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Course of Advanced Corporate Finance

Hedging Strategies and Optimization of Airline Companies

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Introduction

Airline tickets seem to behave in mysterious ways: In a 2018 CNBC article, journalist Tom Chitty explains how airfare ticket pricing has changed from deregulation to today. He explains that nowadays airplane tickets are priced to be "as high as costumers can bear". Still ticket prices are extremely sensitive to changes in fuel prices: This research found that fuel prices account for more than 40% of total costs an airline has to bear. Researchers Moynihan and Al-Zarrad in 2015 found that between 95% and 105% of fuel prices increases are passed on to passengers, even if with some delay. Yet, there is the belief that often, only increases are passed on to travellers, while fuel prices decreases are not: For instance, the Guardian in 2015 named an article "Airlines -but not passengers- see benefits as crude oil prices drop". Between the reasons the article attaches to such a phenomenon, there is fuel price hedging: In fact, the explanation is that if airlines hedge against oil prices increases, they will have a loss when oil prices drop and therefore ticket prices will not decrease.

From this concept, one of the main aims of this thesis project: Finding whether there is a way for airlines to hedge both oil prices increases and decreases (and gain on both). This thesis will test whether different hedging strategies work: It will include hedging through call options to see if normal hedging provides results and it will also include hedging through straddle and strangle option strategies to test whether a strategy that pays off both when oil prices increase and when they decrease is actually feasible for an airline.

Another aim of this thesis work is to check which hedging strategy will be the most successful in increasing airline companies' EBITDAs and therefore their valuation (using comparable EV/EBITDA valuation). Furthermore, another target of this thesis is finding whether the proposed option strategies work in normalizing cash flows and which one worked best. The strategies that the research work will test will be call options at various strike prices, straddles at various strike prices, strangles and collars. All of these option strategies will be explained thoroughly in the "Theory" chapter.

The research covers the period ranging from 2005 to 2018 using quarterly data. The first results, though, arrive in 2006 Q1: This is because the first option in this research can be contracted in 2005 Q1 with expiration 2006 Q1 (one year later), so the first effects of different hedging strategies appear in 2006 Q1. The choice to start in 2005 was settled with the aim to include periods of strong oil prices' increases (e.g. 2008), oil prices' decreases (e.g. 2015) and at least an economic crisis: This allows for a broader view of hedging strategies' performance in different scenarios.

The sample of airline companies in this thesis are American Airlines, Delta, Ryanair, SkyWest, Southwest and United Airlines. The list used to be larger, but plenty of airlines had to be discarded because of reporting inconsistencies of some financials across the considered period.

Of these considered airlines, according to the International Air Transport Association (2018), American ones do not currently hedge future fuel requirements; European airlines, instead, have heavier hedging position with Ryanair heading all airlines with 90% of future expected fuel requirements hedged. According to the same source, one notable exception is Southwest, which is an American airline and yet enters in fuel hedging contracts (64% of expected fuel consumption). Therefore, fuel price hedging is something that is somewhat polarizing, some airlines enter into fuel price hedging contracts and others do not, even in the same period. Moynihan and Al-Zarrad in 2015 even found the research to be divided on the benefits of hedging towards company valuation.

This project aims to see if there is a fuel price hedging strategy (preferably a strategy that hedges both fuel prices' increases and decreases) that allows all the of sample airlines to minimize fuel expenditure and (if possible) normalize cashflows. The thesis will start with an overview of the theory involved, then will discuss the methodologies applied in the research process and in the end will present the results of the research.

Some of the results were decisively clear showing that a strategy comprising call options is the best one to increase company valuation and decrease oil prices. Evidence on the effectiveness of hedging for cashflow normalization, instead, is overly mixed: In fact, on this topic the research could not find a clear cut answer.

Theory

Although, the core of this thesis consists in an experimental research, underlying theory is still a pivotal aspect of how this research was conducted and of the question raised by the thesis itself. This chapter will therefore present the main and relevant theory-related topics touched by the scope of this thesis work.

Basic Materials in Companies and Hedging

Basic Materials in Companies

Basic materials account for a large share of expenses in many industries[1], including the aviation industry: In fact, already in Dutch companies basic materials account up to 50% of total costs[1] and for energy this estimate arrives to 60%[1]; as a result companies are usually decidedly sensitive to changes in costs of basic materials and energy. This is exceptionally true for airlines that have aircraft fuel expense as 42% of their total costs[2].

Generally, the main drivers for the growth or decline of prices of basic materials and energy are entrenched in supply: If external factors hinder the supply of basic materials and energy, their prices are expected to rise[3]. Trade wars and environmental concerns are two of the main drivers for basic materials and energy raise in price[3].

Companies do frequently engage in hedging activities if they are highly basic-material dependent[4]. For many companies, especially in the construction field, this comes into the form of insurance provisions and indemnification. Yet, these measures fail to address unforeseen circumstances in the supply chain: For example, conflicts in the Middle East in the case of oil supply[4]. Another issue with the insurance provision approach is that it fails to take into account price volatility[4].

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[1] Wilting & Hanemaaijer 2014
[2] Internal Research, further detailed in "The airline industry"
[3] Inverto (BCG Company) Research 2018
[4] Moynihan and Al-Zarrad 2015

Hedging in Companies

Hedging risk in basic materials is a tool that many companies use to have more predictable cashflows[5] and it even allows for higher company valuation[6], through higher income[7]. But, from a shareholders' perspective, hedging is not always a clear-cut solution: Hedging, in fact, can be undesirable for two distinct reasons. The first is that shareholders in the company might want to be exposed to the basic materials' risk of that company: For instance, an investor in an airline company that believes that oil prices are expected to fall may prefer this company not to be hedged to take full advantage of his expectation[5]. The second reason is that hedging can be extremely expensive, and shareholders might achieve better results by having their entire portfolios hedged against a certain risk, instead of having individual companies hedging their own basic materials' risk[5]. Researchers Moynihan and Al-Zarrad (2015) explain that hedging in companies, occurs using futures, options and insurance. The first two with the aim to lock materials' prices at a certain level and the latter with the intent to recover increased expenses from basic materials' prices surge. The chapters below will provide a more in-depth analysis on how hedging occurs in airlines.

The Airline Industry

The airline industry is relatively new compared to most industries in developed nations and is characterized by high seasonality[8] and great dependence in earnings from the underlying price of fuel consumed[9]. This was especially true for the companies analysed in this research: In fact, in the sample, fuel related expenses accounted for about 42% of total costs. This means that an increase in fuel prices will inevitably lower airline companies' earnings. Increases in fuel expenses are often passed-through to costumers with varying rates: PWC (2005), in an extensive study in air travel prices in the UK found that air carriers, including low cost, passed on between 90% to 105% of increases of kerosene prices. Though, this happened with some delay[10]. The fact that airplane tickets are usually booked in advance and fuel is consumed at

[5] Damodaran 2014
[6] IATA 2018
[7] Internal research, "Results" chapter of this Thesis
[8] Sturm 2009
[9] Found in the sample of considered companies

take-off of the flight, makes it harder for airline companies to pass on fuel prices increases when kerosene peaks quickly[10].

One notable story of an airline that failed mainly because of rapidly rising fuel prices is Pan-American World Airways. Pan-am used to be one of the biggest airlines in the United States and the first US airline to achieve a transatlantic flight: Basically, it was mainly connecting the United States to the rest of the world[11]. Pan-American World Airways filed for bankruptcy in 1991 and one of the main reasons for the decline of the airline was extreme losses caused by raising fuel prices in the late seventies[12].

The fragility of airlines to movements in fuel prices united with the lack of possibility to pass-on the extra fuel-related costs to costumers efficiently, begs for a solution. Fuel prices' hedging strategies could be the answer to this problem and this thesis aims to find whether these strategies do provide real benefits to the airlines considered in this research.

Hedging in Airlines

Fuel prices can be extremely volatile in nature[13] and as already discussed in this chapter "Oil & Fuel Expenditures" make up a great part of airlines' operating costs. For these reasons, airlines have a natural tendency to hedge fuel price risk. Airlines, hedge using many different tools: Swaps, call options, futures, and collar options[14]. Yet, financial tools are not the only hedging devices used by companies: For instance, Delta also bought a refinery as a mean of hedging (with extremely poor results)[15].

To understand the scale of the problem of fuel price volatility, it is enough to think that a 1$ increase in spot fuel price, might cost airlines an additional $425m$ $[14]. Yet, studies about companies' hedging performance have had mixed results: some research finds it to be

[10] Moynihan Al-Zarrad 2015
[11] FORBES 2013
[12] Bennett 2002
[13] IATA 2018
[14] Moynihan Al-Zarrad 2015
[15] FORBES 2016

beneficial for company valuation and other researchers finds hedging to negative for airline companies[14].

Airlines use different hedging products[14] and achieve remarkably different results and not always positive ones: For instance, Norwegian Airlines claimed a loss related to hedging in 2018 Q4 of about $180m$ €[16] and this placed the airline in a tough spot against competitors[17]. Moreover, Delta Airlines' CEO (in 2016) Ed Bastian admitted that the company lost four billion dollars in fuel price hedging[15]. Ryanair instead managed to achieve remarkable fuel hedging results[19] and Southwest hedging proceeds for the 2003-2008 period were more than four billion dollars[18].

Spanning through the world regions and economic environments, nowadays fuel price hedging seems to be largely adopted by European carries, generally ignored by carriers based in the United States and even outlawed in China[19]. The chart below shows a rather extensive index of airlines and their hedging commitment for 2019 Q1[20].

[16] Exchange rate, NOK EUR as of January 21, 2020
[17] Norwegian 2018 Q4 presentation 2019
[18] Reuters 2008
[19] IATA 2018
[20] IATA 2018, chart taken from IATA's economic chart of the week and changed in design and color scheme

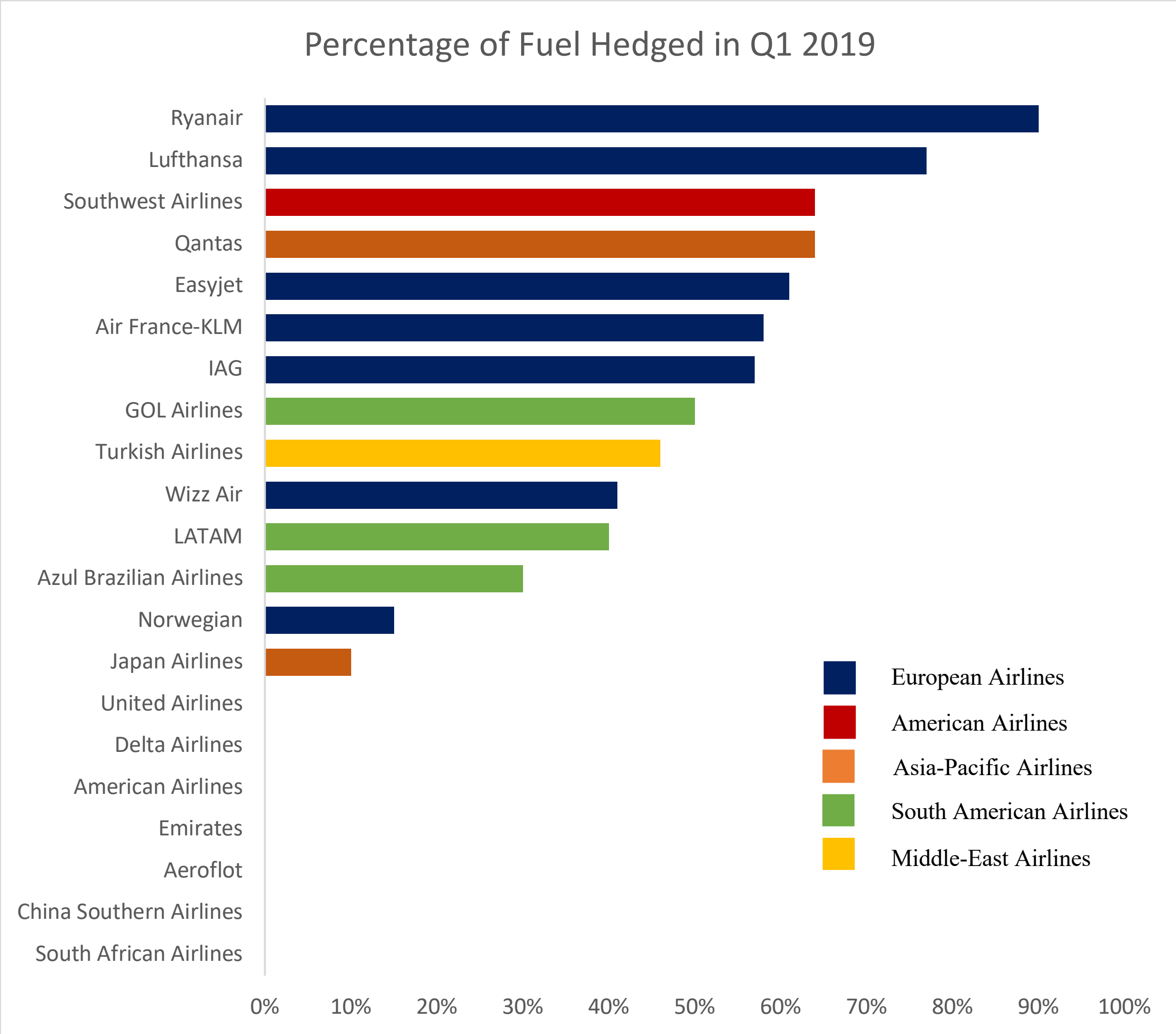

Figure 1: Percentage of Fuel Hedged on Total Expected Consumption 2019 Q1

In the chart above, it is clear to see that European companies are the biggest hedgers among their peers; American airlines, instead, are almost completely missing from the picture. A lot of companies that were successful hedgers in the past continued hedging, while plenty of companies that made severe losses in their hedging strategies, stopped hedging: This is the case for Delta Airlines[21], United Airlines[22], Ryanair[23] and Southwest[24].

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[21] Referring to a 4bn loss in hedging reported above
[22] Wall Street Journal 2016
[23] IATA 2018
[24] Reuters 2008

Option Theory

What are Options?

Options are the focal point of this thesis research: In fact, all strategies presented for hedging purposes in this thesis include at least an option contract. Options are bilateral contracts that give one party the right and not the obligation to buy or sell an underlying asset when certain desired conditions are met in a specified amount of time[25]. Options are therefore financial assets that have their value determined from another asset, called underlying asset[26]. Options can be classified by the way they manage execution timing, on this ground there are two type of options: American and European. The former can be exercised anytime until its expiration date; while the latter can only be exercised at its expiration date[25].

Options can also be classified by the payoffs they allow the contracting parties to collect either before (American) or at (European) expiration date. On this ground, two types of options exist: "Call Options" and "Put Options". The former gives the investor the opportunity to buy the underlying asset in the future at a fixed price; while the latter gives the investor the opportunity to sell the underlying asset at fixed price. The "fixed price" mentioned in the definition above is called "strike price"[26].

From these two basic options, a trader can build plenty of different strategies, this thesis will just cover simple calls, straddles, strangles and collars. This section will cover only these, even if an investor can build many more combinations. In the formulas below, spot refers to the price of the underlying asset and it is assumed that the option will be bought at time t; this count for all options and option strategies covered in this section.

[25] Black and Scholes 1973
[26] Damodaran 2016

Call Options

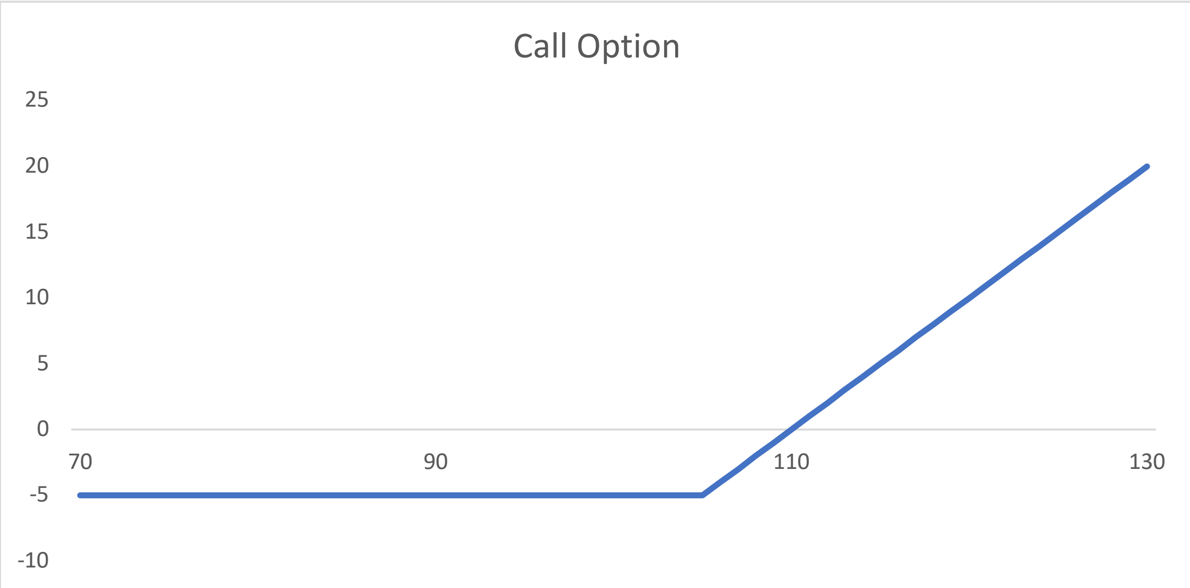

Figure 2: Call Option Strategy Payoff

This option is one of the two basic building blocks of all strategies in this thesis. In this particular example the strike price is 105 € and premium is 5 €. On the horizontal axis lays the spot of the underlying price and the blue line stands for the payoff of the strategy. This option will allow the investor to hedge any price increase in the underlying asset. The premium is the price paid for the option.

The payoff of a call option is calculated in the following way:

$$Option\ price_{t-1} = price\ call_{t-1}$$
$$If\ spot_t > strike\ price:$$
$$Payoff = spot_t - strike\ price - option\ price_{t-1}$$
$$If\ spot_t < strike\ price:$$
$$Payoff = -option\ price_{t-1}$$

In the formula above, spot refers to the price of the underlying asset and it is assumed that the option will be bought at time t; this counts for all options and option strategies covered in this section. Basically the option grants the investor the right (that might be used only if it convenient to do so) to buy the underlying asset at the strike price. Therefore, if the underlying price becomes higher than the strike price, the investor will buy the underlying asset at a lower cost and immediately sell it to turn in a profit.

A call option can also be written and in this case, the investor will receive the premium for holding the option: If then the spot price of the underlying asset exceeds the strike price, then the investor will have to pay the difference between the new spot price and the strike price. These types of options are called "Short Call Option" and are especially useful to create collar option strategies.

Put Options

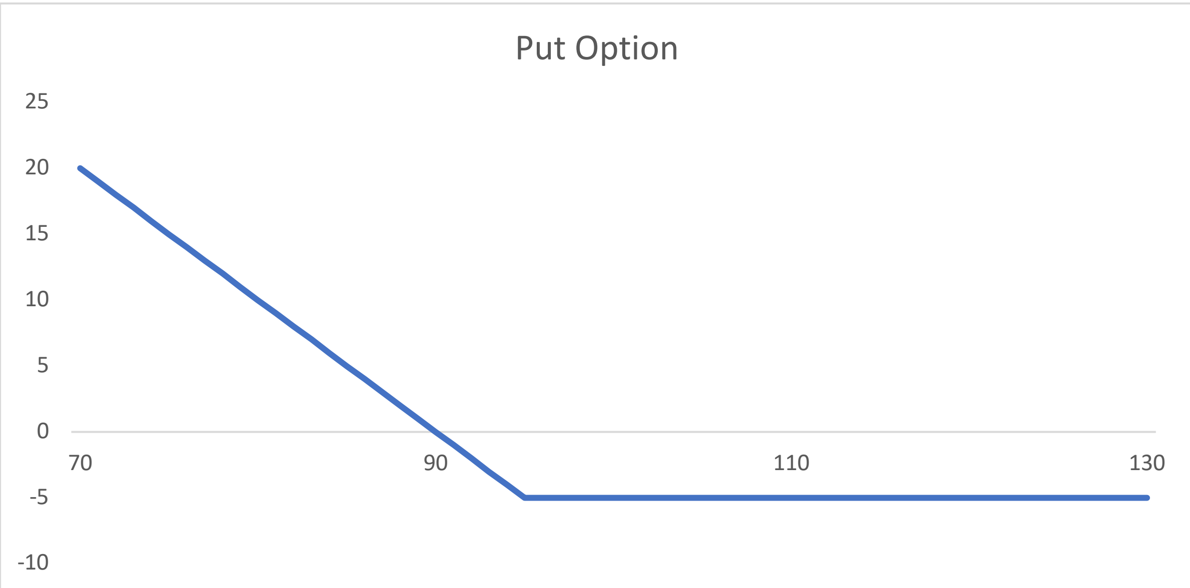

Figure 3: Put Option Strategy Payoff

Put options are the second basic building block to create more complex option strategies. In the chart above the strike price is 95 € and the premium is 5 €. On the horizontal axis lays the spot of the underlying price and the blue line represents the payoff of the strategy. The investor through this option can hedge price declines of the underlying asset.

This option will grant the investor the right (if it is convenient to do so) to sell the underlying asset at the strike price; if the underlying price falls below the strike price, the investor will buy the asset and immediately sell it at the strike price (which is higher). Therefore, the profit for a put option is:

$$Option\ price_{t-1} = price\ put_{t-1}$$
$$If\ spot_t < strike\ price:$$
$$Payoff = strike\ price - spot_t - option\ price_t$$
$$If\ spot_t > strike\ price:$$
$$Payoff = -option\ price_t$$

This option, like the call option above and any other strategy discussed in the thesis can be shorted and the payoff formula will simply be the opposite. Yet, since short put options and the short version of all other strategies (except call options) are not used in the research of the thesis, they will not be further discussed.

Straddle Option Strategy

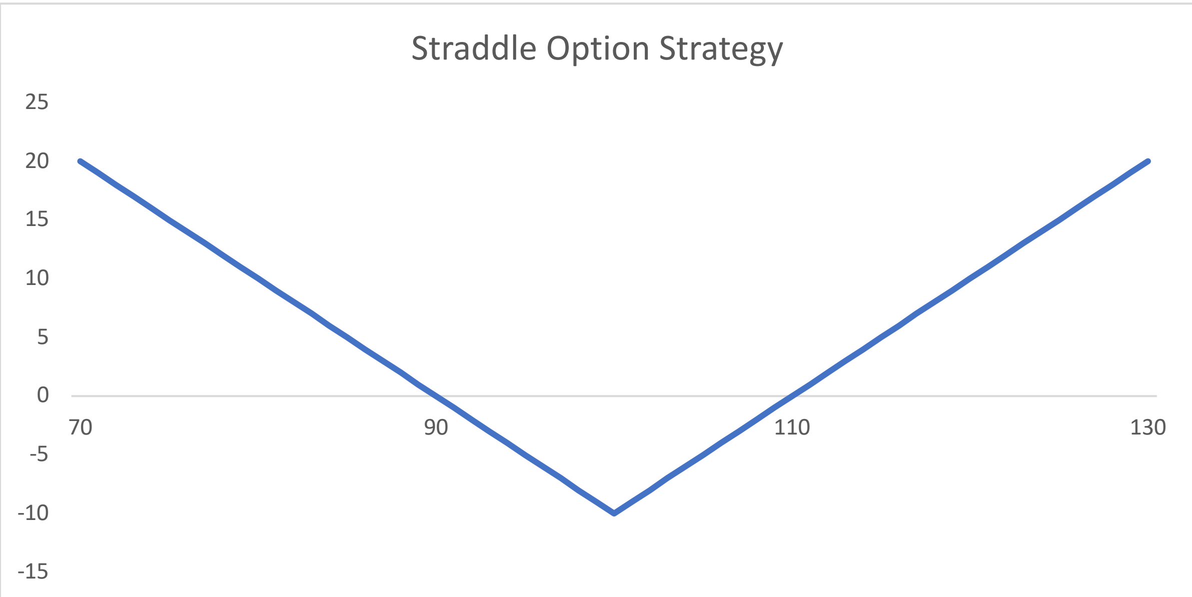

Figure 4: Straddle Option Strategy Payoff

Straddle option strategies are built buying a call and a put option with the same strike price. In the graph above the strike price is 100 € and the premium is 10 €. On the horizontal axis lays the spot of the underlying price and the blue line stands for the payoff of the strategy. As call and put options are bought in conjunction, the investor will have to pay the premium of each. Straddle option strategies are useful if the investor believes that volatility of the underlying will be high, therefore the strategy allows to gain from price movements, whatever their direction.

The payoff of a straddle option strategy can be summarized by the formulas below:

$$Option\ price_{t-1} = price\ call_{t-1} + price\ put_{t-1}$$
$$If\ spot_t > strike\ price:$$
$$Payoff = spot_t - strike\ price - option\ price_t$$
$$If\ spot_t \leq strike\ price:$$
$$Payoff = strike\ price - spot_t - option\ price_t$$

Strangle Option Strategy

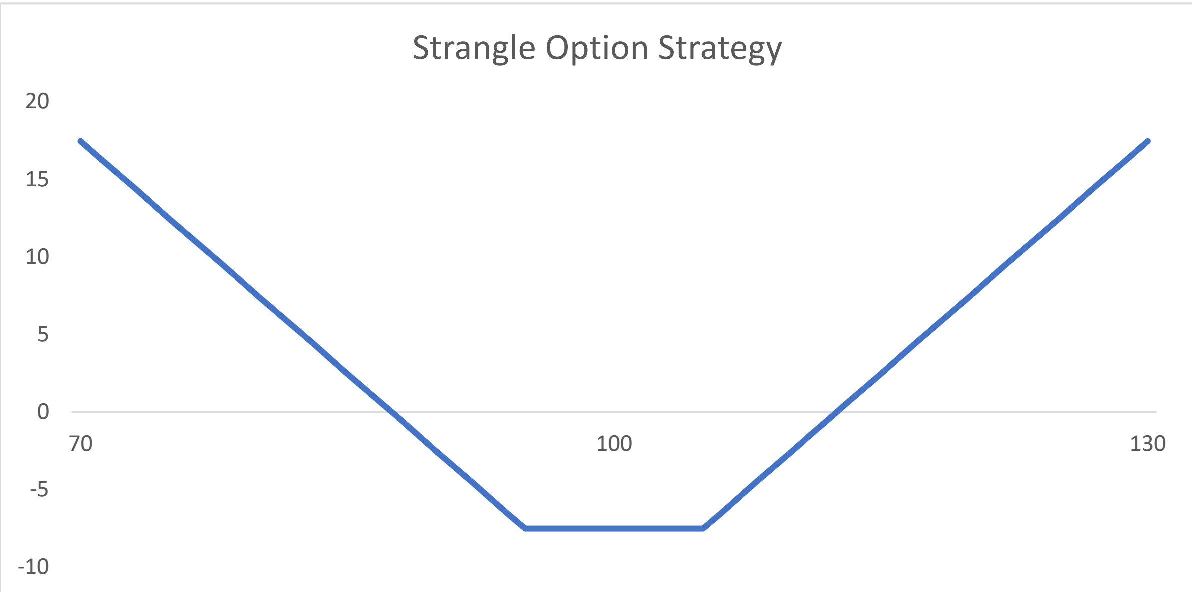

Figure 5: Strangle Option Strategy Payoff

Strangle option strategies have the same rationale of straddles: In fact, they involve as well buying both a call and a put option. Yet, the strike price of such options is "out of the money" and therefore the strike price of the call option will be to a certain degree higher than the price of the underlying asset and the strike price of the put option will be lower than the one of the underlying asset. For example, in the graph above the strike price of the call option is 105 €, strike price of the put option is 95 € and the spot is 100 €; this allows the strategy to be cheaper than the straddle option strategy. In fact, the premium of such strategy in the graph above is 7.5 €. This strategy can be useful if the investor has a less accentuated belief that the price of the underlying asset will become volatile in the future. The investor will be losing less money if the belief proves to be wrong (as the strategy is cheaper than a straddle option strategy), but the payoffs in case of volatility in the underlying assets will also be lower than a straddle option strategy.

In the graph above, the horizontal axis represents the spot of the underlying price and the blue line stands for the payoff of the strategy. The formulas below can summarize this payoff:

$$Option\ price_t = price\ call_{t-1} + price\ put_{t-1}$$

$$If\ spot_t > Strike\ Price_{call}:$$

$$Payoff = spot_t - Strike\ Price_{call} - option\ price_t$$

$$If\ spot_t < Strike\ Price_{put}:$$

$$Payoff = Strike\ Price_{put} - spot_t - option\ price_t$$

$$If\ Strike\ Price_{call} > spot_t > Strike\ Price_{put}:$$

$$Payoff = -option\ price_{t-1}$$

Collar Option Strategies

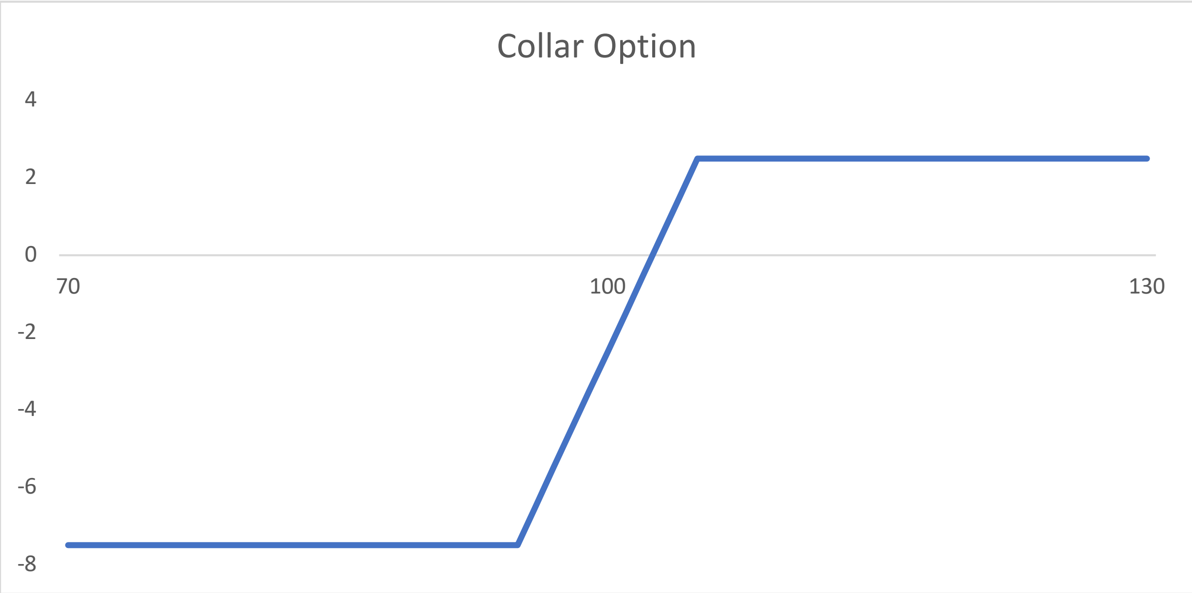

Figure 6: Collar Option Strategy Payoff

Collar options allow for locking prices of the underlying asset a certain threshold. They are built by buying a put option with "out of the money" strike price and writing a call with "out of the money" strike price. Moreover, the investor must also buy the underlying asset to properly build this strategy.

Investors can also build "zero cost collars" that are completely free to build option-wise (the investor will still have to pay for the asset); yet, the research work of the thesis never encountered this options while keeping strike prices reasonable. Therefore, in the graph above the strike price of the put option is 95 € and the strike price of the call option is 105 €; the premium associated to this strategy in the graph is 2.5 €.

The horizontal line of the graph denotes the spot of the underlying price and the blue line stands for the payoff of this strategy. The formulas below can summarize the payoff:

$$Option\ price_{t-1} = price\ put_{t-1} - price\ call_{t-1} + spot_{t-1}$$

$$If\ spot_t > Strike\ Price_{call}:$$

$$Payoff = Strike\ Price_{call} - spot_{t-1} - option\ price_t$$

$$If\ spot_t < Strike\ Price_{put}:$$

$$Payoff = Strike\ Price_{put} - spot_{t-1} - option\ price_t$$

$$If\ Strike\ Price_{call} > spot_t > Strike\ Price_{put}:$$

$$Payoff = spot_t - option\ price_{t-1}$$

Now that all option strategies have been presented, the thesis will continue discussing how these financial assets are priced. This is fundamental for this thesis, because how much airlines pay for options will affect their fuel expenses, EBITDA and how well a certain simulation fared against the base airline results. A way that many researchers used to price options is the Black and Scholes approach that will be described below.

Black and Scholes' Option Pricing

The option pricing model developed by Fischer Black, Myron Scholes and Robert Merton is one of the most used models to price options. The original model was published in 1973 and from there it gave birth to many derivations aiming at relaxing the multiple assumptions of the model.

Assumptions

The research project in this thesis used the original model to price the options and strategies that airlines could use for hedging. The original model is constrained by seven assumptions:

1. Investors know the short-term interest rate and the rate is constant through time (from option acquisition to option expiration)[27].

[27] Black and Scholes 1973

2. Stock prices follow a lognormal distribution with constant variance of the assets' return. This means that stock prices follow a random walk in continuous time and have the variance rate proportional to the square of the stock price[27].

3. Stocks pay no dividend or other distributions[27].

4. The model only works for European options[27].

5. Buying or selling the stock or the options entail no transaction costs[27].

6. The investor can borrow any fraction of the price of a financial asset or to hold it at the short-term interest rate[27].

7. Short selling entails no penalties: A seller that does not own an asset will always accept the price of the buyer and will stipulate a contract with the buyer for the payment of an amount equal to the price of the asset on a future date[27].

The Black and Scholes Formula

For the purpose of this thesis, a detailed explanation of Black and Scholes option pricing through stochastic differential equations is not needed, but these paragraphs will still cover the basics. The "Black and Scholes" model for option pricing assumes first of all that the underlying asset price follows a geometric Brownian motion.

Brownian motions were first used to describe the random motion of particles in a liquid and then described mathematically by many scholars, including Einstein in his paper: "Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen" (1905). A geometric Brownian motion is a stochastic process in continuous time, where the logarithm of the randomly varying underlying asset price follows a Brownian motion[28].

[28] Shinde and Takale 2012

The first step Black and Scholes took towards option pricing was to bring about the concept of "Continuous Time Finance", in which a trader could trade securities in continuous time[29]. From this point, they developed a riskless position in continuous time and, to avoid arbitrage opportunities, the return on this position had to be equal to the risk-free rate[29]. From here the famous Black and Scholes partial differential equation[29]:

$$\frac{df}{dt} + rS\left(\frac{df}{dS}\right) + \frac{1}{2}\sigma^2 S^2\left(\frac{d^2 f}{dS^2}\right) = rf$$

Where f stands for the value of the option, t represents time, S the strike price of the option, σ^2 the variance of the underlying asset and r is the risk-free rate[30].

This equation admits an analytical solution: Indeed the famous Black and Scholes Formula[29]:

$$C = X * N(d1) - S * e^{-r*(T-t)} * N(d2)$$

The formula above is for a call option, where S stands for the execution price of the option; N stands for normal distribution (in this case $N(0,1)$); t stands for the time of option execution (if exercised); T for the acquisition of the option; X the current price of the underlying asset; $d1 = \frac{\log\left(\frac{S}{X}\right)+\left(r+\frac{\sigma^2}{2}\right)*(T-t)}{\sigma*\sqrt{T-t}}$ and $d2 = d1 - \sigma * \sqrt{T-t}$[29].

The formula for a put option, instead will be[31]:

$$P = -X * N(-d1) + S * N(-d2) * e^{-r*(T-t)}$$

Yet, for more clarity, for the rest of the thesis the put and call option price formulas will follow this notation:

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[29] Shah 1997
[30] Yoo 2017
[31] Black and Scholes 1973

$$Price\ Call\ Option = Spot * N(d1) - N(d2) * Strike\ Price * e^{-Risk\ Free * t}$$

$$Price\ Put\ Option = Strike\ Price * e^{-Risk\ Free * t} * N(-d2) - Spot * N(-d1)$$

Now that the underlying theory has been explained, this thesis can build on top the research methodologies and from there obtain results.

Methodologies

Given the scale of the research work, tactical use of different software and methodologies was vital to overcome the fragmentary nature of airliners' reporting: In fact, these companies usually reported vital information to the research in complementary notes, therefore outside the main financial statements and thus was not reported consistently throughout the years. The overall data time span is fourteen years (2005 – 2018), with multiple changes in the accounting standards and in disclosure requirements, so one strongpoint of the research was to derive all data required from information reliably available through the whole timespan and across all companies, with the aim to achieve a consistent comparison.

The aim of the research is twofold: finding the hedging strategy that works best in optimizing fuel prices for airlines (preferably a strategy that hedges fuel prices whatever their direction) and finding the strategy that best normalizes cashflows. To answer to these questions, the methodologies' toolbox must include various tools. First data had to gathered, this has been done with proprietary algorithms and FactSet; then from basic data, other company data (e.g. fuel litres consumed per quarter) was calculated; next the option strategies' prices and payoffs were calculated using the Black and Scholes framework; lastly, scores for different strategies both in the field of fuel price minimization and cashflow normalization were achieved. This allowed the research to individuate the best strategies for fuel price minimization and cashflow normalization.

The key financial of the final scores was EBITDA: As fuel prices decrease, OPEX (or COGS) decreases and therefore EBTIDA increases. Therefore, a higher EBITDA meant a better hedging strategy. Instead for cashflow normalization, the key element was EBITDA standard deviation: A lower EBITDA standard deviation (than reported) meant that the hedging strategy was effective in normalizing cashflows. The chapter below will guide through all the steps and provides details on the methodologies used.

Software and Algorithms

Using Python

Throughout the thesis work, Python proved itself to be an immensely powerful tool and, complemented with Microsoft Excel, it supplied an excellent aid in the research work. Python has a wide scope of possibilities and its applications are extremely comprehensive: from program creation to complex statistical analysis. One of the foremost advantages to this platform is the automation of complex tasks: This was extremely useful in optimizing hedging strategies across a variety of portfolio options, an impossible task if done manually. All data-gathering algorithms have been coded in Python and ran on PyCharm.

PyCharm[32] is the open-source software ("viewer") used to run, view and debug Python code, the viewer's user interface and additional functionalities simplified the entire process of coding and removal of bugs in the code. Python in this project was running in its 3.7 version with the addition of components for increased functionality, called "libraries", such as "Pandas" and "NumPy". The former is essential for data organization in "Data Frames", basically tables filled by algorithms and research with all information about airlines, kerosene spot prices or risk free rates; "Pandas" allows for easy data resampling, especially in time. The latter allows for complex mathematical calculations, essential in Black and Scholes option pricing. Appendix 1 offers a comprehensive list of names and appliance of all Python libraries used in the research.

Gathering the Data

In addition to the six airline companies that are the subject of the final version of this research, eight more were researched; though, not all companies appeared in the final work, mainly because of reporting inconsistency across time and undisclosed data on certain reports. The analysed companies were in total fourteen for a span of fourteen years (2005 – 2018) using quarterly data: This resulted in analysing about 770 total quarterly reports. Manual research

[32] https://www.jetbrains.com/pycharm/

would have been incredibly labour intensive: Instead, a proprietary algorithm coded in Python, automatically gathered the needed data from such annual reports. Apart from the coding effort, this algorithm severely reduced "manual labour". The algorithm in its conclusive version supplied many of the required results with 100% accuracy: If the code "was not completely sure" of a result, it always yielded "Error". The accuracy of the algorithm was reviewed extensively on multiple tests across different companies and different quarterly report types. The obtained numbers were consecutively converted to Euro with FactSet's historical series of EUR/USD exchange rates[33].

The algorithm made a research of such scale reasonable and possible; yet, the program's yielded result was quite often "Error" implying that on multiple occasions the algorithm was not entirely confident of the found data. In this case, there were two possibilities: Annual reports and FactSet. If a company missed only a few datapoints, manual research in annual report was enough. If instead the algorithm could not read the quarterly reports of entire companies, because of complex formatting or critical errors in parsing the files, the software of choice to promptly retrieve such data was FactSet.

FactSet is a financial software that allows the user to view and gather financial data on public companies and some private ones. One of the main advantages of this research venue is that it standardizes financials to keep consistency across all the quarters. Moreover, FactSet allows for immediate currency translation, useful for this case in which the currency of choice is the Euro and most airlines report in Dollars. Still, after running the proprietary algorithm, looking for information on annual reports and even resorting to FactSet, most of the analysed airlines lacked data consistency for the researched items during the target timespan and were therefore discarded. Scorecards on Microsoft Excel hosted those companies, that instead kept consistent results across time. Appendix 2 hosts all scorecards with basic information used in this research.

In order to keep the results consistent, the research work focused on gathering only fundamental items from annual reports and financial databases. Then, if possible, data were

[33] On FactSet USDEUR

derived through operations and manipulation, making few assumptions. The chapter below focuses on these methods to obtain these other items.

Methodologies on Financial Statements

The basic items gathered from annual reports and financial databases were: Revenues, EBITDA, depreciation and fuel & oil expenses (also including hedging expenses). In addition to these, spot fuel price[34] and risk-free rates[35] were added for each scorecard; these two items were the same for each company, in order to maintain consistency in the results.

Fuel Consumption in Litres

Airline companies do often report "Fuel consumed in litres", but fail to do so consistently: in fact, some companies report it only annually and others report it only for certain time frames. So, deriving it from the data was crucial. The method followed in this research project was simply to divide reported oil costs by the spot cost per litre of fuel. This was done for two reasons: Airlines often do not report how much they paid for fuel and keeping consistency between companies. This estimate of fuel litres consumed is not a perfectly accurate one, because it ignores hedging costs and other fuel-related costs in reported oil costs. This was not a problem for the thesis though. Regarding other fuel-related costs it is actually beneficiary to the research work: In fact, by ignoring them, they will always be factored in. Instead, regarding hedging costs, the research attempts to find optimal hedging solutions on top of former ones already put in place by the company. Anyway, as the "Results" chapter will show, option strategies that did not perform well, had extremely low results and would have kept negative outcomes even if the figure was unhedged. The formula underneath will show how the information about hedging and other fuel-related costs is implicitly factored in.

[34] FactSet Code: JTKGC-FDS
[35] FRED

$$Fuel\ Litres = \frac{Oil\ Expense + Hedging\ Performance + Other\ Oil\ Costs}{Spot\ fuel\ price\ per\ litre}$$

$$Hedged\ fuel\ litres = Hedged\ fuel\ price\ per\ litre * Fuel\ litres$$

Past hedging performance will be uninfluential in the scope of this thesis, as new strategies will start from a position that has hedging (when airlines do it) already employed and the only issue to investigate is whether the situation improves with new simulated hedging strategies. Unfortunately, due to lack of data, it is impossible to calculate unhedged figures for fuel litres consumed, as this would require to at least know what option strategies airlines use and this is very rarely reported.

Simulation Methodologies

Assumptions

The research project uses the following assumptions to run option and financial simulations:

1. Airline companies' management team has perfect vision on future oil consumption: This is needed for various option related simulations. In fact, the simulation algorithm accepts as an input the percentage of future fuel consumption that management would like to hedge for the next quarter: This implies that management does know future fuel consumption.

2. All the assumptions for the Black and Scholes model: option pricing in the research project is conducted using Black and Scholes and therefore all of their assumptions count. Summarizing, the assumptions of the model are:

    a. Constant Volatility[36]
    b. Efficient Markets[36]
    c. No Dividends[36]
    d. Interest Rates are Constant and Known[36]

e. Lognormally Distributed Returns[36]
f. No Commissions and Transaction Costs[36]
g. Perfect Market Liquidity[36]

3. All options used are European: as explained in the theory section of this thesis, both American and European options exist. This research project only used European options, this because the basic version of Black and Scholes only allows for European options. Moreover, expiry date of such options is always one year after their acquisition.

4. Airlines can purchase fuel at the spot price: The spot price used in the research is based in the USA and although five out of the six airlines presented in the project are based in North America, this price might not be extremely accurate for Ryanair, which is based in the European Union. Yet, there is a lack of kerosene historical series available for European Union and even that would not be the most accurate series; historical series for Ireland were also unavailable.

5. Airlines only hedge 33% of projected fuel litres consumed: This is based on an average on how much airlines hedge now[37].

Spot and Risk-Free Rate

Spot prices for Kerosene were gathered from FactSet: the exact name of the downloaded series is "Jet Fuel Kerosene-Type U.S. Gulf Coast ($/gal)"[38]. The original series is in US Dollars per gallon, but FactSet allows for instant currency translation to Euro per gallon[39]; then the thesis' code converted gallons to litres[40]. Moreover, FactSet supplied the data monthly and the thesis program resampled the data on a quarterly data, taking the mean price in said period. This series is from the US and might not exactly represent what European

[36] Black and Scholes 1973
[37] IATA 2018
[38] FactSet Code: JTKGC-FDS
[39] Historical Series of Euro/Dollar Exchange Rate, on FactSet USD/EUR
[40] 1 Gallon = 3.78541 Litres

companies pay for jet fuel; yet, very few jet fuel data series are publicly available and all of the found ones were for U.S. Fuel Kerosene Spot.

Regarding the risk-free rate, the research project used three-month US treasury bills supplied by the Federal Reserve Bank of St. Louis[41]. The rate provided was from the secondary market[42] and the data was not seasonally adjusted. The rate was monthly, therefore the Python thesis code had to convert it to quarterly, since the risk-free rates were already yearly percentages, the code only had to take the mean of all monthly observations in the quarter.

Both kerosene spot and risk-free rates were pivotal for the achievement of simulations: risk-free rates play a crucial role in option pricing with Black and Scholes model, while the kerosene spot rate was used on nearly every aspect of the research part of the thesis.

Simulating hedged EBITDAs

The simulation of option prices was by far the most time, labour and computationally intensive part of the whole research. As explained earlier, the framework relies on the Black and Scholes model and starting from modelling simple call and put European options, the research arrived to complex ones such as straddles and collars. The entire process was conducted on Python with the "Hedge with Options" function, created ad-hoc for this thesis.

The function takes year, quarter, option type and strike percentage as inputs. The latter is a measure of how far the option's strike price is from the spot price and is measured as a percentage.

This thesis follows a "one-size fits all" approach: This means that strategies and strike prices' deviation from spot prices never change during periods. This was on purpose, to check if a strategy would have performed well in many different economic environments. In this research, different strike percentages were simulated: from -5%, to 5%. Furthermore, the

[41] https://fred.stlouisfed.org
[42] Code TB3MS

percentage of future fuel litres hedged is 33%, as that is an average of how much many airlines hedged in the considered period[43].

One of the essential elements in modelling option prices using the Black and Scholes approach is the standard deviation of spot prices[44]. The algorithm used in this research proceeded in its calculation by calculating standard deviations from the four quarterly observation before the viewpoint: For instance, if the perspective is 2006 Q1, σ will be the standard deviation between the 2005 Q1, 2005 Q2, 2005 Q3 and 2005 Q4 observations. Calculating standard deviations with historical data from previous periods, and not future ones, is a necessary step to ensure realism in the process: In fact, management does not know future fuel prices' standard deviations. The spot price data series, therefore, has 2004 Q1 as a starting point, such that standard deviations for all quarters of 2005 could be calculated.

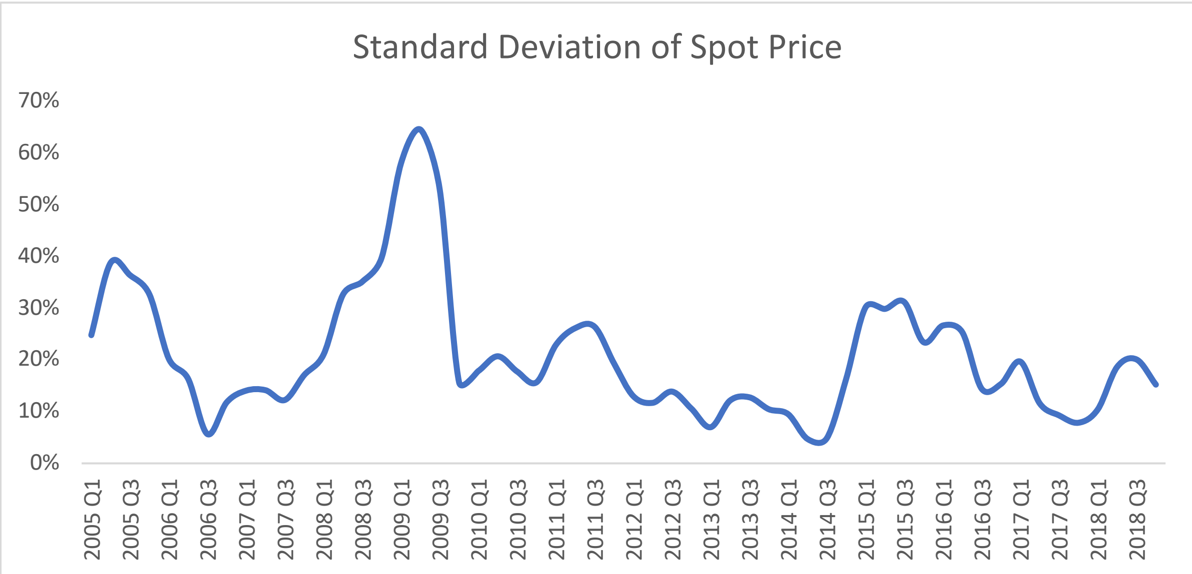


Figure 7: Standard Deviation of Spot Price in Considered Period

Now that all basic components for Black and Scholes option pricing have been presented, it is possible to discuss the basic function that calculated all "Call" and "Put" options in the model: the name in the algorithm is "Euro Vanilla". This function uses the most basic implementation of Black and Scholes option pricing. Inputs are spot price, strike price, time before the option expires (in years), risk-free rate and the type of option required ("Call" or

[43] IATA 2018
[44] Black and Scholes 1973

"Put"). From this simple function, it is easy to build different option strategies and all strategies in this research were built using this building block. Below there is the code of this basic option pricing function.

```
def euro_vanilla(s, k, t, r, sigma, option='call'):
    import numpy as np
    import scipy.stats as si
    # S: spot price
    # K: strike price
    # T: time to maturity expressed in years
    # r: interest rate
    # sigma: volatility of returns of the underlying asset
    d1 = (np.log(s / k) + (r + 0.5 * sigma ** 2) * t) / (sigma * np.sqrt(t))
    d2 = d1-(sigma*np.sqrt(t))
    result = []
    if option == 'call':
        result = (s * si.norm.cdf(d1, 0.0, 1.0) - k * np.exp(-r * t) * si.norm.cdf(d2, 0.0, 1.0))
    if option == 'put':
        result = (k * np.exp(-r * t) * si.norm.cdf(-d2, 0.0, 1.0) - s * si.norm.cdf(-d1, 0.0, 1.0))
    return result
```

Once simple "Call" and "Put" options were computed, the research algorithm switched to calculating option strategies. The aim of the research at this point was to find the which option strategy would have yielded the best results when applied. To do this the research proceeded in four steps: (1) It calculated the payoff of a given option strategy, (2) it subtracted this payoff from spot fuel prices, (3) calculated new fuel expenditure by multiplying the new fuel price by fuel litres consumed and (4) calculated a new EBITDA with the new fuel expenditure. The first step is indeed to calculate the payoff of the option strategies:

- Simple Call: The assumption is that the option is acquired at time t at strike price k. This option strategy has been tested with $k = spot_t * (1 + 5\%)$, $k = spot_t * (1 - 5\%)$ and $k = spot_t$.

  $Option\ Price$: $\quad Option\ price_t = price\ call_t$

  $If\ spot_{t+1} > k$: $\quad Payoff\ =\ spot_{t+1} - k - option\ price_t$

  $If\ spot_{t+1} < k$: $\quad Payoff\ =\ -option\ price_t$

  $New\ Fuel\ Price_{t+1} = Spot_{t+1} - Payoff$

- Straddle: This option strategy implies buying both a "Call" option and a "Put" option with same strike price k. The assumption is that all options that compose this strategy are bought at time t. This option strategy has been tested with $k = spot_t * (1 + 5\%)$, $k = spot_t * (1 - 5\%)$ and $k = spot_t$.

$Option\ Price$: $Option\ price_t = price\ call_t + price\ put_t$

$If\ spot_{t+1} > k$: $Payoff = spot_{t+1} - k - option\ price_t$

$If\ spot_{t+1} \leq k$: $Payoff = k - spot_{t+1} - option\ price_t$

$New\ Fuel\ Price_{t+1} = Spot_{t+1} - Payoff$

- Strangle: This option strategy implies buying both a "Call" option and a "Put" option with different strike prices k. During this research the values of k that were used were $k_{call} = spot_t * (1 + 5\%)$ and $k_{put} = spot_t * (1 - 5\%)$. The assumption is that both options are bought at time t.

$Option\ Price$: $Option\ price_t = price\ call_t + price\ put_t$

$If\ spot_{t+1} > k_{call}$: $Payoff = spot_{t+1} - k_{call} - option\ price_t$

$If\ spot_{t+1} < k_{put}$: $Payoff = k_{put} - spot_{t+1} - option\ price_t$

$If\ k_{call} > spot_{t+1} > k_{put}$: $Payoff = -option\ price_t$

$New\ Fuel\ Price_{t+1} = Spot_{t+1} - Payoff$

- Collar: This option strategy implies buying a "Put" option and writing a "Call" option with different strike prices k; moreover, the strategy implies buying the asset at time t, instead of buying it at $t + 1$ as it happens with all other strategies. During this research the values of k that were used were $k_{call} = spot_t * (1 + 5\%)$ and $k_{put} = spot_t * (1 - 5\%)$. In this case the option price also includes the price of the asset ($spot_t$). The assumption is that both options and the asset are bought at time t.

$Option\ Price$: $\quad Option\ price_t = price\ put_t - price\ call_t + spot_t$

$If\ spot_{t+1} > k_{call}$: $\quad Payoff = k_{call} - spot_{t+1} - option\ price_t$

$If\ spot_{t+1} < k_{put}$: $\quad Payoff = k_{put} - spot_{t+1} - option\ price_t$

$If\ k_{call} > spot_{t+1} > k_{put}$: $\quad Payoff = -option\ price_t$

$New\ Fuel\ Price_{t+1} = -Payoff$

In the collar strategy the fuel is bought one year in advance and then hedged with a long "Put" option and a short "Call" option. So, in $t+1$, there will be no need for the company to buy new fuel for that quarter, as it was already bought when the strategy was put in place. It will buy new fuel repeating the strategy again.

The work went ahead in finding the new oil expenditure with hedged fuel spot. Hedging all the expected future fuel demand is extremely rare in airlines: The airline that hedges most of expected fuel consumption is Ryanair with a strong 90%, but the industry average at the moment is 33% [45]. Therefore, the research project assigned a weight of 33% of the future expected litres of fuel demand to hedging: So only 33% of future fuel consumption is hedged. The new oil expenditure (including hedging) was calculated in the following way:

$$Oil\ Expenditure_{t+1} = (Nf_{t+1} * C_{t+1}) * w + (S_{t+1} * C_{t+1}) * (1 - w)$$

Where w is the weight assigned to hedging, Nf_{t+1} is the new fuel spot found above, C_{t+1} is expected fuel consumption in millions of litres and S_{t+1} is the spot at time $t+1$. By assumption, management has a clear view on expected future oil consumption.

Next, the project continued in finding the new simulated EBITDAs. In the formula below, $Costs$ include all non-fuel related operating expenditure and costs but excludes depreciation. Still, the definitions of t and $t+1$ refer to when the options were contracted, to ensure consistency across the chapter. The following formula shows how simulated EBITDAs were found in the research project:

$$EBITDA\ (Simulated)_{t+1} = Revenues_{t+1} - Costs_{t+1} - Oil\ Expenditure_{t+1}$$

---

[45] IATA 2018

Finally, to easily find which option strategy suited best each company a twofold scoring system was devised. In the first scoring system the reported EBITDA of the company was subtracted from the EBITDA resulting from each option strategy; the second scoring system has the difference between reported EBITDA and simulated EBITDA as a percentage of reported EBITDA for better interpretation of results. The following formulas summarizes the concepts above:

$$Score_1 = \sum_{i=1}^{n} sEBITDA_i - rEBITDA_i$$

$$Score_2 = \sum_{i=1}^{n} \left(\frac{sEBITDA_i}{rEBITDA_i} - 1 \right)$$

In the formulas n stands for total observations, so all quarters from 2006 to 2018; $rEBITDA$ stands for company reported EBITDA; $sEBITDA$ stand for EBITDA simulated from an option strategy.

Score for EBITDA Normalization

Optimizing fuel prices has been the focal point of the research so far; yet, hedging can also be seen as a tool to normalize cashflows[46] and the strategies that optimize efficiently fuel prices might not be the same that achieve this other goal. The scoring devised to assess which option strategy best normalized the cashflow of a given company is slightly more complex: The goal of option strategies in this scenario is to reduce volatility of EBITDAs, so the main tool will be the standard deviation of reported and simulated EBITDAs. Yet, to detrend EBITDA time series and remove the natural growth driver, the research focused on applying the standard deviation on the differences in percentage between EBITDAs: The following formula can summarize this:

[46] Moynihan Al-Zarrad 2015

$$\Delta EBITDA\ (\%) = \frac{EBITDA_t}{EBITDA_{t-1}} - 1$$

Standard deviation was then calculated on the time series resulting from the formula above; yet, these values were expectedly extremely high and as a result, for better representation, the final results were viewed as an increase or decrease in percentage from the reported $\sigma(\Delta EBTIDA_{reported}\ (\%))$ standard deviation, as the formula below shows.

$$Score(\sigma) = \left(\frac{\sigma(\Delta EBITDA_{strategy})}{\sigma(\Delta EBITDA_{reported})} - 1\right)$$

To ensure that no contamination from the standard deviation of reported EBITDA affected the scores of the strategies, the weighting of options in simulating the cost of fuel was ramped up to 100%, even if this is clearly an unrealistic scenario.

Now that all of the research's building blocks have been presented the discussion can continue with results and implications of the findings.

Results and Implications

Results have been fairly consistent through all companies: In fact, the research work found that most option strategies do not provide better fuel hedging than what companies are already doing. Most strategies proved to be underperforming in almost all times considered; only few periods had the considered option strategies performing better than the airlines' results. The only strategy that proved to be effective in this research is the use of only call options. The main factor of underperformance of other option strategies is the elevated option costs compared to fuel spot; this will be discussed later in this chapter.

Finding simulated EBITDAs and Scores

As described in methodologies, calculating simulated EBITDAs is a linear process. This chapter will only provide examples on how simulated EBITDAs and scores were found. The whole process, comprises six steps: Calculating fuel litres consumed, obtaining basic option prices, calculating the payoff of option strategies, obtaining new fuel prices per litre (net of hedging), simulating new EBITDAs and finding the scores associated to each strategy.

Calculating Fuel Litres Consumed and Option Pricing

The first target to be achieved is an estimate of fuel litres consumed, here only the four quarters for 2018 for American Airlines will be displayed. The first items required are fuel expenditure and the spot price for fuel.

American Airlines	2018 Q1	2018 Q2	2018 Q3	2018 Q4
Sales (€ m)	8462.94	9776.85	9937.82	9585.75
EBITDA (€ m)	938.16	1448.52	1216.54	1079.69
Depreciation & Amortization (€ m)	428.80	457.65	472.00	401.38
Fuel & Oil Expense (€ m)	1758.33	2156.40	2355.71	2126.95
Spot (€)	1.54	1.75	1.83	1.74
Liters Consumed (L m)	**1145.08**	**1229.79**	**1285.01**	**1225.45**

All values in this table (except for spot and litres consumed) are in millions of Euros, spot is in Euros and litres consumed are in millions of litres. From this table it can be seen that that "Litres Consumed (M)" are achieved simply dividing "Fuel & Oil Expense" by the spot. E.G.:

$$1145.08 = \frac{1758.33}{1.54}$$

What appears when plotting the historical series of an EBITDA/Litres Consumed ratio, is that expectedly a drop in spot fuel price results in an increase of airline profitability per litre consumed. A clear exception is the fallout from the 2008 crisis: In this period both spot fuel price and EBTIDA/Litres Consumed ratio experience a drop, this may be explained by the fact that the decrease in EBITDA was not driven by fuel-related factors.

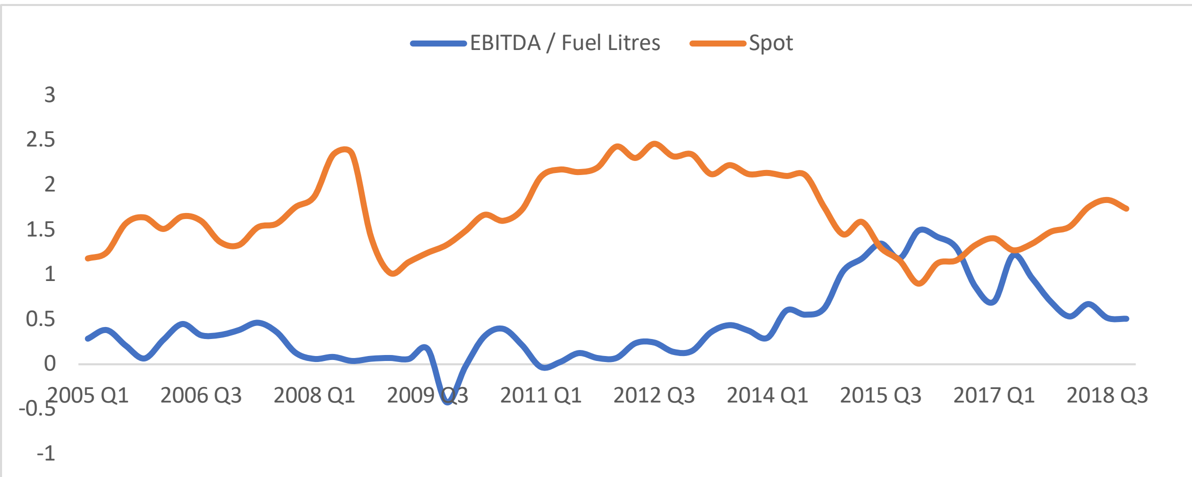


Figure 8: Spot price against Reported EBITDA on Fuel Litres Consumed ratio for American Airlines.

The next step is calculating option prices, the calculations took place in the Python code used for the research, but for visual representation, they have been replicated in the table below.

American Airlines	**2017 Q1**	**2017 Q2**	**2017 Q3**	**2017 Q4**
Spot	€ 1.40	€ 1.27	€ 1.34	€ 1.48
T-Bill Yield	0.59%	0.89%	1.04%	1.21%
σ Spot	19.68%	11.60%	9.28%	7.86%
Strike Price (Spot + 5%)	€ 1.48	€ 1.34	€ 1.41	€ 1.55
d1	-0.12	-0.29	-0.37	-0.43
d2	-0.32	-0.40	-0.46	-0.51
Price Call Option	€ 0.08	€ 0.04	€ 0.03	€ 0.02
Price Put Option	€ 0.68	€ 0.61	€ 0.59	€ 0.58

As in the option pricing paragraph in the "Theory" chapter, $d1$ and $d2$ are obtained using the following formulas:

$$d1 = \frac{\ln\left(\frac{Spot}{Strike\ Price}\right) + \left(Risk\ Free + \frac{1}{2}\sigma^2\right) * t}{\sigma * \sqrt{t}}$$

$$d2 = d1 - \sigma * \sqrt{t}$$

Where σ is the standard deviation of the spot price and t is the time (in years) before the option expires. The items of these formulas are straight forward, except for t that is always 1, as options are expected to expire the year after they are contracted. Once $d1$ and $d2$ are obtained, the prices of calls and puts can be calculated:

$$Price\ Call\ Option = Spot * N(d1) - N(d2) * Strike\ Price * e^{-Risk\ Free*t}$$

$$Price\ Put\ Option = Strike\ Price * e^{-Risk\ Free*t} * N(-d2) - Spot * N(-d1)$$

Payoffs

Payoffs are different for every option strategy and have already been discussed both in the "Theory" chapter and in the option strategies' payoff paragraph of the "Methodologies" chapter. Yet, a table would be great opportunity to see with numbers what the formulas presented early actually mean. The data shows payoffs for the four quarters of 2018 for American Airlines with options contracted in the four quarters of 2017 respectively. Furthermore, the dataset only comprises call options and straddles using a strike price calculated multiplying the spot price using the following formula: $Strike\ Price_{t-1} = Spot_{t-1} * (1 + 5\%)$. These options, in the full research were tested also with $Strike\ Price_{t-1} = Spot_{t-1}$ and $Strike\ Price_{t-1} = Spot_{t-1} * (1 - 5\%)$. Strangles and Collars require both $Strike\ Price_{t-1} = Spot_{t-1} * (1 + 5\%)$ and $trike\ Price_{t-1} = Spot_{t-1} * (1 - 5\%)$ to be built.

American Airlines	2018 Q1	2018 Q2	2018 Q3	2018 Q4
(Values in Euros)				
$Spot_{t-1}$	1.40	1.27	1.34	1.48
$Spot_t$	1.54	1.75	1.83	1.74
Price Call $Option_{t-1}$	0.08	0.04	0.03	0.02
Price Put $Option_{t-1}$	0.82	0.84	0.92	1.04
Strike Price A_{t-1} (Spot + 5%)	1.48	1.34	1.41	1.55
Strike Price B_{t-1} (Spot - 5%)	1.33	1.21	1.28	1.40
Payoff Call $Option_t$ (Strike Price A)	- 0.02	0.38	0.39	0.16
Payoff $Straddle_t$ (Strike Price A)	- 0.21	- 0.66	- 0.53	- 0.61
Payoff Strangle	- 0.23	- 0.71	- 0.67	- 0.79
Payoff Collar	- 2.20	- 2.49	- 2.66	- 2.68

From the table, it is possible to deduce that apart from call options from the second quarter onwards, no strategy performed particularly well.

Calculating New Fuel Expenses

As already discussed in methodologies, new fuel prices for each strategy are found subtracting the payoff of an option strategy to the new spot fuel price. In the table below "Strategy A" is comprised by a simple call option with $Strike\ Price_{t-1} = Spot_{t-1} * (1 + 5\%)$, "Strategy B" is comprised by a "Straddle" option strategy with $Strike\ Price_{t-1} = Spot_{t-1} * (1 + 5\%)$, "Strategy C" is comprised by a "Strangle" option strategy and "Strategy D" is comprised by a "Collar" option strategy: These are respectively the strategies analysed in the table above.

American Airlines	2018 Q1	2018 Q2	2018 Q3	2018 Q4
(Values in Euros)				
Strategy A	- 0.02	0.38	0.39	0.16
Strategy B	- 0.21	- 0.66	- 0.53	- 0.61
Strategy C	- 0.23	- 0.71	- 0.67	- 0.79
Strategy D	- 2.20	- 2.49	- 2.66	- 2.68
Fuel Price per Litre Strategy A	1.56	1.37	1.44	1.58
Fuel Price per Litre Strategy B	1.75	2.41	2.36	2.35
Fuel Price per Litre Strategy C	1.76	2.46	2.50	2.52
Fuel Price per Litre Strategy D	2.20	2.49	2.66	2.68
Spot Fuel Price	1.54	1.75	1.83	1.74

As in the table before only Strategy A achieved better fuel prices than spot: This can be attributed to the low cost of call options[47] and consequently the good hedging value they produce.

The new fuel prices per litre were then multiplied by the fuel litres consumed, that were found above, and a new oil expense was calculated. As the table below shows, the final oil expense per strategy is a weighted sum of reported oil expenses and simulated oil expenses; as

[47] As demonstrated later in the chapter

discussed above, the weight used in this research was 33%. The table contains information on American Airlines for all quarters of 2018 and will focus only on call options with $Strike\ Price_{t-1} = Spot_{t-1} * (1 + 5\%)$ for demonstrative purposes.

American Airlines	2018 Q1	2018 Q2	2018 Q3	2018 Q4
Fuel Price per Litre Call Options (€)	1.56	1.37	1.44	1.58
Fuel Litres Consumed (m)	1145	1230	1285	1225
Simulated Oil Expenses (€ m)	1,785.84	1,689.30	1,850.92	1,932.05
Simulated Oil Expenses (€ m)	1,785.84	1,689.30	1,850.92	1,932.05
Reported Oil Expenses (€ m)	1,758.33	2,156.40	2,355.71	2,126.95
Weighted Oil Expenses (€ m)	1,767.41	2,002.27	2,189.13	2,062.64

Simulated EBITDAs and Scoring Practice

The last step of finding the optimal hedging strategy to minimize fuel prices in airline companies is finding the simulated EBITDAs and assigning them a score on their performance against reported company EBITDA. This procedure follows the method discussed in the chapter "Methodologies".

The table below shows clearly how new simulated EBITDAs are calculated. The simulation part of the new EBITDA is enclosed in oil expenses and so it will be sufficient to calculate the new EBITDA taking revenues, subtracting to it "Costs"[48] and new oil expenses.

[48] Found in methodologies, page 27

American Airlines *(Values in Millions of Euro)*	**2018 Q1**	**2018 Q2**	**2018 Q3**	**2018 Q4**
Revenue	8,462.94	9,776.85	9,937.82	9,585.75
Costs	5,766.45	6,171.94	6,365.57	6,379.11
Weighted Simulated Oil Expenses	1,767.41	2,002.27	2,189.13	2,062.64
Simulated EBITDA	929.08	1,602.66	1,383.12	1,144.01

Once simulated EBITDAs are found, it is possible to calculate scores for each option strategy. Scores are calculated following the two approaches discussed in the "Methodologies" chapter: the sum of the difference between simulated EBITDA and reported EBITDA, and the percentage difference between the same two items. The table below provides an example for scoring practice, it shows scores for all quarters of 2018 for American Airlines, with call options with $Strike\ Price_{t-1} = Spot_{t-1} * (1 + 5\%)$ being the only strategy considered.

American Airlines *(Values in Millions of Euro, excpet for score %)*	**2018 Q1**	**2018 Q2**	**2018 Q3**	**2018 Q4**
Simulated EBITDA	929.08	1,602.66	1,383.12	1,144.01
Reported EBITDA	938.16	1,448.52	1,216.54	1,079.69
Score per quarter	- 9.08	154.14	166.57	64.31
Score per quarter %	- 0.97 %	10.64 %	13.69 %	5.96 %
Score Total	**375.96**			
Score Total %	**29.32%**			

Scores and Results

Scores for all strategies

The table below displays scores for all strategies per company; furthermore, also an average score (in percentage) has been added, to show how much the typical hedging strategy performs in a quarter.

		American	Delta	Ryanair	Skywest	Southwest	United
Call Option Strike = Spot + 5%	Score	818	653	148	73	361	934
	Score %	933%	216%	137%	102%	363%	12775%
	Average %	19%	4%	3%	2%	7%	246%
Call Option Strike = Spot	Score	825	656	159	75	378	987
	Score %	1077%	229%	152%	105%	386%	13529%
	Average %	21%	4%	3%	2%	7%	260%
Call Option Strike = Spot -5%	Score	707	513	151	73	327	906
	Score %	1115%	225%	151%	103%	386%	14013%
	Average %	21%	4%	3%	2%	7%	269%
Straddle Strike = Spot + 5%	Score	-5758	-5992	-910	-366	-3003	-5778
	Score %	-2105%	-986%	-771%	-396%	-1226%	-4030%
	Average %	-40%	-19%	-15%	-8%	-24%	-78%
Straddle Strike = Spot	Score	-8581	-8997	-1300	-504	-4389	-8553
	Score %	-2880%	-1353%	-1042%	-554%	-1720%	-7368%
	Average %	-55%	-27%	-20%	-11%	-33%	-142%
Straddle Strike = Spot - 5%	Score	-12143	-12825	-1792	-648	-6156	-12123
	Score %	-3778%	-1781%	-1385%	-724%	-2273%	-11218%
	Average %	-73%	-35%	-27%	-14%	-44%	-216%
Strangle	Score	-12031	-12686	-1795	-647	-6122	-12094
	Score %	-3900%	-1790%	-1399%	-726%	-2296%	-12457%
	Average %	-75%	-35%	-27%	-14%	-44%	-240%
Collar	Score	-13925	-14712	-2036	-741	-7017	-13781
	Score %	-5147%	-2043%	-1506%	-851%	-2296%	-22464%
	Average %	-99%	-40%	-29%	-16%	-44%	-432%

From the table above, it is easy to spot that the only strategies that had success were call option strategies with various strike prices. The most performing strategy was in fact a call option only strategy with $Strike\ Price_{t-1} = Spot_{t-1}$: This strategy did provide better fuel prices and as a consequence better EBITDAs overall. Still, results were very volatile and scores had either extremely high or extremely low values in some cases. This can be explained by outliers that can greatly affect results. For instance, in 2008 Q3, United Airlines reported an EBITDA of $-1.33€m$; simulated call option EBITDA ($Strike\ Price_{t-1} = Spot_{t-1}$) was $165€m$, this leaves a gain of about $125x$ that dramatically affects both "Score %" and "Average %" scores.

The chart below, instead displays the average of strategy score in percentage across all companies and all time periods considered. To keep the chart readable only calls and straddles with $Strike\ Price_{t-1} = Spot_{t-1}$, have been considered.

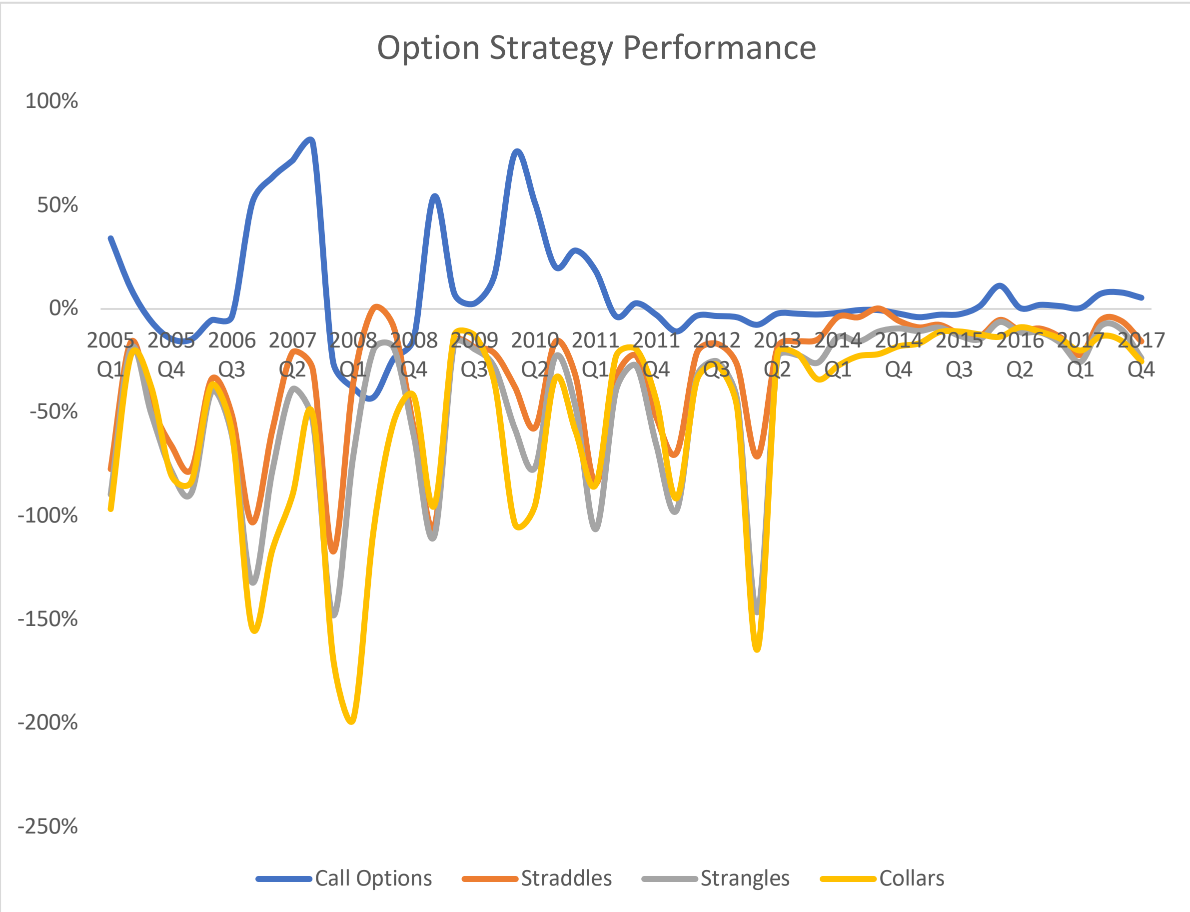


Figure 9: Average Score per Strategy Across Companies. Straddles, Strangles and Collars have their performance greatly affected by the high prices of these strategies as explained later in the chapter.

This chart shows clearly that call options have a better performance than other strategies, this is especially true during 2007. Afterwards call options delivered results in the 2010 price rise and towards the end managed not to lose a lot during the oil prices' slowdown. The other strategies, instead, have been performing poorly. One of the main reasons, as discussed below, is the costs of the options to buy such strategies.

Since the research found call option strategies as only viable way of hedging, the display and comment of results will now just focus on that strategy, in particular the strategy with $Strike\ Price_{t-1} = Spot_{t-1}$. Now the results' display will continue showing series for aggregate yearly reported company EBITDAs against their simulated counterparts.

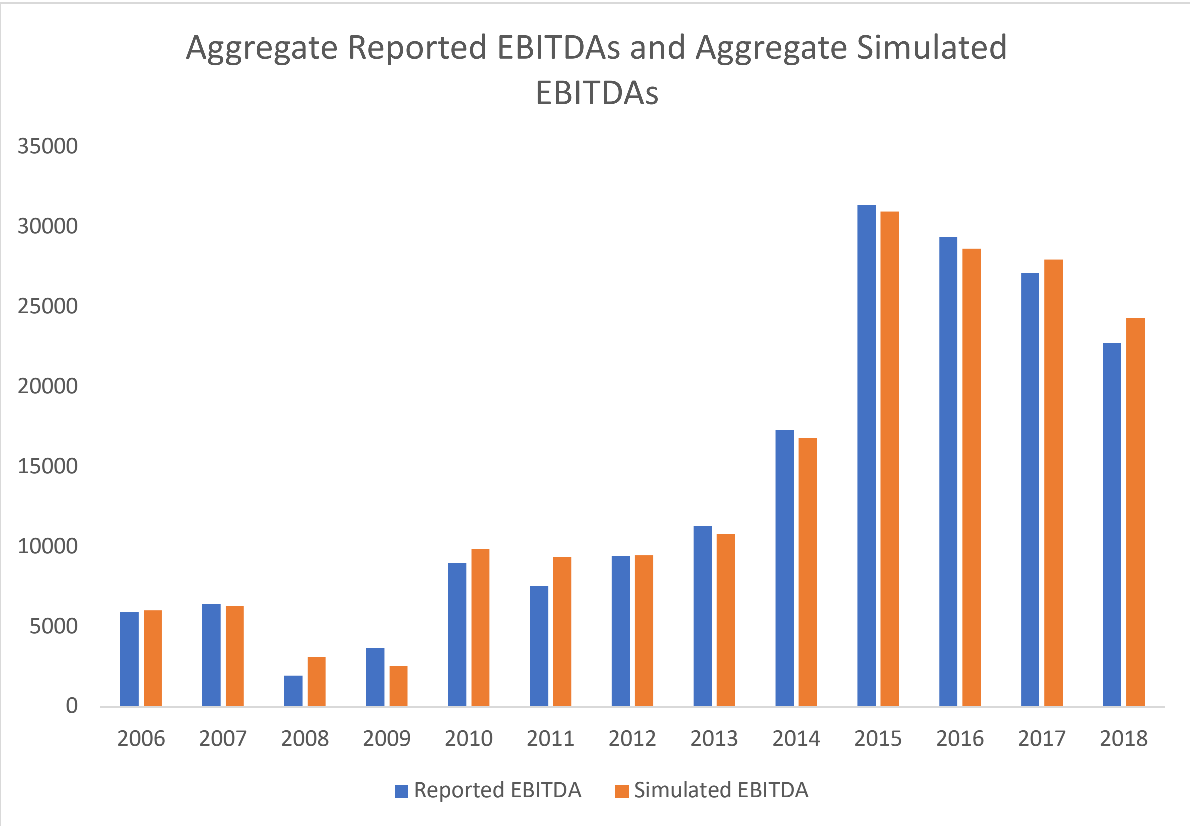


Figure 10: Aggregate Reported EBITDAs against Aggregate Simulated EBITDAs

From the graph it is possible to see that call options can supply a good hedge against raising fuel prices: In fact, whenever spot price increases, simulated EBITDA outperforms the reported one. Most notably are the cases of the 2007 oil price jump, the 2011 rise and the minor increase in 2017. In cases, instead where oil prices dropped, the losses are not that strong: This is also highlighted by the positive score of the strategy, that registers an absolute gain in the period considered. Unfortunately this strategy only hedges against fuel price increases and is not further money-generating for drops in fuel prices; yet, figure 8[49] further highlights how companies have expectedly higher profitability during declines in oil prices and so a strategy that is able to generate a premium during these periods might not be of upmost importance for airlines. Appendix 3 provides charts on Reported EBITDA and simulated EBITDA for all companies and all strategies in this covered in this research.

Implications

The results of the research work are clear: Companies could optimize their fuel costs if they engaged more in hedging through call options. The results shown above, show how the situation would have been in the realistic scenario where companies hedge only 33% of their fuel. In order to fully understand the real movements of such a hedging strategy, the graph below also presents the unrealistic possibility of 100% fuel hedging for Delta airlines.

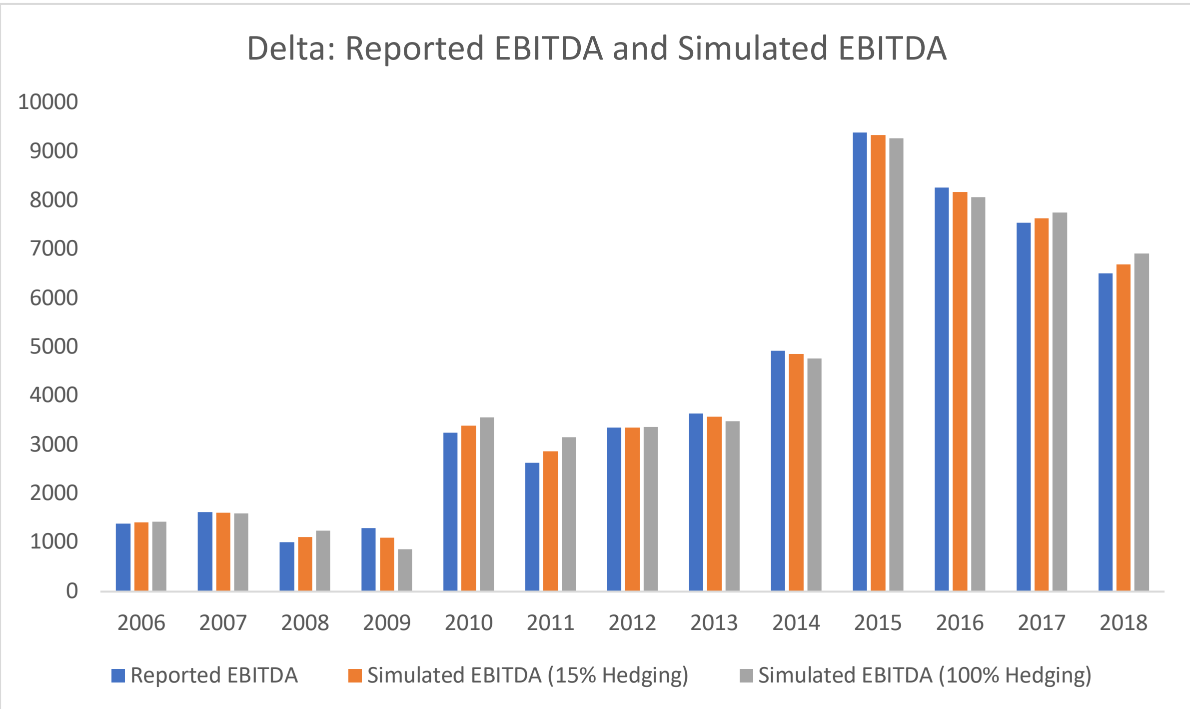


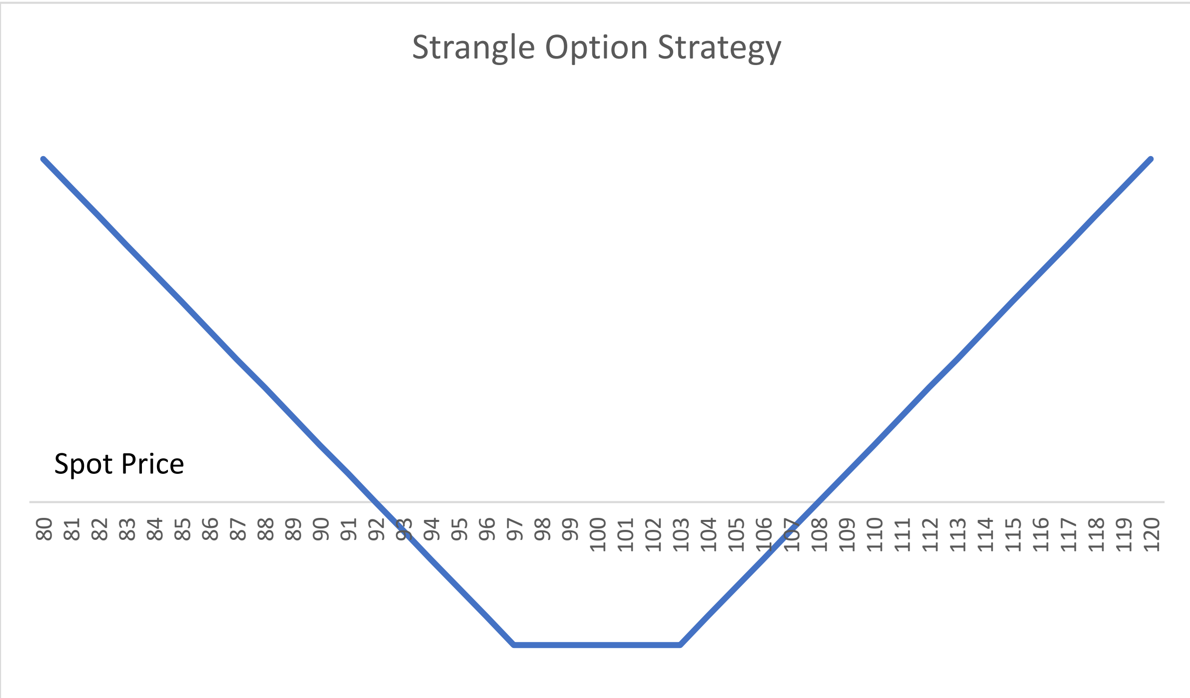
Figure 11: American Airlines, Reported EBITDA, Simulated EBITDA (Hedging 33%), Simulated EBITDA (Hedging 100%)

[49] Page 33

The 100% hedging columns in the graph above expectedly have stronger swings and are more sensitive to fuel prices, than the former 33% hedging ones. This increase in exposure, though results in higher average scores, with very positive +13.58% in average quarterly outperformance of reported EBITDA. Standard deviation, though, is very high: In fact, it reaches 57% when considering quarterly data. The model used in this research proved other strategies to be highly inefficient, mostly due to their high prices.

Cost of Options

A strategy that seemed good on paper but was found to be really underperforming in the research was a strangle options-based strategy. The chart below shows the payoff of such an option:



As the strike prices of the call option and put option are "out of the money", this strategy is slightly cheaper than a straddle option strategy; still it retains the straddle strategy's ability to provide payoffs both in case of a rise in fuel prices and in case of drop in fuel prices. In fact, one of the concerns of using only a call option based strategy, is that the cost of options might severely affect companies' EBITDA when the options are not exercised (fuel prices decline instead of rising); yet, call option premiums (in the Black and Scholes framework at least) proved not to be extremely expensive for airlines as figure 9 shows. In times of low fuel prices, the strategy did not really make extreme losses.

Returning to strangles, what really made this strategy unusable for hedging purposes is the cost of building such a strategy. The chart below shows both simulated fuel price (including the cost of the option) and the cost of the option, for both call options and the strangle option strategy.

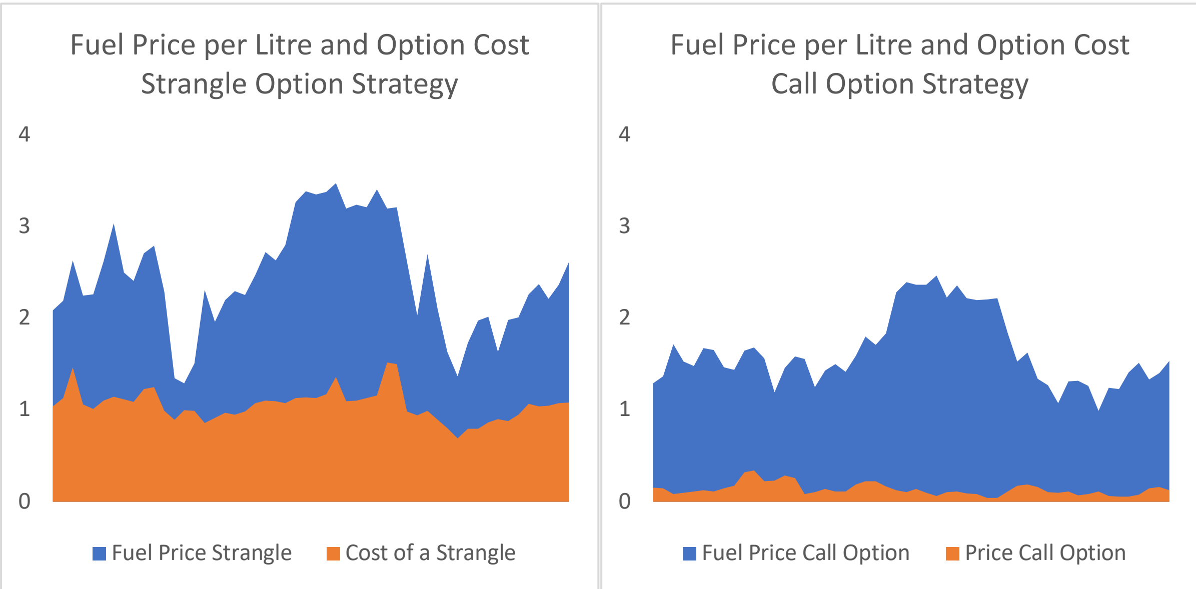


Figure 12: Breakdown of Simulated Fuel Prices with Strangles and Call Options

The two charts above show the breakdown of simulated fuel prices for strangle and call option driven strategies; it is also possible to clearly see the proportion of option price (in orange) of the overall simulated price. There is also a third factor that plays in these charts but is invisible: Option payoff, which excluding option price is always positive for strangles and include some extreme payoff spikes. For call options the payoff excluding option price is also always positive by definition: If there is no premium and prices drop, the company will simply not exercise the option. Appendix 4 supplies information on simulated fuel price and costs of options for every strategy considered in the research.

In summary, many option strategies including strangles and straddles seemed to be a good choice on paper to provide payoffs when oil prices declined and raised; yet, these strategies proved to be very expensive and not a hedging strategy that is suitable for airline companies.

Hedging as Normalization of Cash Flows

Hedging can be seen in two ways: as a protection against losses driven by an increase of the price of a basic material used in a company's operation and as a tool for cashflow normalization[50]. The research and results focused on the first aspect up until this point and now the discussion will continue analysing whether any of the strategies used in the research has cashflow normalization potential. For this analysis, all strategies in the research were used, because one company's aim could be cashflow normalization instead of fuel price optimization and so also loss-making options could still be valid for this scope.

As already stated in the "Methodologies" chapter, the main tool to measure how well a strategy performed in normalizing cashflows was standard deviation of EBITDAs: Differences in percentages of EBITDAs across quarters was the time series used to detrend the natural growth driver. Moreover, the conclusive results are expressed as the percentage difference in standard deviation from the one of percentage difference in reported EBITDAs. The table below condenses the results obtained, with the addition of an "Average" column that represents how a certain strategy fared on average across all companies:

[50] Moynihan Al-Zarrad 2015

	American	Delta	Ryanair	Skywest	Southwest	United	Average	Adj. Average
Call Option Strike = Spot + 5%	-49%	534%	-12%	-2%	-2%	-83%	87%	-16%
Call Option Strike = Spot	-63%	728%	-14%	-2%	-2%	-81%	126%	-20%
Call Option Strike = Spot + 5%	-68%	259%	-16%	-1%	-1%	-78%	33%	-22%
Straddle Strike = Spot + 5%	296%	326%	100%	-2%	150%	-21%	111%	136%
Straddle Strike = Spot	138%	2263%	106%	1%	34%	-16%	477%	70%
Straddle Strike = Spot - 5%	28%	604%	131%	8%	21%	36%	160%	47%
Strangle	160%	676%	148%	7%	15%	7%	191%	108%
Collar	-15%	307%	111%	11%	363%	-42%	150%	117%

In the table above the results are very mixed and vary greatly from company to company: Delta for example seems to have already a very stable EBITDA and so all option strategies increase volatility of the financial. This is the reason for which the last column being "Adjusted Average" has been added: This measure takes an average of volatility per company excluding the best and the least performing ones. This leaves only four company observations, which does not give enough space for a comfortable interpretation of results. Yet, from the achieved results it seems that call option strategies with $Strike\ Price_{t-1} = Spot_{t-1} - 5\%$ are the best at reducing volatility of EBITDA; moreover, call options with $Strike\ Price_{t-1} = Spot_{t-1}$, which are also the best at optimizing fuel prices, are also a valid alternative in decreasing volatility of EBITDA.

Summary of results

The research process arrived to clear conclusions regarding the use of option strategies for the purpose of hedging: A strategy comprising of call options (particularly with $Strike\ Price_{t-1} = Spot_{t-1}$) does averagely decrease the oil expenses of airline companies and therefore increasing EBITDA. Furthermore, this strategy seems to be also valid to normalize cashflows for these companies, even if the results contained the exception of Delta and United Airlines in this case. Therefore, according to the research conducted if airlines would to invest in call options with $Strike\ Price_{t-1} = Spot_{t-1}$, they would achieve lower fuel prices (after hedging) and in most cases lower EBITDA volatility; even if the latter would require an historical company specific research to assess if option strategies would actually benefit from such a strategy.

Conclusion

This thesis, in its introduction and during the whole discussion, proposed to find an answer to some questions. These were whether airlines could use option strategies to hedge against fuel prices' increases without bearing losses with fuel prices' declines; which strategies were the best ones to increase EBITDA (and therefore airline valuation in an EV/EBITDA multiple framework) and whether the proposed strategies worked in normalizing cash flows.

Hedging Competitively When Oil Prices Decline

The most obvious strategies to achieve this target were straddle and strangle option strategies. Because of their pay-off structure, these strategies pay when the underlying asset increases and decreases in price (see figures 4 and 5). Obviously, the research process took in consideration these strategies and tested them: The results were extremely underwhelming. One of the main problems associated with these strategies is their price: The premium to paid for strangles is already high (see figure 13), for straddles this premium is even higher[51]. The performance of these strategies, therefore, suffered greatly from high option prices: Simulations suggest both strategies not to be viable for the analysed airlines in the given period.

Using call options, instead, proved to be practical for airlines: These options are relatively inexpensive to buy (see figure 13) and therefore their premium is low. This means that if oil prices increase, the airline makes a profit; instead, if oil prices decrease, the airline will not exercise the option and will lose only the relatively inexpensive premium. This is a better alternative than futures exactly for the possibility not to exercise the option and buy fuel at a lower price if possible. In fact, simulations suggest that if airlines were to hedge 33% of their expected fuel requirements through call options, they would pay fuel averagely[52] 8.75% less for fuel[53] per quarter during the analysed period.

[51] See "Theory" chapter
[52] Adjusted average, best and worst performances discarded
[53] In the case Strike = Spot

In conclusion, although strategies that pay-off when oil prices decline are not workable for airlines, call options still supply a good hedging strategy that is relatively inexpensive to hold in case aircraft fuel prices decline.

The Best Hedging Strategy

As already discussed in the chapter "Results and Implications", option strategies composed by multiple options did not perform well, because of their overall cost to build. Instead call options really performed well and decreased consistently fuel prices for airlines. The simulations suggest an adjusted averaged[54] decrease of 8.75% in fuel expenses when using this strategy. The chart below shows the adjusted average[54] of this hedging strategy through time:

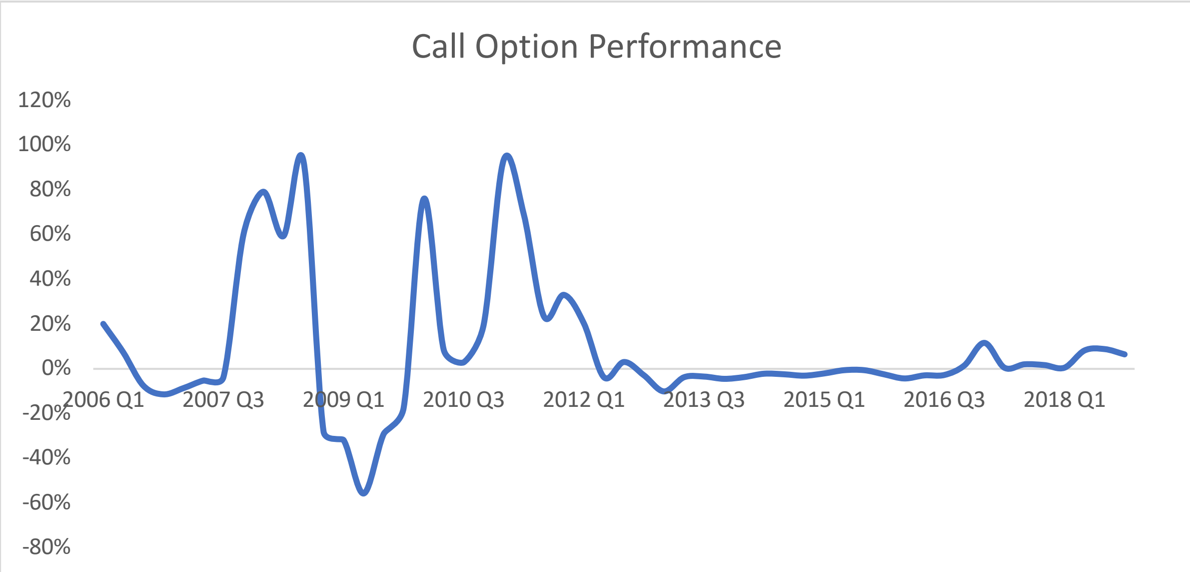


Figure 12: Adjusted Average of Call Option Hedging Performance for all Airlines Through Time. Percentages indicate the percentage decrease (+) or increase (-) of fuel expenditure for the quarter. The case in this graph is strike = spot. In this case airlines are all assumed to hedge 33% of future oil expenditures.

Other strategies analyzed in the research were straddles, strangles and collars. Yet, only call options provided a positive impact on the airlines' EBITDA (and thus valuation). Therefore, it is fair to conclude that the research found call options to be the best hedging strategy of the ones provided.

[54] Removing the best and worst performing airlines with this strategy

Normalizing Cash Flows

Given the aim of finding a hedging strategy that smooths out EBITDA (and therefore cash flows, keeping everything else constant), the research discussed the validity of each strategy by obtaining the standard deviation of EBITDA when each strategy was fully embraced. This means that the research assumed that airlines were going to hedge 100% of their expected fuel consumption. Given this assumption, the results were severely mixed: With an adjusted average[55], the simulations suggest that airlines would have between 16% and 22% less volatility in cash flows with call options, while other results increased volatility. The results, though, were extremely variable from airline to airline.

In conclusion

In conclusion, the research found a strategy comprising only call options to be the best in minimizing fuel expenditures through time and normalizing cashflows (even if the latter is an extremely variable result). Moreover, although call options do not pay-off when oil prices decline, they are still relatively inexpensive to hold and will, thus, provide an extremely flexible hedging solution for airlines to hold.

[55] Removing the highest and lowest results

Appendices

Appendix 1: Python Libraries used and Functions

- Matplotlib: MATLAB-like plotting utility.
- NumPy: MATLAB-like utility for complex mathematical operations and matrix algebra; used for Black and Scholes option price calculation.
- Pandas: Data tool for easy data retrieval and organization. Allows for time reorganization (e.g. quarterly resampling); before being stored into scorecards, all airline documents were hosted in huge data frames (read matrices) for easy data retrieval and classification
- Fitz: PDF to text parser, allows to have a full PDF document parsed to text only files, used to fetch data from annual reports and extract the needed financials.
- SciPy: Library used for advanced statistical calculations; used for Black and Scholes option price calculation.

Appendix 2: Company Scorecards

Because of the length of the series in the research, the scorecards presented in this appendix will only be examples for the quarters of 2018 for all companies.

American Airlines	2018 Q1	2018 Q2	2018 Q3	2018 Q4
Sales	8462.9	9776.9	9937.8	9585.8
EBITDA	938.2	1448.5	1216.5	1079.7
Depreciation adn Amortization	428.8	457.6	472.0	401.4
Fuel & Oil Expense	1758.3	2156.4	2355.7	2127.0
Spot	1.5	1.8	1.8	1.7
Risk-Free	1.6%	1.8%	2.0%	2.3%

Delta	2018 Q1	2018 Q2	2018 Q3	2018 Q4
Sales	8107.4	9886.0	10277.4	9413.1
EBITDA	1174.9	1983.4	1905.2	1453.9
Depreciation adn Amortization	496.3	495.4	498.7	499.5
Fuel & Oil Expense	1510.2	1965.8	2147.6	2039.3
Spot	1.5	1.8	1.8	1.7
Risk-Free	1.6%	1.8%	2.0%	2.3%

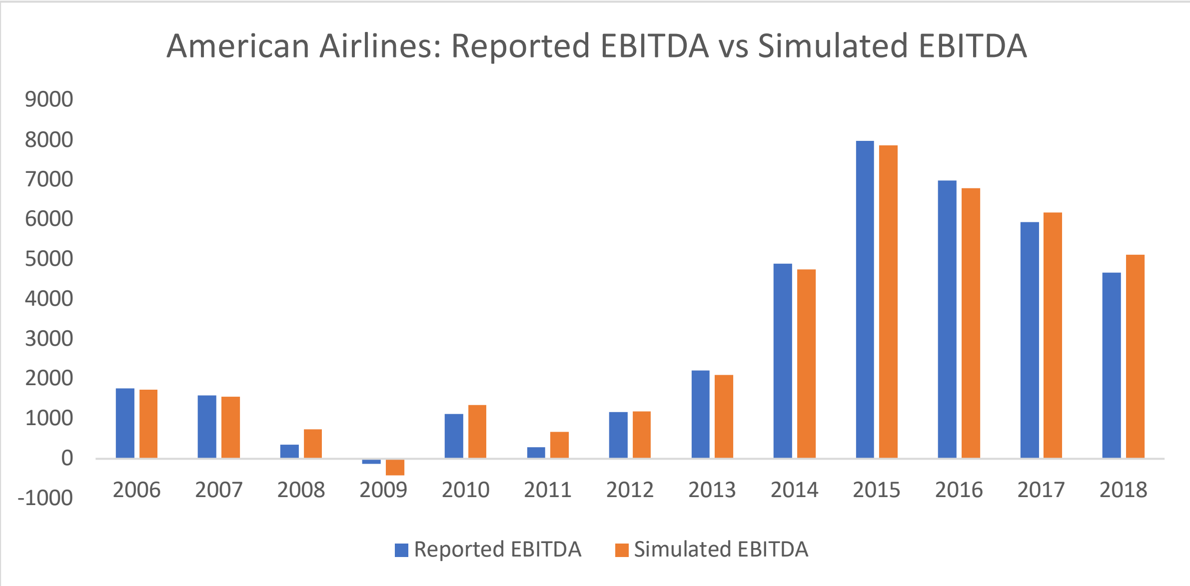
Ryanair	2018 Q1	2018 Q2	2018 Q3	2018 Q4
Sales	1320.8	2078.9	2759.1	1581.4
EBITDA	205.7	527.7	1191.1	202.2
Depreciation adn Amortization	140.8	157.2	162.0	159.3
Fuel & Oil Expense	332.8	398.9	441.1	472.4
Spot	1.5	1.8	1.8	1.7
Risk-Free	1.6%	1.8%	2.0%	2.3%

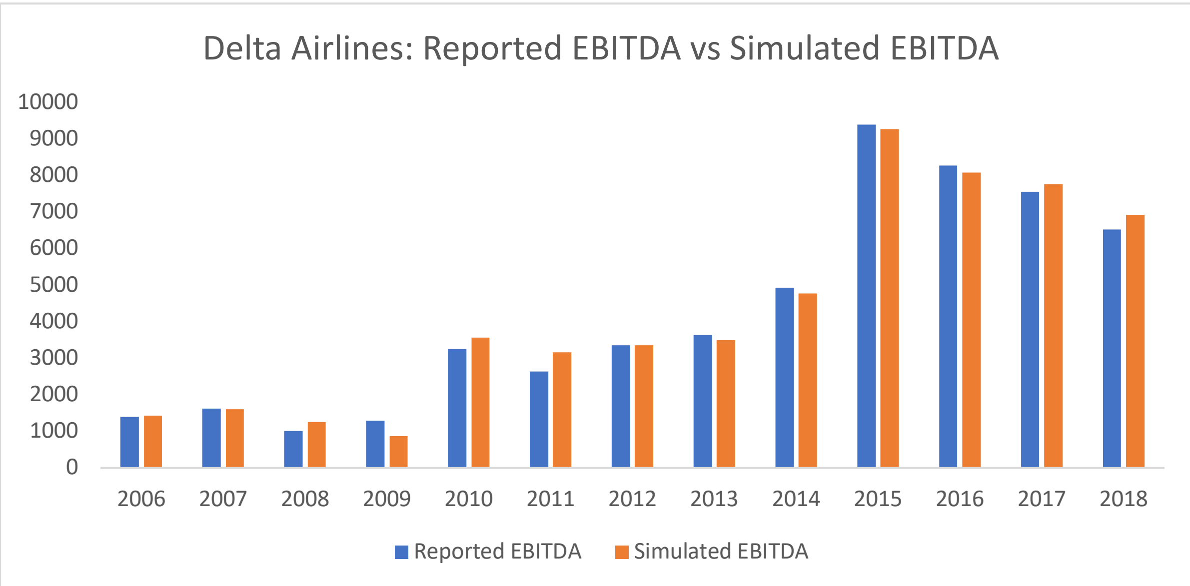
Skywest	2018 Q1	2018 Q2	2018 Q3	2018 Q4
Sales	637.4	676.4	713.0	704.2
EBITDA	134.9	175.8	192.6	183.8
Depreciation adn Amortization	63.1	69.5	74.0	77.3
Fuel & Oil Expense	21.9	25.2	26.0	26.7
Spot	1.5	1.8	1.8	1.7
Risk-Free	1.6%	1.8%	2.0%	2.3%

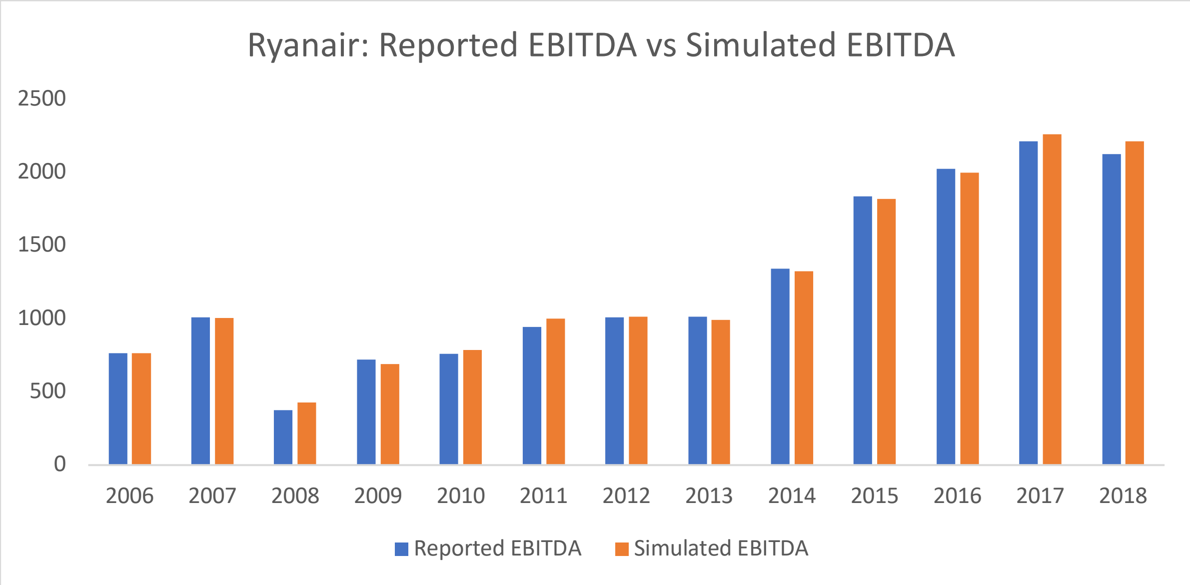
Southwest	2018 Q1	2018 Q2	2018 Q3	2018 Q4
Sales	4022.8	4821.7	4793.1	4998.8
EBITDA	697.3	1048.0	927.7	1007.8
Depreciation adn Amortization	225.4	245.2	258.8	290.1
Fuel & Oil Expense	828.3	1009.3	1036.0	1044.6
Spot	1.5	1.8	1.8	1.7
Risk-Free	1.56%	1.84%	2.04%	2.32%

United Airlines	2018 Q1	2018 Q2	2018 Q3	2018 Q4
Sales	7349.0	9049.7	9459.8	9194.0
EBITDA	685.9	1541.7	1526.1	1335.6
Depreciation adn Amortization	440.2	467.7	484.9	506.5
Fuel & Oil Expense	1598.9	2006.9	2211.3	2085.8
Spot	1.5	1.8	1.8	1.7
Risk-Free	1.6%	1.8%	2.0%	2.3%

Appendix 3: Company Performance, simulated and reported






Ryanair: Reported EBITDA vs Simulated EBITDA
2500
2000
1500
1000
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2007
2008
2009
2010
2011
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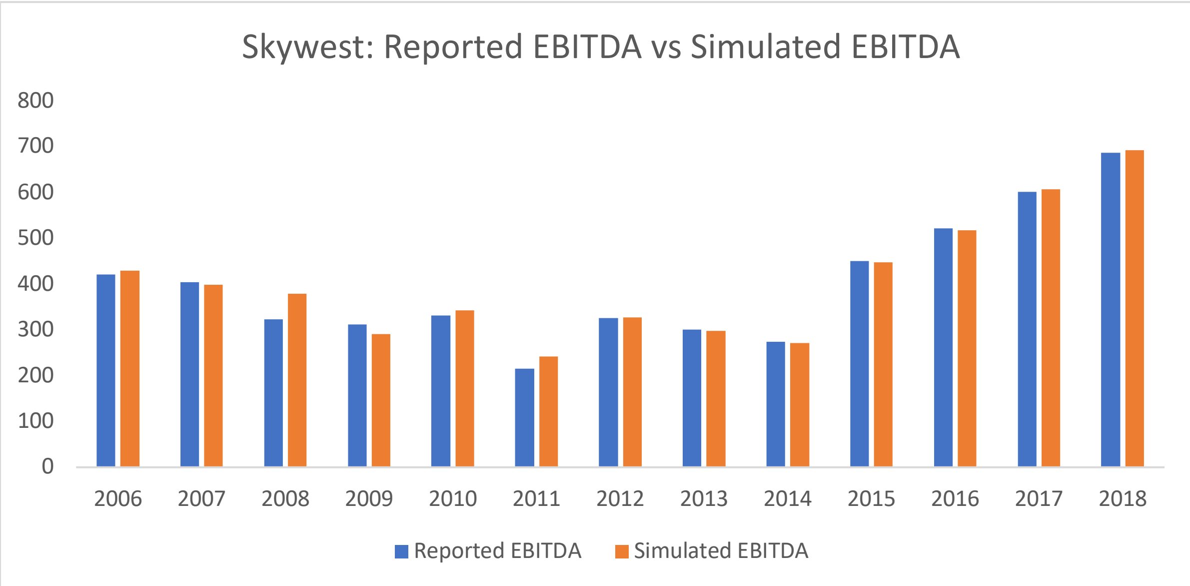
2013
2014
2015
2016
2017
2018
Reported EBITDA
Simulated EBITDA


Skywest: Reported EBITDA vs Simulated EBITDA
800
700
600
500
400
300
200
100
0
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2007
2008
2009
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2011
2012
2013
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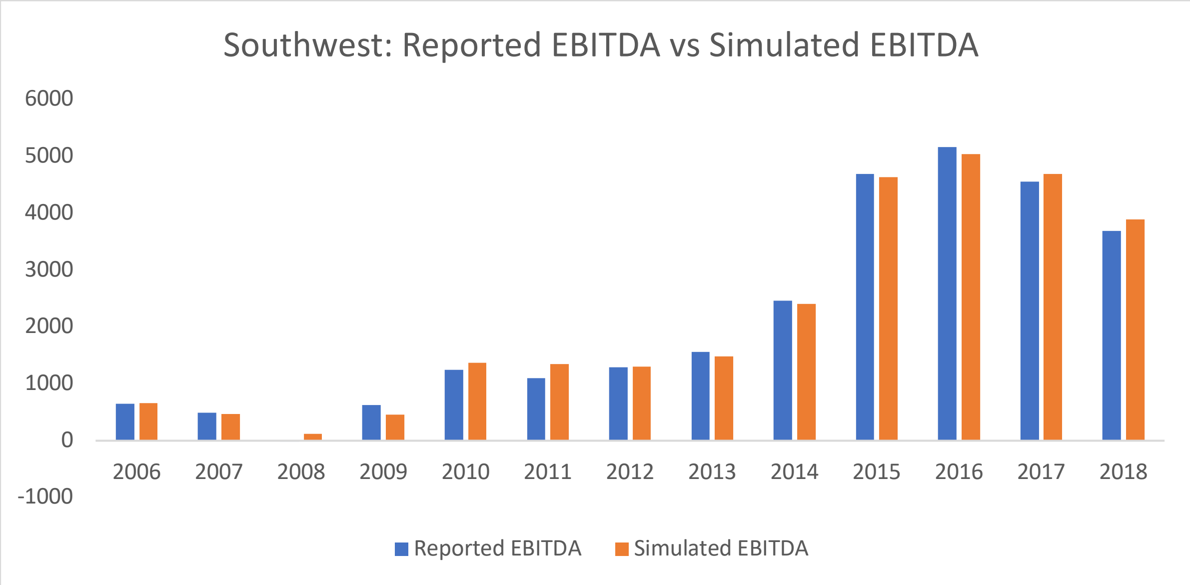
2015
2016
2017
2018
Reported EBITDA
Simulated EBITDA


Southwest: Reported EBITDA vs Simulated EBITDA
6000
5000
4000
3000
2000
1000
0
-1000
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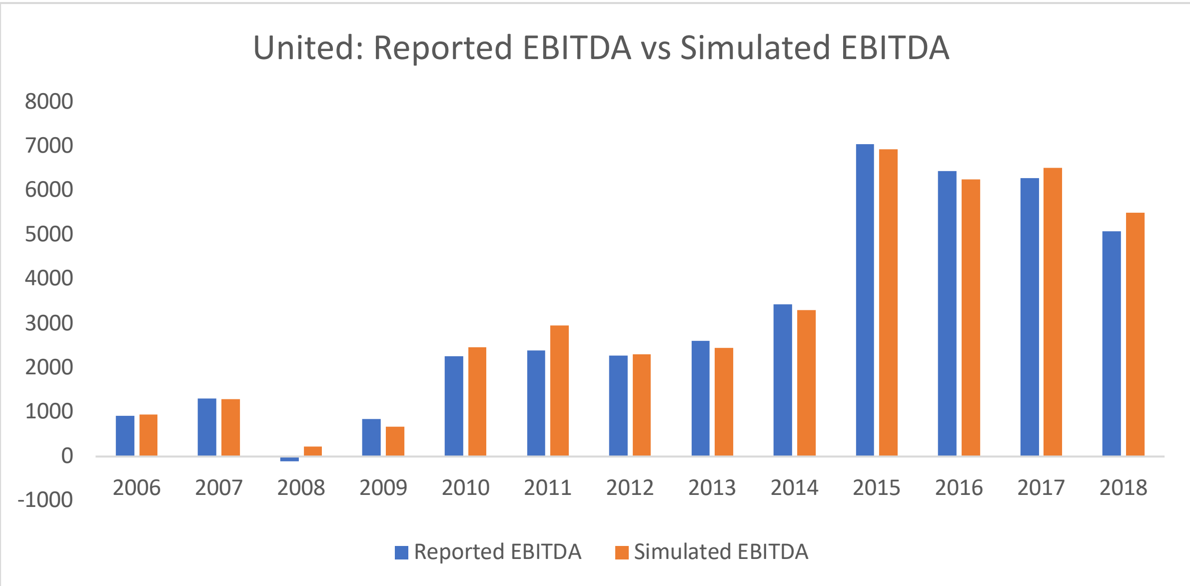
Simulated EBITDA


United: Reported EBITDA vs Simulated EBITDA
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
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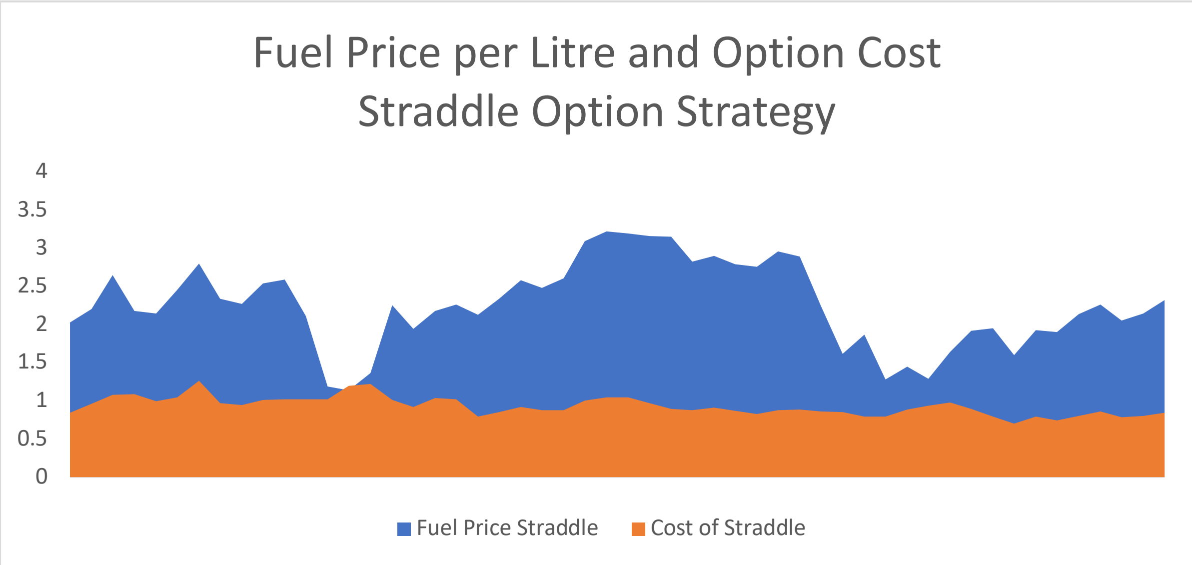
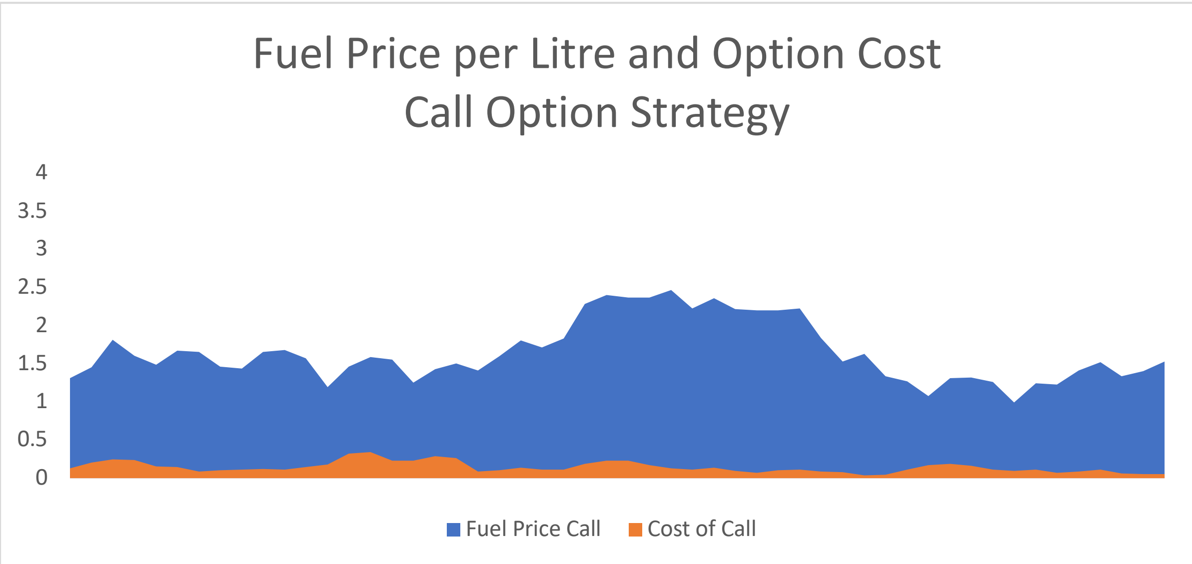
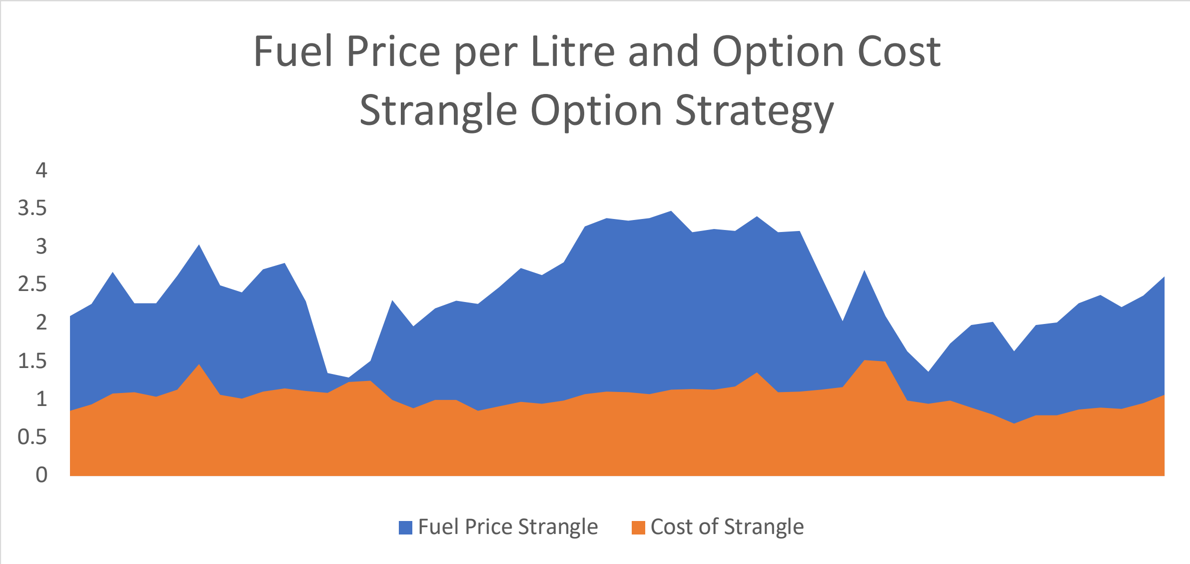
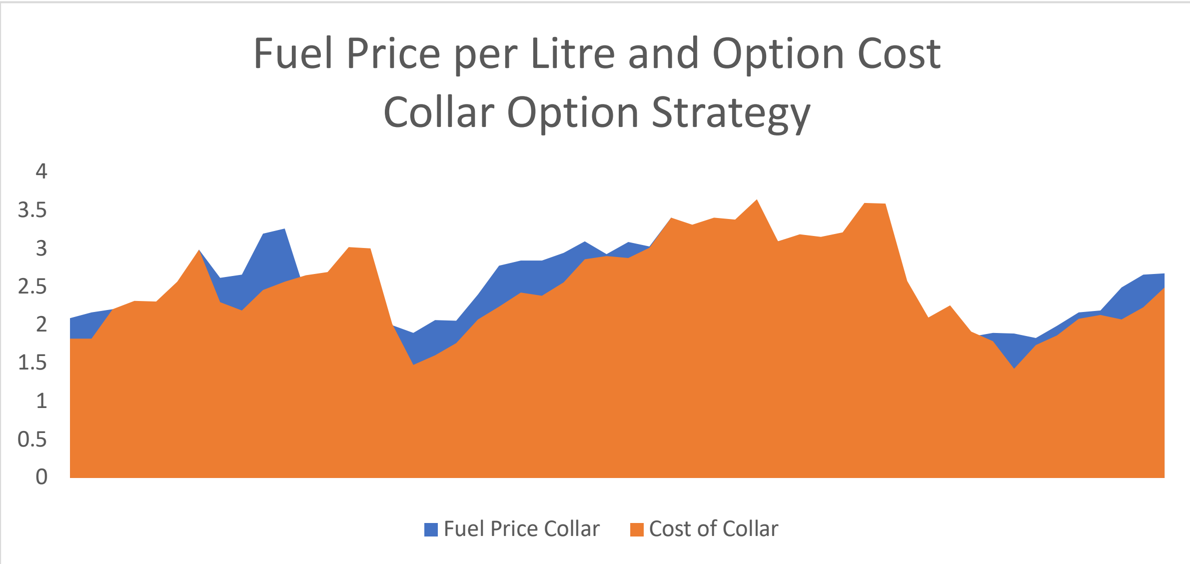
Reported EBITDA
Simulated EBITDA

Appendix 4: Cost of Options compared to total fuel cost






Fuel Price per Litre and Option Cost
Strangle Option Strategy
4
3.5
3
2.5
2
1.5
1
0.5
0
Fuel Price Strangle
Cost of Strangle


Fuel Price per Litre and Option Cost
Collar Option Strategy
4
3.5
3
2.5
2
1.5
1
0.5
0
Fuel Price Collar
Cost of Collar

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Thesis Summary

Introduction

Airline tickets seem to behave in mysterious ways: In a 2018 CNBC article, journalist Tom Chitty explains how airfare ticket pricing has changed from deregulation to today. He explains that nowadays airplane tickets are priced to be "as high as costumers can bear". Still ticket prices are extremely sensitive to changes in fuel prices: This research found that fuel prices account for more than 40% of total costs an airline has to bear. Researchers Moynihan and Al-Zarrad in 2015 found that between 95% and 105% of fuel prices increases are passed on to passengers, even if with some delay. Yet, there is the belief that often, only increases are passed on to travellers, while fuel prices decreases are not: For instance, the Guardian in 2015 named an article "Airlines -but not passengers- see benefits as crude oil prices drop". Between the reasons the article attaches to such a phenomenon, there is fuel price hedging: In fact, the explanation is that if airlines hedge against oil prices increases, they will have a loss when oil prices drop and therefore ticket prices will not decrease.

From this concept, one of the main aims of this thesis project: Finding whether there is a way for airlines to hedge both oil prices increases and decreases (and gain on both). This thesis will test whether different hedging strategies work: It will include hedging through call options to see if normal hedging provides results and it will also include hedging through straddle and strangle option strategies to test whether a strategy that pays off both when oil prices increase and when they decrease is actually feasible for an airline.

Another aim of this thesis work is to check which hedging strategy will be the most successful in increasing airline companies' EBITDAs and therefore their valuation (using comparable EV/EBITDA valuation). Furthermore, another target of this thesis is finding whether the proposed option strategies work in normalizing cash flows and which one worked best. The strategies that the research work will test will be call options at various strike prices, straddles at various strike prices, strangles and collars.

The research covers the period ranging from 2005 to 2018 using quarterly data. The first results, though, arrive in 2006 Q1: This is because the first option in this research can be contracted in 2005 Q1 with expiration 2006 Q1 (one year later), so the first effects of different hedging strategies appear in 2006 Q1. The choice to start in 2005 was settled with the aim to include periods of strong oil prices' increases (e.g. 2008), oil prices' decreases (e.g. 2015) and at least an economic crisis: This allows for a broader view of hedging strategies' performance in different scenarios.

The sample of airline companies in this thesis are American Airlines, Delta, Ryanair, SkyWest, Southwest and United Airlines. The list used to be larger, but plenty of airlines had to be discarded because of reporting inconsistencies of some financials across the considered period.

Of these considered airlines, according to the International Air Transport Association (2018), American ones do not currently hedge future fuel requirements; European airlines, instead, have heavier hedging position with Ryanair heading all airlines with 90% of future expected fuel requirements hedged. According to the same source, one notable exception is Southwest, which is an American airline and yet enters in fuel hedging contracts (64% of expected fuel consumption). Therefore, fuel price hedging is something that is somewhat polarizing, some airlines enter into fuel price hedging contracts and others do not, even in the same period. Moynihan and Al-Zarrad in 2015 even found the research to be divided on the benefits of hedging towards company valuation.

This project aims to see if there is a fuel price hedging strategy (preferably a strategy that hedges both fuel prices' increases and decreases) that allows all the of sample airlines to minimize fuel expenditure and (if possible) normalize cashflows. The thesis will start with an overview of the theory involved, then will discuss the methodologies applied in the research process and in the end will present the results of the research.

Some of the results were decisively clear showing that a strategy comprising call options is the best one to increase company valuation and decrease oil prices. Evidence on the effectiveness of hedging for cashflow normalization, instead, is overly mixed: In fact, on this topic the research could not find a clear cut answer.

Theory

Basic materials account for a large share of expenses in many industries[1], including the aviation industry: In fact, already in Dutch companies basic materials account up to 50% of total costs[1] and for energy this estimate arrives to 60%[1]; as a result companies are usually decidedly sensitive to changes in costs of basic materials and energy. This is exceptionally true for airlines that have aircraft fuel expense as 42% of their total costs[2].

Generally, the main drivers for the growth or decline of prices of basic materials and energy are entrenched in supply: If external factors hinder the supply of basic materials and energy, their prices are expected to rise[3]. Trade wars and environmental concerns are two of the main drivers for basic materials and energy raise in price[3].

Companies do frequently engage in hedging activities if they are highly basic-material dependent[4]. For many companies, especially in the construction field, this comes into the form of insurance provisions and indemnification. Yet, these measures fail to address unforeseen circumstances in the supply chain[4]. Another issue with the insurance provision approach is that it fails to take into account price volatility[4].

Hedging risk in basic materials is a tool that many companies use to have more predictable cashflows[5] and it even allows for higher company valuation[6], through higher income[7]. But, from a shareholders' perspective, hedging is not always a clear-cut solution: Hedging, in fact, can be undesirable for two distinct reasons. The first is that shareholders in the company might want to be exposed to the basic materials' risk of that company[5]. The second reason is that hedging can be extremely expensive, and shareholders might achieve better results by having their entire portfolios hedged against a certain risk, instead of having individual companies hedging their own basic materials' risk[5]. Researchers Moynihan and Al-Zarrad (2015) explain that hedging in companies, occurs using futures, options and insurance. This thesis will focus only on the second strategy.

[1] Wilting & Hanemaaijer 2014
[2] Internal Research, further detailed in "The airline industry"
[3] Inverto (BCG Company) Research 2018
[4] Moynihan and Al-Zarrad 2015
[5] Damodaran 2014
[6] IATA 2018
[7] Internal research, "Results" chapter of this Thesis

The airline industry is characterized by high seasonality[8] and great dependence in earnings from the underlying price of fuel consumed[9]. This was especially true for the companies analysed in this research: In fact, in the sample, fuel related expenses accounted for about 42% of total costs. This means that an increase in fuel prices will inevitably lower airline companies' earnings. Increases in fuel expenses are often passed-through to costumers with varying rates: PWC (2005), in an extensive study in air travel prices in the UK found that air carriers, including low cost, passed on between 90% to 105% of increases of kerosene prices. Though, this happened with some delay[10]. The fact that airplane tickets are usually booked in advance and fuel is consumed at take-off of the flight, makes it harder for airline companies to pass on fuel prices increases when kerosene peaks quickly[10].

To understand the scale of the problem of fuel price volatility, it is enough to think that a $1\$$ increase in spot fuel price, might cost airlines an additional $425m$ $[14]. Yet, studies about companies' hedging performance have had mixed results: some research finds it to be beneficial for company valuation and other researchers finds hedging to negative for airline companies[14].

Spanning through world regions and economic environments, nowadays fuel price hedging seems to be largely adopted by European carries, generally ignored by carriers based in the United States and even outlawed in China[11].

Options are only one type of hedging methods embraced by airlines; yet, this thesis will only focus on them. Options are bilateral contracts that give one party the right and not the obligation to buy or sell an underlying asset when certain desired conditions are met in a specified amount of time[12]. Options are therefore financial assets that have their value determined from another asset, called underlying asset[13]. Options can be classified by the way they manage execution timing, on this ground there are two type of options: American and

[8] Sturm 2009
[9] Found in the sample of considered companies
[10] Moynihan Al-Zarrad 2015
[11] IATA 2018
[12] Black and Scholes 1973
[13] Damodaran 2016

European. The former can be exercised anytime until its expiration date; while the latter can only be exercised at its expiration date[25].

Options can also be classified by the payoffs they allow the contracting parties to collect either before (American) or at (European) expiration date. On this ground, two types of options exist: "Call Options" and "Put Options". The former gives the investor the opportunity to buy the underlying asset in the future at a fixed price; while the latter gives the investor the opportunity to sell the underlying asset at fixed price. The "fixed price" mentioned in the definition above is called "strike price"[26].

From these two basic options, a trader can build plenty of different strategies, this thesis will just cover simple calls, straddles, strangles and collars.

As historical series of option prices do not exist, prices for options in the past had to be derived. One strategy to do this was the Black and Scholes model: This thesis used it for its relative simplicity and because it requires less variables than other models. The "Black and Scholes" model for option pricing assumes that the underlying asset price follows a geometric Brownian motion. The first step Black and Scholes took towards option pricing was to bring about the concept of "Continuous Time Finance", in which a trader could trade securities in continuous time[14]. From this point, they developed a riskless position in continuous time and, to avoid arbitrage opportunities, this position had to be equal to the risk-free rate[29]. From here the famous Black and Scholes partial differential equation[29]:

$$\frac{df}{dt} + rS\left(\frac{df}{dS}\right) + \frac{1}{2}\sigma^2 S^2 \left(\frac{d^2 f}{dS^2}\right) = rf$$

This equation admits an analytical solution: Indeed, the famous Black and Scholes Formula[29]:

$$C = X * N(d1) - S * e^{-r*(T-t)} * N(d2)$$

Methodologies

All data-gathering algorithms and simulations have been coded in Python and ran on PyCharm. PyCharm[15] is the open-source software ("viewer") used to run, view and debug Python code, the viewer's user interface and additional functionalities simplified the entire

[14] Shah 1997
[15] https://www.jetbrains.com/pycharm/

process of coding and removal of bugs in the code. Python in this project was running in its 3.7 version with the addition of components for increased functionality modules, called “libraries”.

In addition to the six airline companies that are the subject of the final version of this research, eight more were researched; though, not all companies appeared in the final work, mainly because of reporting inconsistency across time and undisclosed data on certain reports. A proprietary algorithm retrieved data from these quarterly reports and when the algorithm failed in the task, FactSet and manual analysis of quarterly reports supplied the missing data. FactSet converted the obtained numbers to Euro with EUR/USD exchange rate series[16]. Scorecards on Microsoft Excel hosted those companies, that kept consistent results across time.

The basic items gathered from annual reports and financial databases were: Revenues, EBITDA, depreciation and fuel & oil expenses. In addition to these, spot fuel price[17] and risk-free rates[18] were added for each scorecard; these two items were the same for each company, in order to maintain consistency in the results.

Spot prices for Kerosene were gathered from FactSet[19]. This series is from the US and might not exactly represent what European companies pay for jet fuel; yet, very few suitable jet fuel data series are publicly available and all of the found ones were for U.S. Fuel Kerosene Spot. Regarding the risk-free rate, the research project used three-month US treasury bills supplied by the Federal Reserve Bank of St. Louis[20]. The rate provided was from the secondary market[21] and the data was not seasonally adjusted.

The aim of the research is finding EBITDA of considered airlines with different option portfolios. To calculate option prices, payoffs and new fuel prices, company scorecards required further elements that were derived using different operations in the financial statements. The first figure that the research derived was “Fuel consumed in litres”: Airlines

[16] On FactSet USDEUR
[17] FactSet Code: JTKGC-FDS
[18] FRED
[19] FactSet Code: JTKGC-FDS
[20] https://fred.stlouisfed.org
[21] Code TB3MS

often report this figure, but fail to do so consistently. So, deriving it from the data was crucial. The method followed in this research project was simply to divide reported oil costs by the spot cost per litre of fuel. This estimate of fuel litres consumed is not a perfectly accurate one, because it ignores hedging costs and other fuel-related costs in reported oil costs. This was not a problem for the thesis though. Regarding other fuel-related costs it is actually beneficiary to the research work: In fact, by ignoring them, they will always be factored in. Past hedging performance will be uninfluential in the scope of this thesis, as new strategies will start from a position that has hedging (when airlines do it) already employed and the only issue to investigate is whether the situation improves with new simulated hedging strategies. Unfortunately, due to lack of data, it is impossible to calculate unhedged figures for fuel litres consumed, as this would require to at least know what option strategies airlines use and this is very rarely reported.

The research project uses the following assumptions to run option and financial simulations: (1) Airline companies' management team has perfect vision on future oil consumption, (2) all the assumptions for the Black and Scholes model, (3) all options used are European with expiration one year after their acquisition, (4) airlines can purchase fuel at the spot price, (5) airlines only hedge 33% of projected fuel litres consumed.

Regarding options' simulation, this thesis follows a "one-size fits all" approach: This means that strategies and strike prices' deviation from spot prices never change during periods. This was on purpose, to check if a strategy would have performed well in many different economic environments. Regarding standard deviation of spot prices the algorithm used in this research proceeded in its calculation by calculating standard deviations from the four quarterly observation before the viewpoint.

From all above mentioned data, a function could create option prices using the Black and Scholes method. Inputs are spot price, strike price, time before the option expires (in years), risk-free rate and the type of option required ("Call" or "Put"). From this simple function, it is easy to build different option strategies and all strategies in this research were built using this building block.

Once simple “Call” and “Put” options were computed, the research algorithm switched to calculating option strategies. The aim of the research at this point was to find the which option strategy would have yielded the best results when applied. To do this the research proceeded in four steps: (1) It calculated the payoff of a given option strategy, (2) it subtracted this payoff from spot fuel prices, (3) calculated new fuel expenditure by multiplying the new fuel price by fuel litres consumed and (4) calculated a new EBITDA with the new fuel expenditure.

The new oil expenditure is a weighted sum between the newfound fuel spot price times fuel litres consumed and the old fuel expenditure. The research project assigned a weight of 33% of the future expected litres of fuel demand to hedging.

From new oil expenditure, it is possible to calculate a new simulated EBITDA. This is done by simply taking revenues and subtracting the old “Costs” (COGS and OPEX excluding oil expenditures) and the newfound oil expenditures.

Finally, to easily find which option strategy suited best each company a twofold scoring system was devised. In the first scoring system the reported EBITDA of the company was subtracted from the EBITDA resulting from each option strategy; the second scoring system has the difference between reported EBITDA and simulated EBITDA as a percentage of reported EBITDA for better interpretation of results.

The scoring to assess the effectiveness of option strategies in normalizing cashflows follows these steps: The goal of option strategies in this scenario is to reduce volatility of EBITDAs, so the main tool will be the standard deviation of reported and simulated EBITDAs. Yet, to detrend EBITDA time series and remove the natural growth driver, the research focused on applying the standard deviation on the differences in percentage between EBITDAs. Standard deviation was then calculated on the time series resulting from the formula above; yet, these values were expectedly extremely high and as a result, for better representation, the final results were viewed as an increase or decrease in percentage from the reported standard deviation.

Results and Implications

Results have been fairly consistent through all companies: In fact, the research work found that most option strategies do not provide better fuel hedging than what companies are already doing. Most strategies proved to be underperforming in almost all times considered; only few periods had the considered option strategies performing better than the airlines' results. The only strategy that proved to be effective in this research is the use of only call options.

The most performing strategy was in fact a call option only strategy with $Strike\ Price_{t-1} = Spot_{t-1}$: This strategy did provide better fuel prices and as a consequence better EBITDAs overall. Still, results were very volatile and scores had either extremely high or extremely low values in some cases. The strategy was especially performing during the 2008 crisis and in the 2010 price rise. Between 2015 and 2018 the strategy managed not to generate severe losses, even if oil prices were declining. Other strategies instead performed poorly. One of the main reasons is the elevated costs of the options to buy such strategies.

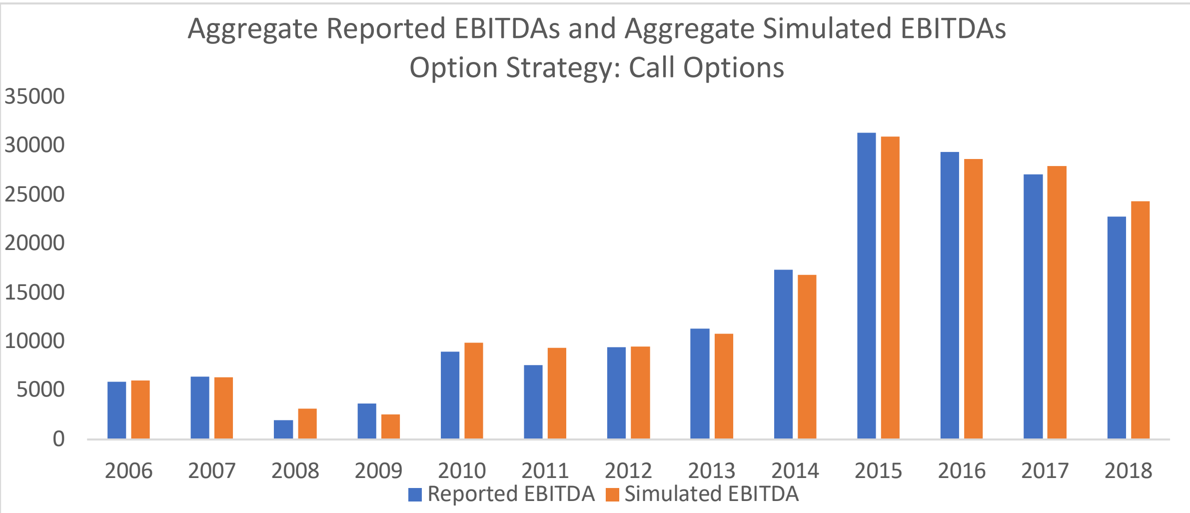

Figure 1: Aggregate Reported EBITDAs against Aggregate Simulated EBITDAs, Call Option (Strike Price = Spot)

The next question to be answered is which strategy performed the best in the field of cashflow normalization. The table below condenses the scores for each strategy, with the addition of an "Average" column that represents how a certain strategy fared on average across all companies. Furthermore, an additional column – "Adjusted Average" – was added: The aim of this column is to remove the outliers that severely affect results. The adjusted average is calculated removing the best and worst performing scores.

	American	Delta	Ryanair	Skywest	Southwest	United	Average	Adj. Average
Call Option Strike = Spot + 5%	-49%	534%	-12%	-2%	-2%	-83%	87%	-16%
Call Option Strike = Spot	-63%	728%	-14%	-2%	-2%	-81%	126%	-20%
Call Option Strike = Spot + 5%	-68%	259%	-16%	-1%	-1%	-78%	33%	-22%
Straddle Strike = Spot + 5%	296%	326%	100%	-2%	150%	-21%	111%	136%
Straddle Strike = Spot	138%	2263%	106%	1%	34%	-16%	477%	70%
Straddle Strike = Spot - 5%	28%	604%	131%	8%	21%	36%	160%	47%
Strangle	160%	676%	148%	7%	15%	7%	191%	108%
Collar	-15%	307%	111%	11%	363%	-42%	150%	117%

In the table above the results are very mixed and vary greatly from company to company. Yet, from the achieved results it seems that call option with $Strike\ Price_{t-1} = Spot_{t-1} - 5\%$ are the best at reducing volatility of EBITDA; moreover, call options with $Strike\ Price_{t-1} = Spot_{t-1}$, which are also the best at optimizing fuel prices, are also a valid alternative in decreasing volatility of EBITDA.

Conclusion

This thesis, in its introduction and during the whole discussion, proposed to find an answer to some questions. These were whether airlines could use option strategies to hedge against fuel prices' increases without losing with fuel prices' declines; which strategies were the best ones to increase EBITDA (and therefore airline valuation in an EV/EBITDA multiple framework) and whether the proposed strategies worked in normalizing cash flows.

The most obvious strategies to achieve hedging whatever the direction of fuel prices were straddle and strangle option strategies. The research process took in consideration these strategies and tested them: The results were extremely underwhelming. One of the main problems associated with these strategies is their steep price. Simulations suggest both strategies not to be viable for the analysed airlines in the given period.

Using call options instead proved to be practical for airlines: These options are relatively inexpensive to buy and therefore their premium is low. This is a better alternative than futures exactly for the possibility not to exercise the option and buy fuel at a lower price if possible. In fact, simulations suggest that if airlines were to hedge 33% of their expected fuel requirements through call options, they would pay fuel averagely[22] 8.75% less for fuel[23] per quarter during the analysed period.

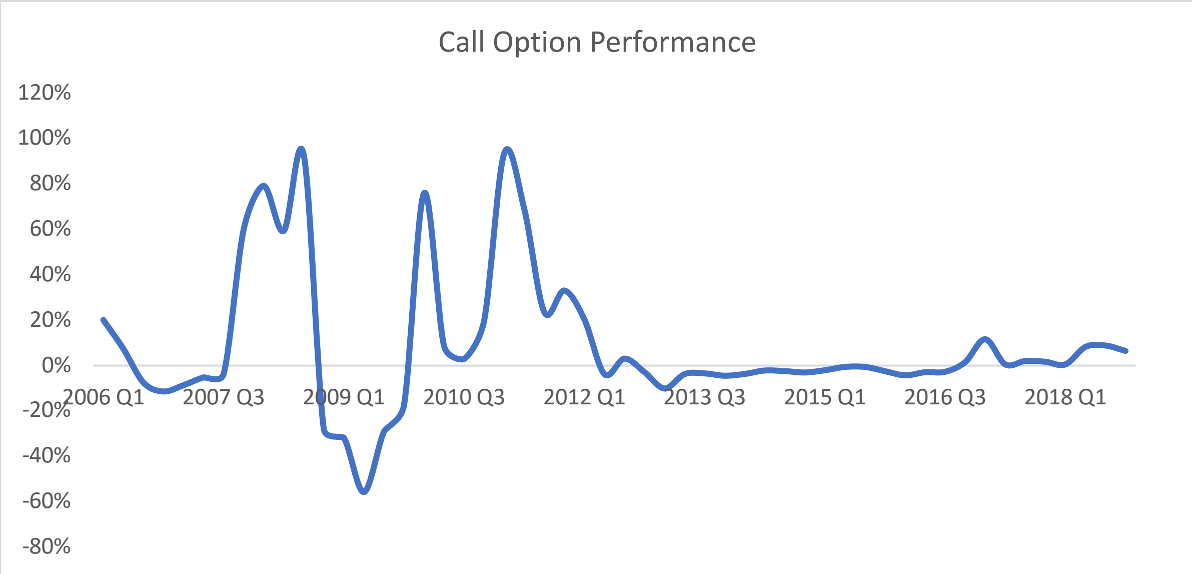

Figure 1: Adjusted Average of Call Option Hedging Performance for all Airlines Through Time. Percentages indicate the percentage decrease (+) or increase (-) of fuel expenditure for the quarter. The case in this graph is strike = spot. In this case airlines are all assumed to hedge 33% of future oil expenditures.

Given the aim of finding a hedging strategy that smooths out EBITDA (and therefore cash flows, keeping everything else constant), the research discussed the validity of each strategy by obtaining the standard deviation of EBITDA when each strategy was fully embraced. This means that the research assumed that airlines were going to hedge 100% of their expected fuel consumption. Given this assumption, the results were severely mixed: With an adjusted average[24], the simulations suggest that airlines would have between 16% and 22% less volatility in cash flows with call options, while other results increased volatility. The results, though, were extremely variable from airline to airline.

[22] Adjusted average, best and worst performances discarded
[23] In the case Strike = Spot
[24] Removing the highest and lowest results

In conclusion, the research found a strategy comprising only call options to be the best in minimizing fuel expenditures through time and normalizing cashflows (even if the latter is an extremely variable result). Moreover, although call options do not pay-off when oil prices decline, they are still relatively inexpensive to hold and will, thus, provide an extremely flexible hedging solution for airlines to hold.