strategies.[4] Ultimately, the successes of hedging actions made today are determined by the outcome of events far in the future. Since the future price of jet fuel or a currency exchange rate is unknown, the outcome of the hedging strategy is unknown; however, hedging can significantly help reduce the range of prices, thereby reducing an airline's exposure to risk.

In order to be successful at hedging, one requires a hypothesis about the price of jet fuel or the currency exchange rate in the future. To form a reasonable hypothesis, an understanding of the factors affecting the risk item is essential. As basic economic theory states, the price of any good is the equilibrium point between the supply and demand for the good. Related to crude oil, the price of oil should be the equilibrium between the supply of crude oil and the demand for crude oil. However, in financial markets, speculation can comprise a significant portion of a commodity's price.

- **Speculation** is the buying (selling) of a good today in the expectation that the future price of the good will go up (down). Therefore, speculation will affect the price of the good today. Buying drives up the price (increase in demand) and selling drives the price down (decrease in demand).

Since commodities are traded on exchanges, if the current belief is that the price of oil will be high in the future, then speculators will be taking stances on oil today that ultimately drives up the price of crude oil today. Therefore, speculation is the component of a commodity's price that is not the result of supply and demand, but of future expectations about the commodity's price. Unlike supply and demand, which contain fundamental underlying market principles, speculation

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[4] Southwest entered into hedging in 1999 when oil was at $11 a barrel (Los Angeles Times, May 30, 2008). The airline chose to hedge only 55% of its fuel use in 2009.

not only creates significant swings in the price of a commodity, but is also difficult to assess and determine.

Since jet fuel represents the greatest risk exposure for an airline, an understanding of the factors impacting the supply and demand for jet fuel is crucial in helping determine a hedging strategy for jet fuel. As jet fuel is a derivative of crude oil, the variables that impact the price of crude oil ultimately affect the price of jet fuel.

***How to Hedge?***

If it has been deemed beneficial to hedge a commodity, the next question involves how to actually hedge? Hedging involves using financial derivatives which are instruments whose payoffs and values are derived from an external source. While hedging involves using multiple financial derivatives, all hedging activity is based upon forward and future contracts.

- **Forward contract:** an agreement between two parties to buy or sell a specified amount of a commodity at a specific price at a specific time in the future.

For illustration purposes only, suppose an airline could potentially agree to buy 10,000 gallons of jet fuel in three months at a price of $3.00 per gallon. At the time of maturity, the airline would physically receive 10,000 gallons of jet fuel and pay the supplier $30,000 for the commodity. The "profitability" for either party would be determined by calculating the difference between the spot price, the price of the commodity at the contract's maturity, versus the forward price, the price of the commodity stated in the forward contract. Assuming that the price of jet fuel at maturity was $2.80 per gallon, the airline would have made a loss of $2,000[5] as a result of entering the forward contract, while the supplier would have recorded a gain of $2,000[6].

Regardless of the gain/loss position of either party at maturity, both sides are expected to perform their end of the agreement.[7] However, while an agreement can be enforceable in a court of law, both sides are taking on some level of credit risk as either party has the potential to default on the forward contract. While credit risk may not be as extensive for some parties, the

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[5] Loss = (Spot Price – Forward Price) * Quantity = ($2.80 - $3.00) * 10,000 = ($0.20) * 10,000 = ($2,000)
[6] Gain = (Forward Price – Spot Price) * Quantity = ($3.00 - $2.80) * 10,000 = $0.20 * 10,000 = $2,000
[7] The airline is expected to pay the supplier $30,000 and the supplier is expected to provide the airline with 10,000 gallons of jet fuel.

ultimate goal of hedging is to reduce risk, and therefore forward contracts are not always the best mechanism to use in a hedging strategy.

The other major problem with forward contracts as a hedging mechanism in the airline industry is that in order for the contract to be honored, the supplier must deliver the commodity. In the example, the supplier would have to provide the airline with 10,000 gallons of jet fuel on a single day. Aside from the logistical problems of delivering 10,000 gallons of jet fuel to the airline, other issues such as the variability of supply and demand create inefficiencies in the hedging strategy.

As a result of these shortcomings, future contacts are one of the more desirable financial derivatives used in hedging as they are similar to forward contracts, but feature more formalized and standardized characteristics.

- **Future contracts**: Standardized contracts with set criteria of the amount, price, and future delivery date of a currency, security, or commodity that are bought and sold at futures exchanges.

The differences between forward contracts and future contracts are shown:

| **Future Contracts** | **Forward Contracts** |
| --- | --- |
| • Standardized | • Not standardized (parties set terms) |
| • Traded on organized exchanges | • Informally traded |
| • Lower default risk | • Higher default risk |
| • Buyer and seller do not contract directly with each other | • The buyer and seller are dependent upon each other |

Just like a stock market, futures markets have real-time listings on the future prices for various durations of future contracts. In the United States, the Chicago Mercantile Exchange (CME) is the largest exchange with future contracts available on a wide range of commodities and currencies, ranging from corn to even weather (CME, 2008). However, for the airline industry, the New York Mercantile Exchange (NYMEX) is probably the most important as that is where crude oil futures are exchanged. Outside of the United States, other major futures markets include the Tokyo International Financial Futures Exchange and the London International Financial Futures Exchange.

As was mentioned, future contracts are standardized contracts with many specifications. The contracts for light sweet crude oil that are traded on the NYMEX are for 1,000 US barrels (42,000 gallons) of light sweet crude oil; however, the future prices are listed in US dollars on a per barrel basis (NYMEX, 2008). All settlement for contracts occur on the $25^{th}$ of the month, or the next appropriate business day. Additionally, the light sweet crude oil futures specify in detail delivery options for the contracts and the appropriate acceptable grade for the crude oil.

Table 13.2 displays six different futures contracts, ranging from one to six months in duration. Regular market trading on the NYMEX occurs from 9am to 2pm; however, electronic trading occurs almost 24 hours, 7 days a week creating differences between the last trade (electronically) and the last settle (regular trading) (NYMEX, 2008). Generally, the future prices for light sweet crude oil increase over duration, reflecting possible positions about crude oil and the fact that, with an increase in duration, suppliers bear an increased amount of risk.

| Table 13.2 | September 9, 2008 futures for light sweet crude oil | | | |
|---|---|---|---|---|
| | **High** | **Low** | **Recent Settle** | **Volume** |
| **Oct 2008** | 106.77 | 101.74 | 103.26 | 332,463 |
| **Nov 2008** | 107.00 | 101.94 | 103.36 | 151,179 |
| **Dec 2008** | 107.35 | 102.33 | 103.74 | 83,521 |
| **Jan 2009** | 106.65 | 102.99 | 104.15 | 19,636 |
| **Feb 2009** | 107.36 | 105.20 | 104.56 | 8,338 |
| **Mar 2009** | 108.18 | 103.96 | 104.96 | 9,571 |
| Source: Compiled by the authors using New York Mercantile Exchange (NYMEX) data | | | | |

Looking at the 4-month futures contract for light sweet crude oil (January 2009), to purchase the contract on September 9, 2008 would cost approximately $104,150 based on the settle price.[8] Based on this fact, futures markets are clearly not for the individual, but are markets more aimed at institutional investors and corporations looking at hedging. While institutional investors and corporations could theoretically take receipt of their futures contract, this is almost never done since buyers and sellers regularly offset their position prior to maturity. Future contracts are settled daily through the market clearinghouse ("market to market"). This is substantially different from forward contracts which are only settled at maturity. This settlement process involves buyers and sellers taking positions on the commodity. A position is a financial stance on a stock or financial derivative.

- **Long position (Long):** An agreement to purchase
- **Short position (Short)**: An agreement to sell

For the airline industry, a major issue for hedging is that their largest and most unpredictable cost, jet fuel, is not a widely traded commodity and is not traded on the New York Mercantile Exchange. While over the counter forward contracts can be created for jet fuel, futures contracts are a much more effective medium (for the reasons described previously), to

[8] Order Cost = Futures Price (Jan 09) * 1,000 barrels = $104.15 * 1,000 = $104,150

hedge with. Because no futures market exists for jet fuel, another widely traded commodity must be used instead. In choosing the commodity with which to hedge, the goal is to find a traded commodity whose prices fluctuate in the same way as jet fuel. Because jet fuel is a byproduct in the refining process of crude oil, other refining byproducts (such as heating oil) are likely to have similar pricing characteristics. Therefore, this makes them suitable hedging commodities.

A methodology for determining a suitable hedging commodity for jet fuel is to take the historical prices for various commodities and calculate the correlation coefficient. The correlation coefficient is a scale free measure of the association between two variables. In practical terms, the correlation coefficient describes how closely the prices of two variables move. A positive correlation indicates that the variables move in the same direction, while a negative correlation implies that they move in the opposite direction. Based on weekly historical spot price data, table 13.3 provides the correlation coefficient to US Gulf Coast Jet Fuel for three NYMEX –traded commodities over one, five, and ten year time periods.

| Table 13.3 | Correlation coefficients for US Gulf Coast Jet Fuel | | |
|---|---|---|---|
| **US Gulf Coast Spot Price Correlation** | | | |
| | **1-Year** | **5-Year** | **10-Year** |
| New York Heating Oil | 0.9978 | 0.9925 | 0.9954 |
| Light Sweet Crude Oil | 0.9906 | 0.9855 | 0.9928 |
| Mont Belvieu, TX Propane | 0.9026 | 0.9698 | 0.9763 |
| Source: Compiled by the author using EIA (Energy Information Administration) data as of August 29, 2008 | | | |

From the correlation coefficients contained in table 13.3, New York Heating Oil would appear to be the best liquid commodity as its correlation coefficients are greater for all periods of time than Light Sweet Crude Oil and Mont Belvieu, Texas Propane. Based on heating oil's one-year correlation coefficient of 0.9978, approximately 99.78% of price fluctuations in Gulf Coast Jet Fuel are also experienced in New York Heating Oil. Since there is no minimum requirement for the correlation coefficient, any of the three liquid commodities could be used in a jet fuel hedging scheme; however, by choosing Mont Belvieu, TX Propane, one would be assuming an increase in basis risk since the correlation coefficient for propane is much lower than New York Heating Oil. Basis risk describes the risk that the value of the commodity being hedged may not change in tandem with the value of the derivative contract.. In essence, basis risk is the proportion of fluctuations in jet fuel prices that are not related to changes in the spot price of the liquid commodities. Using the correlation coefficient the amount of basis risk can be determined by simply subtracting the correlation coefficient from 1. Using the one-year time period, the basis risk for New York Heating Oil is 0.0022 or 0.22% while the basis risk for Mont Belvieu, TX Propane is 0.0974 or 9.74%. As the goal with any hedging program is to reduce the amount of risk being borne, choosing to hedge jet fuel with the commodity that provides the lowest basis risk is the best solution. By reducing basis risk the chance that a fluctuation in the price of jet fuel that does not correspond to a fluctuation in the price of the derivative is minimized. Such fluctuations could potentially cause significant loss on the hedge. However, it should be noted that in order to hedge jet fuel in the futures market, some degree of risk must be borne since jet fuel is not a highly liquid commodity. Based on the correlation coefficients contained in table 13.3, the majority of US carriers that do hedge jet fuel utilize a combination of both New York Heating Oil and Light Sweet Crude Oil.

While the basis risk described above simply refers to the proportion of risk that is borne due to the diversion of price fluctuations between jet fuel and the derivative commodity, basis risk can also be the result of three other primary reasons: product basis risk, time basis risk, and location basis risk. Product basis risk occurs when there is a mismatch in the quality, consistency, or weight of the underlying process. In terms of the airline industry, while crude oil and jet fuel are similar, they are two separate commodities with different product and market characteristics and this could potentially cause distortions in pricing. Time basis risk occurs when there is a mismatch in the timing of the hedge. Since futures contracts have set time periods, time basis risk can occur when the desired time frame of the hedger differs from the stated contract dates. Finally, location basis risk is the result of a mismatch in the price of the product from one location to another. This is particularly common in the aviation industry, where the spot price of jet fuel can vary significantly not only from one location to the next in the United States, but also from country to country.

While the majority of this chapter’s focus has been on jet fuel hedging, currency hedging is also extensively practiced in the aviation industry. Whereas jet fuel is not a highly liquid commodity, currencies are. This significantly reduces the basis risk in currency hedging and enables one to participate in the futures market directly. Regardless of whether one is hedging international currencies or jet fuel, four major derivative instruments are commonly used to help reduce one's risk:

- Swaps (Plain vanilla and differential)
- Call options
- Collars (Zero-cost and premium)
- Futures contracts

It should be noted that derivative strategies are not limited to the four instruments listed above. In fact, there are endless variations of strategies that can be effectively used in a hedging strategy. However, the four major strategies listed above form the basis for the majority of variant derivative instruments.

- *Swaps (Plain vanilla and differential)*

The basis behind any swap is to exchange a floating price for a fixed price over a period of time. A swap is entered into by two parties, with one party assuming the variable price while the other assumes the fixed price. In the case of the airline industry, an airline wishes to reduce their variability in the price of jet fuel; therefore, the airline will assume the fixed price portion of the swap. Since a swap contract does not involve either party taking physical control over the commodity, a swap is deemed an off-balance-sheet financial arrangement where both parties settle their contractual obligations through a transfer of cash. As a result, a swap contract ultimately results in one party "winning" and another party "losing"; therefore, when a swap contract is entered, both parties must have divergent viewpoints on the price fluctuations of the commodity as both parties will enter a swap contract with the sole goal of being the "winner"[9].

Swap contracts can be conducted either through the over-the-counter market or through organized exchanges. In either case, a swap bank is commonly utilized, where a financial institution acts as a facilitator between the two parties.. In the over-the-counter market, a custom contract is created between two parties whereby the quantity, settlement, and time period of the contract are all customizable. These swaps, called plain vanilla swaps, are the most basic and do not cost any money if a swap bank is not used. While it is difficult for airlines to find potential

[9] This of course is exactly the same thing that happens in the stock market when the buyers and sellers of stocks conclude the sale. The buyer believes that the stock will go up while the seller believes that the stock will go down.

partners, swap contracts can be created directly for jet fuel; direct swap contracts for jet fuel reduce the basis risk involved in the hedging strategy. Swap contracts are also routinely formed through organized exchanges for highly liquid commodities. In this case, the New York Mercantile Exchange (NYMEX) acts as the swap bank, with the swap contracts containing fixed quantities and settlement dates. While the futures market does not contain jet fuel, the NYMEX does list a Gulf Coast Jet Fuel Calendar Swap, in addition to the commonly traded Gulf Coast Heating Oil Calendar Swap (NYMEX, 2008). A swap contract where another commodity is being used, such as using heating oil instead of jet fuel, is commonly referred to as a differential swap.

In order to better understand the hedging principles of a swap contract, consider an airline that negotiates a one year swap contract with another party for 100,000 barrels of jet fuel monthly for a fixed price of $130/barrel with settlement performed monthly. The floating price of jet fuel for the swap is based on the monthly average of the sport price of jet fuel according to the Platt's New York Harbor Jet Fuel Price Index (Carter, Rogers, & Simkins, 2003). For the first month after the swap contract was entered, the monthly average spot price for jet fuel was $132/barrel. During the month, the airline would continue to pay the spot price for jet fuel; however, at the settlement date, the airline would make financial arrangements with the other party to provide the airline with a fixed price for the month. For the airline, the monthly settlement amount can be determined by using the formula:

| Settlement Credit/(Cost) = (Monthly Average Spot Price – Fixed Price) * Quantity |
|---|

For the first month, the airline would receive a payment from the other party for $200,000 as a result of the spot price for jet fuel increasing over the amount of the fixed price of $130/barrel.

| Settlement Credit/(Cost)$_1$ = ($132/barrel - $130/barrel) * 100,000 barrel = $200,000 |
|---|

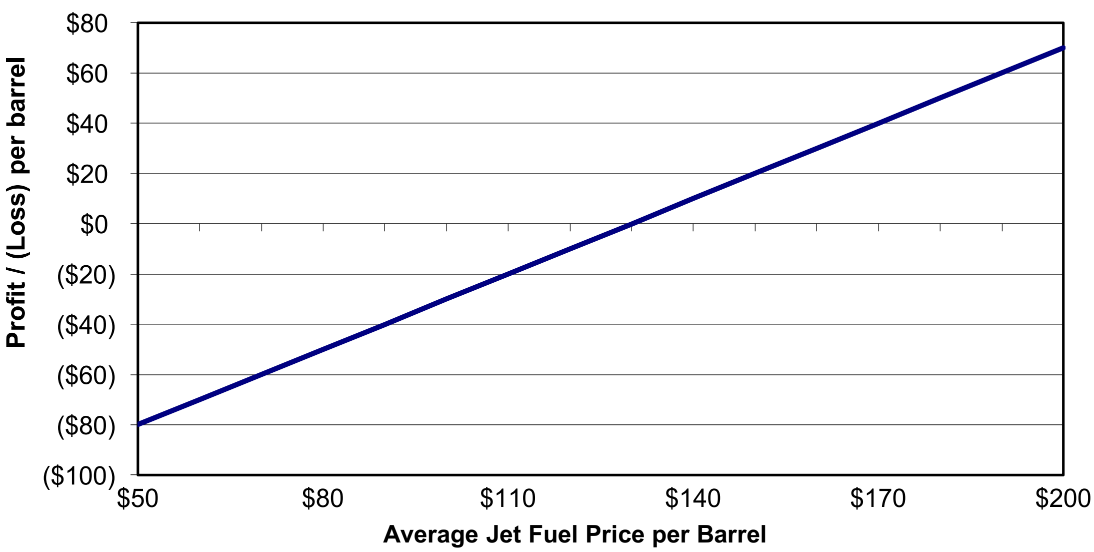
For the second month of the contract, assume the average spot price of jet fuel drops significantly to $125/barrel. In this scenario, the airline will be forced to pay the other party $500,000 as a result of the significant decrease in the spot price of jet fuel.

Settlement Credit/(Cost)$_2$ = ($125/barrel - $130/barrel) * 100,000 barrels = ($500,000)

While the airline may experience substantial variation in settlement payments from month to month, since the airline would continue purchasing jet fuel at the spot price, the settlement payments act as a mechanism to ensure that the airline continues paying a single fixed price for the duration of the contract.

Because of the swap contract, an airline's variability in jet fuel prices are reduced, since the airline is guaranteed to pay an average of $130/barrel for 1.2MM gallons of jet fuel over the one year period of the contract. As a result of this fixed price, determining the "winner" and "loser" in a swap contract is simple. If the average annual spot price for jet fuel exceeds $130/barrel, the airline would receive a gain from hedging activities, while if the average annual spot price was below $130/barrel, the airline would record a loss on hedging activities. Because a swap contract is a zero-sum game (there's only one winner and one loser), the exact opposite win/loss scenario applies to the other party. Figure 13.4 graphically displays the win/loss scenario for the airline utilizing a $130/barrel jet fuel swap contract.

Figure 13.4 Airline Hedging Profit (loss)/barrel for a $130/barrel jet fuel swap



Airline Industry and Fuel Hedging:

As stated earlier, because of the small size and lack of liquidity in jet fuel demand,[10] there is not an organized market where jet fuel options are traded. Therefore, airlines use options on heating oil or diesel fuel whose prices are highly correlated with jet fuel prices and are therefore effective hedges for jet fuel.

- *Call Options*

If it is believed that the price of jet fuel is going to increase in the future, a call option can limit an airline's exposure to soaring jet fuel prices. However, the major benefit of call options is that if the spot price of jet fuel does not exceed the strike price, the airline does not record a hedging loss, except the cost of the options' premiums (Baker, 2007). Therefore, unlike a swap, where an airline records a hedging loss if the price of jet fuel dips below the fixed price, options still provide the airline with the benefit of lower than expected spot prices.

For the airline industry, options are traded on the NYMEX for futures contracts; therefore, options cannot be purchased for jet fuel and must instead be purchased for either heating oil or crude oil. The majority of commodity options are typically available for just the next three months; however, a few long-run oil options could potentially be purchased. Table 13.4 displays a few of the options available on the NYMEX for light sweet crude oil, the most liquid oil option that is traded on the NYMEX, for September 9, 2008. The typical size of an options contract on the NYMEX is for 1,000 barrels of oil, which is 42,000 gallons of oil, the standard size of a futures contract on the NYMEX.

[10] As compared to other financial derivatives.

| Table 13.4 | NYMEX Light Sweet Crude Oil Call Options as at September 9, 2008[11] | | |
|---|---|---|---|
| **Maturity Month** | **Strike Price / barrel** | **Premium / barrel** | **Volume** |
| October-08 | $100 | $4.68 | 196 |
| October-08 | $105 | $2.03 | 252 |
| October-08 | $110 | $0.68 | 472 |
| October-08 | $115 | $0.23 | 675 |
| October-08 | $120 | $0.07 | 317 |
| November-08 | $104 | $5.46 | 335 |
| November-08 | $112 | $2.64 | 125 |
| November-08 | $120 | $1.24 | 121 |
| November-08 | $125 | $0.76 | 99 |
| November-08 | $150 | $0.07 | 276 |
| December-08 | $105 | $7.04 | 55 |
| December-08 | $115 | $3.64 | 23 |
| December-08 | $130 | $1.37 | 37 |
| January-09 | $200 | $0.06 | 142 |
| December-09 | $150 | $4.52 | 2 |
| Source: Compiled by the authors using NYMEX data | | | |

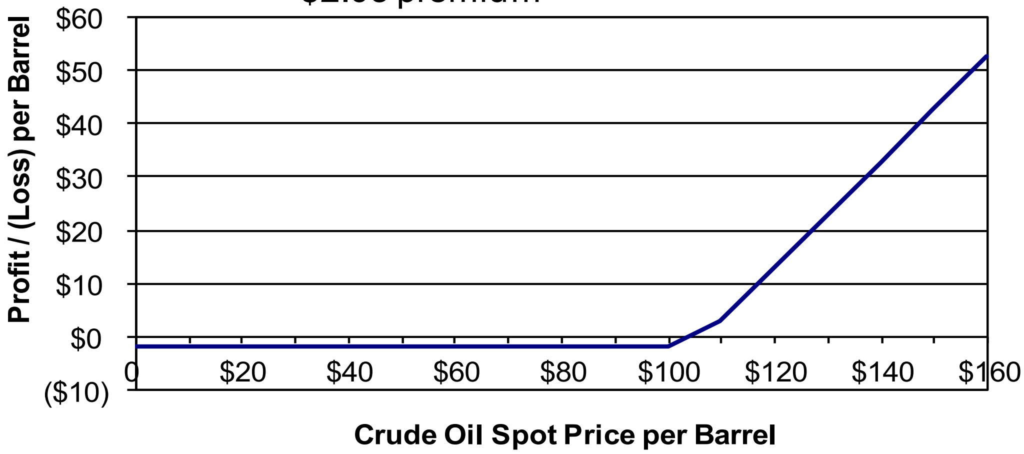
Based on the data from table 13.4, there are a complete range of options available for hedging. The maturity month for an option represents the period by which the holder of the option has the right to purchase the commodity at the strike price. The actual expiration date of the option varies from month to month (depending on holidays and weekends), but usually falls around the middle of the month of the preceding month (NYMEX, 2008). For instance, the maturity date for the October 2008 light sweet crude oil option is actually September 17, 2008 (NYMEX, 2008).

The strike price for an options contract represents the price at which an asset can be purchased. From a hedging standpoint, the strike price represents the ceiling for crude oil and is the maximum that one would pay for crude oil. If the price of crude oil is above the strike price, a hedging gain is recorded (less the premium); while if the price of crude oil is below the strike price, the option is not exercised and the only financial loss to the airline is the premium paid.

[11] Strike prices are actually listed in cents; therefore the strike price of $120 is actually listed as 12000 on the NYMEX. The strike price has been converted in figure 13.7 for the reader's convenience.

This win-loss scenario is depicted in figure 13.5 for the October 2008 option with a strike price of $105 per barrel with a premium of $2.03 per barrel.

Figure 13.5 Airline hedging profit / (loss) per barrel for a $105 strike price call option with a $2.03 premium




An important factor to consider when hedging using call options is that while a hedging loss may not be recorded, cash needs to be spent upfront to purchase call options at the premium price. The issue of spending cash upfront is a major deterrent to many companies, especially airlines, since the company may not have sufficient funds for the investment. This was particularly important after September 11, 2001 where only Southwest Airlines had sufficient funds to invest in jet fuel hedges (Associated Press, 2008, June 30). As the price of oil rose dramatically, only Southwest Airlines benefited from hedges, and this was largely a result of its strong financial position in the past. The amount of money spent on hedge premiums in the airline industry is significant, as Southwest Airlines alone spent $52 million on hedging premiums in 2007 (Associated Press, 2008, June 30).

In order to better understand the impact of option premiums on the win/loss scenario, as depicted in figure 13.5, consider an airline that purchases one October 2008 call option with the strike price of $105 per barrel and the premium of $2.03 per barrel. On the date of purchase, the airline would spend $2,030 to purchase the call option[12]. On September 9, 2008 (8 days prior to the maturity date of the October 2008 option contract) the spot price for a barrel of oil was

[12] Purchase Cost = Call Premium per barrel * 1,000 barrels (call option contract) = $2.03 * 1000 = $2,030

$102.70. Assuming this price for crude oil remains constant until maturity, the airline would not redeem the call option and simply lose the premium of $2,030.

Hedging Gain/(Loss)$_1$ = (Spot Price – Strike Price) * Quantity – (Premium * Quantity)

Hedging Gain/(Loss)$_1$ = ($102.70 - $105) * 1,000 – ($2.03 * 1,000) = $0 - $2,030 = ($2,030)

In a second scenario, assume that at maturity the price of light sweet crude increase to $107.03 per barrel. Since the spot price for crude oil exceeds the strike price, the option would be exercised and the airline would "receive" 1,000 barrels of crude oil at $105 per barrel. The hedging gain for this call option would be $2,030; however, when the option premiums are taken into consideration the total gain is zero and the airline is no better off from their hedging activities.

Hedging Gain/(Loss)$_2$ = (Spot Price – Strike Price) * Quantity – (Premium * Quantity)

Hedging Gain/(Loss)$_2$ = ($107.03 - $105) * 1,000 – ($2.03 * 1,000) = $2,030 - $2,030 = $0

Finally, consider a third scenario where the price of crude oil spikes unexpectedly to $111 per barrel. In this situation, the airline's hedging strategy will have worked as it will record a gain from hedging activities in the amount of $3,970.

Hedging Gain/(Loss)$_3$ = (Spot Price – Strike Price) * Quantity – (Premium * Quantity)

Hedging Gain/(Loss)$_3$ = ($111 - $105) * 1,000 – ($2.03 * 1,000) = $6,000 - $2,030 = $3,970

- *Collars (Zero-cost and premium)*

**Collar:** Purchasing a call option and at the same time selling a put option

Collars require the sale of a put option to compensate for the premium associated with purchasing a call option. While the purchase of call options provides a significant ceiling for a commodity's price, the expense of options premiums either pushes a firm from not using call options, or pushes the strike price to such a high level that it merely guards against a catastrophic increase in the price of the commodity. While the notion of not recording a significant hedging loss is comforting, going long with (purchasing) call options provides a relative amount of volatility, especially if the strike price is substantially above the current spot price. One potential solution to minimize price volatility are collars; these involve going long on a call option, while subsequently going short (selling) on a put option. When combined, both a price ceiling and a price floor are created providing the airline with increased cost certainty. Depending on the specific call and put options that are bought and sold, a collar hedging strategy can be cost free.

**Zero-cost collar**: A collar in which the premium received from selling the put option exactly offsets the cost of purchasing a call option.

**Premium collar:** Occurs when premium of the purchased call option exceeds the cash flow gained from selling the put option; typically more common than a zero-cost collar.

Table 13.5 provides a listing of various put options available for light sweet crude oil on September 9, 2008.

| Table 13. 5 | NYMEX Light Sweet Crude Oil Put Options as at September 9, 2008 | | |
|---|---|---|---|
| **Maturity Month** | **Strike Price / barrel** | **Premium / barrel** | **Volume** |
| October-08 | \$85 | \$0.02 | 615 |
| October-08 | \$90 | \$0.09 | 420 |
| October-08 | \$95 | \$0.41 | 372 |
| October-08 | \$100 | \$1.43 | 464 |
| November-08 | \$85 | \$0.57 | 61 |
| November-08 | \$90 | \$1.24 | 167 |
| November-08 | \$95 | \$2.38 | 34 |
| November-08 | \$104 | \$6.10 | 401 |
| December-08 | \$80 | \$0.76 | 21 |
| December-08 | \$100 | \$5.27 | 134 |
| January-09 | \$95 | \$4.83 | 200 |
| Source: Compiled by the authors using NYMEX data | | | |

In order to construct a zero-cost collar, the premiums for both the call and put options must match. Based on data contained in tables 13.4 and 13.5, one zero-cost collar opportunity exists with a November 2008 maturity.[13] In order to construct the zero-cost collar, an airline would need to sell the November 2008 $90 strike price put option receiving the premium of $1.24 per barrel. Using these proceeds, the airline would then purchase the November 2008 $120 strike price call option. As a result of these transactions, the airline has created a price ceiling of $120 for zero-cost, which is a significant improvement over merely purchasing a call option. The only tradeoff in doing so is that a price floor is established at $90, where if the spot price for crude oil falls below $90, a hedging loss will be recorded. In this particular example, an increased level of oil price certainty is provided to the airline for zero-cost; they will not pay more than $120 per barrel for crude oil and not less than $90 per barrel. This win/loss scenario is depicted in figure 13.6.

Figure 13.6 Airline hedging gain / (loss) per barrel for a zero-cost collar with a call option strike price of $120 / barrel and a put option strike price of $90 / barrel


[13] Actual maturity date for a November 2008 option is October 16, 2008.

While zero-cost collars are an ideal situation, the majority of the time the spread in the strike prices is rather wide. If a much narrower collar is desired, or a collar more heavily weighted to where the price ceiling is closer to the market spot price, then the premium for the purchase of the call option is likely going to exceed the premium received from the sale of the put option. This creates a scenario where a loss can be recorded when the actual spot price at maturity is less than the call option strike price; however, this loss will be substantially less than if one merely went long with call options.

Consider a scenario where the airline wishes to have a price ceiling much closer to the current spot price of $102.70, but wants to reduce their hedging premium cost. By selling one November 2008 $95 per barrel strike price put option, the airline receives a premium of $2,380. Using this revenue, the airline then proceeds to purchase one November 2008 $104 per barrel strike price call option for $5,460. In order to understand the gain/loss implications of a premium collar, consider four scenarios where the spot price of light sweet crude oil at maturity:

- Increases to $112 per barrel
- Increases to $108.08 per barrel
- Remains the same at $102.70 per barrel
- Falls substantially to $90 per barrel

*Scenario One* – When the price of crude oil jumps to $112 per barrel, exceeding the strike price of the call option, the collar strategy provides a hedging gain as the collar premium is offset by the gains incurred from the call option. The hedging gain under this scenario is $3,920.

Hedging Gain/(Loss)$_1$ = (Put Option Premium – Call Option Premium) + (G/(L) Call Option +G/(L) Put Option)

Hedging Gain/(Loss)$_1$ = [($2.38 *1000) – ($5.46 * 1000)] + [(($112 - $105) *1000) + 0]

Hedging Gain/(Loss)$_1$ = [$2,380 - $5,460] + [$7,000] = $3,920

*Scenario Two* – While the price of crude oil jumps to $108.08 in scenario two, exceeding the strike price of the call option, the gain from hedging merely offsets the collar premium, making the airline no better off by hedging. Such a scenario does not exist for zero-cost collars, as there are no premiums to offset. The hedging gain under this scenario is $0.

Hedging Gain/(Loss)$_2$ = (Put Option Premium – Call Option Premium) + (G/(L) Call Option +G/(L) Put Option)

Hedging Gain/(Loss)$_2$ = [($2.38 *1000) – ($5.46 * 1000)] + [(($108.08 - $105) *1000) + 0]

Hedging Gain/(Loss)$_2$ = [$2,380 - $5,460] + [$3,080] = $0

*Scenario Three* – With the price of crude oil remaining constant, the price falls within the collar, with neither the put option nor the call option being exercised. As a result, the airline would only lose the premium in creating the collar, which is $3,080.

Hedging Gain/(Loss)$_3$ = (Put Option Premium – Call Option Premium) + (G/(L) Call Option + G/(L) Put Option)

Hedging Gain/(Loss)$_3$ = [($2.38 * 1000) – ($5.46 * 1000)] + [0 + 0]

Hedging Gain/(Loss)$_3$ = [$2,380 - $5,460] + 0 = ($3,080)

*Scenario Four* - When the spot price of crude oil falls dramatically to $90 per barrel, the price falls below the price floor and not only does the airline receive a hedging loss as a result of going short with a put option, but the airline must also still bear the collar premiums. Under this scenario, the airline records a hedging loss of $8,080

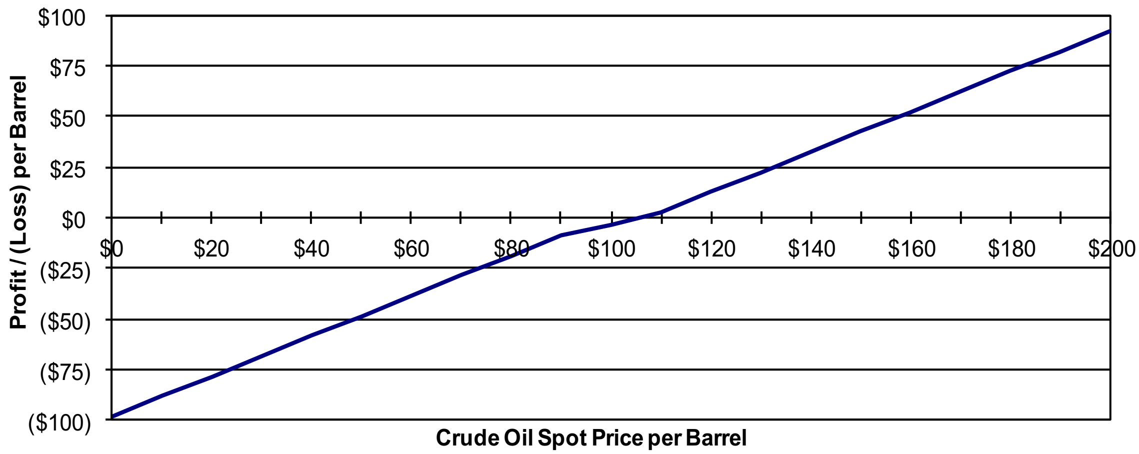
Hedging Gain/(Loss)$_4$ = (Put Option Premium – Call Option Premium) + (G/(L) Call Option + G/(L) Put Option)

Hedging Gain/(Loss)$_4$ = [($2.38 * 1000) – ($5.46 * 1000)] + [0 + (($90 - $95) * 1000)]

Hedging Gain/(Loss)$_4$ = [$2,380 - $5,460] + [0 + ($5,000)] = ($8,080)

Figure 13.7 displays the hedging gain/loss for a particular premium collar on a per barrel basis.

Figure 13.7 Airline hedging gain / (loss) per barrel for a premium collar with a call option strike price of $104/barrel with a premium of $5.46 and a put option strike price of $95/barrel with a premium of $2.38.




While a collar is the typical method of hedging, combinations of going long or short with both put and call options can create a host of options available that can help protect against different risk factors. Each combination of put and call options provides different gain/loss scenarios that may provide a hedging gain or loss depending on the spot price of the commodity. As the ultimate goal of hedging is to reduce one's risk to volatility in the price of a commodity (and hopefully minimize the cost in doing so), each unique combination of put and call options might ultimately serve the purpose.

- *Futures Contracts*

As has been discussed previously, a fourth potential hedging strategy would be to enter into a futures contract providing the airline with a known, hedged price for crude or heating oil at a predetermined point in the future. One of the major benefits of futures contracts is that they are widely traded for as far out as eight years, making them an attractive solution for a long-term hedging strategy (NYMEX, 2008). Since no premiums exit for purchasing and selling futures contracts, futures contracts represent an absolute gain/loss scenario, where if the spot price of the commodity exceeds the futures price at maturity, a hedging gain is recorded and a hedging loss is recorded when the spot price falls below the future price. In essence, a futures contract acts in a similar way to a swap, but does not involve settlements as the contract is for only a month. Table 13.6 details prices for futures contracts as of September 9, 2008 for light sweet crude oil.

| Table 13.6 | Futures Contracts- Light Sweet Crude Oil | | | |
|---|---|---|---|---|
| | **High** | **Low** | **Recent Settle** | **Volume** |
| **Oct 2008** | 106.77 | 101.74 | 103.26 | 332,463 |
| **Nov 2008** | 107.00 | 101.94 | 103.36 | 151,179 |
| **Dec 2008** | 107.35 | 102.33 | 103.74 | 83,521 |
| **Dec 2009** | 108.41 | 105.54 | 106.64 | 16,975 |
| **Dec 2010** | 108.30 | 106.14 | 106.90 | 8,935 |
| **Dec 2011** | 108.00 | 106.03 | 106.69 | 2,482 |
| Source: Compiled by the author using NYMEX data | | | | |

From the data contained in table 13.6, assume an airline wishes to secure a long-term oil hedge and purchases five December 2009 futures contracts at $106.64 / barrel. The initial cost to purchase the futures contract is $533,200.[14] The hedging gain or loss of the futures contract is determined by the spot price for light sweet crude oil at maturity. If the price of light sweet crude oil escalated significantly to $120 per barrel, the airline would record a relatively significant hedging gain of $66,800 for its investment in five futures contracts.

Hedging Gain/(Loss)$_1$ = [(Spot Price – Futures Price) * 1,000 barrels] * # of Contracts

Hedging Gain/(Loss)$_1$ = [($120 - $106.64) * 1,000 barrels] * 5 = [$13.36 *1,000] * 5 = $66,800

Conversely, a hedging loss can be potentially recorded if the spot price for crude oil falls. Assuming that by December 2009 the spot price for crude oil drops to $100 per barrel, the airline

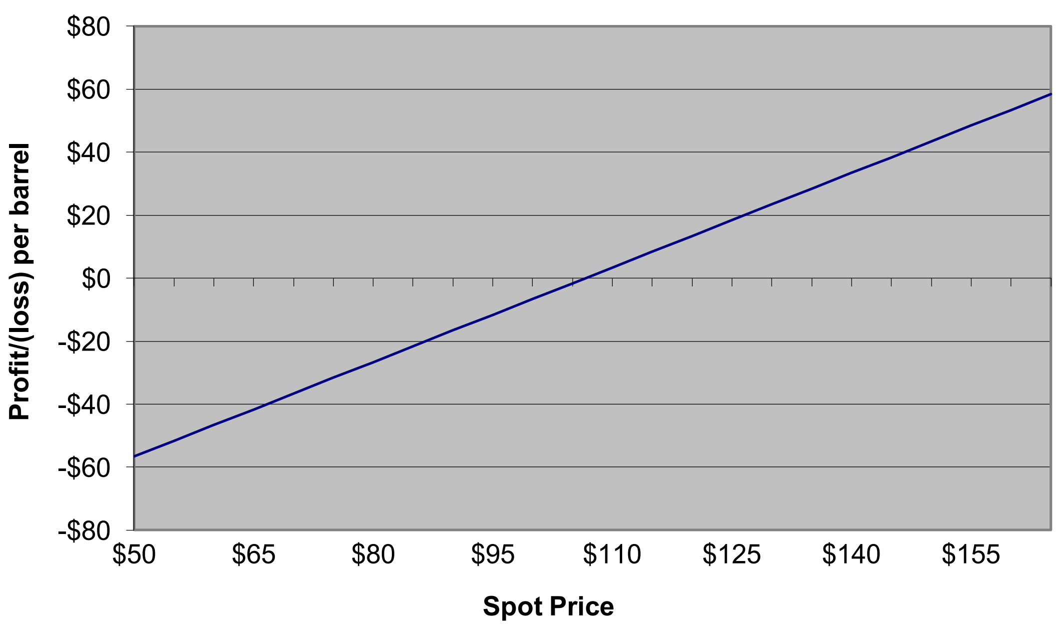
[14] Order Cost = (Futures Price (Dec09) * 1,000 barrels) * # of Contracts = ($106.64 * 1,000) * 5 = $533,200

would end up recording a hedging loss of $33,200, offsetting the positive impact that lower fuel prices would have on the airline.

| |
|---|
| Hedging Gain/$(\text{Loss})_2$ = [(Spot Price – Futures Price) * 1,000 barrels] * # of Contracts |
| Hedging Gain/$(\text{Loss})_2$ = [($100 - $106.64) * 1,000 barrels] * 5 = [($6.64) *1,000] * 5 = ($33,200). |

This simple win/loss scenario is also depicted graphically in figure 13.8.

Figure 13.8 Airline hedging gain / (loss) per barrel for a $106.64 futures contract



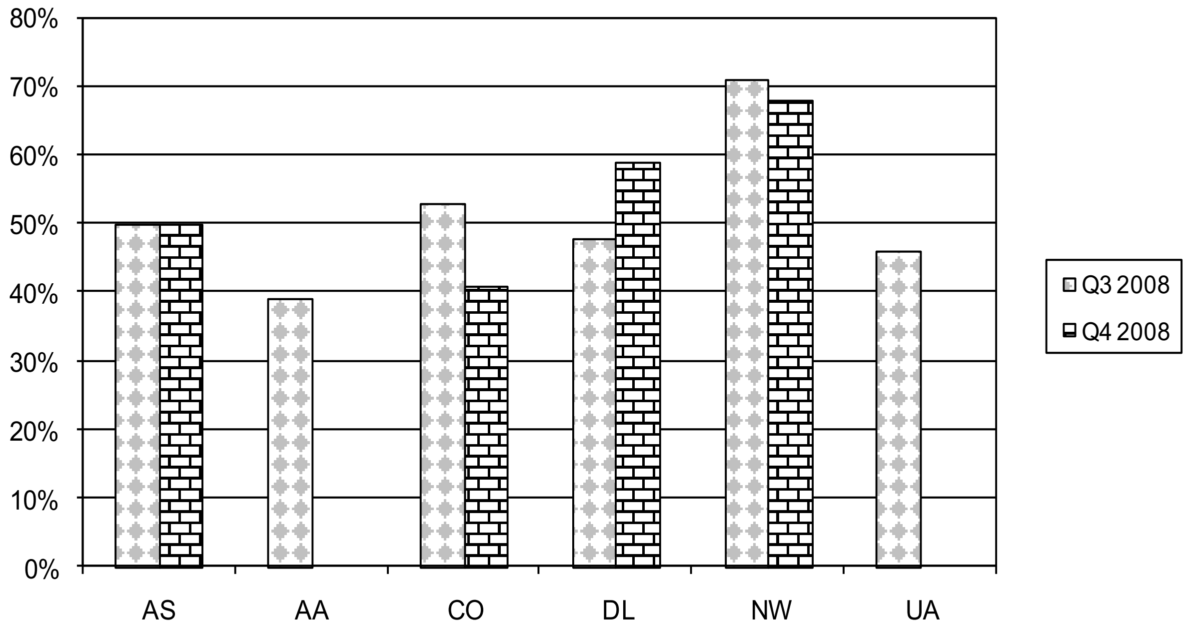

## ***How Much to Hedge?***

As with any decision regarding hedging, the correct amount to hedge is ultimately determined by the spot price of the commodity at the hedges maturity. Ultimately, if the hedge was "in-the-money" an airline would have wanted to hedge the maximum amount as the hedge provided them with a gain; however, if the hedge was "out-of-the-money" then the airline would not have wanted to hedge at all. In fact many airlines, including United and Northwest Airlines, are losing money on their current fuel hedges as they bet that fuel prices would continue to rise after going up to a high of about $140/barrel (Freed, 2008, September 17). Since the profitability of hedging has great disparity, providing no considerable amount of risk minimization, the optimum level of hedging rests where the benefits/costs of hedging are offset by any considerable increase/decrease in the commodity's spot price

Another factor involved in the decision-making concerning the amount to hedge is cash flow. Fuel hedging costs money, and for some strategies, requires premiums to be paid up-front. For airlines, cash flow is always a critical issue and the magnitude of jet fuel purchases requires a significant cash outlay for the airlines to hedge. For instance, in 2007 Southwest Airlines spent $52 million on hedging premiums (Associated Press, 2008, June 30). Since hedges are also commonly purchased on credit, cash and good credit are the major requirements for engaging in hedging activities, and, if an airline has neither of them, they may not be able to hedge to their optimal amount. This is the primary reason why Southwest Airlines was the only US airline that benefitted greatly from fuel hedging in the early 2000's after the industry downturn following the terrorist attacks of 2001.. As a result of the industry downturn, "*…most carriers had terrible creditworthiness and couldn't hedge. Counter-parties feared that carriers would renege on their trade"* (Associated Press, 2008, June 30). Today, Southwest Airlines still reaps the benefit of the strong financial position during the industry downturn, as their fuel hedges still provide them with significant hedging gains. Southwest is hedged at 55-70% of their fuel needs at $51/barrel through 2009 (Southwest Airlines, 2008).

Based on the two factors of risk minimization and cash flow, airlines pursue different levels of jet fuel hedging. Figure 13.9 displays the percentage of jet fuel requirements that are hedged for six US airlines, other than Southwest, based on filings report to the Securities Exchange Commission (SEC) during the third quarter of 2008. From the filings, Northwest Airlines has the greatest proportion of their jet fuel expenses hedged while most of the other airlines have a roughly equal proportion of their jet fuel requirements that are hedged and not hedged. This balance enables them to reap any potential benefits of drops in jet fuel spot prices while also receiving the benefit of hedges if the spot prices increase dramatically. Alaska Airlines (AS) is hedged perfectly at 50% for both quarters, indicating they may have a set strategy where they have exactly half their fuel requirements hedged for the quarter. Such set strategies, as opposed to speculation, are typically more successful in the long-run and provide the greatest decrease in the volatility of fuel prices. Of the six airlines, Northwest Airlines (NW) has the greatest percentage of their jet fuel requirements hedged. A potential explanation for this could be their average fleet age. Northwest's average fleet age is the highest of the six carriers, causing relatively poor fuel efficiency and poor fuel efficiency could cause Northwest to be the most susceptible to changes in jet fuel prices. As a result, their increased jet fuel price volatility would cause them to have higher optimum level of hedging to minimize price variability.

Figure 13.9 Percentage of 2008 Airline Fuel Requirements Hedged




Source: Compiled by the authors using Q3 8-K SEC filings

Another interesting hedging dynamic is how far in the future airlines should hedge. Based on publicly released financial information, the majority of carriers tend to have short hedging time frames where jet fuel requirements are only hedged approximately six months forward. While this shorter time frame typically reduces the probability of large hedging gains, it also reduces the amount of speculation, and risk, that the airline is bearing by hedging far into the future. While long-term hedges can provide lower strike prices, the amount of risk that is being borne is not substantially reduced. Of the six airlines contained in figure 13.9, only two carriers reported hedges beyond 2009, with Alaska Airlines having 14% of 2010's jet fuel requirements hedged, while Delta Air Lines had just 5% of 2010's requirements hedged. Such long-term hedges could potentially be risky if jet fuel prices see sharp declines; however, the structure and minimal size of these particular hedges could help to reduce the risk. Such long-term hedges have paid off extremely well before (for Southwest Airlines) and could do so again for both of these carriers. The appendix to this chapter discusses the Black-Scholes asset pricing model and presents a quantitative example of how this model might be used to value a financial option.

**Summary**

In this chapter we have discussed financial  options. We have looked at call and put options as well as forward and future contracts. Airlines may use financial options to reduce uncertainty and/or risk. One area in particular that airlines engage in is hedging. Hedging is ultimately about reducing one's exposure to variability in the price of a commodity. For the airline industry, jet fuel now represents the largest cost, and with the spot price of jet fuel out of the airlines' control, hedging is a necessary practice for airlines. The reason for this is the desire to reduce risk and to have more constant financial earnings. While many airlines have touted their hedging success stories, jet fuel hedging is not a "win-win" solution with significant hedging losses possible. Additionally, hedging is not free with airlines either having to pay premiums or heightened strike prices to participate. In general the benefits of increased levels of price certainty that hedging provides outweigh the potential of hedging losses for most airlines. While the principles of hedging presented here have focused on jet fuel for airlines, the hedging strategies are universal, applying to multiple industries with any commodity with price variability. In such cases, hedging is an effective tool to minimize risk and provide the company with increased cost/revenue certainty. The appendix to the chapter presented the Black-Scholes Option Pricing Model. This quantitative model can be used to estimate how much an airline might have to pay in premiums for a given hedging strategy. The model does this by calculating the market value of the options the airline might purchase in pursuing their hedging strategy.

## Appendix 1

### The Black-Scholes Option Pricing Model

As previously mentioned the cost (premium) of a financial option depends on the value of the security, the volatility of the security, the strike price and the time until the option expires (time to maturity). In this section we present a model to value financial options called the Black-Scholes Option Pricing Model. If an airline wants to adopt a fuel hedging strategy by purchasing options on commodities such as heating or crude oil it must determine how much the options are going to cost in order to determine the correct strategy; the Black-Scholes Model is one of the tools used to determine the market value of an option. The Black-Scholes Model takes into account the current price of the asset, the strike price of the option, the risk-free interest rate, the volatility of the price of the asset and the time to maturity to calculate the market value of an option (Marshall, 1989). The Black-Scholes Model may be confusing because of all the different terms involved in the equations. Therefore, in order to better understand the model, we present the equations involved, a quantitative example of the model and a graph showing how variations in some of the variables change the value of a financial option.

Black-Scholes Option Pricing Model

$$P_{option} = S_{price} \times N(d_1) - S_{strikeprice} \times e^{-r_{RF} \times t)} \times N(d_2)$$

$$d_1 = \frac{ln(\frac{S_{price}}{S_{strikeprice}}) + (r_{RF} + \frac{\sigma^2}{2}) \times t}{\sigma \times \sqrt{t}}$$

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

Where:

$S_{price}$ = current market price of security

$N(d_1)$ = normal probability distribution of $d_1$

$S_{strikeprice}$ = strike price of financial option

$r_{RF}$ = risk-free interest rate

$t$ = time to maturity (expiration) of the option (in years)

$N(d_2)$ = normal probability distribution of $d_2$

$\sigma$ = instantaneous standard deviation (volatility) of the security

**Example**: Suppose that DirectJet wants to purchase an option for heating oil as part of a fuel hedging strategy. Using the following information, determine the market price of the option according to the Black-Scholes Option Pricing Model.

$S_{strikeprice} = \$100$

$S_{price} = \$100$

$t = 1$

$r_{RF} = 12\%$

$\sigma = .1$

First, we should calculate $d_1$

$$d_1 = \frac{ln(\frac{S_{price}}{S_{strikeprice}}) + (r_{RF} + \sigma^2 / 2) * t}{\sigma * \sqrt{t}}$$

$$d_1 = \frac{ln(\frac{100}{100}) + (.12 + .1^2 / 2) * 1}{.1 * \sqrt{1}}$$

$$d_1 = 1.25$$

Then, calculate $d_2$

$$d_2 = d_1 - \sigma \times \sqrt{t}$$
$$d_2 = 1.25 - .1 \times \sqrt{1}$$
$$d_2 = 1.15$$

**Step 3-** Determine $N(d_1)$ *and* $N(d_2)$ by using a standard normal probability distribution table. Looking at a standard normal distribution table we can determine that $N(d_1)$ *and* $N(d_2)$ equal 0.8944 and 0.8749 respectively

$$\mathrm{N}(\mathrm{d}_1) = 0.8944$$

$$N(d_2) = 0.8749$$

**Step 4-** Calculate the fair market price of the option

$$P_{option} = S_{price} * N(d_1) - S_{strikeprice} * e^{-r_{RF} * t)} * N(d_2)$$
$$P_{option} = 100 * 0.8944 - 100 * e^{-.12*1)} * 0.8749$$
$$P_{option} = \$11.84$$

In figures 13.10, 13.11 and 13.12 we show the effects of time to maturity and volatility on the value of an option. If the volatility of the security or the time to maturity of the option changes, there are large effects on the value of the option. As time to maturity or volatility increases, the price of the option also increases.

Figure 13.10 Effect of Time to Maturity on Option Price

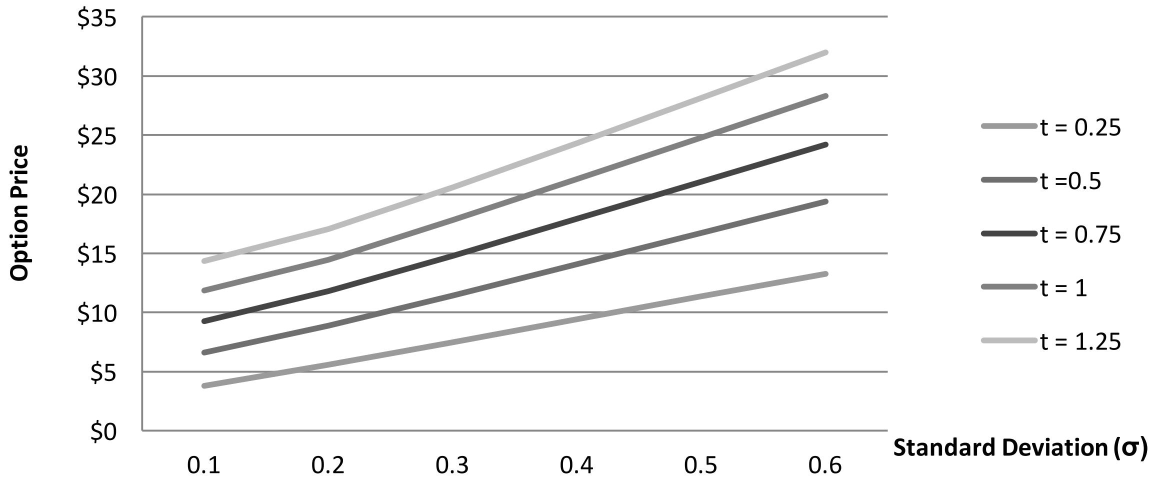



Figure 13.11 Effect of Volatility (σ) on Option Price

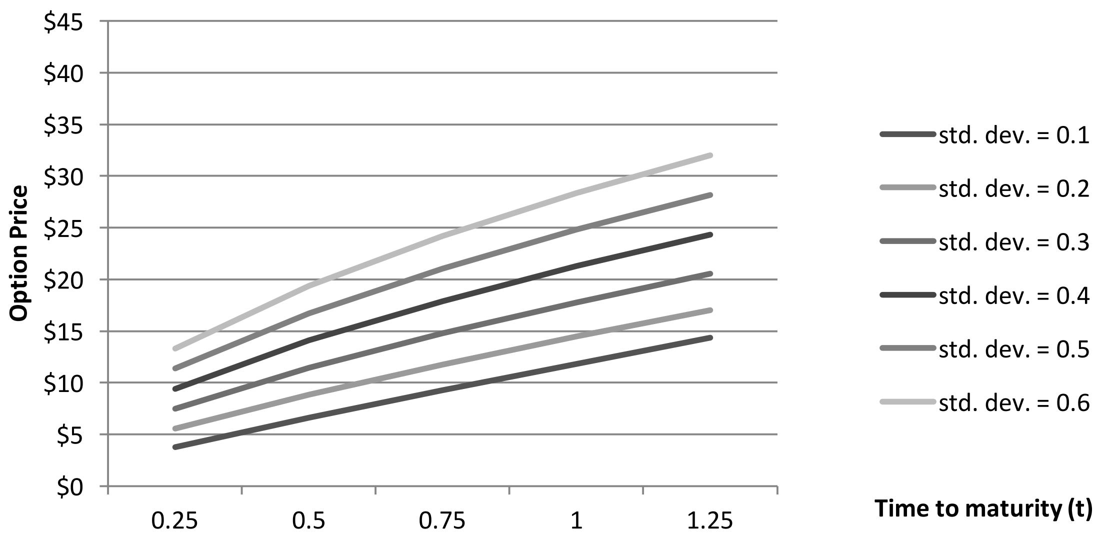
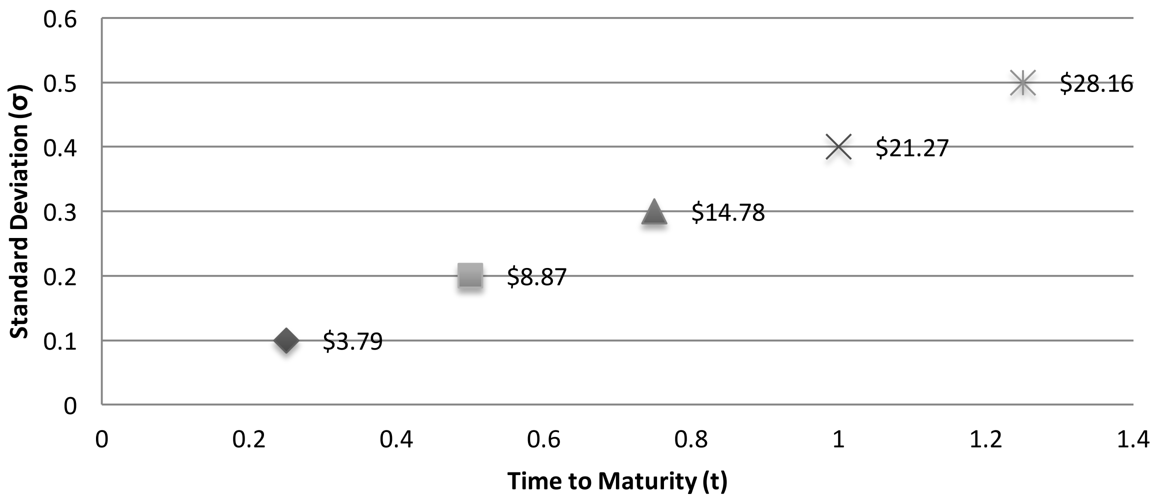


**Figure 13.12 Cumulative Effect of Time to Maturity and Volatility**



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