Fuel Hedging in the Airline Industry
Relations between Risk Exposure, Firm Characteristics and Hedging Practices

Master’s Thesis in
Advanced Economics and Finance
&
Finance and Investments

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May 15, 2018

Number of Pages: 106
Number of Characters: 212,710
Executive Summary

The importance of risk management can no longer be questioned, and even though it has a long history, it is increasing in magnitude each and every day. Whether in organizations or business entities make no difference regarding the beneficial effects of risk management.

The airline industry has proven to be a brilliant choice to examine risk management. More specifically, hedging is in the center. Hedging, in our dissertation, is performed by using different derivatives on different fuel types to lower volatilities of cash flows. Furthermore, there is no evidence of airlines using derivatives for speculative purposes.
Specifically, we do not find any industry-wide standard that connects the type of airline and its respective use of derivatives and/or jet fuels, but combinations of (call) options on crude oil as well as collars and swaps on jet fuel are preferable by the airlines in our sample.
The former, options on crude oil, is an example of cross-commodity hedging and though crude oil is commonly used, we find heating oil to be a better cross-commodity compared to jet fuel.

Throughout the dissertation, two opposing theories help shape the direction and pose an incessantly, critical approach to the preparation. To put it unjustly simple, whether more constrained firms hedge more or less is the essence. The first theory states, if external financing, which is more common for more constrained firms, is costlier than internally generated funds, there is an incentive to hedge. The second theory states, financially constrained firms do not hedge because the return of investing is higher than that of hedging.
Their contradictory conclusions originate from whether the cost of external financing and collateral constraints are included.

By using fixed entity effects as our primary model, we find a negative relationship between net worth and hedge ratios as well as a positive relationship between net financing cost of debt and hedge ratios. Both supports the first of our theories. By using our results, a more detailed discussion of the two opposing theories’ practical application can be executed, especially when the second theory already has been tested empirically previously.

The above constitutes our thesis, and had it not been for space limitations, we would also have looked into credit ratings and currencies. Furthermore, since earlier, empirical findings have found an opposite result than that of ours, it would be of great interest to have more overlapping years; to more critically assess the potential differences.
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1 - Introduction

1.1 - Overview

As firms increase in complexity with respect to scope of operations and the setting in which they operate, uncertainty and thereby risk naturally increases as well. Firms engage in risk management to mitigate these risks, an activity that can take many forms. Some activities lower the probability of unfavorable events, while others simply reduce the impact of these events on the business. With different types of risks, different instruments for mitigating risk and different strategic goals of companies, financial risk management is an extensive field of research.

While risk management is an increasingly important activity, the practice can hardly be considered standardized, hence the extensiveness of the field of research. In the search of better understanding risk management, several questions come to light. One might wonder whether any hedging strategies are used more often than others, or whether certain firms engage more in risk management than others. These questions along with others are what is sought answered in this dissertation.

To expand on the existing knowledge of risk management and following in the footsteps of other studies, the airline industry is chosen as the case industry. When operating in different countries and with different currencies, risk management is increasingly important, and thus suitable for this dissertation. Besides the common risk factors, all airlines are exposed to a risk inherent in their operation: jet fuel price risk. Being a major cost of airlines, and unique to this industry, jet fuel price risk is chosen as the primary focus of this dissertation.

1.2 - Motivation

Financial risk management and derivatives are closely linked, since the latter is comprised of instruments to do the former. Thus, due to our interest in risk management, the primary focus was initially the derivatives per se. However, after having read a vast variety of literature within the field of risk management, a relationship between the airlines’ characteristics and their respective hedge ratios were discovered.

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1 Dissertation and thesis are used interchangeably throughout.
Hedging is loosely defined as activities that lower volatility, and the hedge ratio is next year’s expected fuel consumption hedged. Regarding the above relationship, especially Rampini, Sufi and Viswanathan’s 2014 publication is of interest. Testing the relation between airlines’ net worth and their respective hedge ratios empirically gives a contradictory result when compared to the earlier, theoretical publications of Froot, Scharfstein & Stein from 1993 studying the somewhat same relationship. The scope has subsequently been to try to position our empirical findings in this dissertation somewhere between the two.

As indicated above, hedging and risk management, in this thesis, are two sides of the same coin, and how airlines’ characteristics are related to hedging decisions as well as the importance of fuel types and derivatives lead to the scope of this dissertation:

1.3 - Statement and sub-questions

- Why and how do airline companies hedge jet fuel, and what is the relationship between airlines’ characteristics and the degree of risk management?
  - What is the theoretical reasoning behind hedging?
  - What is the nature of jet fuel price risk, and what strategies do airlines use to hedge this risk?
  - What is the theoretical relationship between firm characteristics and risk management, within and among airlines, and how do our empirical findings differ from or coincide with the theory?
  - Why do our empirical findings differ from or coincide with the theory?

1.4 - Delimitation

Risk management and more specifically hedging is in itself a vast and complex field of study, with many possible areas to explore, necessitating the need of narrowing the scope of the thesis. First off, the thesis focuses solely on financial risk management. To control for differences within industries, a single industry is chosen; the airline industry. The fact that the entire industry is exposed to the same exact risk, jet fuel prices, makes the industry the perfect case for analyzing risk management practices.
Though exchange and interest rate risk are major financial risks for many firms, as well as in the airline industry, the thesis focuses solely on jet fuel price risk.

All analyses are purely quantitative. Analyses will be carried out with regards to jet fuel prices, hedging strategies and cross-hedging, as well as an analysis of firm characteristics and hedge ratios. Hedge ratios are here defined as the hedged share of next year’s expected fuel consumption. For the jet fuel price and cross-hedge analysis, data consists of daily prices of five commodities from 2007-2017. The five commodities are jet fuel, and four commodities used in cross-hedging; WTI crude oil, Brent crude oil, heating oil and gasoil.

For the hedging strategies and hedge ratio analysis, data comprises 142 firm-year observations across 18 airlines from 2009-2017. The 18 airlines are chosen to represent a diversified set of companies, spanning four continents and differing in size, age as well as other characteristics. All airlines are public, so as to make data collection possible through annual reports.

Serving as the theoretical foundation of the thesis, prominent theories like Froot, Scharfstein & Stein (1993), Rampini & Viswanathan (2010) and Rampini, Sufi & Viswanathan (2014) are used, along with more generic financial theory.

1.5 - Structure

The structure of the thesis is as follows. Section 2 contains a literature review, expounding relevant empirical studies within the field of risk management; more specifically within the airline industry. In section 3, the airline industry as well as the jet fuel and oil markets are introduced. Section 4 introduces theories on how hedging adds value, derivatives, and what relationships between firm characteristics and hedging are to be expected. Section 5 presents the data, along with how it was collected. The section also introduces the methodology used in the following analyses. Section 6 is an analysis of jet fuel prices and jet fuel price returns, seeking to determine the distribution of returns and volatility, along with implications for firms. Section 7 presents and explains the derivative hedging strategies used by the airlines in the sample. Section 8 delves into the cross-hedging strategy, seeking to identify the optimal cross-hedging commodity, and whether dynamic or static strategies are best. Section 9 analyzes statistical relationships between different firm characteristics, and the amount of jet fuel hedged, with hypothesized relationships based on the theories presented in section 4. Section 10 holds discussions of the empirical findings in section 9, in relation to the theories of section 4. Section 11 concludes.
2 - Literature Review

Several authors have written articles and dissertations within the subject of risk management, and more specifically hedging, in commodities markets. The scope, however, is typically different from that of this dissertation in that others look at whether jet fuel hedging creates value, as well as cross-hedging and correlations in energy markets more generally.

One of the most applicable to this dissertation, though, is the empirical findings in an article called “Dynamic risk management” (Rampini, Sufi, & Viswanathan, 2014). The authors (Rampini et al., 2014) study the relationship between financing, constraints and risk management, and they use the US airline industry as their empirical laboratory. Three reasons for choosing the airline industry apply; first, jet fuel costs account for a varying but considerable part of the airlines’ (variable) costs. Secondly, the information is readily available in the airlines’ annual reports. Thirdly, by focusing on only one industry, other characteristics can be kept constant.

23 US airlines spanning from 1996 to 2009 were chosen. In the first screens, airlines that are not commercial and airlines that are too small have been excluded. Further, airlines that do not disclose fuel hedge data for the greater part of the investigated period are removed. After the initial screenings, whether the airlines have a fuel pass through agreement or not is emphasized. A fuel pass through agreement is typically a part of an overall agreement in which a major carrier is responsible for the scheduling, pricing and marketing of the route and, more relevant here, provides the jet fuel. The regional airline then provides jet service on a code sharing basis.

The authors (Rampini et al., 2014) define airlines with fuel pass through agreements as being 100% hedged and they thus, effectively, have 16 airlines left in their sample. Concrete evidence from the airline companies’ annual reports is further included to make the relationship between collateral and fuel hedging decisions clear. The airlines specifically mention different derivatives with regards to collateral requirements and adequate liquidity. Airlines normally post cash as collateral, but some also choose to post aircrafts when the collateral needs become too large. Especially, the latter years in their sample (Rampini et al., 2014) are notable, caused by the massive fall in jet fuel prices in the aftermath of the financial crisis in 2008.

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2 An example could be a wet lease which is basically where the lessor provides everything to the lessee, e.g. aircrafts, crew, maintenance etc.
With regards to the airlines’ hedging decisions, the bulk of the airlines explicitly state that they use derivatives to manage risk and hence not for speculative or trading purposes. That being said, the airlines in the sample generally hedge less than 50%, and on average only 20% of next year’s expected jet fuel consumption.

In the examined period, both large increases and large decreases in jet fuel prices are observed, resulting in jet fuel comprising a larger and smaller part of the variable costs, ceteris paribus, but their data does not indicate that the overall jet fuel price level affects hedging decisions.

On the other hand, what their data does show is the relationship of net worth and hedge ratios, remembering the definition of the latter as the fraction of next year’s expected fuel expenses hedged. Rampini et al. (2014) set up five measures of net worth, among others market value and book value, and perform a cross-sectional analysis. They find positive correlations between all measures of net worth and hedge ratios, whereas scaled net worth measures (by total assets) and credit ratings are (the most) significant. To isolate within-airline variations in measures of net worth, airline fixed effects regressions are performed. Rampini et al. (2014) continue to find positive correlations across the different measures of net worth with a high degree of significance (especially in the WLS estimation); now suggesting a robust relation between net worth and hedge ratios.

By using both OLS and WLS estimations in cross-sectional and fixed effects regressions, the authors (Rampini et al., 2014) have clarified that airlines with a higher net worth have a higher hedge ratio, ceteris paribus.

The theoretical part of the article is examined in section 4, and it supports the empirical findings summarized above.

Another relevant piece of literature is the dissertation “Is jet fuel hedging in the airline industry valuable? A case study of Southwest Airlines and Deutsche Lufthansa” (Breistein, 2009). The essential question the author seeks to answer is “Should airlines hedge their jet fuel price exposure?”. The sample mainly covers the years 1999 through 2008, and it is argued that due to the raising energy prices in that period, hedging has been extremely valuable to Southwest and Lufthansa. It would seem that it counters the article above (Rampini et al., 2014) with regards to how general jet fuel price levels affect hedging decisions. However, the dissertation by Breistein (2009) focuses on absolute gains from hedging activities, while Rampini et al. (2014) focus on relative figures; namely hedge ratios.
More recently, a dissertation by the name of “Hedging and Firm Value in the European Airline Industry” (Pagh, 2016) has been released. The author looks into eight European airlines in the period ranging from 2001 through 2010. One of the working hypotheses is “Smaller firms hedge more than larger firms”, with the argumentation that smaller firms need to ensure stable cash flows to a higher degree than larger firms, in order to have sufficient cash to meet all obligations. The results from the regressions contradict the above hypothesis in that the coefficient for “Size”, calculated as the natural logarithm of the market value of the firm, is positively related to the hedge ratio. Unfortunately, no evidence supporting the author’s essential question is found; whether airlines that hedge are more valuable than airlines that do not. Many arguments for the lack of evidence between hedging and firm value are stated but especially how to measure derivatives at fair value is emphasized. It has been a requirement in IFRS since 2005 but is continuing problematic due to the (increasing) complexities of derivatives and derivative strategies.
3 - Markets

3.1 - The airline industry

The airline industry is characterized by many firms, both international and a few purely domestic. Though originating in different countries, differing in the age of the company, among other features, many of the same characteristics are found across the sample airlines. This section illustrates some of these similarities and seeks to illustrate the overall trends of the industry.

Table 3.1 displays the most recent credit ratings of the airlines rated by Standard & Poor’s. The credit ratings are long-term ratings. Credit ratings range from AAA to D, AAA being the best investment grade and D the speculative grade with firms defaulting on financial commitments (Standard & Poor’s, 2018).

According to Standard & Poor’s, firms with credit rating BBB is of investment grade. Investment Grade means that the firm has “Adequate capacity to meet financial commitments but more subject to adverse economic conditions”. Firms with ratings BB are of speculative grade, meaning that the firm is “Less vulnerable in the near-term but faces major ongoing uncertainties to adverse business, financial and economic conditions”. The lowest grade in the table above, B, is also a speculative grade and is “More vulnerable to adverse business, financial and economic conditions but currently has the capacity to meet financial commitments” (Standard & Poor’s, 2018). The credit ratings indicate that the firms in the airline industry as a whole, though with varying levels of capacity to meet financial commitments, are exposed to “adverse economic conditions”. Several firm characteristics can be the reason as to why these credit ratings are rather low, and one might expect to find the same characteristics across the sample airlines.

One such characteristic is the high leverage ratio. The average leverage ratio in the airline industry, based on the panel data used for this thesis, is about 73%. Though 73% is a high leverage ratio, there is some dispersion amongst companies, including instances of negative equity. In the panel data, the leverage ratio ranges from 35% to 142%. As implied by these numbers, the leverage ratio of the airline industry is positively skewed, meaning that the dispersion in above average leverage ratios is high. A leverage ratio above 100% implies negative equity. This might seem
counterintuitive as this would imply financial distress or even bankruptcy. The negative ratio is most often due to accounting policies, and hence the negative equity is only an accounting number.

With many firms in the market, competition is tough, putting pressure on prices. The bulk of the companies in the industry is operating on a tight margin, with an average EBIT-margin of about 8%. This number also varies quite a bit; from -25% to 47%.

A low EBIT-margin implies high operating expenses (OPEX), with OPEX making up an average of 91% of revenue. Of all the OPEX cost items, salary is the highest, with jet fuel costs as a close second. Of total OPEX, jet fuel accounts for 31% of these costs, on average. With an average OPEX of 91%, and an average jet fuel cost share of 31% (of OPEX), jet fuel makes up 28% of revenue on average. The jet fuel costs used for this calculation is after gains and losses on hedging activities are taken into account.

Even though the level of the jet fuel cost share varies across airlines, there is a common trend in the airline fuel cost share across all airlines. The last two years display the lowest jet fuel cost level in the sample period. However, even with the recent trends of diminishing jet fuel costs, jet fuel is a large operating cost, and airlines are therefore largely exposed to a (jet fuel) price risk factor. Due to the proportion of jet fuel costs in relation to revenue, large fluctuations in jet fuel price have immense consequences for airlines, especially when highly levered.

EBIT-margins, leverage ratios and a large exposure to external risks are all more than likely some of the determining factors when it comes to the credit ratings of the airlines. With the average of the industry exhibiting low margins, high leverage and large exposure to jet fuel price risk, an industry-wide low credit rating is of no surprise.

Considering the relation of these three factors, and the credit ratings, reducing the risk should be of great interest for the firms. These circumstances make the airline industry an interesting industry to analyze when considering hedging theory and the practice of hedging.
3.2 - Jet fuel

This section serves to provide an overview of the jet fuel market, and the implications the market structure has for the airlines. Jet fuel is a distillate of crude oil, Brent crude oil if sold in Europe and WTI crude oil if sold in the US, and accounts for approximately 7% of the refined products of this (cf. figure 3.1). The rest of the distillates are distillate fuel oil, including ultra-low sulfur distillate, kerosene, liquid petroleum gas, motor gasoline, residual fuel oil and other products. Ultra-low sulfur distillate is also referred to as either heating oil if produced in the US or gasoil if produced in Europe. It should be noted that jet fuel is often called jet kerosene. Kerosene can however also be used for other things than jet fuel, hence the distinction between jet fuel and kerosene in the graph above. Daily jet fuel production is about 5,902 thousand barrels pr. day (EIA, 2017), with the US being the biggest producer accounting for 26% of aggregate jet fuel production. China is second with a production of 627 thousand barrels pr. day, producing 10.6% of the total jet fuel produced (EIA, 2017).

As with production, the US is the major consumer of jet fuel, consuming just about 25% of the world’s total jet fuel consumption. China is also second with regards to consumption. The jet fuel market is an Over-The-Counter (OTC) market, meaning that there is no exchange traded regulated market for the commodity (ICE, 2012). Not being an exchange traded commodity has some implications, more specifically that certain financial instruments are not readily available. Though not available through an exchange, they can still be agreed upon between the two (or more) counterparties trading. That is, futures and options contracts can still be established outside of an exchange. Entering into an OTC contract entails counterparty credit risk, risk that needs to be mitigated. Counterparty credit risk is the risk that the other party cannot meet its obligations and therefore defaults on the contract. This risk can be mitigated by using a clearing house (ICE, 2012) that works as an intermediary, bearing (some of) the risk. As the jet fuel market is an OTC market, hedging exposure to jet fuel directly is more difficult than hedging an exchange traded commodity, even when considering the existence of OTC contracts and clearing houses. However, OTC derivative contracts can be customized with regards to quantity, whereas exchange traded contracts are, to some extent, standardized.
As opposed to jet fuel, the other fuel types along with crude oil are exchange traded. Being exchange traded, gasoil, heating oil, Brent crude oil and WTI crude oil have exchange traded derivative contracts. Hedging these commodities is therefore more straightforward. Jet fuel prices are highly volatile, more so than other fuel types (as will become evident in later sections), possibly owing to the relatively small market and the fact that it is an OTC market. OTC markets lack the transparency, liquidity and regulation conveyed by an exchange (International Monetary Fund, 2017). Due to the lack of regulation in the market, and limited access to real-time information on prices, pricing of derivatives and assets in general is complicated. Furthermore, not being able to clearly identify market participants and their positions increase the potential risk when participating in OTC market trading.

The implications for the airline industry are that the ability to hedge the risk exposure to jet fuel is worsened by the fact that jet fuel is traded OTC. With no standardized exchange trade contracts, airlines must enter into customized OTC derivative contracts. The ability to customize is of course a bonus feature of the OTC market but might not outweigh the potential costs stemming from the lack of liquidity, lack of transparency and the counterparty credit risk of the OTC market.

Since jet fuel is a distillate of crude oil along with gasoil/heating oil, price returns among these are often highly correlated. The high correlation between jet fuel and the other fuel types, allow airlines to make use of the exchange traded commodities for hedging purposes. This is referred to as cross-hedging and will be explored further later on. By making use of exchange traded contracts to hedge jet fuel, counterparty credit risk is mitigated, but hedging now hinges on the correlation structure as well as the volatility of the derivatives as well as jet fuel spot price.
4 – Theory

This section outlines the relevant theory for this dissertation. First off, the rationale behind hedging is set forth, followed by three major theories of the relationship between firm characteristics and hedging. The section ends with a description of various financial derivatives, and the theory behind cross-hedging.

4.1 - Rationale behind hedging

The following section outlines the most prominent theories on why hedging adds value to the firm. With an offset in the Modigliani-Miller theory on “The Cost of Capital, Corporation Finance, and the Theory of Investment” (1958), the section demonstrates how hedging can add value when the assumptions of Modigliani and Miller are relaxed.

4.1.1. - Hedging as a result of market imperfections

Hedging is defined as activities that lower the volatility of cash flows or firm value (Jorion, 2007). According to Modigliani and Miller (1958), the value of the firm should be independent of the firm’s capital structure, i.e. how it chooses to finance its investments. That is, according to Modigliani and Miller, hedging should not add value.

According to Modigliani and Miller (1958), investors themselves could hedge away the idiosyncratic risk by creating a well-balanced portfolio. Even if factor-risk persists in this portfolio, investors could make use of derivatives or take either long or short positions in the factors the portfolio is exposed to. This way, the investor would be indifferent as to whether the firm hedges or not, as the investors can mitigate the risks themselves (Hillier, Grinblatt & Titman, 2012).

According to the above, hedging does not add value to the firm, and if investors prefer hedged returns, they can hedge themselves. So why do firms hedge?

The Modigliani-Miller (1958) theory hinges on strong assumptions of frictionless, perfect markets. These assumptions do not hold in the real world, and relaxing these assumptions is what creates potential for hedging to be value-adding for the firm and hence the incentives for firms to hedge. Since the diversification of an investor’s portfolio reduces much of the risk from external factors, the cost of capital for the companies is likely to remain more or less the same after hedging. Thus, the only way hedging can add value to the firm is by increasing the expected cash flows of the firm (Hillier, Grinblatt & Titman, 2012).
Due to the presence of imperfections such as taxes, several reasons for hedging exist. Hedging increases the value of the firm by (Hillier, Grinblatt & Titman, 2012):

- Lowering cost of financial distress.
- Lowering taxes.
- Lowering agency costs.
- Timing of cash flows and investment opportunities.
- Improving information to base decisions upon.

**Lowering costs of financial distress** is achieved by lowering the probability of unfavorable outcomes (Hillier, Grinblatt & Titman, 2012). Lowering the probability lowers the indirect costs, such as the cost of debt. A higher probability of financial distress will most likely result in a lower credit rating, increasing the cost of debt through higher interest rates. This rationale is increasingly important as the leverage ratio of the firm increases, as seen below. For the firm to achieve a lower cost of debt in the form of lower interest rates, the firm has to credibly signal its intention to hedge (Smith & Stulz, 1985).

By hedging, the company can shift its cash flow distribution, as seen in figure 4.1 below.

![Figure 4.1: Distribution of unhedged and hedged cash flows. - Source: Hillier, Grinblatt & Titman (2012)](image)

In Figure 4.1, the firm enters financial distress when cash flows are below $20 million. In this case, hedging lowers the expected value of cash flows, but it also reduces volatility. By reducing volatility, the firm lessens the likelihood of financial distress, as indicated by the smaller area below $20 million. Lowering the probability of financial distress, lowers the indirect cost of financial distress. This has an effect on how much debt the company can take on. This is especially valuable, if having debt is valuable to the firm. Modigliani and Miller (1958) argue that in the world with perfect capital
markets, there is no trade-off between equity and debt. The Weighted Cost of Capital (WACC) stays the same regardless of the weighting of equity and debt. However, as mentioned earlier, this theory is built on several underlying assumptions. Relaxing these leads to the introduction of both an added cost of debt and an added bonus of debt. The cost is in the form of financial distress costs, and the bonus is in the form of the tax shield. That is, the firm can increase its debt level to take advantage of the tax shield, but at some point, the distress costs will be too high, and adding more debt will only damage the firm. This outcome justifies the added value of hedging when approaching financial distress. By lowering the probability of financial distress, hedging not only lowers the distress costs, but the debt level can be increased, allowing for a larger tax-shield effect.

Figure 4.2: The value of the firm as a function of the debt level of the firm, with D1 and D2 being the optimal debt level for an unhedged and hedged firm respectively. For illustrative purposes only. - Source: Own contribution

Figure 4.2 illustrates the effect. D2 is the optimal debt level of a hedged firm, allowing for a higher debt level due to the lower financial distress costs. The higher debt level increases the tax shield and thereby increases the value of the firm (Hillier, Grinblatt & Titman, 2012).

One important factor to consider is of course the costs of hedging. If these exceed the reductions in distress costs achieved through hedging, hedging is no longer profitable. One might assume that hedging costs are to be more or less proportional to firm size, whereas bankruptcy costs are likely not to be (Smith & Stulz, 1985). Knowing this, one would expect more hedging for smaller firms, as the costs do not exceed the reductions.

The lowering taxes rationale assumes a convex tax function. By reducing volatility in cash flows, hedging lowers the effective tax payments of the firm (Smith & Stulz, 1985). The more convex the tax function, the more value hedging adds. The hedge effect is also present if corporate taxes are
higher on profits than on deductions on losses. The situation of a convex tax function is illustrated in the figure below.

![Diagram](image)

**Figure 4.3:** Illustration of the “lowering taxes” rationale of hedging. — Source: Smith & Stulz (1985)

$V_j$ and $V_k$ are the two possible firm values in state $j$ and $k$, respectively, and $E(V)$ is the expected value of the firm. $E(T)$ is then the corresponding expected tax liability, without hedging. When hedging, the firm value is fixed at $E(V)$ but since it is no longer an expected value, the tax liability is lower; $E(T:H)$ (Jensen’s inequality) (Smith & Stulz, 1985). The graph clearly illustrates that the expected value of the hedged firm, $E(V-T:H)$, is higher than the value of the unhedged firm $E(V-T)$. It even shows the break-even point at which hedging is profitable when considering the cost of hedging. If the costs of hedging exceed $C^*$, the costs will reduce the value to a point at which the after-tax value is the same as without hedging.

As an example, consider a firm with revenues in a different currency than its home currency. In the next period, the firm receives revenue of 20 in the foreign currency. The exchange rate is either 2.5 or 5, both equally likely, but the company can fix the exchange rate at 3.75. The revenue for the next period would look like this:

<table>
<thead>
<tr>
<th>Revenue in home currency</th>
<th>Low rate</th>
<th>High rate</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhedged</td>
<td>50</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>Hedged</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
</tbody>
</table>

*Table 4.1: Revenue distribution next period of the unhedged and hedged firm. — Source: Own contribution*
The company also pays a corporate tax. The tax is a convex function of the value of the firm, as illustrated below.

![Tax function of the firm](image)

*Figure 4.4: Tax function of the firm; the tax rate in % on the Y axis, and the pre-tax income on the X axis. – Source: Own contribution*

The resulting after tax income of the above is reported in the table below.

<table>
<thead>
<tr>
<th>Income after taxes</th>
<th>Low rate</th>
<th>High rate</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhedged</td>
<td>48</td>
<td>60</td>
<td>54</td>
</tr>
<tr>
<td>Hedged</td>
<td>62</td>
<td>62</td>
<td>62</td>
</tr>
</tbody>
</table>

*Table 4.2: Income after taxes for the unhedged and hedged firm. – Source: Own contribution*

In the above example, a cost of hedging of about 4 will leave the company indifferent between hedging and remaining unhedged, as the income after taxes will be equal.

*Lowering agency costs* is accomplished by making management performance more visible in firm cash flows by reducing volatility owing to other factors. The factor risk to reduce is that of the factors, management cannot control. That is, if the manager’s performance is to be based on the success of implementing a new cost-cutting strategy, factors such as exchange rates, interest rates etc. should not affect the performance. Reducing the impact of external factors, reduces the ability of managers to blame bad performance on other factors. It also motivates managers to perform better, since successful implementation of strategies are not muddled by adverse price movements in external risk factors (Hillier, Grinblatt & Titman, 2012).

All in all, reducing the exposure to external risk factors, allows for the better monitoring of managers, thereby reducing agency costs.
Timing cash flows and investment opportunities is accomplished by shifting gains from one period to a period with losses. By averaging the cash flows over a period, the firm can make sure it has the right amount of capital, should an investment opportunity arise. Not having the capital needed results in either foregone positive NPV investments or having to raise new and more expensive capital. This adds value if raising external capital is more expensive than using internal cash flows, an assumption which will be further explored in the following section. The value added is highly dependent on whether the success of future strategic plans relies on the volatility of cash flows. The more the volatility affects the success of strategic plans, the larger the added value of hedging is (Hillier, Grinblatt & Titman, 2012).

Improved information is achieved by providing management with better data. Not only does hedging help monitor managers but it also makes the job of managers easier. By reducing the volatility of profits from different business units, the actual performance of these are easier to derive. With more accurate performance data, managers can allocate capital more efficiently. As hedging improves monitoring of managers, it also increases the manager’s ability to monitor the managers of other business units. In addition to this, firms that engage in risk management often have a better understanding of the markets of their external risk factors. Using this information, the firms can make better capital allocation decisions (Hillier, Grinblatt & Titman, 2012).

4.1.2. - Factors not related to market imperfections

Besides the incentives above, there might also be other factors related to why the firms, and not the shareholders, hedge. These factors are not market imperfections themselves but are related to why it might be easier for firms to manage the risk, or other incentives for firms to do so. These include:

- Economies of scale.
- Factor risk asymmetric information.
- Compensation schemes.

Economies of scale

According to the Modigliani-Miller (1958) theory, transaction costs should be non-existent, making it just as easy for shareholders to make use of hedging strategies. Reality is however different in that transaction costs are much lower for corporations than for shareholders (economy of scale). Besides the transaction costs, investors might also have high costs when obtaining the knowledge
needed to hedge the risk factors a given company is exposed to - a cost that only increases with the size of the portfolio (Hillier, Grinblatt & Titman, 2012).

**Factor risk asymmetric information**

Through the exposure of external risk factors and engagement in risk management, companies attain a more detailed understanding of the markets of risk factors to which they are exposed (Hillier, Grinblatt & Titman, 2012). This creates a case for asymmetric information in which the firm knows more about the markets than shareholders, giving firm a comparative advantage in taking on the hedging activities instead of shareholders.

**Compensation schemes**

Managers are assumed to be, as with other agents in financial markets, risk averse. Often times, a compensation scheme will be in place, relating compensation to firm value, often as an increasing function. The relation between firm value and compensation as well as the utility function of the manager are crucial in determining the optimal hedging strategy for the manager. Often, the manager will hedge his position through the firm itself. Three outcomes exist (Smith & Stulz, 1985):

1. *The manager’s wealth function is a concave function of firm value, as is the utility function of the manager.*
   
   In this case, by the logic of Jensen’s inequality, hedging will increase the value of the compensation for the manager, with an optimal hedge ratio of 100%.

2. *The manager’s wealth function is a convex function of firm value, but utility is still concave to firm value.*
   
   If this is true, only partial hedging will take place. Compensation is higher if the firm does not hedge, but the manager is risk averse (given the concavity of the utility function), so some hedging will add value.

3. *The utility function of the manager is convex in firm value.* The convex utility function implies that the manager should not hedge at all. With a convex utility function, the manager is essentially acting as a risk-seeker.

Even though the manager is the one exposed to the risk, the manager might engage in risk management through the firm itself. This is due to the firm’s comparative advantage of hedging over the manager. These are, as explained before, economies of scale and transaction costs (Smith & Stulz, 1985).
4.2 - Froot, Scharfstein & Stein (1993)

In their 1993 paper, Froot, Scharfstein & Stein (1993) developed a general framework for analyzing corporate risk management in which they take investment and financing policies into account. They examine the distinction between externally and internally generated funds, and the associated costs, especially in order to decide whether to hedge or not. A lot of existing literature focuses on “hedging mechanics”, for instance why hedging makes sense, but lacks guidance thereof. This leaves questions like what can be hedged; by how much; and using what kinds of instruments; unanswered. According to Modigliani-Miller (1958), hedging does not add value to the company, since investors are able to select their own portfolio to adjust their exposure to, for instance, oil prices. The authors (Froot et al., 1993) find that if externally generated funds, i.e. external financing, are more expensive than internally generated funds, a rationale for risk management, or hedging, might exist. The reasoning behind it stems from the variability in cash flows which is generally undesirable if output is a concave function of investment, as it typically is in neoclassical theory. The concavity is either caused by increasing marginal costs of external financing and/or by decreasing marginal productivity in investments. The variability interferes negatively with investments and financing, and to the extent that hedging can reduce the variability, it can increase the value of the firm. Other rationales for hedging are mentioned in the text, among others managerial motives and taxes, but the strongest is argued to be the one mentioned above, the costs of externally generated funds.

The authors (Froot et al., 1993) build a general framework that illustrates the benefits of hedging; essentially an optimization model of external financing. The setting is a firm that has a two-period investment and financing decision.

In period zero \((t = 0)\), the firm chooses the amount of liquid assets\(^3\), \(w\), to be hedged. In period one, the firm then decides its investment expenditures, \(I\), and, consequently, the amount of internal, \(w\), and external, \(e\), financing, thus \(I = w + e\).

In period two, the output, \(f(I)\), from the investment is realized and (outside) investors are repaid, i.e. receiving \(e\). Without external financing, the NPV of the investment is \(F(I) = f(I) - I\). The discount factor is assumed to be 0%, and the costs of external financing is \(C(e), C'(e) \geq 0\), where \(C\) could arise from a variety of costs, e.g. bankruptcy, informational asymmetries etc.

\(^3\) Also called internally generated funds, (internal) wealth or internal resources.
To determine the optimal amount of hedging, the model is solved by going through the framework backwards from period one. In \( t = 1 \), the firm has internal resources, \( w \), from \( t = 0 \), and chooses external financing, \( e \), to maximize net expected profits: \( P(w) = \max[F(I) - C(e)] \). The first-order condition for this problem is \( F'(I) = f'(I) - 1 = C'(e) \), using the formula for the NPV of the investment from above (without external financing) and that \( e = I - w \). When \( C'(e) > 0 \), i.e. costs are (strictly) increasing in external financing, the first-order condition implies that there is an underinvestment (see figure 4.5 below). The optimal level of investment \((I^*)\) is thus below the first-best level \((I^{fb})\), where the latter would set \( f'(I) = 1 \) and \( F'(I) = 0 \) [which equals a maximum because of the concavity of \( F(I) \)].

\[
F(I) = \text{NPV}
\]

\[
F'(I^{fb}) = 0
\]

\[
F'(I^*) = C'(e) > 0
\]

\( I^* \) equal the optimal investment for a firm if costs of externally generated funds are increasing in debt. \( I^{fb} \) is the investment of a firm if cost of externally generated funds is constant, \( fb \) meaning first-best.

Source: Own contribution

In period zero, the firm decides its level of hedging as described above. The firm chooses to hedge if \( P''(w) < 0 \), i.e. if \( P(w) \), the net expected profits, is concave (see figure 4.6 below). In other words, the interaction between investment and financing determines the level of hedging, in that

\[
P''(w) = \frac{-f''(I)C'(e)}{f'(I)C'(e)}
\]

where \( f''(I) \) represents the investment considerations and \( C''(e) \) the financing considerations. The concavity of the net expected profits, \( P(w) \), comes from the concavity of the investment technology, i.e. decreasing marginal returns on investments, and from the convexity of the financing cost function, i.e. increasing marginal external financing costs.
The investment’s concavity and its positive relation to internal wealth are the two conditions that have to be satisfied for hedging to be beneficial. The two conditions cause $P''(w) < 0$ (as above).

It is possible to carry the theory described above on to hedging with changing investment and financing opportunities, i.e. to incorporate randomness in the opportunities.

For linear hedging, the decision for internal funds can be written as $w = w_0(h + (1 - h)\epsilon)$, where $h$ is the firm’s hedge ratio and $\epsilon$ is uncertainty, the latter defined as the return on risky assets. As an example of uncertainty, if $x_0$ is a current price (of e.g. a forward), and $q_1$ is the future spot price, $\frac{q_1}{x_0}$ is equal to $\epsilon$. Since the decision is normally distributed, the wealth is unaffected by the hedge ratio.

In order to model changing investment opportunities, the NPV formula from above becomes $F(I) = \theta F(I) - I$, where $\theta = \alpha(\epsilon - \bar{\epsilon}) + 1$. Here $\alpha$ is the correlation between the investment opportunity and the risk to be hedged.

In $t = 0$, the firm chooses $h$ to maximize expected profits or stated mathematically, $\max E[P(w)]$. The first-order condition can be written as $\text{cov}(P'(w), \epsilon) = 0$. The optimal hedge ratio insulates $P'(w)$ from fluctuations in the variable that is being hedged. From the first-order condition, the optimal hedge ratio can be deducted as

$$h^* = 1 + a \frac{E\left[\frac{f(I)P'(w)}{\theta f(I)}\right]}{w_0P''(w)}$$

where the bar indicates expected values.
If $a > 0$, i.e. positive correlation between the investment opportunity and the risk to be hedged, the firm will not want to hedge as much (remembering $P''(w) < 0$). The uncertainty, $\epsilon$, and the cash flows are positively correlated, and the more sensitive the investment opportunities are to $\epsilon$, the smaller the optimal hedge ratio is. If the investment opportunities are extremely sensitive to the risk variable, the hedge ratio can become negative.

If $a < 0$, it makes sense to overhedge, $h^* > 1$, which means having more cash when $\epsilon$ is low, and vice versa, but the firm might consequently have negative resources in some states. The capital market will therefore require a credit risk premium when signing contracts with the firm in question, rendering the overhedge less profitable. The same reasoning applies to the mentioned underhedging above, why the hedge ratio typically will be between 0 and 1.

Up to this point, the external financing has been exogenously given. In order to incorporate changing financing opportunities, the $C(e)$ function can be generalized to include the effect of shocks to a firm’s cash flows. The new function is therefore $C(e, \phi)$ where $\phi = \delta (\epsilon - \bar{\epsilon}) + 1$. $\delta$ measures the strength of (or sensitivity to) the correlation between the assets and the risk variable, $\epsilon$. If we assume that $C''(e, \phi) < 0$ for fixed first-period wealth, and that there is zero correlation between the investment opportunities and the risk variable, i.e. $a = 0$, the optimal hedge ratio becomes

$$h^* = 1 + \delta \frac{C''(e, \phi)}{w_o \rho_{ln(w)}}$$

where the bar (again) indicates expected values.

In words, the more sensitive the assets are to the risk variable, the higher the optimal hedge ratio is. Hedging now allows the firm to fund its investments and yet, it conserves on borrowing when external financing is more expensive. As we are only looking at linear hedging decisions (so far), investments are not insulated from shocks to the risk variable - even though $a = 0$.

Linear hedging strategies cannot maximize value to the extent that nonlinear hedging strategies can. For nonlinear hedging strategies, $w^* = w^*(\epsilon)$ describes the optimal level of wealth for every value of uncertainty, $\epsilon$, still in order to maximize expected profits.

The same basic setup from linear hedging strategies also applies on nonlinear hedging strategies, with the introduction of the frequency distribution of the random variable in addition. To avoid a trivial and somewhat tedious exposition, the nonlinear hedging strategies are better understood with a numerical example using options.
Table 4.3: Numerical example of non-linear hedging strategy, using options. – Source: Froot et al. (1993)

The example operates with three equally possible states. The three states’ first-bests are the ones where \( f'(I) = 1 \), i.e. the maximum in figure 4.5. Assuming the firm has no access to external financing, the firm will be forced into bankruptcy at any level of investment below 6. The no-hedging strategies are also included. If the firm can only enter into futures contracts, the state one’s (internal) wealth can be improved at the expense of state three’s wealth, due to the setup of the futures contracts. If options are then introduced, a combination of futures and options can lead to the same payoffs as the first-bests. In this example, a value-maximizing strategy involves buying one put option in state one and three call options in state 2 (cf. section 4.5 - Derivatives). The former pays 1 in state one and zero otherwise, and the latter either pays 1 or 0 in state three, for each of the call options. In that way, the cash imbalances emerging from the futures in state two and three are eliminated. The price of the options is calculated as \( \frac{1+0+2}{3} = 1 \). Thus, options can be used to maximize value when hedge ratios are variable; potentially combined with futures.

The authors (Froot et al., 1993) argue that when external financing is more expensive than internal financing, an incentive to hedge exists. An unhedged firm may have to underinvest due to external financing being too costly or impossible to raise, while a hedged firm will have enough internal funds at hand to exploit attractive investment opportunities.

The main argument emerges from the variability in cash flows which is undesirable for concave investment functions, in that variability affects investments and financing negatively. Thus, by reducing variability, hedging can increase firm value and more specifically, nonlinear hedging instruments allow firms to enter into more precise hedges than linear instruments.

In short, the optimal hedging strategy, comprising the amount of hedging and specific instruments, depends on the interaction between investment and financing opportunities.
4.3 - Rampini & Viswanathan (2010)

Rampini and Viswanathan (2010) seek to explain the relation between financial constraints, collateral and risk management. In this section, model III.A of their 2010 paper will be described, both with regards to assumptions and implications.

The model of net worth and the relation to risk management by Rampini and Viswanathan is set in a world with only two goods; consumption goods and capital. The economy consists of firms and lenders, lenders being deep-pocketed and not able to run the firms themselves. The aim of the theory and model is to explore the relation between net worth and risk management, given uncertainty about future technology levels (Rampini & Viswanathan, 2010).

Time is finite with a horizon of $T$, in this case starting at time 0, and ending at time 2 at which time all of net worth is paid out as dividends. Dividends are assumed to be 0 throughout the rest of the model. At time 1, there are five possible states, $s_1$ through $s_5$, the set of these being $S^t$. The probability of each state is denoted by $p(s^t)$. The likelihood of each state is equal, meaning that $p(s^t) = 0.2$ for each state. The only difference between each of these states is the technology of the firm. The firm will choose the amount to invest at time 0, given that it knows the probability distribution of future states at time 1.

At time 1, the firm receives the income from the investment at time 0 and then proceed to invest all of this, while exhausting all of the debt capacity. At time 2, only one state exists.

The only decision of the firm in this model is the amount of investment at time 0 and thereby also the amount of financial slack (hedging) at time 0. Everything else is given as a function of this decision.

Firms seek to maximize net worth, $E \left[ \sum_{t=0}^{T} \beta^t d_t \right]$, with $d_t$ being dividends. Both firms and lenders discount future cash flows at a rate of $\beta \leq 1$, the time preference.

Firms are endowed with an initial net worth of $w_0$, chosen exogenously, and no capital in time 0. Capital can be bought and sold at price $q(s^t)$, assumed to be constant across time for this model and equal to 1, hence subscripts on $q$ are ignored going forward.

Furthermore, firms can borrow money from the lenders at rate $R = \frac{1}{\beta}$, up to a rate $\theta$, the collateralization rate, of invested capital. The collateralization rate in the model is fixed at 0.8, and $R \approx 1.05$, given $\beta = 0.95$. 

To produce the consumption goods, only capital is needed. The production function of firms is a neoclassical production function given by $F(k_t) = A(s^{t+1})k^\alpha_t$, with $A$ being the technology in state $s^{t+1}$ and $k_t$ being invested capital at time $t$. $\alpha$ is constant throughout time and is set to be 0.33. As mentioned, technology is the only parameter that differs in each state. Technology is $\frac{s}{10}$ in each state, $s$ being the state index from 1 to 5. Time 2 technology is 1.5, regardless of what state came before time 2.

The production function is concave and thereby exhibits diminishing marginal returns to invested capital. The different technology in the five states shifts the marginal return on invested capital. In states with low technology, the marginal return on investing more capital is lower than states in which technology is high.

At time 2, the marginal return on capital is highly dependent on the amount the firm invests, as technology is now the same regardless of the previous state. All else being equal, lower net worth and hence lower capital investment will result in higher marginal return on invested capital, given that the production function exhibits diminishing marginal returns to invested capital.

When borrowing from the lenders, firms are subject to limited enforcement; the firms can default on promises made, and abscond with any capital gains or cash flows, along with a share $(1 - \theta)$ of invested capital. Lenders can only claim $\theta$ of invested capital and have no ways of claiming cash flows to compensate losses in the case of default. Since lenders know this, firms can borrow state-contingent amount $b_1$ at time 0, as long as it satisfies the collateral constraint $q\theta k_0 \geq R b_1$. That is, the repayment of debt cannot exceed the value of collateralized capital in the next period. The same inequality is true for the firm at time 1.

The above relations result in the time 0 budget constraint $w_0 + E[b_1|s^0] \geq d(s^0) + qk_0$.

The firm can either exhaust all of its debt capacity or keep financial slack, defined as $h(s^{t+1}) = q\theta k_0 - Rb(s^{t+1})$. Financial slack is the amount of debt capacity not exhausted by the debt undertaken. By not exhausting debt capacity, the firm saves the cost of the debt, $R$. Keeping financial slack is considered risk management in this model.
At time $t + 1$, net worth is defined as $w_{t+1} = A(s^{t+1})k_t^0 + qk_t - Rb_{t+1}$. That is, net worth is equal to the return on invested capital at time $t$, less the cost of repaying debt at $t + 1$. For time $t + 1$, the firm is once again posed with the choice of how much to borrow, how much to invest and whether or not to pay out dividends.

To quantify the trade-off between investment and risk management, the return on internal funds first need to be defined. First off, the model assumes that firms always pay the minimum down payment on capital, $\mathcal{D}(s^t) = q - R^{-1}q$. Return on internal funds employed by the firm is then defined as $R_{t+1}(k_t, s) \equiv \frac{A_{t+1}(s^{t+1})ak_t^{p-1}+q(1-\theta)}{\mathcal{D}_t}$. That is, return on internal funds is the change in net worth in time $t + 1$ divided by the minimum down payment on capital in time $t$. The numerator is the net worth of $t + 1$ differentiated with respect to $k_0$. As mentioned earlier, the production function in this model exhibits diminishing marginal return to invested capital. It follows that the return on internal funds also exhibit diminishing marginal return to invested capital.

The firm is exposed to a trade-off between investing capital at time 0 or keeping financial slack for risk management purposes. The trade-off results in the important first-order condition:

$$E[R_1(k_0)R_2(k_1)] \geq RR_2(k_1(s), s)$$

Do take note of the fact that the left side is the expected return of all states whereas the right side is state-specific. The intuition and rationale behind the above first-order condition should be clear; firms will invest more in capital at time 0, as long as the expected marginal return of investing one more unit of capital, the left side, is above the return of conserving debt capacity at time 0, the right side.

To summarize, the firm is posed with a maximization problem, seeking to maximize the return on wealth and debt capacity, with a trade-off between invested capital and risk management. The firm can credibly collateralize the invested capital up to 0.8 or 80% of the invested capital. The cost of debt, and the return on financial slack, is given by $R \equiv 1.05$. $\alpha$ is fixed at 0.33, an $q$ is fixed at 1. The only parameter not fixed across time is technology that follows the earlier explained pattern.

The results are shown in the figures 4.7, 4.8 and 4.9 below. Firms with low net worth will not engage in risk management. For these firms, the return on investing internal funds are higher than
the return on conserving debt capacity, i.e. hedging. As net worth increases, so does the return on hedging, hence the firm will engage in risk management.

Figure 4.7: Investment $k_0$ at time 0 (solid line) and state-contingent borrowing $b_1(s)$ (dashed lines) as a function of net worth at time 0. – Source: Rampini & Viswanathan (2010)

Figure 4.8: Financial slack $h_1(s)$ as a function of net worth at time 0. – Source: Rampini & Viswanathan (2010)

Figure 4.9: Capital investment $k_1(s)$ and borrowing $b_2(s)$ as a function of net worth at time 0.

Figure 4.7 illustrates the state-contingent borrowing for each state (the dashed lines). The solid line is the actual invested capital at time 0, given that the firm receives debt equal to a weighted average of the state-contingent debt levels. As marginal return on invested capital diminishes, so does the state-contingent debt progressively for each state, starting with the state with the lowest technology (state 1) at point $w'$. This is evident by the dashed-line for state 1 (the lowest of the lines in figure 4.7), breaking off from the rest. This is accompanied by an increase in financial slack, i.e. hedging, for state 1 in figure 4.8.

Figure 4.9 illustrates the amount invested at time 1 for each state $s$. Capital invested starts of lowest for state 1 and increases for each state. As net worth at time 0 increases, the firm engages in risk management, leading to higher invested capital at time 1, progressively for each state. The effect is first seen for state 1 (the lowest solid line) at a net worth (0) of $w'$. Capital invested at time 1 is the same for all states for which the firm saves net worth. As net worth increases, the firm engages in more and more risk management up until net worth $w^*$ has been reached. At this point forward, the firm conserves net worth for all states, capital invested at time 0 is constant and capital invested at time 1 is the same for all states and increasing.

The gradual increase in risk management as a function of net worth is one of the reasons why one might find imperfect hedges, i.e. hedge ratios not equal to 1. That is, risk management is not binary; firms differ in the amount of risk management engagement depending on their net worth.

The choice of parameters will naturally impact these results. Anything, that increases the marginal return on invested capital at time 0, increases the level of net worth at which the firm first engages in risk management. Increasing marginal return on invested capital for all levels decreases the amount of risk management for all levels of net worth, all else being equal.

Given the production function used in the model, a higher $\alpha$ will result in a higher return on invested capital, all else being equal. A higher $\theta$, meaning higher collateralization, also increases the marginal return on invested capital at time 0. A higher $\beta$ indicates a lower $R$, i.e. a lower return on risk management, lowering the right-hand side of the trade-off condition. That is, one would expect firms that can collateralize using a high share of invested capital, with low diminishing marginal return on invested capital and with higher $\beta$, to engage less in risk management than other firms, given the same level of time 0 net worth. The higher $\beta$ results in a lower $R$, suggesting lower costs of leverage as well as lower return on alternative investments.
In the model, every firm is assumed to have the same production function. In a situation where firms differ in productivity, firms that are more productive at the margin will, all else being equal, engage in less risk management than its counterparts.

In conclusion, firms with higher net worth will engage in more risk management, as evident by the figures. A threshold exists, and firms will not engage in risk management at all below that. After this point, firms will hedge increasingly more and more states and at some point, they will hedge all future states.

4.4 - Rampini & Viswanathan (2014)

More recently, Rampini, Sufi and Viswanathan (2014) have refined their 2010 article (Rampini and Viswanathan, 2010) by considering commodity price risk management (in practice) and by fine-tuning their model. While the empirical findings in the article is a part of the literature review in this dissertation, the scope of this section is their dynamic model of firm financing and risk management.

Firms are financially constrained which is the key determinant of their choice of investment, financing and risk management policies. Firms are generally risk neutral but effectively risk averse in net worth (because they are financially constrained), and profit functions are convex and decreasing in input prices. With that in mind, the working hypothesis becomes something like: ”More constrained firms should engage in less risk management”.

As the 2014 article (Rampini et al., 2014) builds on the 2010 article (Rampini and Viswanathan, 2010), the notation is (generally) unaffected but a few equations have been altered a bit. In order for the reader to potentially read this section separately, the letters (and equations) are being defined continuously, though the reader might have seen some of it in the previous section.

The firm operates within the standard neoclassical production function with decreasing returns to scale, where the production requires capital, \( k \), and an input good next period, \( x' \). The output is then \( \hat{A}'k^{\hat{a}}x'^{\phi} \), where \( \hat{a} > 0, \phi > 0, \hat{a} + \phi < 1 \), and \( \hat{A}'(> 0) \) is the total factor productivity next period. Generally, the prime indicates variables measurable with respect to next period.

The firm seeks to maximize the expected discounted present value of dividends, given the current state, \( s \), and its current net worth, \( w \). The firm then chooses the current dividend, \( d \), capital, state-
contingent borrowing next period, \( b' \), and state-contingent forward purchases. The amount of forward purchases is \( x_f' \) at the forward price \( p_f' \), as opposed to the spot price \( p' \), for all states \( s' \) next period. When \( p_f' > p' \), the contracts have to be collateralized. Because firms can abscond with all cash flows and a fraction \( 1 - \theta \) of capital, the firms need to collateralize all contracts \( < \theta \) of the resale value of depreciated capital. Specifically, the collateral has to cover the loans, \( Rb' \), where \( R \) is the risk-neutral lenders’ discounted payments \( (R < \beta^{-1}) \) and \( \beta \) is a discount factor, as well as the net promises, \((p' - p_f')x_f'\), introduced above.

The theory (Rampini et al., 2014) is built on five propositions. Proposition 1 is the profit function, no. 2 emphasizes collateral constraints, no. 3 is a hypothesis about risk management by severely constrained firms, no. 4 looks into asymmetric risk management policies, and lastly, no. 5 focuses on the concavity of the hedging payoffs.

The model is a static profit maximization problem with regards to the firm’s input choice or put differently, regarding input price risk management. The induced within-period profit function is 

\[
\pi(k) \equiv \max(x') \tilde{A}'k^\alpha x'^\phi - p'x' \equiv A'k^\alpha, \quad \text{where} \quad \alpha \equiv \frac{\tilde{\alpha}}{1-\phi} \quad \text{and} \quad A' \equiv \tilde{A}'(1-\phi)\phi^{\frac{\phi}{1-\phi}}p'^{-\phi}. 
\]

\( A' \) is the effective productivity, and the profit function is convex in spot prices, \( p' \).

Though, the convexity is not relevant because hedging is not evaluated in spot prices, but in \( x_f' \) and \( p_f' \). The intuition behind hedging is derived from the profit function in that higher spot prices mean lower profits (and thus net worth). The firms act as if risk averse in net worth and might therefore be interested in hedging states where input prices are high to ensure net worth going forward, i.e. firm value is concave in net worth. This concavity is the firm’s motivation for risk management because the spot prices determine the effective productivity and net worth, while commodity price risk management shifts net worth across states with different productivity and cash flows. The approach is different than the ad-hoc approach, referred to by the authors (Rampini et al., 2014), often used in received theory (Adam, Dasgupta, and Titman (2007)) and Mackay and Moeller (2007)), the latter (mistakenly) evaluating hedging in spot prices and assuming that profit functions are convex in input prices (and therefore no hedging motive would exist).

As mentioned above, the firms are collaterally constrained which can be put mathematically as 

\[
\theta k(1 - \delta) \geq Rb' + (p_f' - p')x_f', \quad \text{where} \quad \theta \quad \text{is the collateralizable share of capital and} \quad \delta \quad \text{is the depreciation (of capital).} 
\]

The formula thus states that the collateralizable fraction of depreciated
capital has to be larger than or equal to the promised repayments of the loans plus the net promises that count against the collateral constraint, i.e. the latter being what the counterparties keep if the firm defaults.

Based on their theory, the authors (Rampini et al., 2014) arrive at two important implications; firms generally only manage risk partly, and constrained firms, i.e. firms with sufficiently low net worth, manage risk to an even lesser extent. This trade-off between firm financing and risk management is depicted in figure 4.10 below.

![Diagram](image)

Figure 4.10: Two-state process, illustrating financing needs, investments and risk management. –

Source: Rampini et al. (2014)

The figure illustrates a two-state process where financing needs for investments override hedging concerns when net worth is sufficiently low. If that is the case, the firm shifts as much net worth as it can to the current period \((t)\), and does therefore not shift net worth from high net worth states \(w(s')\) to low ones \(w(s'')\) next period \((t + 1)\).

Low net worth implies a high marginal product of capital, and the firm needs all of its capital in all states next period, rendering risk management impossible. If the firm in fact did engage in risk management, the consequent could be downsizing and in order to avoid that, the firm rather chooses to use its limited net worth to finance capital going forward.

Assuming that the input prices are the only source of uncertainty, the firm’s hedging policy becomes the following: “… the firm hedges all commodity prices next period above a certain threshold, if it hedges at all, effectively ensuring a lower bound on the firm’s net worth next period” (Rampini et al., 2014). To avoid falling below the lower bound, the optimal risk management policy with a concave payoff is the one ensuring that the sum of the policy’s payoff plus the profit from
operations and the resale value of capital net of debt is constant across all states. As explained earlier, profits are decreasing and convex in input prices which in turn cause a hedging policy that is increasing and concave in input prices.

To recapitulate and conclude, the theory in the authors’ 2014 article (Rampini et al., 2014) is a direct continuation of their 2010 article (Rampini and Viswanathan, 2010); the main differences being the consideration of commodity price risk management (in practice) in the former and the extensive construction of the five-state model in the latter.

4.5 - Derivatives

4.5.1. - Forwards

A forward contract is an agreement between two parties to trade an asset at a given, future time at a price determined today. The party who is obliged to buy the underlying asset is buying or having a long position, while the party who is obliged to sell the underlying asset is selling or having a short position. The determined price today is called the delivery or strike price, and the time for the future trade is called the delivery time, expiration date or strike date. In other words, the price today is locked for the future delivery of the underlying asset, thereby eliminating uncertainty regarding future cash flows. On the contrary, a trade that is executed immediately is called a spot trade, and the related price is called the spot price.

The payment for a long position is \( S(T) - K \), where \( S(T) \) is the price of the underlying asset at expiration, and \( K \) is the delivery price. For a short position, consequently, the payment is \( K - S(T) \). The payment can either be settled as actual delivery, i.e. the party with the short position delivers \( x \) (agreed) units of the underlying asset to the party with the long position who pays the predetermined price \( K \). The other settlement type is cash payments where only the cash amount is transferred, i.e. the amount \( S(T) - K \) is transferred between the parties. The latter being the vast majority of forward trades (Munk, 2000). When the delivery price, \( K \), is set to render the net present value of the forward equal to zero, the delivery price is equal to the forward price. The forward price is used to determine the forward’s later cash flows.

\[ \text{If that is the case, we need to account for ‘storage costs’ when looking at commodities.} \]
The implications of forwards are twofold, dependent on what side of the trade an investor is interested in. If he wants to be certain about the future price of an asset, he can go long and thereby secure the price today. On the other hand, if he wants to sell an asset, regardless of whether he has it or not, at a future time, he can lock in the sales price today by shorting the forward. Consequently, he will not gain (as much) from a beneficial change in the underlying asset but, at the same time, he will not lose (as much) from an unfavorable change in the underlying asset. Simply put, forwards are useful to mitigate risk, especially when the future payments are certain with regards to date and size.

Forwards are traded on over-the-counter (OTC) markets. Contrary to exchanges, OTC markets are typically (more) unregulated and can be determined freely between two (or more) parties. There is not necessarily a ‘clearing house’ that insures enough liquidity to guarantee all payments, and a substantial counterparty credit risk might therefore exist. The main reason why forwards typically cannot be traded on organized markets is because of the lack of standardization with regards to the forward price, the amount of the underlying asset and the (potential) delivery time of the underlying assets. There would simply be infinitely many unique series of contracts if a forward market existed as a regular exchange. It is a possibility, however, as a market becomes more and more standardized that the OTC market would be identical to a regular exchange.

4.5.2. - Futures

Futures are quite similar to forwards but differ in that futures are standardized contracts that are traded at an exchange. Furthermore, the futures are said to be marked-to-market, meaning that the futures’ price changes are settled daily. A forward and a future for the same underlying asset, the same delivery price and expiration date should have the same price at expiration (equal to the spot price); regardless of whether the changes are ‘settled’ daily or at expiration. Before expiration, the forward and future price can differ significantly, depending on the magnitude of the (daily) changes in the future’s price and also the risk-free rate.

The futures are thus traded at organized markets as standardized contracts in relation to the underlying asset, the size of the contract and the expiration date. Only certain assets can be used as underlying (e.g. Brent crude oil), a standard size is used (e.g. 1,000 barrels) and the contracts typically expires every month or every three months. Due to the marking-to-market system, the investors need to have a margin account at a clearing house. When the two parties have entered into a contract, the buyer pays an initial margin to his margin account at the clearing house. At any
time, a minimum amount needs to be present at the account, called the maintenance margin. If the remaining amount is below the maintenance margin as a consequence of the daily settlements, the investor receives a margin call where he is required to deposit the difference between the actual amount and the current maintenance margin. Thus, the margin account makes sure that the investors honor their agreements (to a higher extent than when the settlement only happens at expiration).

In the same way as forwards, futures can be used to mitigate risk. The future market is more regulated and thus more secure but namely because of the former, the future market might not initially fulfill the investors’ specific needs. If it does not and if the futures are being used to mitigate risk, it is important to look into other markets that have high correlations with the assets in question. By doing that, investors will then be able to manage risk to a large extent using futures.

4.5.3. - Swaps

In a swap agreement, two parties transfer their future payments with each other. Generally, typical swaps are interest rate and currency swaps, but jet fuel swaps are common among airline companies. Swaps are traded on OTC-markets resulting in a vast variety of ‘swappable’ assets (cf. above).

A common example of an interest rate swap is where fixed interest rate payments are switched to variable ones, called a plain vanilla interest rate swap. The payments have the same currency and the same principal. The usual variable interest rate is a money market rate, for instance a LIBOR-rate\(^5\), which is the rate that the international financial markets offer other banks for loans without requiring collateral. An example, the three-month USD LIBOR is the interest rate that banks offer on a three-month loan denominated in American dollars. The fixed interest rate is set in such a way that the value of the swap is zero when the agreement is entered. As mentioned above, the swaps are traded on OTC-markets which makes all kinds of maturities possible, but the typical maturity is between two and ten years.

If a variable interest rate loan is transformed into a fixed interest rate loan, it is called liability transformation. If it is the other way around, it is called asset transformation. Technically, one party pays fixed interest rate payments and receives variable payments, a payer swap, and the other party pays variable interest rate payments and receives fixed payments, a receiver swap. Interest rate swaps can be used to mitigate risks as well as to speculate in future interest rates. Differences

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\(^5\) London InterBank Offered Rate
in bankruptcy risks might give companies different comparative advantages which is why an interest rate swap might be preferable.

A currency swap simply switches payments denominated in one currency out with payments denominated in another. In its most simple form, the payments of interest rates and the principal on a fixed bullet loan are exchanged from one currency to a different one. It is primarily used to mitigate long term currency risk but is also used to speculate in different currencies. As with interest rate swaps, companies might be willing to initiate in a currency swap due to different comparative advantages.

As an example, consider a Danish investor who exchanges a loan in DKK with a loan in USD which corresponds to buying a Danish bond and selling an American bond.

The value of the swap in DKK is then \( V(t) = B(t) - S(t)B_f(t) \), where \( B(t) \) is the value of the Danish bond (in DKK), \( B_f(t) \) is the value of the American bond (in USD), and \( S(t) \) is the spot price on DKK/USD. As with interest rate swaps, investors need to be aware of the bankruptcy risks because the bonds are not risk free (as opposed to e.g. government bonds).

Anything can basically be swapped but as a last asset, and most relevant for this thesis, jet fuel swaps will be considered. Jet fuel swaps differ from oil futures or jet fuel forwards in that the swap is settled based on the average price over the course of the month (and thus not at one specific point in time) (Mercatus Energy Advisors, 2016). For example, a company may be interested in locking in a fixed price for a portion of its anticipated jet fuel price exposure in some period in the future, typically settled at a specific date every month, but might as well be quarterly. If it buys a jet fuel swap from a counterparty, and the spot fuel price is higher than the average price in that month, the company will profit. If the spot jet fuel price turns out to be lower, the airline will have to pay (to its counterparty). Since swaps are based on average prices over the course of e.g. a month, they might be more in accordance with the airlines’ risk management policies compared to forwards and futures.

4.5.4. - Options

Contrary to forwards or futures, an option is a contract that gives the buyer the right to perform a future transaction of an underlying asset on terms agreed upon when signing the contract. The investor is thus not obliged to do so if the development of the underlying asset is not in his favor. A call option gives the buyer the right to buy a certain amount of the underlying asset at a predetermined price, at or before maturity. A put option gives the buyer the right to sell a certain
amount of the underlying asset at a predetermined price, at or before maturity. The predetermined price is called the exercise price or the strike price. If the investor can exercise at any time before or at maturity, the option is called an American option. If he can only do so at maturity, the option is called a European option. Even though the definition of American options is that they can be exercised at any time before or at maturity, in practice they can only be exercised at certain dates or in parts of the options’ duration. Despite the options’ names, it does not necessarily have anything to do with where they are traded. Both American and European options are traded on exchanges as well as OTC-markets.

As with (almost) any other derivative, it is possible to short the call or put option. If that is the case, the investor is said to write an option. If you write a call, you sell an option to another investor who can buy the underlying asset from you at a price $K$. If you write a put, you sell an option to another investor who can sell the underlying asset to you at a price $K$; meaning you have to buy the asset if the investor chooses to exercise. The payoffs are depicted in figure 4.11.

![Payoff of options](image)

*Figure 4.11: Payoff of options. From top left, to bottom right; Long call, short call, long put and short put. – Source: Munk (2000)*
The options only cause payments if the investor chooses to exercise. The investor who issues (writes) the option receives an option premium, i.e. the price of the option, regardless of whether it is exercised or not.

The buyer of a call option only chooses to exercise if $S(T) - K > 0$, or in words; if the underlying asset, $S(T)$, has a value at time $T$ (at maturity) larger than the exercise price, $K$. Similarly, the buyer of a put option only chooses to exercise if $K - S(T) > 0$.

When $S(t) > K$ for a call option and $K > S(t)$ for a put option, the options are said to be in-the-money, where $S(t)$ is the spot price of the underlying asset. When $S(t) < K$ for a call and $K < S(t)$ for a put, the options are out-of-the-money. For both calls and puts, if $S(t) = K$, the options are at-the-money.

The respective value of European calls and puts are
\[
C(T;T,k) = \max\{S(T) - K, 0\}
\]
\[
P(T;T,k) = \max\{K - S(T), 0\}
\]

The respective value of American calls and puts are
\[
Ca(t;T,K) = \max\{S(t) - K, 0\}
\]
\[
Pa(t;T,K) = \max\{K - S(t), 0\}
\]

where $t \leq T$.

As explained above, the price of the underlying asset affects call options positively and put options negatively. Analogously, the exercise price affects call options negatively and put options positively. The time to maturity together with the volatility affect all options positively, reflecting higher option prices for higher and longer uncertainties about future asset prices. The discount rate and the dividend are looked further into under the Black-Scholes below.

All factors that affect the options’ prices are tabularized below.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Call price</th>
<th>Put price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>European</td>
<td>American</td>
</tr>
<tr>
<td>Price of underlying asset, $S(t)$</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Exercise price, $K$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Time to expiration, $T-t$</td>
<td>(+)</td>
<td>+</td>
</tr>
<tr>
<td>Discount rate, $r$</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Dividends, $D$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Volatility, $\sigma$</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 4.4: Factor affecting the price of options, and the direction of the effect. The effects are given an increase of the respective factor. – Source: Own contribution
As with forwards and futures, options can be used to mitigate risks. Using the former, uncertainty can be eliminated completely but consequently, if the underlying asset performs better than expected, forwards and futures will also eliminate profits. If investors use options instead, they can reduce losses in bad times and still profit in good times. As with anything else in this world, there is no free lunch. The investor has to pay the option price regardless of the development of the underlying asset (and thus incur a cost).

Simultaneously, options can be used to speculate in the development of the underlying assets, e.g. if the investor believes that the price of the underlying asset will grow, he can write a put and receive a premium today, i.e. the option price, with the expectation that the option will not be exercised by the counterparty at maturity (out-of-the-money).

Option pricing can be achieved by using either the binomial model or the Black-Scholes’ model. The fundamental idea in the two models is the same but they differ in two, significant ways. First, the binomial model operates in discrete time where the Black-Scholes’ model operates in continuous time. Second, the binomial model can easily be applied to (all kinds of) American options while the Black-Scholes’ model can only be used partially and requires some assumptions in order to be applicable (at all) on American options. The latter model can however be used to price American call options that do not have payments before maturity because it would never be optimal to exercise those before maturity and thus, the concerned American call is equal to a European call (Munk, 2000).

The reason for no early exercising is twofold: the call has to be paid earlier, meaning having less (otherwise) invested money that may yield a return, and since the uncertainty is higher for longer times to expirations, the option should be kept as long as possible.

For a high number of periods, the Black-Scholes can be used as an approximation for pricing American options, because as the number of periods in the binomial model approaches infinity, the option price in the binomial model converges towards the option price in the Black-Scholes’.

4.6 - Cross-hedging

Cross-hedging is a method used for hedging risk exposure but using derivatives of other assets than the price that is hedged (Hull, 2012). Cross-hedging makes use of a highly correlated asset, with a more liquid and preferably exchange traded derivatives market, to hedge the exposure of the risk to which a firm is exposed to. More specifically, the correlation between the spot price of
an asset to be hedged and the derivatives price of the cross-hedge asset to be used are of interest. Most often, futures are used in cross-hedging.

Another use for cross-hedging is for portfolio managers with a diversified portfolio. To hedge the portfolio, a manager might use index futures contracts (Bodie, Kane, & Marcus, 2014). This way, the portfolio manager can hedge away any market movements and achieve either a risk-free return (if the hedge is perfect), or hope to achieve a higher return if the portfolio is well-chosen and delivers a positive alpha or excess return (Hull, 2012). This is often a strategy employed by hedge funds; to hedge market risk and leave only the risk the hedge funds want behind (Pedersen, 2015).

The idea of cross-hedging is to offset losses on spot prices in the exposed commodity with gains on the cross hedge. So, correlation between exposed commodity spot price and the future’s price of the cross commodity needs to be high, to make sure timing is right.

When hedging using a derivative of the asset whose price is the object of hedging, the natural hedge ratio is 1, if the firm wishes to mitigate all risk. That is, the firm hedges the same amount of the underlying asset that it is exposed to. When using derivatives on other assets than the one being hedged, a hedge ratio of 1 is not optimal. Instead, a Minimum Variance Hedge Ratio (MVHR) is used (Hull, 2012). The formula is given as $h^* = \frac{\rho \sigma(S)}{\sigma(F)}$, where $h^*$ is the optimal hedge ratio, $\rho$ is the correlation between the spot price and future’s price, $\sigma(S)$ is the spot price volatility as measured by spot price return standard deviation, and $\sigma(F)$ the futures price volatility analogously. Hedge effectiveness is defined as the $R^2$ of a regression of spot price returns on futures price return over the same period of time. This is also defined as $\rho^2$. The minimum variance hedge ratio reduces, as the name implies, the variance of the portfolio, as illustrated below.

![Figure 4.12: Illustration of MVHR. – Source: Hull (2012)](image)

Deviations from this could be considered speculation, e.g. if the firm increases variance deliberately to try and make a profit on the hedge (Hull, 2012).
The standard deviation ratio in the above accounts for the magnitude difference in price fluctuations between the two assets. Intuitively, if the spot price is more volatile than the futures price, the hedge ratio needs to be increased in order to account for these larger price changes.

As futures are often sold as standardized contracts, with standardized quantities of the underlying asset, one needs to calculate the number of contracts to buy, given the risk exposure and MVHR. The equation is $N^* = \frac{h \cdot Q_A}{Q_F}$, with $Q_A$ being the exposure size and $Q_F$ being the standard size of the futures contracts.

Using futures for hedging entails daily settlements. These settlements can be accounted for by $N^* = \frac{h \cdot V_A}{V_F}$, with $V_A$ and $V_F$ being the spot price and futures price, respectively. As the prices move, small adjustments would be needed. This however makes little difference in the effectiveness of the hedge (Hull, 2012). This is only if the firms use futures to hedge. Other derivatives without daily settlements, such as forwards, could be used.

As with other strategies also using futures contracts, firms are exposed to basis risk when engaging in cross-hedging. Basis risk is the difference between the spot and futures price. In a perfect market, the spot price will be equal to the futures price at the time of delivery. However, if contracts need to be liquidated at an earlier time, the price might not have converged in the expected pattern. If the prices are not moving in lock-step, this might result in a loss for the firm. This risk is of course higher when cross-hedging, as the spot price and futures price are not connected to the same asset. (Bodie, Kane, & Marcus, 2014)
5 – Data and Methodology

Data for this thesis will be split into two; price data for jet fuel and other oil products, and airline industry data. Summary statistics for all variables used can be found in appendix 1.

5.1 - Price data

For the analysis of spot price movements along with the optimal cross-hedging vehicle, spot prices of U.S. Gulf Coast Jet-Fuel are used. That is, the spot price of jet fuel sold in PADD 3, i.e. the Gulf Coast of USA (EIA, 2012). By only using U.S. Gulf Coast spot prices it is assumed that the spot price and spot price distribution is the same for all jet fuel sold around the world, i.e. market are efficient. Even though this is a strong assumption, it is a necessary one. Due to the limitations of OTC-markets, as explained earlier, complete market data on the spot price of jet fuel is not readily available.

Futures prices used are ICE (Intercontinental Exchange) futures. The futures data for the cross-hedging analysis is a combination of data from Investing.com along with QUANDL. The reason for this is the limited accessibility to historical data on both platforms. A combination of both of these allows for a larger time-series of futures prices. Great care has been taken to assure that prices are consistent and compatible between the two platforms. The futures prices used are prices on one-month futures, also called nearest-month contracts. Nearest-month is defined as futures with expiration in the next month, and delivery in the month following the expiration month. Using futures with short maturity for cross-hedge analysis is in line with the recommendations of earlier cross-hedge studies (Turner & Lim, 2015).

Due to limitations in the availability of futures prices, the data period has been set to the 3rd of May 2007 to 31st of December 2017. Data is daily, allowing for in-depth analysis as well as ability to convert data to weekly, monthly and yearly data.

5.1.1. - Data result

The number of daily observations amount to 2,795 for each commodity considered. Table 5.1 summarizes each of the price time-series of the commodities. Skewness and kurtosis are not reported, as these moments are hardly of interest with non-stationary processes like price data. Min, mean, max and standard deviation are in dollars pr. barrel.
Table 5.1: Summary statistics of jet fuel and cross-commodity candidates.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet Fuel</td>
<td>2,795</td>
<td>95.52</td>
<td>31.02</td>
<td>33.77</td>
<td>202.19</td>
</tr>
<tr>
<td>WTI Crude</td>
<td>2,795</td>
<td>76.47</td>
<td>24.17</td>
<td>26.21</td>
<td>145.29</td>
</tr>
<tr>
<td>Brent Crude</td>
<td>2,795</td>
<td>82.16</td>
<td>27.13</td>
<td>27.88</td>
<td>146.08</td>
</tr>
<tr>
<td>Heating Oil</td>
<td>2,795</td>
<td>96.62</td>
<td>29.01</td>
<td>36.36</td>
<td>172.45</td>
</tr>
<tr>
<td>Gasoil</td>
<td>2,795</td>
<td>95.69</td>
<td>30.24</td>
<td>33.19</td>
<td>177.89</td>
</tr>
</tbody>
</table>

Values are in USD pr. barrel, except N. Source: Own contribution

5.1.2. - Data validity

The price data is assumed to be of high quality, given the many data points with 10+ years of daily data points. The number of data points along with the contextual time span of the data provides a solid data foundation for analyses of return distribution and the correlation structure between jet fuel spot prices and other fuel futures. Even considering monthly data, the 128 months of data for each price is considered enough to produce valid results.

The fact that jet fuel prices is the spot price for PADD 3 jet fuel could be considered a validity problem when it comes to extending conclusions to a global scale. The problem is one inherent in the structure of OTC-markets, and one that cannot be amended; hence the problem is outside the scope of this thesis.

The futures prices are all exchange traded, and therefore assumed to be valid.

5.2 - Airline industry data

Data for the regression analysis on the airline industry is based on annual reports for each airline. The data therefore only includes public firms, due to the availability of data. Whenever the company is part of a group, group level data is used. The difference in financial years is briefly considered in the discussion but has little impact on the overall analysis.

United Airlines is the result of a merger between United and Continental Airlines in 2010. United was the acquiring company, hence the numbers for United Airlines in 2009 are numbers from United’s annual report.

Due to different reporting needs and regulations, the airlines report various measures and accounting numbers. For example, some firms report their EBITDAR, some EBITDA, some EBIT and some firms report none of these. To make data comparable, measures need to be
standardized. Operational expenses, revenue and jet fuel costs are more or less defined and reported the same way across all airlines, hence little correction was needed. As EBIT is rarely reported, this has been compiled using the income statements for each year. In this thesis, EBIT is defined as:

\[
EBIT = Revenue - OPEX - Other\ costs + other\ income
\]

One could leave out other costs and other income in the above, resulting in a different EBIT, but considering the size of these, it is unlikely that this would lead to significant different results.

Hedge ratios have been gathered by the same methodology, i.e. by scanning through annual reports. The hedge ratio is defined as the share of next year’s expected fuel that is hedged at the time of reporting. In a few instances, only the hedged amount in metric tons was stated. To calculate the hedge ratio, this amount was divided by the next year’s fuel consumption. This is an approximation of the hedge ratio that of course relies heavily on the assumption that airlines forecast their fuel needs correctly.

Other book values such as current assets, cash and cash equivalents and current liabilities are also extracted from the annual reports. These need little or no adjustments, as they are accounting standardized and thereby comparable between airlines.

Differences in currencies are not considered, as the metrics of interest are of relative character, cancelling out currencies.

Book-value of equity is easily extracted by the same annual reports, whereas market value of equity is a calculation combining information from the annual reports, with historical financial data from Yahoo Finance. To calculate the market value of equity, the number of outstanding shares (excluding treasury shares) is multiplied with the closing price of the month ending the financial year of a given company.

\[
Market\ value\ of\ equity = Outstanding\ shares \times Share\ close\ price\ at\ time\ of\ reporting
\]

Whenever a firm has multiple share classes, the number of shares for each class is multiplied with their respective price. For firms listed on multiple exchanges, the price used is the price on the home-exchange. This is only applicable if the cross-listing is managed in such a way that the same shares can be traded across the exchanges.

The number of outstanding shares used is the number recorded at the last day of the financial year. For some airlines, most often American, the number of shares at close of financial year is not mentioned. Instead, they post the number of shares at the time of filing the report. With share repurchases and sometimes issuances happening continuously throughout the year, this number is
likely not to be the same as at year end, however this discrepancy is assumed to be of minor importance, as no major share repurchase schemes were carried out in the reporting period.

The annual reports are also the source of information on instruments as well as assets used for hedging.

5.2.1. - Data result

The sample period is from 2009-2016, across 18 airlines. This results in 142 firm-year observations. Table 5.2 summarizes all the airlines used, along with the first and last observation year, and the average of net worth scaled by total assets. Spirit Airlines went public in 2011, hence there are no observations before this date.

Table 5.2: Summary statistics of the airlines included in the thesis. - Source: Own contribution

<table>
<thead>
<tr>
<th>Entity</th>
<th>First year</th>
<th>Last year</th>
<th>Average book value net worth</th>
<th>Average market cap value net worth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Canada</td>
<td>2009</td>
<td>2016</td>
<td>-8.1 %</td>
<td>11.9 %</td>
</tr>
<tr>
<td>Air New Zealand</td>
<td>2009</td>
<td>2016</td>
<td>31.2 %</td>
<td>29.3 %</td>
</tr>
<tr>
<td>AirAsia</td>
<td>2009</td>
<td>2016</td>
<td>26.4 %</td>
<td>34.5 %</td>
</tr>
<tr>
<td>Alaska Air</td>
<td>2009</td>
<td>2016</td>
<td>27.9 %</td>
<td>37.2 %</td>
</tr>
<tr>
<td>China Southern Airlines</td>
<td>2009</td>
<td>2016</td>
<td>23.2 %</td>
<td>31.3 %</td>
</tr>
<tr>
<td>Delta Airlines</td>
<td>2009</td>
<td>2016</td>
<td>9.7 %</td>
<td>11.2 %</td>
</tr>
<tr>
<td>EasyJet</td>
<td>2009</td>
<td>2016</td>
<td>42.9 %</td>
<td>55.7 %</td>
</tr>
<tr>
<td>JetBlue</td>
<td>2009</td>
<td>2016</td>
<td>30.1 %</td>
<td>36.0 %</td>
</tr>
<tr>
<td>Lufthansa</td>
<td>2009</td>
<td>2016</td>
<td>22.8 %</td>
<td>31.2 %</td>
</tr>
<tr>
<td>Norwegian</td>
<td>2009</td>
<td>2016</td>
<td>18.6 %</td>
<td>34.4 %</td>
</tr>
<tr>
<td>Qantas</td>
<td>2009</td>
<td>2016</td>
<td>25.1 %</td>
<td>33.6 %</td>
</tr>
<tr>
<td>Ryanair</td>
<td>2009</td>
<td>2016</td>
<td>35.7 %</td>
<td>59.1 %</td>
</tr>
<tr>
<td>SAS</td>
<td>2009</td>
<td>2016</td>
<td>24.0 %</td>
<td>18.2 %</td>
</tr>
<tr>
<td>Singapore Airlines</td>
<td>2009</td>
<td>2016</td>
<td>58.5 %</td>
<td>38.1 %</td>
</tr>
<tr>
<td>Southwest</td>
<td>2009</td>
<td>2016</td>
<td>37.1 %</td>
<td>53.8 %</td>
</tr>
<tr>
<td>Spirit Airlines</td>
<td>2011</td>
<td>2016</td>
<td>57.7 %</td>
<td>78.7 %</td>
</tr>
<tr>
<td>Turkish Airlines</td>
<td>2009</td>
<td>2016</td>
<td>30.6 %</td>
<td>28.5 %</td>
</tr>
<tr>
<td>United Airlines</td>
<td>2009</td>
<td>2016</td>
<td>6.7 %</td>
<td>26.3 %</td>
</tr>
</tbody>
</table>

5.2.2. - Choice of independent variables for hedge ratio regression analysis

Net worth is, in line with Rampini, Sufi & Viswanathan (2014), chosen to be both the equity-to-assets ratio based on the book-value of equity and the market cap. That is, net worth is considered as the accounting term and as the market valuation term. Since book-value of equity is an accounting number, it is possible for this to be negative, as evident by the resulting firm data. Absolute values of net worth are not considered as explanatory variables, as ratios will better capture the financial health of the companies and make it comparable. Besides net worth measures, the following measures are also collected or computed from the annual reports.
The current ratio and quick ratio are computed, using current assets, current liabilities and cash and cash equivalents from the balance sheets. The debt level is considered as an independent variable; the amount of short- and long-term debt, scaled by total assets. Net finance cost of debt scaled by revenue is also included.

Table 5.3 below contains summary statistics of these statistics along with summary statistics on fuel costs relative to OPEX, and OPEX relative to revenue.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hedge Ratio</td>
<td>142</td>
<td>36 %</td>
<td>28 %</td>
<td>0</td>
<td>95 %</td>
</tr>
<tr>
<td>Book-value net worth</td>
<td>142</td>
<td>27 %</td>
<td>17 %</td>
<td>-42 %</td>
<td>65 %</td>
</tr>
<tr>
<td>Market-cap net worth</td>
<td>142</td>
<td>37 %</td>
<td>20 %</td>
<td>2 %</td>
<td>90 %</td>
</tr>
<tr>
<td>Current Ratio</td>
<td>142</td>
<td>0.985</td>
<td>0.414</td>
<td>0.203</td>
<td>2.202</td>
</tr>
<tr>
<td>Quick Ratio</td>
<td>142</td>
<td>0.513</td>
<td>0.356</td>
<td>0.061</td>
<td>1.730</td>
</tr>
<tr>
<td>Debt level</td>
<td>142</td>
<td>31 %</td>
<td>14 %</td>
<td>0 %</td>
<td>66.7 %</td>
</tr>
<tr>
<td>Net finance cost of debt</td>
<td>142</td>
<td>1.6 %</td>
<td>1.8 %</td>
<td>-3.1 %</td>
<td>9.3 %</td>
</tr>
<tr>
<td>Fuel cost relative to OPEX</td>
<td>142</td>
<td>31 %</td>
<td>8 %</td>
<td>15 %</td>
<td>53 %</td>
</tr>
<tr>
<td>OPEX relative to revenue</td>
<td>142</td>
<td>91 %</td>
<td>8 %</td>
<td>69 %</td>
<td>125 %</td>
</tr>
</tbody>
</table>

Table 5.3: Summary statistics of the variables used for regression analysis, along with fuel costs relative to OPEX, and OPEX relative to revenue. - Source: Own contribution

Notice the large standard deviation for hedge ratio and the net worth measures. Looking at this table, it would seem the data includes enough variation to explore a relationship between hedge ratio and net worth.

5.2.3. - Data validity

The validity in question when it comes to the airline data is that of internal validity. Internal validity is whether the results of the analysis can be said to be valid for the population of the sample (Stock & Watson, 9.1 Internal and External Validity, 2012). The data validity is considered high in this aspect, as the sample includes firms from all over the world, as well as both small and large firms. The data exhibits enough variation to enable exploration of the relationships in question. If data had little variation, it is uncertain how well the data would perform when testing for significant relationships.
The only part of the data that is of lower quality than the rest is the market cap data. This is due to the few firms where number of shares were reported the date the report was closed and made public. This creates a discrepancy between the book value of equity and the market cap, as these are not stated the same date.

The sample size is considered large enough to reach statistically significant conclusions. Regardless of the assumption, t-statistics and thereby the significance tests take the sample size into account. However, to compute the tests, one needs to assume that the estimators are t-distributed. The central limit theorem states that this is, to some extent, true for large samples of data. It is assumed that the sample size here is sufficient in creating t-distributed variables. In any case, the critical values used for hypothesis testing will take the sample size into account.

5.3 - Methodology

It is assumed that the reader has knowledge of statistics at a basic level. Hence the following will only explain what is considered outside the scope of basic statistics knowledge.

5.3.1. - Jet fuel prices

The jet fuel price analysis will start off with a visual analysis of the price levels. No clear methodology is used, as this is purely a visual analysis.

To analyze returns on spot prices as well as futures prices, the returns are calculated both as regular (simple) returns, and as logarithm returns. Taking the logarithm has some implications for the results. First of all, growth in the price level is de-exponentialized, allowing for a better visualization of growth, something that will become evident in the respective analysis. The logarithmic return is calculated using:

\[ R_t = \ln(P_t) - \ln(P_{t-1}) \]

One downside to log returns are that positive and negative changes are not evenly affected by taking logs. Negative returns have a bigger impact than positive returns do. This effect is larger, the larger the changes are. That is, for small returns, log returns are a good estimator of the simple return. For larger returns, the estimate differs from the simple return. Since jet fuel prices exhibit large volatility, simple returns are considered for most analyses, but log returns are also included when applicable.

Several distributions are considered as the population distribution of jet fuel price returns. To determine the best-fitting distribution, maximum likelihood estimation is used, using log-likelihood
as the information criterion. The model with the highest log-likelihood measure is the best estimate of the distribution. One can interpret this as a measure of how likely it is to obtain the given sample, given the distribution in question (Rupert & Matteson, 5.2 Parametric Models and Parsimony, 2015).

Another way to visualize this, is by using quantile quantile plots (qqplots). The qqplot plots theoretical quantiles of a given distribution, against observed quantiles in the sample data. In order for the distribution to fit the data, the plot has to form a straight line.

GARCH extensions are used to test whether volatility clustering is present, since GARCH allows for modelling of conditional volatility in time series. Models are of the specification ARIMA(p_m, d, q_m)+GARCH(p_v, q_v), with p, d and q being the number of lagged parameters included. The GARCH error model specification is (Ruppert & Matteson, 2015):

\[ a_t = \sigma_t \varepsilon_t \]

With \( \sigma_t \) being:

\[ \sigma_t = \sqrt{\omega + \sum_{i=1}^{p_v} \alpha_i \cdot a_{t-i}^2 + \sum_{j=1}^{q_v} \beta_j \cdot \sigma_{t-j}^2} \]

\( a_t \) takes the place of the error term in the ARIMA model, hence it is the deviations from the mean model. Though the above looks frightening, it is quite intuitive. \( \alpha \) allows for the volatility to depend on previous deviations from the mean model, and \( \beta \) allows volatility to depend on the previous value of volatility. The sum of these two parameters is called the persistence and give an idea of how long-lived volatility clusters are; the closer to 1, the longer volatility clusters persist (Ruppert & Matteson, 2015).

For ARIMA and GARCH models, the choice of information criterion is often between either AIC or BIC as information criteria. As more parameters are added to the models, the maximum likelihood will increase, hence the criteria both penalize the models for adding more parameters. For an added parameter to be included, the marginal added likelihood has to exceed the penalty of adding the new parameter. BIC is more conservative than AIC, penalizing the models more for each added parameter. To choose the best model, one must choose the model with the lowest AIC or BIC, whichever information criteria is chosen (Ruppert & Matteson, 2015).

To determine if data is stationary, the Augmented Dickey Fuller test and the Ljung Box test are employed. Augmented Dickey Fuller tests the presence of a unit root, whereas Ljung Box tests whether x lags of autocorrelations can be considered 0.

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5.3.2. - The use of derivatives

The methods used in the analysis of the use of derivatives are quite simple, as it is a somewhat cross-sectional analysis of the industry. The analysis seeks to determine the most common hedging practices in the industry, whether any patterns in the use of derivatives exist and also the implications of the use of the derivatives. Lastly, one company is chosen to constitute a detailed case study.

5.3.4. - Cross-commodity hedging

For cross-commodity hedging, the Minimum-Variance Hedge-Ratio (MVHR) is used to determine the hedge ratio at any point in time:

$$h^* = \frac{\rho \sigma(S)}{\sigma(F)}$$

As evident by the equation, correlations and standard deviations need to be estimated. For this, various lag periods are considered. The longer the period these numbers are calculated over, the more stable the parameters will be throughout. However, this also means that temporary structural breaks in the value of these parameters are not picked up. The trade-off then lies between stable estimates, and more estimates that better show the changes in these parameters throughout time. To determine the effectiveness and robustness of such a hedge, the strategy is back-tested on the actual data. When back-testing it is important to have timing in mind. That is, when is information public, and when can the firms react on this and implement changes. This will often mean that decisions are based on time-lagged values of the decision variable (correlation and standard deviation in this case). Transaction costs will not be included in the calculations but will be mentioned in the section nonetheless.

The measure used to determine the best suited commodity for cross-hedging is the $R^2$ value of a simple linear regression. The linear regression is constructed as the jet fuel price returns ($R_S$) regressed on the cross-commodity futures price returns ($R_F$). That is:

$$R_S = \beta_0 + \beta_1 * R_F + \epsilon$$

For strategies not easily approximated by linear regression, an $R^2$-analogue is computed:

$$R^2 = 1 - \frac{SSE}{SST} = 1 - \frac{Var(R_h)}{Var(R_S)}$$

With $R_h$ being the return of the hedged portfolio, and $R_S$ being the return of the spot jet fuel prices. The best strategy is the one achieving the highest $R^2$ value.
5.3.5. - Hedge ratio analysis

To analyze the relation between net worth and hedge ratio, several regressions are computed. First, a simple regression on the data as a whole (i.e. considering the data as cross-sectional) is computed. After this, a regression with entity and time fixed effects is computed. The purpose of entity fixed effects is to control for unobserved variables that vary across entities but not across time for these entities (Stock & Watson, 2012). Doing this allows for better estimation of the isolated effect of other independent variables, by omitting constant differences between the firms. Entity fixed effects are implemented by including a dummy variable for each entity, or in this case, each airline. The regression method used is a general OLS regression.

The population model is:

\[ Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_i \]

With \( \beta_0 \) being the intercept, \( \beta_1 \) is the coefficient of the independent variable of interest, and \( \beta_2 \) is the entity fixed effects coefficient, the unobserved characteristics. The fact that it is entity fixed, that is constant across time, is evident by the lack of the time subscript on the variable, \( Z \).

The fixed effect regression model defines another term, \( \alpha_i = \beta_0 + \beta_2 Z \), the entity fixed effects themselves. The regressions model is then:

\[ Y_{it} = \beta_1 X_{it} + \alpha_i + \epsilon_{it} \]

This essentially creates an intercept for each entity in the model but with the same average effect of the independent variable on the dependent variable. The entity fixed effects term can be expanded to show all dummy variables for each entity. Note that when doing this, it is important to leave out one of the entities to avoid the dummy variable trap. The model is then:

\[ Y_{it} = \beta_0 + \beta_1 X_{it} + \gamma_2 D2_i + \gamma_3 D3_i + \cdots + \gamma_n Dn_i + \epsilon_{it} \]

, with \( n \) being the number of entities in the sample.

The two equations are identical in the resulting estimate of \( \beta_1 \), the coefficient of interest.

The same logic and method can be applied to a time variable, resulting in an entity and time fixed effects regression.

A word of warning: variables that are correlated with X, and change over time, need to be included in the regression. If not, these will enter into the dummy variables (as these include all unobserved Y variables), and affect the estimation process, resulting in omitted variable bias (Stock & Watson, 2012). However, for omitted variable bias to be present, the variable also needs to have some explanatory effect on the dependent variable. Omitting the variable violates one of the regression assumptions, and thereby gives a biased regression estimate. A positively correlated omitted
variable overstates the effect of the already included variable on the dependent variable. The opposite is true of negatively correlated omitted variables (Stock & Watson, 2012).

Ordinary t-tests are used to tests whether a single coefficient is significant. The t-statistic of a regression estimate is calculated by (Newbol, Carlson, & Thorne, 2013):

$$ t_\beta = \frac{\hat{\beta} - \beta_h}{s.e.\hat{\beta}} = \frac{\hat{\beta}}{s.e.\hat{\beta}} $$

With $\beta_h$ being the hypothesized beta, in this case 0, hence why it exits the equation.

To avoid problems of heteroskedasticity, robust standard errors are used for hypothesis testing. These will, in most cases, be more conservative than normal OLS standard errors. However, in some cases the robust standard errors might be less conservative, depending on the correlation between the squared residuals and the independent variables. Nonetheless, robust standard errors are assumed to produce better results with the aim of hypothesis testing, hence these are the ones used in the analysis. Even if heteroskedasticity is not present, robust standard errors will be close to the standard error estimates of OLS and will not alter the coefficient estimates.

Besides testing for the significance of just one variable, it is possible to test whether several variables can be considered to be insignificant; a test on a subset of covariates. The test is carried out by computing the F-statistic (Newbold, Carlson, & Thorne, 2013):

$$ F = \frac{(SSE(R) - SSE)}{\frac{SSE}{n-k-1}} $$

, where SSE(R) and SSE are the Sum of Squared Errors of the restricted model and the full model, respectively, with restricted meaning the model without the excluded variables. n is the number of observations, k is the number of variables in the full model and R is the number of excluded variables in the restricted model; the model subset that is tested. The null-hypothesis of the test is that the restricted model is better, and the alternative hypothesis is that the extra variable (R) improves on the prediction of the dependent variable. Formally it can be written as:

$$ y = \beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k + A_1 z_1 + \ldots + A_R z_R + \epsilon $$

, which is the model in question, with $\Lambda$ being the subset variables tested to be equal to zero. The hypothesis of testing the simultaneous significance of a subset of variables is then stated by:

$$ H_0: A_1 = A_2 = \ldots = A_R = 0 $$

$$ H_1: At least one \ A_j \neq 0 \ (j=1, \ldots, R) $$
The critical value of the test is $F_{R, n-k-r-1, \alpha}$. If the F statistic exceeds the critical value, $H_0$ is rejected, and $H_1$ is accepted as being true.

The above assumes that the residuals of the model are normally distributed. Using heteroskedastic robust methods, the test statistic is approximated by $F^{*}R$, and the critical value is instead $\chi^2_{R, \alpha}$.

The method is applied to year fixed effects in the hedge ratio analysis.

When considering multiple models, $R^2$-adjusted is the coefficient of determination, or the indicator of which model best fits the data, i.e. the explanatory power. $R^2$-adjusted indicates how well the independent variables explain the dependent variable, while penalizing the model for each variable included in the model.

The regression models can be easily run in RStudio, the statistical computing program used in this thesis. The output reported in this thesis does not include the entity coefficients themselves, however these can be found in the appendix 4.
6 - Jet Fuel Price Analysis

The following section consists of an analysis of jet fuel price levels and jet fuel price returns. Findings in the following serve to emphasize the importance of risk management and jet fuel price hedging in the airline industry, in relation to the nature and magnitude of the risk exposure. The analysis starts with a short visual analysis of the jet fuel price levels, both in real and log form, as a deep dive quantitative analysis of these make little sense, due to the non-stationarity of levels data.

The analysis then moves on to a return analysis. The return analysis aims to identify the distribution of returns, as well as the volatility of the returns, and the potential of volatility clustering.

6.1 - Jet fuel price levels

![Jet fuel price levels chart]

Figure 6.1: Daily jet fuel spot prices, USD pr. gallon. Data range: 3rd of May 2007 to 29th of December 2017 –
Source: Own contribution

Figure 6.1 depicts the daily jet fuel spot prices in dollars pr. gallon. The graph indicates periods ranging from 1-3 years with trends, but there is no clear and persistent trend during the entire period. From around start 2011 to mid 2014, the price was seemingly stable around a price of just under $3 pr. gallon. Other than that, the price is continuously changing.

The lowest price recorded in the period was $0.804 pr. gallon the 20th of January 2016, whereas the highest price recorded was $4.814 pr. gallon on the 12th of September 2008. That is, the maximum price is about 6 times as large as the minimum price.
Data shows no evidence of seasonality, however there are multiple highs and lows in the price. Most prominent is the spike following the fall of September 2008. Within only a few days, the price reached the highest jet fuel price in history, succeeded by a fall to a long time low. After the stable period of primo 2011 to mid 2014, the prices took another drastic fall, though over a longer period of time than the 2008 incident.

Figure 5.2 illustrates the same jet fuel prices, but log-transformed. Log-transforming data makes it easier to visualize percentage changes, as relative changes now show up with the same size on the y-axis.

Note that the rapid rise and fall in 2008 now look different. The increase does not seem as extreme, as the subsequent decrease. There are two sides to this story. First of all, the relative sizes of the decrease are now more or less the same. On a normal level graph, a 10 % decrease will look more extreme if the level was 100, than if it was 50, but on a log graph these would look the same, i.e. the y-axis difference would be the same. Another thing to have in mind is that large positive changes are smaller in log return, and large negative returns are larger in log returns. This is one of the deficiencies of using log prices. The sharp rise of 38% in real returns in 2008 is now 32% using log prices. The following decrease is 24% in real terms but 27% in log terms.

For the rest of the period however, returns were much smaller, and hence this effect of using log prices is also much smaller. For large changes such as 8%, the difference is only about 0.4 percentage points. Using log prices clearly illustrate greater volatility, since the price movements from 2014 and going forward are bigger than what the first graph depicts.

Figure 6.2: Log transformed daily jet fuel spot prices, USD pr. gallon. Data range: 3rd of May 2007 to 29th of December 2017 - Source: Own contribution
As with other financial data, looking at returns often makes more sense when determining characteristics of the data. Price returns allows for computations of various summary statistics, often of greater moments, since return data is assumed to be stationary. Jet fuel price data itself is not stationary, hence statistics like mean and skewness make little sense. The graphs above are however still important in understanding the impact jet fuel prices can have on airlines.

Going forward, the analysis will make use of simple returns, and not returns calculated by the log approximation.

6.2 - Jet fuel price returns distribution
Data is often assumed to be normally distributed, as this makes hypothesis testing possible and very straightforward. For financial data, the assumption rarely holds in reality. Financial data often has heavier tails than normal distributions and is in some cases skewed (Rupert & Matteson, 5.5 Heavy-Tailed Distributions, 2015). With that in mind, the following will explore the distribution of jet fuel price returns to identify the distribution of jet fuel returns. The models tested in the following are a normal distribution, a student t-distribution and a skewed student t-distribution. To determine the best matching distribution, the log-likelihood measure is used. However, before delving into the distribution analysis, one must first make sure data is stationary. Data can be either a non-stationary, a weakly stationary and a strong stationary process. If data is only weakly stationary, mean and variances will be constant over time, however other moments might change with time. The Augmented Dickey-Fuller test is used to test the hypothesis of stationarity. The null-hypothesis of this test is that data has a unit-root, and is therefore not stationary. If the null-hypothesis is rejected, data is considered stationary. The result of the test is:

```
Augmented Dickey-Fuller Test

data:  Jet_fuel_price$Change
Dickey-Fuller = -13.438, Lag order = 14, p-value = 0.01
alternative hypothesis: stationary
```

Figure 6.3: Augmented Dickey-Fuller Test of Jet fuel price returns output from RStudio.
– Source: Own contribution

As the p-value is below 0.01 (RStudio will not print lower p-values for the ADF test), the null-hypothesis is rejected, and data is considered stationary. The same conclusions can be reached by looking at the data itself in figure 6.4 below, along with the ACF plot in figure 6.5.
Figure 6.4: Daily jet fuel price return. Data range: 4th of May 2007 to 29th of December 2017
- Source: Own contribution

Figure 6.5: Daily jet fuel price returns ACF (Autocorrelation Function) plot
- Source: Own contribution

Though data exhibits stationarity around a mean of 0 in figure 6.4, the notion of stationary variance is up for discussion. The analysis turns to this later on, hence data will be considered stationary for now.

The only concerning lag in figure 6.5 is lag 2. This is slightly outside of the confidence interval lines. Running a Ljung-Box test reveals that the autocorrelations are considered to be 0 at a 5% confidence level, but not at a 1% confidence level.

Seeing as it is only one lag and a very small autocorrelation, stationarity is assumed.

Now that data can safely be regarded as stationary, the distribution models can be tested. The table below summarizes the parameterization of each of the three models, using maximum likelihood estimation.
Table 6.1 indicates that the skewed student t-distribution is the best choice of model, however the log-likelihood difference is quite small when comparing to the student t-distribution. As with other models in finance, and models in general, a trade-off exists between complexity and usefulness. A “cost-benefit” analysis could be carried out to consider whether the improvement in log-likelihood more than offsets the increased complexity. With a difference of this negligible size, the student t-distribution is accepted as the appropriate model of the return. Nonetheless, the positive skewness is acknowledged. The positive skewness indicates a heavier positive tail, i.e. higher possibilities of positive returns than negative returns.

Plotting the distribution curves of the normal and student t-distribution in figure 6.6 emphasize the difference between the two distributions. The red and blue lines are the student t-distribution and the normal distribution, respectively.

![Figure 6.6: Probability density functions. Student t-distribution, normal distribution, centered and right tail displayed.](image)

Looking at the graph above, it is clear that the student t-distribution has a higher kurtosis, i.e. more mass over the mean, but also longer tails. The longer tails become more evident when zooming in on the tails, seen in the right panel of figure 6.6.
The skewed student t-distribution is not included in the graphs above, as it differs only slightly, and is almost indistinguishable from the student t-distribution.

As a final test, one can compare qqplots of the two different distributions, as seen in figure 6.7:

![Figure 6.7: Quantile quantile plots of the student t-distribution (left) and the normal distribution (right).](source)

The aim of qqplots is to see whether theoretical quantiles of a given distribution match the actual quantiles of the sample. If the plot forms a straight line, the sample fits the theoretical quantiles (cf. section 5.3 - methodology). Looking at the normal quantile plot on the right, the data seems to fit a normal distribution quite well along the middle quantiles. However, the problem arises when one moves toward the far ends of the quantiles. For both the negative and positive theoretical quantiles, the tails are heavier in the jet fuel price return data. The left graph shows a much clearer linear relationship, without any worrying deviations. The only deviations are the extreme returns from 2008, amounting to about 5 or 6 extreme observations, of a sample size of 2794 data points. With this in mind, along with the arguments from earlier, the student t-distribution is considered the appropriate model of the jet fuel price return distribution.

Figure 6.8 displays daily jet fuel spot price returns. The red lines are the 95% confidence intervals of the previously identified student t-distribution.
Confidence intervals are calculated using the equation:

$$[\mu - \sigma \cdot t_{1-\alpha/2}; \mu + \sigma \cdot t_{1-\alpha/2}]$$

With $t_{1,\alpha/2}$ being the critical value of the 95% confidence interval for the student t-distribution; 3.18 in this case. That is, 95% of observed jet fuel price returns should fall within the interval of $+\pm 3.18$ standard deviations of the mean. For a normal distribution, this would be between -1.96 and 1.96; a result of the difference in the probability distributions. Note that these confidence intervals are based on parameterization. These intervals contain more than 95% of the data in the above, since parameterization does not always equal the observed data.

The average return is 0%, and the daily standard deviation is 2.34%, resulting in a 95% confidence interval of $[-7.44\%; 7.44\%]$. Table 6.2 summarizes standard deviations and confidence intervals for daily, monthly and yearly returns.

<table>
<thead>
<tr>
<th></th>
<th>Daily</th>
<th>Monthly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation</td>
<td>2.34 %</td>
<td>9.91 %</td>
<td>35.85 %</td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td>[-7.44%7.44%]</td>
<td>[-31.51%31.51%]</td>
<td>[-114.03%114.03%]</td>
</tr>
</tbody>
</table>

*Table 6.2: Standard deviation and confidence intervals for daily, monthly and yearly jet fuel price returns*

As evident by the table, the yearly standard deviation is quite high, at 35.85%.

According to the IFRS standards (2005), firms are required to do sensitivity analyses of their risk exposure. The sensitivity analysis used by most firms is a 10% change, both positive and negative,
on jet fuel prices. With a yearly volatility of the above magnitude, this “stress” is hardly enough to truly show the exposure of the firms in the industry. The sensitivity level is set by each entity themselves, and the only requirement is that it is “reasonably possible” (IASCF, 2005).

This standard deviation used so far is on the full period, and as can be seen in figure 6.8, volatility differs throughout the time period. If standard deviation is calculated on the daily historical returns lagged up to one year, the minimum standard deviation is 1.02% and the maximum is 4.63%.

That is, yearly volatility is at least 16.6% (by approximation) using this method. Still with this volatility, the 10% stress is not even one standard deviation from the mean return. IASCF (2005) states that the change interval should not be worst case or stressed. However, an interval that is not even one standard deviation from the mean is hardly a sensitivity analysis. Of course, this depends very much on the definition of what is “reasonably” possible.

In the data used for this analysis, about 70% of the year-on-year returns exceed this [-10%; 10%] interval. That is, in this period, it was more likely for the return to be outside of the interval than within it. This would indicate that the return interval is indeed too narrow.

6.3 - Time series analysis and volatility clustering

In the previous section, the distribution of jet fuel price returns was determined. In this section, jet fuel returns will be analyzed as a time series as to identify the presence of volatility clustering. As noted earlier, jet fuel returns are stationary, hence this need not be considered once more in this section.

RStudio has a function called “auto.arima”, and by running this, using BIC as information criterion, results in an ARIMA(0,0,0) model. Considering most ARIMA models of financial data are with 1 or 2 orders, this model is quite interesting and could indicate the need of an ARCH or even GARCH extension. Using AIC, the optimal model is an ARIMA(0,0,3) model. This level of MA is quite high and could once again indicate the need for ARCH or GARCH model.

GARCH models allow for volatility to be conditional of time, i.e. the volatility is not unconditional.

By testing different model specifications, the optimal ARIMA+GARCH model of jet fuel returns is an ARIMA(0,0,0) with a GARCH(1,1) extension. The BIC score for the ARIMA(0,0,0) model is -4.6583, whereas it is -5.0408 for the model with the GARCH extension. Though a small difference, it does indicate some autocorrelation between the conditional volatility of jet fuel price returns, indicating volatility clustering is present, just as data would suggest in figure 6.8. An
ARIMA process of order (0,0,0) indicates that jet fuel prices follow a random walk. According to the ARIMA(0,0,0) model, the best guess of the jet fuel return tomorrow is the mean return plus some unknown shock known as the error term.

The estimates for the GARCH parameters $\alpha$ and $\beta$ are 0.0829 and 0.9131, respectively. The $\alpha$ parameter is an indicator of how much past return shocks affect the volatility of today. The $\beta$ parameter is a measure of how quickly the volatility shocks die out (cf. section 5.3 – Methodology). With an estimate of 0.9131, volatility decays slowly over time. For this model, the persistence, i.e. the sum of $\alpha$ and $\beta$, is 0.996, which is considered a high persistence.

In conclusion, the time series analysis indicates that future jet fuel returns are uncorrelated to past returns, and therefore the mean return of 0% is the best guess of the return tomorrow. The volatility exhibits volatility clustering, meaning that the conditional volatility is correlated with lagged values of the conditional volatility.

The visual analysis of jet fuel prices indicates only short-lived random trends. The range of prices during the sample period was wide, with the maximum price being almost six times as high as the lowest. Even though this is over a long period, and prices were not constant at these levels, such a price difference is alarming for airlines with jet fuel is about 31% of the operational expenses.

In accordance with financial theory (Rupert & Matteson, 2015), the jet fuel price returns distribution is determined to have fat tails, indicating a higher possibility of large price changes. Monthly and yearly confidence intervals were determined to be $[-31.51\%; 31.51\%]$ and $[-114.03\%; 114.03\%]$ at a 95% confidence level. Comparing these confidence intervals to the sensitivity analysis of the airlines indicate that sensitivity analyses need to be revised with higher “stress” levels.

Both the visual analysis and the following time series analysis find evidence of volatility clustering. The ARIMA parameters are all determined to be 0, but a GARCH model is fitted, with high persistence. That is, increases in volatility are generally long-lived in the data. The fact that the ARIMA parameters are all 0 leads to the conclusion that historical jet fuel price returns contain little information on future returns.

With jet fuel prices exhibiting no clear trends, high volatility and volatility clustering, firms are considered highly exposed to cash flow risk. The high risk in terms of volatile prices coupled with low profit margins further boost the attractiveness of hedging in the airline industry.
7 - The Use of Derivatives

As explained in section 4, a vast variety of derivatives exist and by combining them, the possibilities are infinite. That being said, the airline companies in this sample have rather clear preferences of derivatives. To put it straightforward, the airlines’ typical (hedging) portfolios consist of options on crude oil as well as collars and swaps on jet fuel. Besides these more prevalent strategies; puts, collars, cracks, spreads, forwards and futures are being sporadically applied. Heating oil and gasoil are also being used as the underlying assets occasionally. The different derivative strategies are explained in more detail below.

Air New Zealand, referred to as Air NZ in the following, has been chosen as a case study due to its extensive degree of details on their hedge portfolio. The company releases a one-pager quarterly\(^6\) comprising their fuel hedge positions at a specific date, expounding their current use of derivatives. The one-pager includes detail such as the underlying assets of the derivatives, the amount hedged, the prices of the derivatives and the expected fuel consumption of the next year. All the one-pagers chosen here are from April or May in its respective years.

Air NZ follows different strategies over the examined period with a frequently changing and diverse portfolio of derivatives. Looking into their strategies somewhat chronologically, with particular weight on the years where new derivatives are being introduced, yields the following discoveries.

In April 2009 (“Fuel Hedge Position as at 21 April 09”), the firm engaged in three different types of derivative strategies on two different fuels: WTI Collars, WTI bought put spreads, Singapore Jet bought puts and Singapore Jet Collars.

The exact prices and amounts for FY09 Q4\(^7\) are summarized in table 7.1. Particularly, the Singapore Jet Collars stick out with regards to its magnitude; approximately 85% of the total hedge ratio of 79% of next quarter’s estimated fuel consumption.

\(^6\) Can be found in their investor relations, cf. bibliography

\(^7\) Their fiscal years are different from calendar years.
A traditional (costless) collar is a combination of a bought call option which constitutes the ceiling (or cap), and a sold put option which is the floor (Mercatus Energy Advisors, 2016). In other words, the call option secures the airline company when jet fuel prices are appreciating, and the put option is sold to finance the price of the call, consequently rendering the collar costless. The ideal situation for the airline company is when the jet fuel prices end above the call’s strike price, which is equivalent to a saving in jet fuel costs. The worst situation is when the jet fuel prices end below the put’s strike price, meaning the company cannot reap the (full) benefits of lower jet fuel prices. Between the two strike prices, none of the options are in the money, and thus will not be exercised, and the airline company will have to buy the jet fuel in the spot market directly. Collars come in different variants, the most notable forms being the three- and four-way collars. The former is simply a traditional, costless collar from above with another added put option, and the latter follows. It is a way of reducing downside risk in that the airline company now has two floors with different strike prices. When jet fuel prices are declining, the airline pays less (two different prices) for the jet fuel that it is obliged to buy (sold put) from its counterparties. The four-way collar, obviously, has three floors, i.e. three different sold put options.

As a concrete example of collars, the Singapore Jet Collars’ FY09 Q4 numbers from Air New Zealand’s April 2009 fuel hedge positions constitute the graph in figure 7.1:
Air NZ has (jet collar) hedged approximately 1.2m barrels of jet fuel at a ceiling price of USD 104.97 and a floor price at USD 88.21. At prices between USD 88.21 and USD 104.97, none of the options will be exercised. Below USD 88.21, Air NZ will have to pay exactly 88.21 per barrel (sold put), regardless of the actual price of the jet fuel. Above USD 104.97, Air NZ will be able to buy the jet fuel at USD 104.97 (bought call), regardless of the actual price of the jet fuel.

The last derivative from April 2009 that needs to be introduced is the put spread. A put spread is created by simultaneously buying and selling an equal number of put options with different strike prices (The Options Guide, 2017). The resulting portfolio has, like collars, both a ceiling and a floor price. Air NZ writes in its fuel hedge positions’ notes that it uses its puts to partially offset the losses generated from its established collar hedges should the markets continue to fall.

The above analysis focuses on the nearest quarter, April to June 2009, but later on, the hedge ratio for the next (fiscal) year is of interest.

In Air NZ’ April 2009 hedge report (“Fuel Hedge Position as at 21 April 09”), looking at ‘FY10 Total’ (see table 6.3) yields rather different results. The hedge ratio is 27%, and WTI Collars now constitute around 77% of that with Singapore Jet Collars making up the remainder. The WTI Collars only differ from Singapore Jet Collars on the type of fuel (and consequently the price).
same graph as above (figure 7.1) can be drawn with a ceiling of USD 60.94 and a floor of USD 36.70 per barrel of WTI crude oil.

The difference between next quarter’s and next fiscal year’s hedge ratio is in line with received hedging theory (Turner & Lim, 2015). Due to highly volatile markets, it is considered unnecessarily risky to hedge over longer periods of time in that the strike prices easily get out of step with the actual fuel markets. The different choices of fuel types next quarter and next fiscal year are similarly sound. Singapore Jet is not traded on any known exchange and consequently, other things equal, has higher transaction costs, less transparency and, most importantly, is less liquid. Therefore, when the horizon is longer, the airline might prefer the more standardized and tradeable alternative; WTI crude oil. Though, the choice of WTI, which then works as a cross-hedging commodity, incites some other issues; particularly hedge effectiveness based on correlations and volatilities.

In Air NZ’ 2011 hedge report (“Fuel Hedge Position as at 19 May 2011”) only one derivative strategy on two different types of fuels is applied; WTI collars and Singapore Jet collars. They were both introduced above, and the 2011 report is included to showcase the high (short-term) hedge ratio of 95%, and Air NZ’ large hedging gains (see table 7.2 below).

<table>
<thead>
<tr>
<th>Units</th>
<th>FY11 Q4</th>
<th>Total FY12</th>
<th>Total FY12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Apr-Jun</td>
<td>1st Half</td>
<td>2nd Half</td>
</tr>
<tr>
<td>WTI collars</td>
<td>Barrels</td>
<td>1,280,000</td>
<td>2,692,500</td>
</tr>
<tr>
<td>Volume</td>
<td>USD</td>
<td>87.42</td>
<td>100.82</td>
</tr>
<tr>
<td>Ceiling Price</td>
<td>USD</td>
<td>77.19</td>
<td>97.38</td>
</tr>
<tr>
<td>Floor Price</td>
<td>USD</td>
<td>300,000</td>
<td>98.37</td>
</tr>
<tr>
<td>Singapore Jet collars</td>
<td>Barrels</td>
<td>89.29</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>USD</td>
<td>300,000</td>
<td></td>
</tr>
<tr>
<td>Ceiling Price</td>
<td>USD</td>
<td>98.37</td>
<td></td>
</tr>
<tr>
<td>Floor Price</td>
<td>USD</td>
<td>89.29</td>
<td></td>
</tr>
<tr>
<td>Total hedged</td>
<td>Barrels</td>
<td>1,580,000</td>
<td>2,692,500</td>
</tr>
<tr>
<td>Estimated fuel consumption</td>
<td>Barrels</td>
<td>1,662,444</td>
<td>3,858,111</td>
</tr>
<tr>
<td>Hedge ratio</td>
<td>95%</td>
<td>70%</td>
<td>10%</td>
</tr>
<tr>
<td>Compensation from fuel hedges (1)</td>
<td>USD</td>
<td>31,035,000</td>
<td>11,256,000</td>
</tr>
<tr>
<td>Purchase cost of options</td>
<td>USD</td>
<td>(4,238,759)</td>
<td>(7,442,075)</td>
</tr>
<tr>
<td>Net compensation from hedges (2)</td>
<td>USD</td>
<td>26,796,241</td>
<td>3,813,925</td>
</tr>
</tbody>
</table>

Table 7.2: Air New Zealand hedge positions as of 19th of May 2011. - Source: Air New Zealand (2011) - “Fuel Hedge Position as at 19 May 2011”

As before, their hedge ratio is markedly lower in the fiscal year 2012 than in the nearest quarter (40% and 95%, respectively) but they are no longer as invested in jet fuel hedging contracts as before (less than 20% short-term and 0% next fiscal year). It seems that Air NZ has changed its strategy in that hedging jet fuel directly was a large part of their total hedge ratios presented in 2009 and 2010, as opposed to 2011.
Lastly, in Air NZ’ 2013 hedge report (“Fuel Hedge Position as at 8 May 2013”) three different derivatives on two different fuels are applied. The Brent Swaps account for around 55% of the current quarter’s hedge ratio of 78%, and around 28% of the 29.5% hedged expected fuel consumption in the 2014 fiscal year.

A swap is not an actual strategy and has therefore been introduced in the derivatives section above and, consequently, Air NZ’ use of swaps will only be shortly examined here.

Air NZ has Brent Swaps (“Fuel Hedge Position as at 8 May 2013”) with a strike price of USD 107.76 per barrel of Brent crude oil for its FY13 Q4 (see table 7.3 below).

<table>
<thead>
<tr>
<th>Units</th>
<th>FY13 Q4 Apr-Jun</th>
<th>Total FY14 1st Half</th>
<th>Total FY14 2nd Half</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brent Swaps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>Barrels</td>
<td>717,500</td>
<td>607,500</td>
</tr>
<tr>
<td>Price</td>
<td>USD</td>
<td>107.76</td>
<td>108.08</td>
</tr>
<tr>
<td>Brent Collars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>Barrels</td>
<td>385,000</td>
<td>1,412,500</td>
</tr>
<tr>
<td>Ceiling Price</td>
<td>USD</td>
<td>109.99</td>
<td>105.66</td>
</tr>
<tr>
<td>Floor Price</td>
<td>USD</td>
<td>104.58</td>
<td>96.23</td>
</tr>
<tr>
<td>WTI Collars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>Barrels</td>
<td>92,500</td>
<td>96.73</td>
</tr>
<tr>
<td>Ceiling Price</td>
<td>USD</td>
<td>96.73</td>
<td></td>
</tr>
<tr>
<td>Floor Price</td>
<td>USD</td>
<td>78.65</td>
<td></td>
</tr>
<tr>
<td>WTI Calls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>Barrels</td>
<td>90,000</td>
<td>111.11</td>
</tr>
<tr>
<td>Ceiling Price</td>
<td>USD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total hedged</td>
<td>Barrels</td>
<td>1,285,000</td>
<td>2,020,000</td>
</tr>
<tr>
<td>Estimated fuel consumption</td>
<td>Barrels</td>
<td>1,654,938</td>
<td>3,738,560</td>
</tr>
<tr>
<td>Hedge ratio</td>
<td>%</td>
<td>78%</td>
<td>54%</td>
</tr>
<tr>
<td>Compensation from fuel hedges (1)</td>
<td>USD</td>
<td>2,570,910</td>
<td>3,515,743</td>
</tr>
<tr>
<td>Purchase cost of options</td>
<td>USD</td>
<td>(2,364,175)</td>
<td>(329,000)</td>
</tr>
<tr>
<td>Net compensation from hedges (2)</td>
<td>USD</td>
<td>206,735</td>
<td>3,186,743</td>
</tr>
</tbody>
</table>

*Table 7.3: Air New Zealand hedge positions as of 8th of May 2013.*

- Source: Air New Zealand (2013) - “Fuel Hedge Position as at 8 May 2013”

It is not crystal clear whether Air NZ’ swaps are monthly or quarterly but either way, if the average jet fuel spot price is above USD 107.76 over the course of a month or a quarter, the airline saves the difference between the strike price and the spot price at settlement. On the other hand, if the average jet fuel price ends below the swap’s strike price, the airline will have to pay its counterparties the difference.

While Air NZ has the most extensive fuel hedging descriptions, it does not mean that the other airlines in the sample do not hedge, quite the contrary. All the airlines’ most applied derivatives and fuel types are summarized in table 7.4.
First, a small caveat: some of the airlines (particularly those with an asterisk) are not clear about magnitude and actual use of derivatives and fuel types; they merely state what they can do and not what they actually do. Second, the primary derivative and the primary fuel type are typically combined but it applies to a lesser extent to the secondary ones (e.g. an airline can easily use its primary derivative on its secondary fuel type, too).

These warnings aside, the selected airlines operate with some unintroduced concepts or even hedging strategies; cracks, caps and other spread options, though the latter is rather broad and has been introduced partially under put spreads above.

The crack (spread) is simply the price between crude oil and one of its distillates, e.g. jet fuel. As an example of a crack (spread) swap strategy, the hedger pays the floating price of jet fuel and receives the floating price of crude oil plus the crack (spread) (Investment & Finance, 2013). Alternatively, it is possible to swap a floating crack (spread) margin for a fixed one, and vice versa. From table 7.4 above it is emphasized for the airlines that mention cracks directly, but it cannot be precluded that airlines use crack swaps (partially) when they write (plain) swaps.

Caps have actually been mentioned before as a part of a collar; the ceiling, but has not been introduced directly. As we recall, it is simply purchased call options securing the maximum price that the airline risks to pay for its jet fuel.

Other spread options can, as the name clearly indicates, manifest in all sorts of derivative strategies. The spreads applied by the airline above are zero-cost options, thus the price paid for the bought option is equal to the price received for the sold option. An example is a bear spread which is a
strategy where the hedger sells a put and a call option at the same strike price (and expiration), A, and buys a put and a call at a higher strike price, B. The graph might look like this:

![Diagram](image)

Figure 7.2: Illustration of a bear spread. – Source: Australian Securities Exchange (2011)

Ideally, the price ends between A and B, and the hedger will receive the difference between A and B less the cost of the spread. Similarly, a bull spread which is just the opposite of a bear spread exists. The names, bear versus bull, obviously reveal the hedger’s future prospects.

To return to the introduction to this section, airlines mainly have options on crude oil and collars and swaps on jet fuel. No clear relationship between countries or continents and application of derivatives seems to emerge. Whether the size of the airline affects its chosen derivatives and fuel types is also questionable. Initially, it looks like smaller airlines hedge more using jet fuel as the underlying asset than larger airlines, but some large airlines use jet fuel too.

The analysis above is included to give the reader an idea of the types of derivatives and fuel types, airlines use. A real understanding of these could easily be a dissertation of its own, but the scope of this dissertation is not to find relationships between airlines and what kinds of derivatives and fuel types they use, but rather what firm characteristics that affect hedging decisions, and vice versa.
8 - Cross-Hedging

As mentioned in the previous section, airlines sometimes make use of what is known as cross-hedging. The empirical data shows that there is no clear standard of what commodity to use for cross-hedging, however crude oil is often used. The following analysis will explore cross-hedging further and discuss implications and effectiveness of cross-hedging itself, along with what commodity is the optimal to be used for cross-hedging.

Cross-hedging makes use of an asset that is highly correlated to the risk exposure, with a more liquid and preferably exchange traded derivatives market. For airlines, the candidates for the cross commodity are WTI crude oil and No. 2 heating oil sold on the New York Mercantile Exchange, and their European counterparts Brent crude oil and gasoil sold on the Intercontinental Exchange (ICE). The idea is to offset the high jet fuel prices, with gains on the futures of the cross hedge. So, the correlation between jet fuel spot price returns and the futures price returns of the cross commodity needs to be high.

The hedge ratio used, the Minimum Variance Hedge Ratio (MVHR), is given by (cf. section 3.6 - Cross-hedging theory):

$$ h^* = \rho \frac{\sigma_r(s)}{\sigma_r(f)} $$

Besides the correlation of the spot price and futures price being important, the correlation between the volatilities might also be of interest. If the volatility of the spot price increases, without the volatility of futures price increasing, the hedge position needs to be rebalanced to compensate for the bigger price swings. A high correlation between the volatilities mitigates this problem, if it means the volatility ratio stays more or less the same.

The MVHR includes only two parameters, the correlation and the standard deviations. The following sections will address each of these in turn, before consolidating these to determine the optimal commodity to be used for cross-hedging jet fuel.

8.1 - Correlation structure

An important parameter when choosing the commodity to use for cross hedging is the correlation with the asset to be hedged; jet fuel.

Table 8.1 below contains the correlation structure of the returns of spot and futures prices.
Clearly all the candidates are, as one would assume, highly correlated with jet fuel spot price changes. At least, this holds for the full sample period. The table indicates stronger correlations with the other distillates, heating oil and gasoil. This could indicate a supply/demand relation between all distillates, maybe due to the global economic setting, more so than with the crude oils. Though full period correlations are useful, one might want to see what the correlation structure looks like with a time-dependent correlation, i.e. a rolling correlation based on x time lags. A word of warning when choosing the rolling period; larger periods will smooth out the correlation fluctuations, whereas shorter periods will show greater detail. This is however not without compromise. Shorter rolling-periods will result in the correlation being chosen on fewer data points, resulting in a greater variance in the correlation. Choosing a rolling period that is too long, will result in too little variation in the correlation.

First, to get an overall picture, correlation is calculated on a 1 year rolling period (265 trading days). The result is depicted in figure 8.1.

Not surprisingly, the correlations follow more or less the same pattern. The correlations are somewhat stable for much of the time period, but there are significant drops in the correlations at given points in time. Comparing this to the jet fuel price data from earlier (cf. section 6.2 - Jet Fuel price returns distribution), it becomes evident that correlation breaks down, when volatility in jet

Table 8.1: Correlation between futures contracts price returns and jet fuel spot price returns, full period.

– Source: Own contribution

<table>
<thead>
<tr>
<th></th>
<th>Jet fuel</th>
<th>WTI Crude Oil</th>
<th>Brent Crude Oil</th>
<th>Heating Oil</th>
<th>Gasoil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet fuel</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WTI Crude Oil</td>
<td>0.80</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brent Crude Oil</td>
<td>0.88</td>
<td>0.92</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating Oil</td>
<td>0.93</td>
<td>0.87</td>
<td>0.95</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Gasoil</td>
<td>0.92</td>
<td>0.86</td>
<td>0.94</td>
<td>0.97</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Figure 8.1: 1 year rolling window correlation between monthly jet fuel spot price returns and futures price returns

– Source: Own contribution
fuel prices increases. Surprisingly, WTI crude has a very unstable correlation with jet fuel and is consistently below the correlations of the other commodities.

The same exercise is done with a rolling period of 44 trading days, two months of trades, to show even greater detail. The results are depicted in figure 8.2.

![Figure 8.2: 2 months rolling correlation between monthly jet fuel spot price returns and futures price returns](image)

As one would expect, 2-months rolling correlations exhibit higher volatility, with correlations even being negative at times. WTI crude is still often less correlated than the other alternatives, sometimes exhibiting spikes when other correlations are more or less stable.

From the above graphs, it is apparent that WTI crude is not the optimal commodity to be used for cross-hedging.

Ranking the correlations of the 44 trading days’ data, from highest to lowest correlation, the most often highly correlated asset is Heating oil. This is the highest correlated asset in 2,176 of the 2,731 observations, about 80% of the time. This is also in accordance with the graph for 1-year correlation.

Based on the above, Heating oil is the best commodity to be used for jet fuel cross-hedging, based solely on the correlation with jet fuel.

### 8.2 - Volatility structure

Summary statistics of the monthly returns of each of the commodities are presented in table 8.2.

<table>
<thead>
<tr>
<th></th>
<th>Spot Jet fuel</th>
<th>WTI Crude Oil</th>
<th>Brent Crude Oil</th>
<th>Heating Oil</th>
<th>Gasoil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>-49.07%</td>
<td>-41.37%</td>
<td>-40.69%</td>
<td>-36.08%</td>
<td>-35.05%</td>
</tr>
<tr>
<td>Average</td>
<td>0.42%</td>
<td>0.48%</td>
<td>0.44%</td>
<td>0.45%</td>
<td>0.41%</td>
</tr>
<tr>
<td>Median</td>
<td>0.90%</td>
<td>1.05%</td>
<td>0.97%</td>
<td>0.50%</td>
<td>0.60%</td>
</tr>
<tr>
<td>Max</td>
<td>52.97%</td>
<td>49.08%</td>
<td>33.23%</td>
<td>36.33%</td>
<td>31.31%</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>9.91%</td>
<td>10.34%</td>
<td>9.66%</td>
<td>9.09%</td>
<td>9.26%</td>
</tr>
</tbody>
</table>

*Table 8.2: Summary statistics of monthly returns on spot jet fuel and futures prices, full period.*
The table clearly illustrates great dispersion in returns, with a monthly standard deviation between 9.09% and 10.34% for all of the commodities. To much surprise, jet fuel spot prices are not the most volatile; WTI crude oil futures exhibit higher volatility.

As with correlations, allowing for rolling standard deviations might uncover interesting patterns in the volatility.

The first rolling window considered is once again a 1-year rolling window and is depicted in figure 8.3.

The graph indicates that jet fuel, crude oil and other fuel types follow a similar volatility pattern. The graph is rather smooth, owing to the fact that the rolling window is a full year. The graph also reflects the increased volatility of end 2008, followed by a longer period of relatively stable returns, until 2014 where volatility once again rises. Data for 2008 show that the fuel types heating oil and gasoil were less affected than crude oils and jet fuel.

As one would expect with a rolling window of this size, the graph is very smooth and might not show all fluctuations in volatility, hence the two-month rolling window is also computed, and depicted in figure 8.4.
The graph indicates, once again, that all of the commodities exhibit more or less the same volatility pattern. However, jet fuel has some periods of increased volatility; without spikes in volatility of the other fuels. This will most likely result in the (cross) hedge failing at these times, as the hedge ratio is dependent on the standard deviation ratio. At other times, the data exhibits increased volatility in WTI crude, whereas there is no increased volatility in jet fuel, and the other fuels. When the spread between volatilities increase, meaning the ratio changes, the hedge might not cover fluctuations in the risk exposure. One can illustrate this using a two-month rolling window volatility ratio.

![2 months rolling volatility ratio](image)

Figure 8.5: 2 months rolling volatility ratio of monthly returns – Source: Own contribution

Figure 8.5 shows variation in the volatility ratio, however heating oil and gasoil seem to be more stable in the volatility ratio. Stable volatility ratios would allow for firms to hold positions for longer times, without having to rebalance too often and thereby incurring transaction costs.

8.3 - Testing hedge quality

From the above analysis, heating oil is determined to be the best commodity for cross hedging. Heating oil has the highest correlation with jet fuel over time, both over the full period and when allowing for fluctuations in correlation. Heating oil is also the commodity with the smallest changes in the volatility ratio between jet fuel and the commodity.

To test the effectiveness of the constant hedge ratio, one can run regressions with Y being spot price returns and X being futures price returns. The estimated beta coefficient is the hedge ratio, and $R^2$ is then the hedge effectiveness, with values close to 1 being best. Running such regressions on each of the commodities result in the regression output summarized in table 8.3.
Table 8.3: OLS regressions for each commodity futures return, with jet fuel returns as the dependent variable. Model 1: WTI Crude, model 2: Brent Crude, model 3: Heating Oil, model 4: Gasoil. Output is created using RStudio.

Significance levels: *: 10%, **: 5%, ***: 1% – Source: Own contribution

The beta coefficients estimated are all significant and can also be estimated using the full period values for correlations and standard deviations, using the MVHR equation.

R² is also reported. In line with the findings in the previous sections, heating oil is the commodity best suited for hedging jet fuel prices. WTI crude is considered a very poor cross-hedging commodity, with a hedge effectiveness of only 0.638.

Another way of seeing the effect of the hedge is to see how the volatility of the portfolio compares to the volatility of the spot exposure.

The monthly spot price volatility of jet fuel is, as stated earlier, 9.91%. Using heating oil as the hedging commodity, the volatility falls to 3.54%; a sizeable reduction in volatility. Using WTI crude, the volatility is 5.96%.

Since R-squared in a simple (1 independent variable) linear regression is simply the correlation squared, hedge effectiveness relies solely on the correlation between the spot price returns and the futures price returns.

The same measure of effectiveness can be calculated for the “dynamic” hedge ratios of 1-year and 2-months. To do this, a portfolio is constructed of the spot jet fuel and futures on each of the other commodities. The hedge effectiveness measure is the R² analogue described in the methodology section (cf. section 5.3 - Methodology).

The closer the measure is to 1, the better the hedge achieved.
Table 8.4 summarizes the hedge effectiveness of using a fixed hedge ratio, one-year rolling hedge ratio and two-month rolling hedge ratio.

<table>
<thead>
<tr>
<th></th>
<th>WTI Crude</th>
<th>Brent Crude</th>
<th>Heating Oil</th>
<th>Gasoil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant hedge ratio</td>
<td>0.64</td>
<td>0.77</td>
<td>0.87</td>
<td>0.84</td>
</tr>
<tr>
<td>1 year rolling</td>
<td>0.61</td>
<td>0.76</td>
<td>0.86</td>
<td>0.84</td>
</tr>
<tr>
<td>2 months rolling</td>
<td>0.61</td>
<td>0.76</td>
<td>0.86</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Table 8.4: Hedge effectiveness ratio for differing hedge ratio strategies, calculated using the R² analogue.

Source: Own contribution

Surprisingly, allowing for varying hedge ratios actually results in worse hedge effectiveness, albeit a small difference. As surprising as this is, it is possibly due to the nature of correlations. When correlation decreases, it simply means that there is a lesser statistical relationship between the two variables. Changing the hedge ratio does not “solve” the problem of lower correlation. It merely lowers the effect of adverse changes (mismatching in the direction of returns on the spot and futures prices). Also, the correlation is historical, and may not be a good estimator of the future correlation. All in all, it would seem that it evens out over the full data period, resulting in the similar hedge effectiveness from either constant or dynamic hedge ratios. This result might differ if one chooses different data periods or using futures with longer time to maturity.

In practice, the full-period hedge ratio assumes that the firms know the parameterization at all times, which is not possible in the real world. Hence, for practical purposes, the rolling window methods are most likely the best way of estimating the hedge ratio itself. Though a different estimation method, the upshot of heating oil being the best suited commodity still holds.

The above analysis concludes that heating oil is the best commodity to use for cross-hedging. Next after heating oil, gasoil is the best commodity to use. The hedge quality of both of these are high when using the R-squared value as an estimator of quality. Moreover, the cross-hedges significantly reduce the volatility of the spot price.

Though not a perfect hedge, using cross-hedging is certainly a viable method of hedging jet fuel prices, when using the correct commodity; heating oil.
9 - Hedge Ratio Analysis

The following section contains various tests of statistical relationships between firm characteristics and hedge ratios; statistical relationships implying correlation, not (necessarily) causality. For each characteristic, a relationship is hypothesized, and outputs are summarized. The section includes comments on the regression results. Further discussion of results in relation to theory is saved for the discussion in section 9.

Fixed effects coefficient will not be included in the regression outputs below, as they take up too much space, and are not of interest in the following. The full models can be found in appendix 2. Plots of the independent variables as the X-variable, and Hedge Ratios as the Y-variable can be found in appendix 3.

Due to the specification of the entity fixed effects models, one of the airlines are included in the constant, so as to avoid the dummy trap (cf. section 5.3 - Methodology). The entity is, chosen arbitrarily, Air Canada. Regressions exploring only one independent variable (excess of the entity fixed effects), all follow the same model specification, hence these will not be repeated for every model. The specifications are as follows.

Cross-sectional model

\[
Hedge \text{ ratio}_{it} = \beta_0 + \beta_1 \times \text{Independent Variable}_{it} + \epsilon
\]

Fixed effects model

\[
Hedge \text{ ratio}_{it} = \beta_0 + \beta_1 \times \text{Independent Variable}_{it} + \gamma_i \times \text{Airline}_i + \epsilon
\]

9.1 - Net worth

Hypothesis – Book value of net worth

Rampini and Viswanathan (2010) and Rampini, Sufi and Viswanathan (2014) hypothesize a relationship between net worth and hedge ratio. To test this hypothesis, net worth is defined as the book value of equity, scaled by total assets:

\[
\text{Net worth}_{Book \text{ value}} = \frac{\text{Book value of equity}}{\text{Total liabilities} + \text{Book value of equity}}
\]

The relationship hypothesized is positive; higher net worth makes the return on hedging exceed the return of investments, hence firms hedge.

The hypothesis follows from Rampini et al. (2014):

\text{Firms with higher net worth are less financially constrained, and therefore hedge more than firms with lower net worth.}
Regression

The model output is summarized below:

<table>
<thead>
<tr>
<th>Net worth (book) regressions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Net worth (book)</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>Observations</td>
</tr>
<tr>
<td>$R^2$</td>
</tr>
<tr>
<td>$R^2$-adjusted</td>
</tr>
<tr>
<td>F-statistic</td>
</tr>
</tbody>
</table>

*Table 9.1: Book value of net worth, scaled by total assets. Full model output can be found in appendix 2.*

Significance levels: *: 10%, **: 5%, ***: 1% – Source: Own contribution

Book value of net worth is significant in both the cross-sectional and fixed effects models; at a 10% and 1% significance level, respectively. While exhibiting a positive relationship in the cross-sectional model, book value of net worth exhibits a negative relationship with hedge ratio in the fixed effects model. Plotting the hedge ratio and net worth in a scatterplot further illustrates the statistical significance the fixed effects model. Figure 8.1 depicts the data grouped by airline, with an individual trend line added for every airline.

![Figure 8.1: Hedge ratio plotted against book value of net worth, scaled by total assets, grouped by airline. Added trendline for each entity. Output constructed in RStudio. – Source: Own contribution](image)

The data exhibits a negative relationship for many of the airlines while some are positive and some display rather arbitrary relationships. Grouping the data allows one to see the effect of entity fixed effects in the
model. The main part of the data is centered within a net worth of about 0 to 0.4 but hedge ratios vary greatly within. The majority of the trend lines are negative, hence the negative and significant coefficient of net worth in the model. The groupings of each firm’s hedge ratio and net worth observations illustrate that airline specific observations are clustered at different levels of hedge ratios. These differences in the average level of hedge ratio within each firm are what is caught by the entity fixed effects method.

Hypothesis – Market value of net worth

The rationale for the hypothesis, and the hypothesis itself, directly follows the previous test of book value of equity. The difference is the measure used for net worth; market value instead of book value:

\[
\text{Net worth}_{\text{Market}} = \frac{\text{Market value of equity}}{\text{Book value of liabilities + Market value of equity}}
\]

Market value as an estimator of net worth takes the markets’ valuation of equity into account. That is, this measure is not an accounting measure but instead how the market values the equity, given the current market conditions and the firm’s use of its assets.

As this is just a different measure of net worth, the same hypothesized relationship of Rampini et al. (2014) holds:

*Firms with higher net worth are less financially constrained, and therefore hedge more than firms with lower net worth.*

Regression

The results of the regression are summarized in table 9.2 below:

<table>
<thead>
<tr>
<th>Net worth (market) regressions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Hedge Ratio</strong></td>
</tr>
<tr>
<td>Cross Sectional</td>
</tr>
<tr>
<td>Fixed effects</td>
</tr>
<tr>
<td><strong>Net worth (market)</strong></td>
</tr>
<tr>
<td>(0.126)</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
</tr>
<tr>
<td>(0.046)</td>
</tr>
<tr>
<td>Observations</td>
</tr>
<tr>
<td><strong>R2</strong></td>
</tr>
<tr>
<td><strong>R2 adjusted</strong></td>
</tr>
<tr>
<td>F statistic</td>
</tr>
</tbody>
</table>

*Table 9.2: Market value of net worth, scaled by total assets (Total liabilities + Market value of equity). Full model output can be found in appendix 2. Significance levels: *: 10%, **: 5%, ***: 1% – Source: Own contribution*

As evident from the table, market value of net worth is only significant in the fixed effects model. The sign is the same as in the book value of net worth, though a smaller and less significant coefficient.
9.2 - Liquidity ratios

**Hypothesis – current ratio**

Rampini and Viswanathan (2010) state that firms that are financially constrained hedge less than firms that are not financially constrained. An alternative measure of financial constraint or financial health to consider, is the current ratio. The current ratio is defined as:

\[
\text{Current ratio} = \frac{\text{Current assets}}{\text{Current liabilities}}
\]

The higher ratio, the less constrained a firm is, and the more effectively the firm employs its capital. That is, to some extent because if it is too high, the firm probably does not invest optimally. Essentially, it is a liquidity measure of how much of current liabilities that can be paid off using current assets; normally the period of interest is less than one year.

From the above, the following hypothesis emerges:

*Higher current ratios indicate healthier firms that are less financially constrained. Firms with higher current ratios are expected to hedge more than firms with lower current ratios.*

**Regression**

The results are summarized in table 9.3.

<table>
<thead>
<tr>
<th>Current ratio regressions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hedge Ratio</strong></td>
</tr>
<tr>
<td><strong>Cross Sectional</strong></td>
</tr>
<tr>
<td>Current Ratio</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Observations</td>
</tr>
<tr>
<td>R²</td>
</tr>
<tr>
<td>R²-adjusted</td>
</tr>
<tr>
<td>F-statistic</td>
</tr>
</tbody>
</table>

*Table 9.3: Current ratio. Full model output can be found in appendix 2. Significance levels: *: 10%, **: 5%, ***: 1% –
Source: Own contribution*

The cross-sectional model indicates that the current ratio is significant at a 5% significance level, and with a positive coefficient. Despite the significant statistical relationship, the cross-sectional model poorly explains all variation, as evident by the R² value of 0.068. That is, 6.8% of the variation in hedge ratio is explained by the variation in the current ratio.

Running the fixed entity model results in a much higher adjusted R² of 0.685, but simultaneously rendering the current ratio insignificant. The explanatory power thus stems from the fixed effects, not the current ratio, hence the latter is not considered a good explanatory variable with regards to the hedge ratio.
Hypothesis – quick ratio

Another measure of liquidity of a firm is the quick ratio. The quick ratio is hypothesized for the same reason as the current ratio above; due to financial constraints. The quick ratio is defined as follows:

$$\text{Quick ratio} = \frac{\text{cash + cash equivalents}}{\text{current liabilities}}$$

The intuition of the quick ratio is that it measures how much of the current liabilities that can be paid off with the cash at hand, i.e. the most liquid assets.

The hypothesis follows that of the current ratio:

*Higher quick ratios indicate healthier firms that are less financially constrained. Firms with higher quick ratios are expected to hedge more than firms with lower quick ratios.*

Regression

The results are summarized in table 9.4.

### Quick ratio regressions

<table>
<thead>
<tr>
<th></th>
<th>Hedge Ratio Cross Sectional</th>
<th>Hedge Ratio Fixed effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quick Ratio</strong></td>
<td>-0.019 (0.076)</td>
<td>-0.046 (0.074)</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>0.353*** (0.045)</td>
<td>0.226*** (0.050)</td>
</tr>
<tr>
<td>Observations</td>
<td>142</td>
<td>142</td>
</tr>
<tr>
<td>R²</td>
<td>0.002</td>
<td>0.723</td>
</tr>
<tr>
<td>R²-adjusted</td>
<td>-0.005</td>
<td>0.683</td>
</tr>
<tr>
<td>F-statistic</td>
<td>0.265 (df=1; 140)</td>
<td>17.864*** (df=18;121)</td>
</tr>
</tbody>
</table>

*Table 9.4: Quick ratio. Full model output can be found in appendix 2. Significance levels: *: 10%, **: 5%, ***: 1% – Source: Own contribution*

As seen above, the quick ratios add no significant explanatory value in neither of the models, though the fixed effects still have a relatively high explanatory power (0.683).

9.3 - Debt related variables

Hypothesis – debt level

As mentioned in section 4, one of the ways hedging can add value to a firm is by reducing the interest rate levels by decreasing the costs of financial distress. Doing this also allows for higher debt levels, all else being equal. This implies a relationship between high debt levels and high hedge ratios, relative to firms with
lower debt levels. In this case, debt is defined as interest bearing financial liabilities and short- and long-term debt; hence not all liabilities.

\[
\text{Debt level} = \frac{\text{Short and long term interest bearing liabilities}}{\text{Total assets}}
\]

This also follows the ideas of Froot, Scharfstein and Stein (1993), when costs of external financing are increasing in the level of debt.

The hypothesis follows:

According to the theory stated in section 3, and the ideas of Froot et al. (1993), one would expect a positive relationship between the level of debt and the hedge ratio.

Regression

Results of the regression are summarized in table 9.5.

<table>
<thead>
<tr>
<th></th>
<th>Hedge Ratio Cross Sectional</th>
<th>Hedge Ratio Fixed effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt to assets</td>
<td>-0.096 (0.154)</td>
<td>0.058 (0.208)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.391*** (0.054)</td>
<td>0.170** (0.083)</td>
</tr>
<tr>
<td>Observations</td>
<td>142</td>
<td>142</td>
</tr>
<tr>
<td>R²</td>
<td>0.002</td>
<td>0.713</td>
</tr>
<tr>
<td>R² adjusted</td>
<td>-0.005</td>
<td>0.682</td>
</tr>
<tr>
<td>F-statistic</td>
<td>0.324 (df = 1, 149)</td>
<td>17.818*** (df=18,123)</td>
</tr>
</tbody>
</table>

Table 9.5: Debt level. Full model output can be found in appendix 2. Significance levels: *: 10%, **: 5%, ***: 1% – Source: Own contribution

As the table indicates, the debt level is a poor explanatory variable when it comes to the hedge ratio. The variable is insignificant in both the cross-sectional and fixed effects model. The reason for a high R² adjusted value in the fixed effects model is the entity fixed effects.

Hypothesis – net financing cost of debt

An alternative to using short and long interest-bearing liabilities to indicate debt levels, one could use the costs of financing from the income statement. In doing so, one focuses only on the financing cost of debt, not all capital; that is, it does not focus on the implied cost of equity capital.

Following the debt level regression logic, high financing cost of debt implies high debt levels. One would therefore expect, once again, a positive relationship.
To make the financing cost of debt comparable across firms, a ratio is computed;

\[
\text{Net finance costs of debt ratio} = \frac{\text{Finance costs} - \text{Finance income}}{\text{Revenue}},
\]

, with finance costs and income considered in absolute values, to obtain a positive ratio with respect to revenue.

The hypothesis is as follows:

High net financing cost of debt indicates high debt levels. According to Froot et al. (1993), a positive relationship exists between net financing cost of debt and hedge ratio.

Regression

Results of the regression are summarized in table 9.6.

Table 9.6: Net finance costs to revenue (or net financing cost of debt ratio). Full model output can be found in appendix 2. Significance levels: *: 10%, **: 5%, ***: 1% – Source: Own contribution

The net financing cost of debt ratio is highly significant in both the cross-sectional model and the fixed effects model; at a 5% and 1% significance level, respectively. The size of the coefficient is rather large which is due to the definition of the variable. A unit increase in the variable would imply net financing cost of debt to increase by 100% of the revenue – highly unlikely. The coefficients take on two different signs, negative in the cross-sectional model and positive in the fixed effects model. The panel data is depicted in figure 9.2 below.
Figure 9.2: Hedge ratio plotted against net finance cost of debt ratio, grouped by airline. – Source: Own contribution

Data exhibits both positive and negative statistical relations between the net financing cost of debt ratio and hedge ratio. Once again, entity fixed effects exhibit high significance.

9.4 - Multiple model

Having tested various explanatory variables, a model is created using all variables that show significance in the past regressions. As the net worth value, the book value is chosen. For definitions of the included variables, please refer to the respective regression.

The models are specified as follows:

**Cross-sectional model**

\[
Hedge\ ratio_{it} = \beta_0 + \beta_1 \cdot Net\ finance\ costs\ to\ revenue_{it} + \beta_2 \cdot Net\ worth_{it} + \beta_3 \cdot Current\ ratio_{it} + \epsilon
\]

**Fixed effects model**

\[
Hedge\ ratio_{it} = \beta_0 + \beta_1 \cdot Net\ finance\ costs\ to\ revenue_{it} + \beta_2 \cdot Net\ worth_{it} + \beta_3 \cdot Current\ ratio_{it} + \gamma_i \cdot Airline_i + \epsilon
\]

The hypothesis for each of the included variables are also the same from each of the respective regressions.
Regression

Results of the regression are summarized in table 9.7.

### Multiple variable regressions

<table>
<thead>
<tr>
<th></th>
<th>Hedge Ratio Cross Sectional</th>
<th>Hedge Ratio Fixed effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net finance costs to</td>
<td>-2.249*</td>
<td>2.892***</td>
</tr>
<tr>
<td>revenue</td>
<td>(1.294)</td>
<td>(0.776)</td>
</tr>
<tr>
<td>Net worth (Book)</td>
<td>-0.070</td>
<td>-0.267**</td>
</tr>
<tr>
<td></td>
<td>(0.136)</td>
<td>(0.110)</td>
</tr>
<tr>
<td>Current ratio</td>
<td>0.183**</td>
<td>-0.079</td>
</tr>
<tr>
<td></td>
<td>(0.074)</td>
<td>(0.062)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.236***</td>
<td>0.178***</td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
<td>(0.068)</td>
</tr>
<tr>
<td>Observations</td>
<td>142</td>
<td>142</td>
</tr>
<tr>
<td>R²</td>
<td>0.086</td>
<td>0.745</td>
</tr>
<tr>
<td>R²-adjusted</td>
<td>0.086</td>
<td>0.703</td>
</tr>
<tr>
<td>F-statistic</td>
<td>4.338*** (df= 3; 138)</td>
<td>17.672*** (df=20.121)</td>
</tr>
</tbody>
</table>

**Table 9.7:** Full model containing all of the above significant variables. Full model output can be found in appendix 2.

**Significance levels:** *: 10%, **: 5%, ***: 1% – Source: Own contribution

Seeing as book value of net worth is insignificant in the cross-sectional model and current ratio is insignificant in the fixed effects model, these are excluded from the respective models, to arrive at the following model.

### Multiple variable regressions

<table>
<thead>
<tr>
<th></th>
<th>Hedge Ratio Cross Sectional</th>
<th>Hedge Ratio Fixed effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net finance costs to</td>
<td>-2.036*</td>
<td>2.720***</td>
</tr>
<tr>
<td>revenue</td>
<td>(1.170)</td>
<td>(0.854)</td>
</tr>
<tr>
<td>Net worth (Book)</td>
<td></td>
<td>-0.276**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.112)</td>
</tr>
<tr>
<td>Current ratio</td>
<td>0.171**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.070)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.226***</td>
<td>0.101***</td>
</tr>
<tr>
<td></td>
<td>(0.070)</td>
<td>(0.068)</td>
</tr>
<tr>
<td>Observations</td>
<td>142</td>
<td>142</td>
</tr>
<tr>
<td>R²</td>
<td>0.085</td>
<td>0.742</td>
</tr>
<tr>
<td>R²-adjusted</td>
<td>0.072</td>
<td>0.702</td>
</tr>
<tr>
<td>F-statistic</td>
<td>6.435*** (df = 2; 139)</td>
<td>38.441*** (df=19.122)</td>
</tr>
</tbody>
</table>

**Table 9.8:** Model containing all of the above significant variables – excluding Book value of net worth in cross-sectional, and Current ratio in the fixed effects model. Full model output can be found in appendix 2.

**Significance levels:** *: 10%, **: 5%, ***: 1% – Source: Own contribution
Net finance costs (i.e. net financing cost of debt) is still significant in both models, though at a lower level for the cross-sectional model. Signs of the coefficient remain the same for all included variables, as in the individual models. The size of the coefficient of net financing cost of debt has diminished somewhat in the fixed effects model. R² adjusted values are the highest achieved throughout all regression models; 0.072 for the cross-sectional model, and 0.702 for the fixed effects model, as expected.

9.5 - Speculation or hedging

Another factor that may play in to hedging decisions might be one that is not a firm characteristic; the trend of jet fuel prices. The idea is that if jet fuel prices have seen appreciation within the last few months, firms will have incentives to hedge more. However, one could also think of higher prices leading to a price fall if jet fuel is considered overpriced. The direction of the relationship is therefore unknown; however, the test is still carried out. If the following models turn out significant, it would indicate that the firms speculate in the fuel prices rather than hedge, given the definition of hedging lowering volatility of cash flows. That is, the aim of hedging is not to “win” on hedging activities but rather to win and lose every year, alternating to even out the price fluctuations.

To test whether the momentum of jet fuel prices matter, two different measures of momentum are calculated; the return over the past six months, and arithmetic average return over the past six months.

\[ R_{6\text{ months}} = \frac{(P_t - P_{t-6\text{ months}})}{P_{t-6\text{ months}}} \]
\[ Arithmetic\ \text{return} = \frac{\sum_{t=1}^{n} R_t}{n} \]

With n being the number of observations in the past 6 months.

The hypothesis is as follows:

*If following the definition of hedging - to lower volatility of cash flows - recent trends of jet fuel prices should have no effects on (future) hedge ratios.*

**Regression**

Four models are specified; a cross-sectional and fixed effects model for each of the momentum measures.

**Cross-sectional model**

\[ Hedge\ ratio_{it} = \hat{\beta}_0 + \hat{\beta}_1 * 6 - Months - Momentum(\text{arit and geom})_{it} + \varepsilon \]

**Fixed effects model**

\[ Hedge\ ratio_{it} = \hat{\beta}_0 + \hat{\beta}_1 * 6 - Months - Momentum(\text{arit and geom}) + \gamma_{it} * Airline_i + \gamma_t * Year_t + \varepsilon \]
The output is summarized in table 9.9 below.

### 6 Months momentum regressions

<table>
<thead>
<tr>
<th></th>
<th>Hedge Ratio Cross Sectional</th>
<th>Hedge Ratio Fixed effects</th>
<th>Hedge Ratio Cross Sectional</th>
<th>Hedge Ratio Fixed effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>6 months return</strong></td>
<td>0.080 (0.095)</td>
<td>0.038 (0.051)</td>
<td>9.293 (11.231)</td>
<td>4.663 (6.188)</td>
</tr>
<tr>
<td><strong>Momentum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Arithmetic average return)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>0.362*** (0.023)</td>
<td>0.197*** (0.016)</td>
<td>0.362*** (0.023)</td>
<td>0.197*** (0.016)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>142</td>
<td>142</td>
<td>142</td>
<td>142</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>0.605</td>
<td>0.724</td>
<td>0.605</td>
<td>0.724</td>
</tr>
<tr>
<td><strong>R²-adjusted</strong></td>
<td>0.002</td>
<td>0.683</td>
<td>-0.002</td>
<td>0.683</td>
</tr>
<tr>
<td><strong>F-statistic</strong></td>
<td>0.707 (df1:140)</td>
<td>17.897*** (df=18,123)</td>
<td>0.686 (df1:140)</td>
<td>17.995*** (df=18,123)</td>
</tr>
</tbody>
</table>

Table 9.9: Models including return and momentum of jet fuel prices as an explanatory variable. Full model output can be found in appendix 2. Significance levels: *: 10%, **: 5%, ***: 1% – Source: Own contribution

As evident from the table, there is no evidence of any firms following momentum strategies. Airlines do not seem to speculate in jet fuel prices.
10 - Discussion

10.1 - Discussion of robustness

10.1.1. - Hedge ratios

The models considered in this thesis regress the amount of next year’s fuel consumption that is hedged, on various firm characteristics. Some characteristics are found to be statistically significant in explaining some of the variation in hedge ratios, while other measures fail at this.

Theories on hedging are, as with any other theory and models, highly dependent on assumptions and depict simplified versions of the real world. This is also true when it comes to theories on hedging. This thesis focuses solely on the amount of jet fuel hedging, and thus on no other type of hedging. Though jet fuel accounts for a large share of the costs of firms in the airline industry, it is hardly the only risk exposure of the airlines. By only focusing on jet fuel hedging, other hedging activities are effectively ignored and therefore not taken into account when computing hedge ratios. This may cause problems, all depending on the relation between hedging of jet fuel and other hedging activities within the airlines.

10.1.2. - Multicollinearity in the full model

The authors assume a relationship between the debt level and the net financing cost of debt ratio. If there is a relationship between these, there is also likely to be a relationship between the net worth and the net financing cost of debt ratio. One must be careful to not include variables that allow for multicollinearity in the regression model. To mitigate this, the correlation between the variables in question are calculated. If the correlation of the variables is too close to unit, one of the variables most be omitted from the model. The correlation between the net financing cost of debt ratio and net worth is calculated to be -0.34, and it therefore poses no problem of multicollinearity.

10.1.3. - The firms of the dataset

Firms included in data are considered to be representative of the airline industry. Instead of just focusing on one area of the world, or even just one country, the data includes 18 firms spread across the world. Some large, some small, some cheap and some expensive, the variation in airlines make for an interesting dataset with great diversity. With firms from so many different areas of the world, there is bound to be great difference in certain firm characteristics; characteristics that are
hard to quantify such as culture etc. Running fixed effects models mitigate this problem, allowing for isolation of the explanatory variables in question.

10.1.4. - Data collection method

Data is collected manually by looking through all 142 annual reports that make up the 142 firm-year observations in the dataset. Manually looking through all the annual reports naturally introduces the possibility of human error. The authors of the thesis have taken great care to double check the data and are confident in the robustness and credibility of the data collected. That is, remaining errors in data, if any, are considered to have insignificant impact on conclusions, as the regression coefficient are significant at a high level. High significance implies a strong relationship, hence small errors are unlikely to change this.

10.2 - Discussion of regression analysis and theory

Before delving into the discussion of the regression results, it is important to note that the authors of this thesis seek to remain somewhat objective when it comes to the hypotheses. That is, the regression hypotheses are purely the product of the selected financial theory. The following section will discuss the results presented in the previous section, in relation to the financial theory chosen for this thesis.

10.2.1. - Net worth

Two different measures of net worth are considered in the regression analysis in the previous section. First, the book value of net worth was tested, thereafter the market value of net worth. The book value of net worth models of the regression analysis find both a positive and negative statistical relationship between net worth and hedge ratios; positive for the cross-sectional model and negative for the fixed effects model. The cross-sectional model implies that firms with high net worth, on average hedge more than firms with lower net worth. The opposite is true for the entity fixed effects model. For the market value of net worth, only the entity fixed effects model is significant. The model implies the same negative relationship as the book value of net worth, though a smaller coefficient and lower significance.

Rampini and Viswanathan (2010) and Rampini, Sufi and Viswanathan (2014) hypothesize a positive relationship of net worth and risk management. In their papers, Rampini et al. (2010 &
2014) refer to Froot, Scharfstein and Stein to bring attention to the limitations of the latter’s 1993 theory. Having discussed the limitations of the 1993 theory, Rampini et al. (2010 & 2014) continue to discuss their improvements upon this. The main difference, and hence the main mechanic driving the relationship, is the one of financial constraints due to limited enforcement. Limited enforcement was not introduced in the Froot et al. text (1993), a big caveat to this theory if one is to believe Rampini and Viswanathan (2010). This radically changes the postulated relationship; high net worth is positively correlated with high risk management engagement.

The results of the cross-sectional model accept the hypothesis of Rampini et al. (2010 & 2014), whereas both entity fixed effects model reject this hypothesis; the identified relationship is negative rather than positive. When looking at these results, the effect of entity fixed effects models become evident. Overall, a positive statistical relationship exists, but when controlling for unobserved variables within firms, the relationship is negative.

Looking at the two measures of net worth, book value and market value, the significance in the entity fixed effects models is clearly different. Book value is highly significant, whereas the market value relationship is not as strong. This is in accordance with Rampini and Viswanathan (2010), as net worth as defined by Rampini and Viswanathan as the book value. That is, Rampini and Viswanathan (2010) define the collateralizable assets of the company as the capital invested. Hence a measure of net worth should measure the tangible assets that are up for collateralization. Since the book value of equity is an accounting number, it is tied to the assets of the company. It essentially measures the 1-0 share of the assets.

Market value of equity on the other hand is detached for assets, as it contains other value such as the discounted cash flows of the firm. As stated in Rampini et al. (2010), only the invested capital can be posted as collated, not future earnings. Though the market value of equity is indeed an indicator of the value of a firm, it is hardly an efficient estimator of what can be considered collateral for counterparties. That being said, the market value of net worth is still significant to some extent, possibly owing to the fact that book value of equity and market value of net worth often have some correlation. This is found to be true for the airline data used in this thesis.

So why do we find a negative relationship, instead of the in theory suggested positive one? Surely, improving upon the assumptions of what is already considered one of the pillars within risk management theory, Froot et al. (1993), would lead to a more realistic model. While it is correct that the inclusion of limited enforcement advances the theory to a new level, the key mechanic of
Froot et al. (1993) is ignored. Implications of the combination of the two models should be considered, as discussed in the following.

The decision “mechanic” or inequality of Rampini and Viswanathan (2010) is:

\[ E[R_1(k_0)R_2(k_1)] \geq RR_2(k_1(s), s) \]

The left-hand side is the return on investment whereas the right-hand side is the return on hedging. For an extended walk-through of the inequality, please refer to the respective theory in section 3. As long as this inequality is true, the firm continues to invest (Rampini & Viswanathan, Collateral, Risk Management and the Distribution of Debt Capacity, 2010). The trade-off between investment and hedging happens when the marginal return on hedging is higher than that of investing. \( R_1 \) and \( R_2 \) are variables that depend on the amount invested (as evident by the \( k_0 \) and \( k_1 \) in the parentheses), while \( R \) is the cost of debt financing, and is constant. That is, Rampini and Viswanathan (2010) keep the cost of debt financing constant, the exact variable responsible for the hypothesis of Froot et al. (1993).

Not allowing for variation in cost of debt financing leaves out a very significant mechanic, and one that could potentially lead to the opposite relationship of what Rampini et al. (2010 & 2014) hypothesize.

To see this, consider two firms; one where \( R \) is higher than that of the other. All else being equal, the firm with the high \( R \) will hedge more, as the right-hand side is now larger more often than for the other firm. What could induce this higher \( R \)?

\( R \) is given by \( 1/\beta \) in the model, \( \beta \) being the time preference of lenders. For \( R \) to be bigger, \( \beta \) must be lower, meaning that lenders value short time value higher than long term. A higher \( R \), and a lower \( \beta \), is to be expected if an investment is risky. According to Froot et al. (1993), \( R \) is increasing in the debt level, i.e. the investment is riskier. From a lenders perspective, risk would be increasing in the amount of the firms’ investment financed by debt.

The result of the Rampini et al. (2010) state model is that firms completely exhaust debt capacity when net worth is low, i.e. they take on as much debt as possible. If \( R \) is allowed to vary with debt level, one would see an increase in \( R \) when the debt level is increased. This increase in \( R \) increases the return on hedging (the right-hand side), meaning firms will invest less and hedge more in the beginning. As firms grow, less debt capacity is needed, hence \( R \) diminishes, and as does the right-hand side of the equation above; the amount hedged is lowered. That is, including a variable \( R \) would likely affect the results of the model greatly, and that is believed to be one of the reasons as to why our data exhibits a negative statistical relationship.
The choice of the value of the other parameters of the model are not considered as being the explanation for the discrepancy between the results of this thesis and the theory of Rampini et al. (2010). Other parameters would only alter the strength of the relationship, not the direction.

Though data exhibits a strong negative statistical relationship between book value of net worth and hedge ratio, the relationship is not perfect. Looking at figure 5.16 of observations grouped by airline, some of the airlines do actually have a positive relationship between net worth and hedge ratio. This would indicate that net worth is not the only variable explaining the variation in hedge ratios.

Whether the effects of including a variable R is enough to alter the hypothesis of Rampini et al. (2010 and 2014), and thereby make our results consistent with this, is unknown. However, ignoring such an important aspect, at least when considering other theories, is sure to have an impact. Further advances in risk management theory should focus on a combination of the theories, instead of viewing them as isolated.

10.2.2. - Liquidity ratios

We consider two different measures of liquidity; the Current ratio and Quick ratio. Both ratios were tested as independent variables, using both a cross-sectional and entity fixed effects model. Of the four models computed, only the Current ratio cross-sectional model was significant. Though a significant independent variable, it must be noted that the explanatory power of the model is rather low. The variable determines a weak but positive average relation between Current ratio and hedge ratio.

The rationale of liquidity ratios being estimators of the hedge ratio, is that the liquidity ratios indicate the financial health of a firm. The ratios essentially compare the amount of assets that can be converted within a short amount of time, current and cash, to the current liabilities. That is, what share of the short-term liabilities are covered by either current assets, or even more liquid assets; cash and cash equivalents. The higher the ratio, the healthier a firm is (again, to some extent), since current liabilities can be covered by current assets, or cash. Alternatively, one can also think of the liquidity ratios as an indicator of whether the firm can meet short term liabilities. If this is not possible, the firm will have to meet the liabilities by raising capital in other, often more expensive ways.
If the liquidity ratios can be considered efficient estimators for, whether a firm is financially constraint, one would expect a positive correlation between liquidity ratios and hedge ratios. This logic follows that of Rampini et al. (2010 & 2014).

As the cross-sectional Current ratio model is significant, and with a positive coefficient estimate, the model fits the hypothesis. Though interesting, the explanatory power is quite low. The current ratio therefore only indicates an average relationship, while explains little of the total variation. When including entity fixed effects, all liquidity ratios are insignificant. As quick ratio is not significant in any model, the ratio is not considered a good estimator of the degree of financial constraint, and hence not a good independent variable to determine hedge ratios. Though the current ratio model exhibits poor explanatory power, the model is interesting, as it has the same sign as the cross-sectional book value of net worth has. Compared to the cross-sectional model of net worth, the explanatory power is actually rather high.

So why do we not see the suggested relationship in the fixed effects model, and why do we hardly see any relationship at all? The fact that only the cross-sectional is significant is worrying. Usually introducing entity fixed effects would allow for the isolation of an independent variable’s effect, but in this case, the effect of the ratios is insignificant.

The reason for the poor significance and performance of the estimated model may be due to the limitations of liquidity ratios. One could argue that liquidity ratios only tell half the story, since one only considers the current side. But since the airlines rarely hedge cash flows that occur after a year, focusing on current assets and liabilities make sense. Also, depending on how one defines financial constraints, the usefulness of liquidity ratios is debatable. However, if current assets, for example, are more than enough to cover the current liabilities, the excess current assets can potentially be used as short-term collateral. That is, of course, if the asset type is one that can be used for collateral. This is also true if one considers the quick ratio.

The problem with the current ratio is that the current assets may include assets that are not available for collateral. The problem of the quick ratio may be the opposite; it is too conservative in its estimate of the assets available for collateralization.

In conclusion, liquidity ratios only have limited explanatory power with regards to the variation in hedge ratios. Problems may arise from liquidity ratios incorrectly signaling the health and
collateralizable assets of the firms. One could imagine computing similar ratios but focusing more on just assets that are available for collateralization.

10.2.3. - Debt related variables

In order to determine how debt affects hedging decisions, four regressions on two independent variables were run. The first variable, debt levels, did not provide any significant results, neither in the cross-sectional nor the entity-fixed model. In return, the second variable, net financing cost of debt, was significant in both models, but with different signs. In the cross-sectional model, the variable in question is negatively related with the hedge ratio, i.e. higher net financing cost of debt is related to lower hedge ratios. On the contrary, in the entity-fixed model, higher net financing cost of debt is related to higher hedge ratios.

The latter is both more significant than the former and based on panel data, which has proven to have a large explanatory power on hedge ratios, and the relationship between net financing cost of debt and hedge ratios is thus supposedly overall positive (remembering the differing relationships in table 9.8).

As we recall from the beginning of section 4, theory, the companies seek to maximize net expected profits by maximizing output given investments and/or minimizing the costs of external financing. The authors (Froot et al., 1993) examine the relationship between financing and hedging, particularly emphasizing the rationale for hedging when external financing is more costly than internal financing. They conclude that more financially constrained firms need to hedge in order to have sufficient internal funds to take advantage of attractive investment opportunities or put differently, a positive relationship between costs of external financing and hedging exists.

From, among others, the rationale behind hedging section, hedging is defined as activities that lower volatility of cash flows (or firm value). Hedging can help the companies meet obligations, enter into attractive investment projects and lower (indirect) distress costs. Besides the costs of external financing versus internally generated funds, the costs of hedging need to be below savings in (indirect) distress costs. The rationale behind hedging supports a positive relationship between external financing costs and hedging.

Net financing cost of debt and external financing are synonyms here and therefore, the positive relationship in the results from the regression is in accordance with the positive relationship in the theory (Froot et al., 1993). Thus, when debt is expensive, an incentive to hedge is prevalent,
empirically as well as theoretically. Net financing cost of debt to revenue is argued to be higher if the firm has lower revenues (remembering the formula), and debt costs are positively related to the magnitude of debt, and hence negatively related to net worth. The rationale behind hedging substantiates our reconciling regression results and theory (Froot et al., 1993).

Now, all the above supports the same relationship: higher financing cost, which is more plausible for firms with lower net worth, is related to higher hedge ratios. The relationship is seemingly contrary to the newer theory (Rampini and Viswanathan, 2010 & Rampini et al., 2014) but one need to tread warily. The newer theory does not consider financing costs per se, but merely firm size expressed as net worth. The relationship pointed out above is not robust enough to present resolute conclusions, but the surprisingly conflicting conclusions are of continued interest.

10.2.4. - Speculation versus hedging

In our analysis, we tested momentum in jet fuel prices; does the general jet fuel price level affect the airlines’ hedging decisions? Seemingly no, and hence in line with what some of the airlines state directly in their annual reports.

Clearly, hedged airlines gain (relative to unhedged airlines) on raising jet fuel prices but it comes at a cost which is either a direct cost (e.g. the price of a bought option) or by not being able to take the full advantage when jet fuel prices fall (e.g. the sold put option in a traditional collar). When the purpose of hedging is to lower volatility and not to speculate, the general jet fuel price level is of no interest, which is seen above, but who does not want to make money while locking in relatively lower prices for jet fuel? Normally, there is an upward or downward trend and therefore, if one were to use derivatives for speculative purposes, it could turn out to be a good idea to hedge less, short-term, when jet fuel prices are descending and more when jet fuel prices are ascending - in that way only losing money when the trend changes direction.

That being said, airlines do not serve as trade divisions in e.g. investment banks, and to use hedging solely to lower volatility on one of the airlines’ largest variable cost seems very reasonable.

10.3 - Fixed effects

Having tested several hypotheses in the previous section, a pattern of significance emerges. When looking at the explanatory power (R$^2$) of each model, it is clear that cross-sectional models have little explanatory power. The highest achieved power of a cross-sectional model is an R$^2$ value of 0.041; the current ratio model. However, when one includes fixed effects in every model, the
explanatory power is significantly increased. Even for fixed effects models where other independent variables are insignificant (such as the current ratio model), the explanatory power as measured by $R^2$ adjusted is at least 0.69. Clearly the fixed effects contain some information not caught by other independent variables.

10.3.1. - Time fixed effects

The models in the previous section include only entity fixed effects, however time fixed effects were also tested. For all models, a test of whether adding time effects added value was computed (using the F test described in the data and method section, section 5.3 - Methodology).

The test can be summarized by the hypotheses:

$$H_0: a_1 = a_2 = \ldots = a_R = 0 \text{ \( \Rightarrow \) Year fixed effects are insignificant.}$$

$$H_1: \text{At least one } a_j \neq 0 \quad (j=1, \ldots, R) \text{ \( \Rightarrow \) Year fixed effects are significant.}$$

With $a_1$ through $a_R$ being the regression estimates of entity fixed effects.

All restricted models, that is models without the time variables, were found to be better models than the expanded models; $H_0$ was never rejected. All models were tested at a 95% significance level. Even using the more conservative heteroskedastic robust test statistic, all restricted models were accepted as the correct model; time fixed effects are not present.

One thing must be noted in this regard. The airline data consists of companies with varying financial years, hence the fixed effect for e.g. 2016 will be different for airlines with different financial years. Excluding companies with financial years ending on other dates than the 31st of December results in the same conclusion as the above; year fixed effects are not significant. One could include a variable for all different financial-year ending dates, but this would create too many variables in the model, considering the size of the dataset.

Implications of this is that there are no significant year fixed effects that affect the hedge ratios, only entity fixed effects. This begs the question; what are these fixed entity effects comprised of?
10.3.2. - Entity fixed effects

To figure out what entity fixed effects might exist, the firm entity fixed effects model is computed, and summarized in table 10.1. It is important to note the interpretation of the regression results. Since the variables in the regression, the dummy variables signaling each entity, are binary and hence do not act as regular variables, the coefficient interpretation is quite different from regular regressions. The coefficients explain changes in the average hedging level, relative to the constant in the regression. The constant contains the dummy variable of one of the entities, Air Canada in this case, along with any other data-wide information, as what is usual with constants. That is, the regression coefficients are changes in the average hedge ratio, relative to Air Canada’s average hedge ratio. The fact that Air Canada is contained within the constant is of no meaning. Air Canada is chosen purely arbitrarily given the data fed into the model. As evident by the table, the explanatory power of the model becomes quite high just by including fixed entity effects.

The following discusses what fixed entity effects may include, and if other types of entities than the firms themselves could be considered. It is important to remember that entity fixed effects are, by definition, unobservable, hence it is hard to reach resolute conclusions regarding entity fixed effects.

10.3.3. - Risk culture and risk politics

Risk culture, as with all other types of culture, is hard to observe and quantify, and therefore hard to include in a regression. This is likely to be a big part of the information conveyed by the entity fixed effects variables. The culture can be the approach to risk in a company, or even (as touched upon in the following subsection) in a region or country. Either the firm itself does not value risk management as high as others, or the shareholders might not value it; an important factor as management theoretically have to act in the interest of shareholders. If culture differs substantially
between entities, it is of no surprise to see significant fixed entity effects in the data. Besides an unknown cultural approach to risk, risk politics might also have been set up. The board of directors can set limits within which firms are allowed to operate; for example, they can set a hedge interval of 60-80% of next year’s expected jet fuel consumption. Such limitations on hedging activities significantly affect the fixed entity effects exhibited in the data.

10.3.4. - Region/continent

The risk culture can vary between firms but might also be different across regions or continents. The airline data for this thesis contains firms from four different continents of the world; North America, Europe, Asia and Australia\(^8\), distributed as seen below:

<table>
<thead>
<tr>
<th>Continent</th>
<th>Airlines</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>Air Canada, Alaska Air, Delta Airlines, JetBlue, Southwest, Spirit Airlines, United Airlines</td>
</tr>
<tr>
<td>Europe</td>
<td>EasyJet, Lufthansa, Norwegian, Ryanair, SAS</td>
</tr>
<tr>
<td>Asia</td>
<td>AirAsia, China Southern Airlines, Singapore Airlines, Turkish Airlines</td>
</tr>
<tr>
<td>Australia</td>
<td>Air New Zealand, Qantas</td>
</tr>
</tbody>
</table>

*Table 10.2: Airlines split by continent. – Source: Own contribution*

The region or continent of airlines might also contain significant fixed effects, if competition and regulatory environment differ substantially. Regulations on the amount of risk a company can take on will likely affect the hedge ratio level in the given region, if the regulation is region-wide. Increased competition may also lead to differences in hedge ratio levels. Airlines in regions of increased competition are likely to be operating on low margins, as competition drives down prices. Once operating on low margins, firms could possibly experience liquidity problems, hence incentivizing jet fuel hedging to decrease cash flow volatility. Accessibility to financial markets, and transaction costs within these, also likely affect the hedge ratio level. If transaction costs are high, hedging exposure will be costlier to these firms, hence one would expect to see lower hedge ratios for these firms, all else being equal. Regions or continents are therefore also likely to have significant effects on the hedge ratio. The model of continents as explanatory variables can be found in appendix 2. As expected, continents are highly significant but nowhere near the extent of entity fixed effects on firm level.

---

8 Used as a proxy for Oceania
To summarize, data shows no significance of year fixed effects; however, entity fixed effects are indeed very significant. The fact that year fixed effects are not significant are interesting, in that it may indicate that global economic factors have little effect on the hedging strategies. Another possibility, somewhat unlikely, is that firms operate in isolated markets, and are not affected by the same factors, i.e. there are no omitted variables constant across entities, but not across time; the very definition of time fixed effects. This would be true if the firms operate only locally and are never exposed to the same global environment. With the nature of operations of the airline industry, this is thus considered highly unlikely.

The risk culture is considered the main contributor of entity fixed effects. Risk culture is unlikely to be the same across the world, much less across firms, as culture is often based on historical events. The economic history of the companies differs substantially; the previous economic success or failure of a company exposed to risk, likely has an effect on the risk culture.

Risk culture, as well as other fixed effects, may also differ across continents or regions. Continents and regions might have more or less similar views on risk, as well as being exposed to much of the same regulatory environment. On a continent or region level, the competitive environment also adds to the fixed effects. Price wars can lead to low margins, making the need for cash flow volatility management more important. Airline data shows significant effects of continents.

The upshot of all this is that the firm fixed effects are comprised of risk culture, and thereby the history of the firms. There is also likely to be other fixed effects when one considers other entities, such as regions or continents; for example, the regulatory and competitive environment. Continent fixed effect does not allow for enough variation within firms, hence the explanatory power of continents in a model are lower than that of firm level fixed effects. That is, firm culture is likely to be different from the overall culture of an area. This culture, the historical background of a company, the previous experiences with risk, and differing business models are all reasons as to why entity fixed effects are highly significant.

10.4 - Currencies
Another interesting variable to consider is the home-currency used by the airlines. This is a special case for jet fuel hedging. Jet fuel prices are denominated in USD, as are other fuel types used for hedging. This means that firms exposed to jet fuel price risk are automatically exposed to currency risk. American firms are the only ones not exposed to currency risk through jet fuel risk. What is
interesting then is if the currency is correlated with jet fuel prices. Currencies that are correlated with oil prices are sometimes referred to as petrocurrencies.

The idea is that firms whose currency cross (home-currency/USD) is negatively correlated to jet fuel prices, hedge less. That is, the currency exposure acts as a sort of natural hedge towards the jet fuel prices. If on the other hand correlation is positive, jet fuel prices and the currency cross might move the same way, either leading to drastic increases or decreases in effective jet fuel price. The problem is not only one of correlation, but also volatility. Jet fuel prices are likely more volatile than currencies, so even with a negative correlation, jet fuel prices would probably decrease more than the currency cross would increase, and vice versa.

One might think that drastic decreases in jet fuel prices are in favor of the airlines, however this is not in line with the definition of hedging; decreasing volatility of cash flows.

The combination of jet fuel price risk and currency then leads to the question; which exposure should companies hedge? Jet fuel prices are more volatile, hence induce the most volatility in cash flows. But jet fuel is more difficult to hedge than currencies; currencies are also OTC markets, but being the biggest market in the world, derivatives are readily available.

The sign of the correlation is hard to estimate, as many factors play in to this. That being said, USA is the biggest producer of jet fuel in the world, so jet fuel prices are likely to be somewhat correlated with appreciation or depreciation of the USD. Other countries that produce oil themselves might also experience correlation with jet fuel prices; more so the bigger the share of GDP stems from oil production. Also, countries that trade jet fuel and oil with USA are expected to have higher correlation.

Whether a currency can be considered a petrocurrency, and the direction of the correlation, can greatly alter the need for risk management and expose firms to a more complex risk situation. The net currency exposure of the firm is also of interest. If the net exposure is zero, i.e. the firm spends as many USD as it receives in USD, the firm would not hedge currencies, and the whole petrocurrency discussion is of no interest.

Currencies can easily be included into the models but given the composition of the airline dataset, this would create problems when running the regression. Several currencies and airlines would be perfectly correlated, as many of the currencies in the dataset are only used by one airline. The model is still computed and included in appendix 2. More data needs to be gathered on both jet fuel and currency hedging for this analysis to add value. It is considered further below.
10.5 - Further studies

Throughout the thesis, the authors have become aware of other variables or aspects of hedging that could be of interest but which, due to time and space limitations, did not make it into the thesis.

As was briefly touched upon previously, currencies is one such variable. The correlation of currencies and jet fuel prices, the existence of petrocurrencies, can potentially lead to natural hedges. To test this hypothesis, one would need data of more firms with the same currencies, as to not just catch single entity fixed effects as explained in the discussion. Also, the hedge ratios of next year’s currency exposure would also be needed for the analysis. One would also need to obtain the net currency exposure of all operations, and the currency exposure as a result of jet fuel price exposure.

Rampini et al. (2014) include a credit rating variable in their empirical study. Historical information on this is relatively easy to retrieve for US airlines but not for the global portfolio of airlines in this thesis. Including credit ratings is of interest, as this is a highly significant variable in the Rampini et al. (2014) paper. One could also seek to determine possible causality of the credit ratings and hedge ratios. That is, does hedging lead to higher credit ratings, since the firm is then less exposed, or does higher credit ratings lead to higher hedge ratios, due to collateralization mechanics of the Rampini et al. theories (2010 & 2014). This can be tested using lagged values of the variables. For example, one could regress the credit rating (converted to a numerical index) on last year’s hedge ratio of every firm. Positive significance could imply hedge ratios resulting in higher credit ratings. To further tests the theories of Rampini et al. (2010 & 2014), more detailed data on available collateral would be needed. As this is considered one of the main drivers of the mechanics of their hypothesized relationship, surely this should be of interest when testing their theory. Some parts of what they, and we as well, define as net worth may not be available for collateral, hence should not be considered as part of this.

To further test the idea of Froot et al. (1993), gathering data on the explicit cost of external financing would allow for more accurate testing. Once again, this is considered the main driver of the hypothesized relationship. Net finance cost of debt was already included in the analyses of this thesis but based on numbers from the annual report. Reporting rules might alter what is considered costs of external financing in the reports, and what is actually the costs of external financing. Identifying the correct costs might leader to better testing of the hypothesis.
As is evident by the figures 8.1 and 8.2, depicting data grouped by airlines, the slope of the trendlines vary substantially, even between positive and negative values. It is clear that there are other factors, possibly correlated with net worth, that could add value to the determination of relationships. One could search for variables, dummy or random, that indicate whether the relationship is positive or negative.
11 - Conclusion

Risk management has always been practiced, partly under different names and partly without the practitioners’ actual knowing, but it is far from exhausted. Practicing risk management by means of derivatives is a newer phenomenon and due to the nature of derivatives, it is an interminable field of research. The importance of risk management, and derivatives, needs empirical testing, and the airline industry constitute the ideal environment. The airline industry is rather homogeneous, making comparisons easier, and the relevant information is readily available.

Through a distribution and time series analysis, we find that jet fuel price returns are highly volatile, with long tails and exhibiting persistent volatility clustering. With jet fuel prices making up a large part of operating costs, the volatility of jet fuel leaves airlines highly exposed to cash flow risk.

When performing risk management, which here is defined as activities that lower volatilities i.e. hedging, the companies have to consider what fuel type and what derivative to use. In our sample, airlines primarily have options on crude oil, which is an example of cross-hedging, and collars and swaps on jet fuel, though no clear industry-wide standard exists. It was impossible to find any patterns linking airlines and specific fuel types and/or derivatives, e.g. if hedging decisions are affected by geography or by size. Regarding fuel types, we find somewhat contradicting results. As stated above, options on crude oil is diligently used, though heating oil is a better fuel type for cross-hedging, as seen from their correlation with jet fuel.

Our dissertation builds on two conflicting findings.
In the first one (Froot et al., 1993), hedging should be practiced when external financing is more expensive than internally generated funds, which is true for firms with high debt-levels. Thus, the relationship between debt-levels and hedge ratios is positive.
In the second one (Rampini and Viswanathan, 2010), firms with higher net worth will engage in hedging. The argument comes from the return on investing internal funds being higher than the return on conserving debt capacity, i.e. on the return on hedging, up until a threshold after which hedging is increasingly applied.
The most decisive reasons for the opposite findings in the two theories, and the most relevant reasons for this dissertation, are the cost of external financing and collateral constraints. An interesting theory could come from trying to merge, align and update the two.
To test the relationships propounded in the opposing theories, we run multiple regressions of differing specifications. All models are computed as both cross-sectional and fixed-entity effects model, with fixed entity effects models proving to be superior to cross-sectional models. That is, risk culture and risk politics are most likely to account for the majority of the variation between airlines.

The statistical relationships emerging from our models are significant and highly in accordance with Froot et al. (1993); visualized through a negative relationship between net worth and hedge ratios, and also through a positive relationship between net financing cost of debt and hedge ratios. More financially constrained firms hedge more. They are more limited at the margin, and they cannot afford to forego potential, positive NPV investments.

Our findings are opposed to the empirical findings in Rampini, Sufi and Viswanathan (2014). Aligned with their 2010 model (Rampini and Viswanathan, 2010), using the American airline industry as their playground, they find a positive relationship between net worth and hedge ratios. The exact reason for why the data fits their model is unclear, and we can simply direct the attention to their choice of data.

In conclusion; jet fuel poses an immense risk for airlines. Hedging activities are rather inconsistent between airlines, with airlines using a multitude of diverse option strategies and using several different commodities as the underlying assets. Our empirical study finds a negative correlation between net worth and the amount of next year’s fuel consumption hedged, as well as a positive relationship between net financing cost of debt and hedge ratios. These findings are found to be in favor of the Froot et al. theory from 1993. Though these findings are significant, most of the variation in hedge ratios most likely stems from the differing risk cultures and politics within airlines.

The findings in our dissertation contribute to the field of risk management by examining firm characteristics’ relations with hedge ratios. Despite obtaining significant results, further studying is warranted. The results of our dissertation should serve as supporting inspiration and foundation.
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https://www.eia.gov/beta/international/

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## Investor Relations

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Commodities Price Data

https://www.eia.gov/dnav/pet/hist/EER_EPJK_PF4_RGC_DPGD.htm

Investing.com. Futures prices of WTI crude oil, Brent crude oil, heating oil and gasoil.
https://www.investing.com/

Quandl. Futures prices of WTI crude oil, Brent crude oil, heating oil and gasoil.
https://www.quandl.com/
Appendices

1. Summary statistics of relevant data
2. Regression output of entity fixed effects models
3. Data plots of chosen independent variables and hedge ratios
4. R code for jet fuel return analysis
5. R code for hedge ratio analysis
Appendix 1 - Summary statistics of relevant data

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**Airline data**

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Appendix 2 – full entity fixed effects models

Hedge ratio ~ Book value of net worth

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Hedge ratio ~ Market value of net worth

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Note: *p<0.1; **p<0.05; ***p<0.01
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<td>factor(Airline)Singapore airlines*</td>
<td>0.155**</td>
<td>(0.076)</td>
</tr>
<tr>
<td>factor(Airline)Southwest</td>
<td>0.068</td>
<td>(0.081)</td>
</tr>
<tr>
<td>factor(Airline)Spirit airlines</td>
<td>-0.045</td>
<td>(0.086)</td>
</tr>
<tr>
<td>factor(Airline)Turkish Airlines</td>
<td>0.226***</td>
<td>(0.043)</td>
</tr>
<tr>
<td>factor(Airline)United Airlines</td>
<td>0.031</td>
<td>(0.047)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.209***</td>
<td>(0.072)</td>
</tr>
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</table>

Note: *p<0.1; **p<0.05; ***p<0.01
### Hedge ratio ~ Quick ratio

<table>
<thead>
<tr>
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<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick_ratio</td>
<td>-0.046</td>
<td>(0.074)</td>
</tr>
<tr>
<td>factor(Airline) Air New Zealand**</td>
<td>0.150***</td>
<td>(0.040)</td>
</tr>
<tr>
<td>factor(Airline) AirAsia</td>
<td>0.059</td>
<td>(0.088)</td>
</tr>
<tr>
<td>factor(Airline) Alaska Air</td>
<td>0.273***</td>
<td>(0.024)</td>
</tr>
<tr>
<td>factor(Airline) China Southern Airlines</td>
<td>-0.217***</td>
<td>(0.037)</td>
</tr>
<tr>
<td>factor(Airline) Delta Airlines</td>
<td>-0.139**</td>
<td>(0.063)</td>
</tr>
<tr>
<td>factor(Airline) EasyJet</td>
<td>0.563***</td>
<td>(0.020)</td>
</tr>
<tr>
<td>factor(Airline) Jetblue</td>
<td>-0.036</td>
<td>(0.059)</td>
</tr>
<tr>
<td>factor(Airline) Lufthansa</td>
<td>0.514***</td>
<td>(0.044)</td>
</tr>
<tr>
<td>factor(Airline) Norwegian</td>
<td>0.002</td>
<td>(0.070)</td>
</tr>
<tr>
<td>factor(Airline) Qantas**</td>
<td>0.283***</td>
<td>(0.107)</td>
</tr>
<tr>
<td>factor(Airline) Ryanair*</td>
<td>0.678***</td>
<td>(0.029)</td>
</tr>
<tr>
<td>factor(Airline) SAS**</td>
<td>0.296***</td>
<td>(0.029)</td>
</tr>
<tr>
<td>factor(Airline) Singapore airlines*</td>
<td>0.143*</td>
<td>(0.075)</td>
</tr>
<tr>
<td>factor(Airline) Southwest</td>
<td>0.059</td>
<td>(0.084)</td>
</tr>
<tr>
<td>factor(Airline) Spirit airlines</td>
<td>-0.072</td>
<td>(0.081)</td>
</tr>
<tr>
<td>factor(Airline) Turkish Airlines</td>
<td>0.213***</td>
<td>(0.055)</td>
</tr>
<tr>
<td>factor(Airline) United Airlines</td>
<td>0.035</td>
<td>(0.048)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.226***</td>
<td>(0.050)</td>
</tr>
</tbody>
</table>

Note: *p<0.1; **p<0.05; ***p<0.01
Hedge ratio ~ Debt level

<table>
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<th>Standard Error</th>
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<td>Debt.level</td>
<td>0.058</td>
<td>(0.181)</td>
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<tr>
<td>factor(Airline)Air New Zealand* *</td>
<td>0.159***</td>
<td>(0.050)</td>
</tr>
<tr>
<td>factor(Airline)AirAsia</td>
<td>0.056</td>
<td>(0.100)</td>
</tr>
<tr>
<td>factor(Airline)Alaska Air</td>
<td>0.279***</td>
<td>(0.046)</td>
</tr>
<tr>
<td>factor(Airline)China Southern Airlines</td>
<td>-0.190***</td>
<td>(0.025)</td>
</tr>
<tr>
<td>factor(Airline)Delta Airlines</td>
<td>-0.107</td>
<td>(0.068)</td>
</tr>
<tr>
<td>factor(Airline)EasyJet</td>
<td>0.579***</td>
<td>(0.050)</td>
</tr>
<tr>
<td>factor(Airline)Jetblue</td>
<td>-0.014</td>
<td>(0.050)</td>
</tr>
<tr>
<td>factor(Airline)Lufthansa</td>
<td>0.552***</td>
<td>(0.047)</td>
</tr>
<tr>
<td>factor(Airline)Norwegian</td>
<td>0.020</td>
<td>(0.070)</td>
</tr>
<tr>
<td>factor(Airline)Qantas* * *</td>
<td>0.300**</td>
<td>(0.115)</td>
</tr>
<tr>
<td>factor(Airline)Ryanair*</td>
<td>0.673***</td>
<td>(0.031)</td>
</tr>
<tr>
<td>factor(Airline)SAS* *</td>
<td>0.313***</td>
<td>(0.029)</td>
</tr>
<tr>
<td>factor(Airline)Singapore airlines*</td>
<td>0.156</td>
<td>(0.101)</td>
</tr>
<tr>
<td>factor(Airline)Southwest</td>
<td>0.092</td>
<td>(0.091)</td>
</tr>
<tr>
<td>factor(Airline)Spirit airlines</td>
<td>-0.095</td>
<td>(0.083)</td>
</tr>
<tr>
<td>factor(Airline)Turkish Airlines</td>
<td>0.229***</td>
<td>(0.048)</td>
</tr>
<tr>
<td>factor(Airline)United Airlines</td>
<td>0.057</td>
<td>(0.048)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.170**</td>
<td>(0.083)</td>
</tr>
</tbody>
</table>

Note: *p<0.1; **p<0.05; ***p<0.01
Hedge ratio ~ Net finance cost of debt

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net.finance.revenue</td>
<td>3.221***</td>
<td>0.854</td>
</tr>
<tr>
<td>factor(Airline)Air New Zealand* **</td>
<td>0.199***</td>
<td>0.045</td>
</tr>
<tr>
<td>factor(Airline)AirAsia</td>
<td>-0.056</td>
<td>0.082</td>
</tr>
<tr>
<td>factor(Airline)Alaska Air</td>
<td>0.316***</td>
<td>0.022</td>
</tr>
<tr>
<td>factor(Airline)China Southern Airlines</td>
<td>-0.163***</td>
<td>0.019</td>
</tr>
<tr>
<td>factor(Airline)Delta Airlines</td>
<td>-0.103**</td>
<td>0.048</td>
</tr>
<tr>
<td>factor(Airline)EasyJet</td>
<td>0.642***</td>
<td>0.032</td>
</tr>
<tr>
<td>factor(Airline)Jetblue</td>
<td>-0.043</td>
<td>0.034</td>
</tr>
<tr>
<td>factor(Airline)Lufthansa</td>
<td>0.591***</td>
<td>0.026</td>
</tr>
<tr>
<td>factor(Airline)Norwegian</td>
<td>0.074</td>
<td>0.069</td>
</tr>
<tr>
<td>factor(Airline)Qantas* **</td>
<td>0.345***</td>
<td>0.112</td>
</tr>
<tr>
<td>factor(Airline)Ryanair*</td>
<td>0.709***</td>
<td>0.033</td>
</tr>
<tr>
<td>factor(Airline)SAS* *</td>
<td>0.334***</td>
<td>0.027</td>
</tr>
<tr>
<td>factor(Airline)Singapore airlines*</td>
<td>0.220***</td>
<td>0.075</td>
</tr>
<tr>
<td>factor(Airline)Southwest</td>
<td>0.134*</td>
<td>0.078</td>
</tr>
<tr>
<td>factor(Airline)Spirit airlines</td>
<td>-0.054</td>
<td>0.057</td>
</tr>
<tr>
<td>factor(Airline)Turkish Airlines</td>
<td>0.319***</td>
<td>0.059</td>
</tr>
<tr>
<td>factor(Airline)United Airlines</td>
<td>0.066*</td>
<td>0.038</td>
</tr>
<tr>
<td>Constant</td>
<td>0.110***</td>
<td>0.028</td>
</tr>
</tbody>
</table>

Note: *p<0.1; **p<0.05; ***p<0.01
Hedge ratio ~ Net finance cost of debt + Net worth

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net.worth</td>
<td>-0.276**</td>
<td>(0.112)</td>
</tr>
<tr>
<td>Net.finance.revenue</td>
<td>2.720***</td>
<td>(0.854)</td>
</tr>
<tr>
<td>factor(Airline)Air New Zealand* *</td>
<td>0.300***</td>
<td>(0.062)</td>
</tr>
<tr>
<td>factor(Airline)AirAsia</td>
<td>0.059</td>
<td>(0.085)</td>
</tr>
<tr>
<td>factor(Airline)Alaska Air</td>
<td>0.408***</td>
<td>(0.045)</td>
</tr>
<tr>
<td>factor(Airline)China Southern Airlines</td>
<td>-0.076*</td>
<td>(0.042)</td>
</tr>
<tr>
<td>factor(Airline)Delta Airlines</td>
<td>-0.056</td>
<td>(0.054)</td>
</tr>
<tr>
<td>factor(Airline)EasyJet</td>
<td>0.771***</td>
<td>(0.065)</td>
</tr>
<tr>
<td>factor(Airline)Jetblue</td>
<td>0.066</td>
<td>(0.056)</td>
</tr>
<tr>
<td>factor(Airline)Lufthansa</td>
<td>0.668***</td>
<td>(0.041)</td>
</tr>
<tr>
<td>factor(Airline)Norwegian</td>
<td>0.139*</td>
<td>(0.075)</td>
</tr>
<tr>
<td>factor(Airline)Qantas* *</td>
<td>0.428***</td>
<td>(0.125)</td>
</tr>
<tr>
<td>factor(Airline)Ryanair*</td>
<td>0.824***</td>
<td>(0.058)</td>
</tr>
<tr>
<td>factor(Airline)SAS* *</td>
<td>0.418***</td>
<td>(0.047)</td>
</tr>
<tr>
<td>factor(Airline)Singapore airlines*</td>
<td>0.390***</td>
<td>(0.104)</td>
</tr>
<tr>
<td>factor(Airline)Southwest</td>
<td>0.250***</td>
<td>(0.095)</td>
</tr>
<tr>
<td>factor(Airline)Spirit airlines</td>
<td>0.118</td>
<td>(0.095)</td>
</tr>
<tr>
<td>factor(Airline)Turkish Airlines</td>
<td>0.412***</td>
<td>(0.064)</td>
</tr>
<tr>
<td>factor(Airline)United Airlines</td>
<td>0.104***</td>
<td>(0.033)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.101***</td>
<td>(0.027)</td>
</tr>
</tbody>
</table>

Note: *p<0.1; **p<0.05; ***p<0.01
Hedge ratio ~ Half year return

<table>
<thead>
<tr>
<th>Factor</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half.year.return</td>
<td>0.038</td>
<td>(0.051)</td>
</tr>
<tr>
<td>factor(Airline)Air New Zealand</td>
<td>0.146***</td>
<td>(0.040)</td>
</tr>
<tr>
<td>factor(Airline)AirAsia</td>
<td>0.062</td>
<td>(0.093)</td>
</tr>
<tr>
<td>factor(Airline)Alaska Air</td>
<td>0.266***</td>
<td>(0.020)</td>
</tr>
<tr>
<td>factor(Airline)China Southern Airlines</td>
<td>-0.196***</td>
<td>(0.016)</td>
</tr>
<tr>
<td>factor(Airline)Delta Airlines</td>
<td>-0.119**</td>
<td>(0.050)</td>
</tr>
<tr>
<td>factor(Airline)EasyJet</td>
<td>0.562***</td>
<td>(0.023)</td>
</tr>
<tr>
<td>factor(Airline)Jetblue</td>
<td>-0.020</td>
<td>(0.044)</td>
</tr>
<tr>
<td>factor(Airline)Lufthansa</td>
<td>0.539***</td>
<td>(0.022)</td>
</tr>
<tr>
<td>factor(Airline)Norwegian</td>
<td>0.016</td>
<td>(0.072)</td>
</tr>
<tr>
<td>factor(Airline)Qantas</td>
<td>0.288***</td>
<td>(0.108)</td>
</tr>
<tr>
<td>factor(Airline)Ryanair</td>
<td>0.670***</td>
<td>(0.029)</td>
</tr>
<tr>
<td>factor(Airline)SAS*</td>
<td>0.306***</td>
<td>(0.022)</td>
</tr>
<tr>
<td>factor(Airline)Singapore airlines</td>
<td>0.135*</td>
<td>(0.071)</td>
</tr>
<tr>
<td>factor(Airline)Southwest</td>
<td>0.076</td>
<td>(0.076)</td>
</tr>
<tr>
<td>factor(Airline)Spirit airlines</td>
<td>-0.111**</td>
<td>(0.055)</td>
</tr>
<tr>
<td>factor(Airline)Turkish Airlines</td>
<td>0.229***</td>
<td>(0.051)</td>
</tr>
<tr>
<td>factor(Airline)United Airlines</td>
<td>0.049</td>
<td>(0.042)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.197***</td>
<td>(0.016)</td>
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</table>

Note: *p<0.1; **p<0.05; ***p<0.01
Hedge ratio ~ Half year momentum

<table>
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<tr>
<td>Half.year.momentum</td>
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<tr>
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</tr>
<tr>
<td>factor(Airline)Air New Zealand* *</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)AirAsia</td>
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<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)Alaska Air</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)China Southern Airlines</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)Delta Airlines</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)EasyJet</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)Jetblue</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)Lufthansa</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)Norwegian</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)Qantas* * *</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>factor(Airline)Ryanair*</td>
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<td></td>
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<tr>
<td>factor(Airline)SAS* *</td>
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<tr>
<td>factor(Airline)Singapore airlines*</td>
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<td></td>
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<td>factor(Airline)Southwest</td>
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<td></td>
</tr>
<tr>
<td>factor(Airline)Spirit airlines</td>
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<td></td>
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<td>factor(Airline)Turkish Airlines</td>
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<td>factor(Airline)United Airlines</td>
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<td></td>
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<tr>
<td>Constant</td>
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Note: *p<0.1; **p<0.05; ***p<0.01
### Hedge ratio ~ Continents

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<th>P-value</th>
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<td>factor(Continent)Australia</td>
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</tr>
<tr>
<td>factor(Continent)Europe</td>
<td>0.362***</td>
<td>(0.058)</td>
</tr>
<tr>
<td>factor(Continent)North america</td>
<td>-0.032</td>
<td>(0.048)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.253***</td>
<td>(0.041)</td>
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</table>

**Note:**  
*p<0.1; **p<0.05; ***p<0.01
### Hedge ratio ~ Currencies

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<td>factor(Currency)MYR</td>
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<tr>
<td>factor(Currency)NOK</td>
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<td>factor(Currency)NZD</td>
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<td></td>
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<td>factor(Currency)RMB</td>
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<td>factor(Currency)SEK</td>
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<td>factor(Currency)TRY</td>
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<td>factor(Currency)USD</td>
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<tr>
<td>Constant</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Note: *p<0.1; **p<0.05; ***p<0.01
Appendix 3 – Data plots

*Market and book value of net worth ratio.*

*Net worth (book) and hedge ratio*
Net worth (market) and hedge ratio

Current ratio and hedge ratio
Quick ratio and hedge ratio

Debt level and hedge ratio
Net finance cost of debt and hedge ratio

Continent boxplot
Appendix 4 – RStudio raw code – Jet fuel price analysis

```r
require(MASS)
require(fitdistrplus)
require(fGarch)
require(tseries)
require(forecast)
require(rugarch)
require(limma)

# Setting working directory
setwd("/Users/frederikkobbernagel/Dropbox/Speciale/Data/Jet fuel distribution analysis")

# load CSV file
Jet_fuel_price <- read.csv("Jet fuel price for R.csv", header=TRUE, sep=";", skip=0)

# remove NA from data
Jet_fuel_price <- na.omit(Jet_fuel_price)

##--------------------- Fitting distributions ---------------------

# Fitting normal distribution
normal_jet_fuel <- fitdistr(Jet_fuel_price$Change, "normal")

# fitting student-t distribution
student_t_jet_fuel <- stdFit(Jet_fuel_price$Change)

# fitting skew student-t distribution
skew_student_t_jet_fuel <- sstdFit(Jet_fuel_price$Change)

##--------------------- Printing output of distributions ---------------------

# printing normal function and loglik
normal_jet_fuel
logLik(normal_jet_fuel)

# printing student-t function and loglik
```

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student_t_jet_fuel
logLik(student_t_jet_fuel)

# printing skew student-t function and loglik
skew_student_t_jet_fuel
logLik(skew_student_t_jet_fuel)

## Plotting distributions

# Normal distribution
curve(dnorm(x, mean=0.0002541160, sd=0.023496441), from = (-0.15),
to = 0.15, n = 1000,
   col="Blue", ylim=c(0, 30), xlab="x", ylab="frequency")

# Student-t distribution
curve(dstd(x, mean=-1.697973e-05, sd=2.340052e-02, nu=3.1477614896),
from=-0.15, to=0.15,
n=1000, col="Red", add=TRUE, ylim=TRUE)

# Skew student t distribution
curve(dsstd(x, mean=0.0001418461, sd=0.0233931600, nu=3.2910239921,
xi=1.0140238278),
from=-0.15, to=0.15, n=1000, col="Green", add=TRUE)

## Plotting tail curves

# Normal distribution right tail
curve(dnorm(x, mean=0.0002541160, sd=0.023496441), from = (0.05), to = 0.15, n = 1000,
   col="Blue", ylim=c(0, 5), xlab="x", ylab="frequency")

# Student-t distribution right tail
curve(dstd(x, mean=-1.697973e-05, sd=2.340052e-02, nu=3.1477614896),
from=0.05, to=0.15,
   n=1000, col="Red", add=TRUE, ylim=TRUE)

## QQ plots

## qqplot for student-t distribution
qqplot(rt(2794, df=3.29), Jet_fuel_price$Change, xlab="Theoretical Quantiles", ylab="Sample Quantiles")

##qq plot for normal distribution

qqnorm(Jet_fuel_price$Change)
qqline(Jet_fuel_price$Change, col=2)

##----------------------- Time series analysis -----------------------

#Augmented Dickey-Fuller test - H0=non-stationary H1=stationary
adf.test(Jet_fuel_price$Change)

#H0= time series is non-stationary
#H1= time series is stationary
#Test rejects H0, time series is stationary at a 1% significance level.

#ACF plot of jet fuel returns
acf(Jet_fuel_price$Change)

#Ljung-Box test H0=
Box.test(Jet_fuel_price$Change, lag=10, type="Ljung-Box")

#H0= At least 1 of X=10 lags are different from 0
#H1= All lags are 0
#Test rejects H0, time series is stationary at a 5% significance level.

## plotting time series
plot(as.ts(Jet_fuel_price$Change))

##----------------------- ARIMA models -----------------------

#Auto arima
auto.arima.jet.fuel <- auto.arima(Jet_fuel_price$Change, max.p=5, max.q=5, stationary = TRUE, seasonal = FALSE, ic="aic")
# Printing auto arima output
auto.arima.jet.fuel

# Plot of residuals from model
acf(auto.arima.jet.fuel$residuals)
plot(as.ts(auto.arima.jet.fuel$residuals))

## ARIMA GARCH models

## The following tests various ARIMA and GARCH combinations.

# GARCH model - ARIMA(0,0,3) GARCH(0,0)
arma.garch.1 = ugarchspec(mean.model=list(armaOrder=c(0,3)),
                            variance.model=list(garchOrder=c(0,0)))
Jet.fuel.garch.1 = ugarchfit(data=Jet_fuel_price$Change,
                             spec=arma.garch.1, solver="hybrid")
show(Jet.fuel.garch.1)

# GARCH model - ARIMA(0,0,0) GARCH(1,1) - better model than
# ARIMA(0,0,0)
arma.garch.2 = ugarchspec(mean.model=list(armaOrder=c(0,0)),
                            variance.model=list(garchOrder=c(1,1)))
Jet.fuel.garch.2 = ugarchfit(data=Jet_fuel_price$Change,
                             spec=arma.garch.2, solver="hybrid")
show(Jet.fuel.garch.2)

# GARCH model - ARIMA(0,0,1) GARCH(1,1)
arma.garch.3 = ugarchspec(mean.model=list(armaOrder=c(0,1)),
                            variance.model=list(garchOrder=c(1,1)))
Jet.fuel.garch.3 = ugarchfit(data=Jet_fuel_price$Change,
                             spec=arma.garch.3, solver="hybrid")
show(Jet.fuel.garch.3)

# GARCH model - ARIMA(1,0,0) GARCH(1,1)
arma.garch.4 = ugarchspec(mean.model=list(armaOrder=c(1,0)),
                            variance.model=list(garchOrder=c(1,1)))
Jet.fuel.garch.4 = ugarchfit(data=Jet_fuel_price$Change,
                             spec=arma.garch.4, solver="hybrid")
show(Jet.fuel.garch.4)
```
#GARCH model - ARIMA(0,0,2) GARCH(1,1)
arma.garch.5 = ugarchspec(mean.model=list(armaOrder=c(0,2)),
                          variance.model=list(garchOrder=c(1,1)))
Jet.fuel.garch.5 = ugarchfit(data=Jet_fuel_price$Change,
spec=arma.garch.5, solver="hybrid")
show(Jet.fuel.garch.5)

#GARCH model - ARIMA(0,0,3) GARCH(1,1)
arma.garch.6 = ugarchspec(mean.model=list(armaOrder=c(0,3)),
                          variance.model=list(garchOrder=c(1,1)))
Jet.fuel.garch.6 = ugarchfit(data=Jet_fuel_price$Change,
spec=arma.garch.6, solver="hybrid")
show(Jet.fuel.garch.6)

#GARCH model - ARIMA(0,0,3) GARCH(0,1)
arma.garch.6 = ugarchspec(mean.model=list(armaOrder=c(0,3)),
                          variance.model=list(garchOrder=c(0,1)))
Jet.fuel.garch.6 = ugarchfit(data=Jet_fuel_price$Change,
spec=arma.garch.6, solver="hybrid")
show(Jet.fuel.garch.6)

#GARCH model - ARIMA(0,0,3) GARCH(1,0)
arma.garch.6 = ugarchspec(mean.model=list(armaOrder=c(0,3)),
                          variance.model=list(garchOrder=c(1,0)))
Jet.fuel.garch.6 = ugarchfit(data=Jet_fuel_price$Change,
spec=arma.garch.6, solver="hybrid")
show(Jet.fuel.garch.6)

#GARCH model - ARIMA(1,0,1) GARCH(1,1)
arma.garch.7 = ugarchspec(mean.model=list(armaOrder=c(1,1)),
                          variance.model=list(garchOrder=c(1,1)))
Jet.fuel.garch.7 = ugarchfit(data=Jet_fuel_price$Change,
spec=arma.garch.7, solver="hybrid")
show(Jet.fuel.garch.7)

#ARCH model - ARIMA(0,0,0) GARCH(1,0)
arma.arch.1 = ugarchspec(mean.model=list(armaOrder=c(0,0)),
                          variance.model=list(garchOrder=c(1,0)))
Jet.fuel.arch.1 = ugarchfit(data=Jet_fuel_price$Change,
spec=arma.arch.1, solver="hybrid")
show(Jet.fuel.arch.1)
```
#ARCH model - ARIMA(0,0,0) GARCH(0,1)
arma.arch.1 = ugarchspec(mean.model=list(armaOrder=c(0,0)),
                        variance.model=list(garchOrder=c(0,1)))
Jet.fuel.arch.1 = ugarchfit(data=Jet_fuel_price$Change,
spec=arma.arch.1, solver="hybrid")
show(Jet.fuel.arch.1)
Appendix 5 – RStudio raw code – Hedge ratio analysis

```r
## Loading packages required
require(stargazer)
require(AER)
require(ggplot2)
require(car)
require(MASS)

## Setting working directory
setwd("/Users/frederikkobbernagel/Dropbox/Speciale/Data/Airline Hedge Ratio analysis")

## Loading data
Hedge_ratio_data <- read.delim("Airline Hedge ratio.csv", sep=";", header=TRUE, skip=0, stringsAsFactors=TRUE)

## Creating data table with firms having debt ratios
With_debt <- Hedge_ratio_data[c(1:120, 124:142), c(1:17)]

## Creating data table with firms with financial-year January-December Year effects <- Hedge_ratio_data[c(1:8, 17:48, 57:80, 113:142), c(1:17)]

## Descriptive statistics
stargazer(Hedge_ratio_data, summary=TRUE, type="text")

## Plotting data
plot(Hedge_ratio_data$Net.worth, Hedge_ratio_data$Market_net_worth, main="Market/Book", xlab="Book value", ylab="Market value")
plot(Hedge_ratio_data$Net.worth, Hedge_ratio_data$Hedge_ratio, main="Hedge ratio ~ Net worth (book)", xlab="Net worth (book)", ylab="Hedge ratio")
plot(Hedge_ratio_data$Market_net_worth, Hedge_ratio_data$Hedge_ratio, main="Hedge ratio ~ Net worth (market)", xlab="Net worth (market)", ylab="Hedge ratio")
plot(Hedge_ratio_data$Current_ratio, Hedge_ratio_data$Hedge_ratio, main="Hedge ratio ~ Current ratio", xlab="Current Ratio", ylab="Hedge ratio")
plot(Hedge_ratio_data$Quick_ratio, Hedge_ratio_data$Hedge_ratio, main="Hedge ratio ~ Quick ratio", xlab="Quick ratio", ylab="Hedge ratio")
plot(Hedge_ratio_data$Debt.level, Hedge_ratio_data$Hedge_ratio, main="Hedge ratio ~ Debt level", xlab="Debt level", ylab="Hedge ratio")
plot(Hedge_ratio_data$Net.finance.revenue, Hedge_ratio_data$Hedge_ratio,
```

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main="Hedge ratio ~ Net finance cost of debt", xlab="Net finance cost of debt", ylab="Hedge ratio")

plot(Hedge_ratio_data$Continent, Hedge_ratio_data$Hedge_ratio, 
    main="Continent boxplot", xlab="Continent", ylab="Hedge ratio")

plot(Hedge_ratio_data$Net.worth, Hedge_ratio_data$Net.finance.revenue, 
    main="Net finance cost of debt ~ Net worth", xlab="Net worth", 
    ylab="Net finance cost of debt")

## Plotting panel data

colors <- c("blue", "red", "green", "black", "magenta", "cyan", 
             "orange", "gray", "blue", "red", "green", "black", 
             "magenta", "cyan", "orange", "gray", "blue", "red")

## Book value of net worth and hedge ratio

scatterplot(Hedge_ratio_data$Hedge_ratio~Hedge_ratio_data$Net.worth, 
            groups=Hedge_ratio_data$Airline, col=colors, smooth=FALSE, 
            xlab="Net worth", ylab="Hedge ratio", legend="legend")

## Net finance cost of debt and hedge ratio

scatterplot(Hedge_ratio_data$Hedge_ratio~Hedge_ratio_data$Net.finance.revenue, 
            groups=Hedge_ratio_data$Airline, col=colors, smooth=FALSE, 
            xlab="Finance cost ratio", ylab="Hedge ratio", legend="legend")

#---------------------------- Models ----------------------------------

## In the following, stargazer is used to summarize model outputs.
## Stargazer(coeftest(Model, vcov=sandwich), type="text") applies 
## robust standard errors
## to the models, to account for heteroskedastic error terms.
## Stargazer(Model, type="text") allows for extraction of R-squared 
## values and F-tests.

#--------------------- Book value of net worth ---------------------

## Book value of net worth - cross-sectional

Net_worth_book <- lm(Hedge_ratio~Net.worth, 
                      data=Hedge_ratio_data)

stargazer(coeftest(Net_worth_book, vcov=sandwich), type="text")
stargazer(Net_worth_book, type="text")

## Book value of net worth - fixed effects

Net_worth_book_fixed <- 
                        lm(Hedge_ratio~Net.worth+factor(Airline)+factor(Year), 
                          data=Hedge_ratio_data)
## Book value of net worth - fixed effects - restricted

```
Net_worth_book_fixed_restric <- lm(Hedge_ratio~Net.worth+factor(Airline),
     data=Hedge_ratio_data)
```

```
stargazer(coeftest(Net_worth_book_fixed_restric, vcov=sandwich), type="text")
stargazer(Net_worth_book_fixed_restric, type="text")
```

## Testing for exclusion of years

## Squared errors

```
Hedge_ratio_data$SSE_full <- residuals(Net_worth_book_fixed)^2
Hedge_ratio_data$SSE_restric <- residuals(Net_worth_book_fixed_restric)^2
```

## calculating F test statistic

```
((sum(Hedge_ratio_data$SSE_restric)-sum(Hedge_ratio_data$SSE_full))/7)/
((sum(Hedge_ratio_data$SSE_full)/(142-1-18)))
```

## Calculating critical value

```
qf(0.95, df1=7, df2=116)
```

## H0: Restricted is better
## H1: Full model is better
## Test accepts H0

### Market value of net worth - cross-sectional

```
Net_worth_market <- lm(Hedge_ratio~Market_net_worth,
     data=Hedge_ratio_data)
```

```
stargazer(coeftest(Net_worth_market, vcov=sandwich), type="text")
stargazer(Net_worth_market, type="text")
```

## Market value of net worth - Fixed effects

```
Net_worth_market_fixed <- lm(Hedge_ratio~Market_net_worth+factor(Airline)+factor(Year),
     data=Hedge_ratio_data)
```

```
stargazer(coeftest(Net_worth_market_fixed, vcov=sandwich), type="text")
stargazer(Net_worth_market_fixed, type="text")
```

## Market value of net worth - fixed effects - restricted

```
Net_worth_market_fixed_restric <- lm(Hedge_ratio~Market_net_worth+factor(Airline),
     data=Hedge_ratio_data)
```

```
stargazer(coeftest(Net_worth_market_fixed_restric, vcov=sandwich), type="text")
stargazer(Net_worth_market_fixed_restric, type="text")
```
stargazer(coeftest(Net_worth_market_fixed_restric, vcov=sandwich), type="text")
stargazer(Net_worth_market_fixed_restric, type="text")

## Testing for exclusion of years
## Squared errors
Hedge_ratio_data$SSE_full_market <- residuals(Net_worth_market_fixed)^2
Hedge_ratio_data$SSE_restric_market <- residuals(Net_finance_fixed_restric)^2

## calculating F test statistic
((sum(Hedge_ratio_data$SSE_restric_market) - sum(Hedge_ratio_data$SSE_full_market))/7)/
  ((sum(Hedge_ratio_data$SSE_full_market)/(142-1-18)))

## Calculating critical value
qf(0.95, df1=7, df2=116)

## H0: Restricted is better
## H1: Full model is better
## Test accepts H0

#----------------------------- Current ratio -----------------------------

## Current ratio - cross-sectional
Current_ratio <- lm(Hedge_ratio~Current_ratio, data=Hedge_ratio_data)

stargazer(coeftest(Current_ratio, vcov=sandwich), type="text")
stargazer(Current_ratio, type="text")

## Current ratio - Fixed effects
Current_ratio_fixed <-
  lm(Hedge_ratio~Current_ratio+factor(Airline)+factor(Year), data=Hedge_ratio_data)

stargazer(coeftest(Current_ratio_fixed, vcov=sandwich), type="text")
stargazer(Current_ratio_fixed, type="text")

## Current ratio - Fixed effects - restricted
Current_ratio_fixed_restric <-
  lm(Hedge_ratio~Current_ratio+factor(Airline), data=Hedge_ratio_data)

stargazer(coeftest(Current_ratio_fixed_restric, vcov=sandwich), type="text")
stargazer(Current_ratio_fixed_restric, type="text")

## Testing for exclusion of years
## Squared errors
Hedge_ratio_data$SSE_full_current <- residuals(Current_ratio_fixed)^2
Hedge_ratio_data$SSE_restric_current <- residuals(Current_ratio_fixed_restric)^2

## calculating F test statistic
((sum(Hedge_ratio_data$SSE_restric_current) - sum(Hedge_ratio_data$SSE_full_current))/7)/((sum(Hedge_ratio_data$SSE_full_current)/(142-1-18)))

## Calculating critical value
qf(0.95, df1=7, df2=116)

## H0: Restricted is better
## H1: Full model is better
## Test accepts H0

#-------------------------- Quick ratio --------------------------

## Quick ratio - cross-sectional
Quick_ratio <- lm(Hedge_ratio~Quick_ratio, data=Hedge_ratio_data)
stargazer(coeftest(Quick_ratio_model, vcov=sandwich), type="text")
stargazer(Quick_ratio, type="text")

## Quick ratio - Fixed effects
Quick_ratio_fixed <- lm(Hedge_ratio~Quick_ratio+factor(Airline)+factor(Year), data=Hedge_ratio_data)
stargazer(Quick_ratio_fixed, type="text")
stargazer(coeftest(Quick_ratio_fixed, vcov=sandwich), type="text")

## Quick ratio - Fixed effects - restricted
Quick_ratio_fixed_restric <- lm(Hedge_ratio~Quick_ratio+factor(Airline), data=Hedge_ratio_data)
stargazer(coeftest(Quick_ratio_fixed_restric, vcov=sandwich), type="text")
stargazer(Quick_ratio_fixed_restric, type="text")

## Testing for exclusion of years
## Squared errors
Hedge_ratio_data$SSE_full_quick <- residuals(Quick_ratio_fixed)^2
Hedge_ratio_data$SSE_restric_quick <- residuals(Quick_ratio_fixed_restric)^2

## calculating F test statistic
((sum(Hedge_ratio_data$SSE_restric_quick) -
    sum(Hedge_ratio_data$SSE_full_quick))/7)/
((sum(Hedge_ratio_data$SSE_full_quick)/(142-1-18)))

## Calculating critical value
qf(0.95, df1=7, df2=116)

## H0: Restricted is better
## H1: Full model is better
## Test accepts H0

#--------------------------- Net Finance costs to revenue ---------------------------

## Net finance costs to revenue - cross-sectional
Net_finance <- lm(Hedge_ratio~Net.finance.revenue,
data=Hedge_ratio_data)

stargazer(coeftest(Net_finance, vcov=sandwich), type="text")
stargazer(Net_finance, type="text")

## Net finance costs to revenue - Fixed effects
Net_finance_fixed <-
    lm(Hedge_ratio~Net.finance.revenue+factor(Airline)+factor(Year),
        data=Hedge_ratio_data)

stargazer(coeftest(Net_finance_fixed, vcov=sandwich), type="text")
stargazer(Net_finance_fixed, type="text")

## Net finance costs to revenue - Fixed effects - restricted
Net_finance_fixed_restric <-
    lm(Hedge_ratio~Net.finance.revenue+factor(Airline),
        data=Hedge_ratio_data)

stargazer(coeftest(Net_finance_fixed_restric, vcov=sandwich),
    type="text")
stargazer(Net_finance_fixed_restric, type="text")

## Testing for exclusion of years
## Squared errors
Hedge_ratio_data$SSE_full_finance <- residuals(Net_finance_fixed)^2
Hedge_ratio_data$SSE_restric_finance <-
    residuals(Net_finance_fixed_restric)^2

## calculating F test statistic
((sum(Hedge_ratio_data$SSE_restric_finance) -
    sum(Hedge_ratio_data$SSE_full_finance))/7)/
((sum(Hedge_ratio_data$SSE_full_finance)/(142-1-18)))

## Calculating critical value
qf(0.95, df1=7, df2=116)
## H0: Restricted is better
## H1: Full model is better
## Test accepts H0

#----------------------
Debt level
#----------------------

## Debt to assets - cross-sectional
Debt_to_assets <- lm(Hedge_ratio~Debt.level, 
data=Hedge_ratio_data)
stargazer(coeftest(Debt_to_assets, vcov=sandwich), type="text")
stargazer(Debt_to_assets, type="text")

## Debt to assets - Fixed effects
Debt_to_assets_fixed <- lm(Hedge_ratio~Debt.level+factor(Airline)+factor(Year), 
data=Hedge_ratio_data)
stargazer(coeftest(Debt_to_assets_fixed, vcov=sandwich), type="text")
stargazer(Debt_to_assets_fixed, type="text")

## Debt to assets - Fixed effects - restricted
Debt_to_assets_fixed_restric <- lm(Hedge_ratio~Debt.level+factor(Airline), 
data=Hedge_ratio_data)
stargazer(coeftest(Debt_to_assets_fixed_restric, vcov=sandwich), type="text")
stargazer(Debt_to_assets_fixed_restric, type="text")

## Testing for exclusion of years
## Squared errors
Hedge_ratio_data$SSE_full_debt <- residuals(Debt_to_assets_fixed)^2
Hedge_ratio_data$SSE_restric_debt <- residuals(Debt_to_assets_fixed_restric)^2

## calculating F test statistic
((sum(Hedge_ratio_data$SSE_restric_debt)-
  sum(Hedge_ratio_data$SSE_full_debt))/7)/
  ((sum(Hedge_ratio_data$SSE_full_debt)/(142-1-18)))

## Calculating critical value
qf(0.95, df1=7, df2=116)

## H0: Restricted is better
## H1: Full model is better
## Test accepts H0
# Model with multiple variables

## Full model - cross-sectional

```
full_model <- lm(Hedge_ratio~Net.worth+Current_ratio+Net.finance.revenue, 
                 data=Hedge_ratio_data)

stargazer(coeftest(full_model, vcov=sandwich), type="text")
stargazer(full_model, type="text")
```

## Full model - Fixed effects

```
full_model_fixed <- lm(Hedge_ratio~Net.worth+Current_ratio+Net.finance.revenue+factor(Airline)+factor(Year), 
                        data=Hedge_ratio_data)

stargazer(coeftest(full_model_fixed, vcov=sandwich), type="text")
stargazer(full_model_fixed, type="text")
```

## Full model - Fixed effects - restricted

```
full_model_fixed_restric <- lm(Hedge_ratio~Net.worth+Current_ratio+Net.finance.revenue+factor(Airline), 
                                data=Hedge_ratio_data)

stargazer(coeftest(full_model_fixed_restric, vcov=sandwich), type="text")
stargazer(full_model_fixed_restric, type="text")
```

## Testing for exclusion of years

## Squared errors

```
Hedge_ratio_data$SSE_full_full <- residuals(full_model_fixed)^2
Hedge_ratio_data$SSE_restric_full <- residuals(full_model_fixed_restric)^2
```

## calculating F test statistic

```
((sum(Hedge_ratio_data$SSE_restric_full) 
  - sum(Hedge_ratio_data$SSE_full_full))/7)/ 
  ((sum(Hedge_ratio_data$SSE_full_full)/(142-1-20)))
```

## Calculating critical value

```
qf(0.95, df1=7, df2=114)
```

## H0: Restricted is better
## H1: Full model is better
## Test accepts H0

## Full model excluding net worth - Cross-sectional

```
full_model_excl_NW <- lm(Hedge_ratio~Current_ratio+Net.finance.revenue, 
                         data=Hedge_ratio_data)

stargazer(coeftest(full_model_excl_NW, vcov=sandwich), type="text")
```
## Full model excluding current ratio - Fixed effects - restricted

```r
full_model_fixed_restric_excl_current <- lm(Hedge_ratio~Net.worth+Net.finance.revenue+factor(Airline), data=Hedge_ratio_data)
```

stargazer(coeftest(full_model_fixed_restric_excl_current, vcov=sandwich), type="text")
stargazer(full_model_fixed_restric_excl_current, type="text")

#---------------------- Momentum ----------------------

## Half year return cross-sectional

```r
HY_return <- lm(Hedge_ratio~Half.year.return, data=Hedge_ratio_data)
```

stargazer(coeftest(HY_return, vcov=sandwich), type="text")
stargazer(HY_return, type="text")

## Half year return fixed effects

```r
HY_return_fixed <- lm(Hedge_ratio~Half.year.return+factor(Airline), data=Hedge_ratio_data)
```

stargazer(coeftest(HY_return_fixed, vcov=sandwich), type="text")
stargazer(HY_return_fixed, type="text")

## Arithmetic momentum cross-sectional

```r
Arithmetic <- lm(Hedge_ratio~Half.year.momentum, data=Hedge_ratio_data)
```

stargazer(coeftest(Arithmetic, vcov=sandwich), type="text")
stargazer(Arithmetic, type="text")

## Arithmetic momentum fixed effects

```r
Arithmetic_fixed <- lm(Hedge_ratio~Half.year.momentum+factor(Airline), data=Hedge_ratio_data)
```

stargazer(coeftest(Arithmetic_fixed, vcov=sandwich), type="text")
stargazer(Arithmetic_fixed, type="text")

#----------------------------- Other models -----------------------------

## The models in the following are not reported in the thesis itself, but are
## referred to in the discussion, and will be included in the appendix. 
## In the following, stargazer is used to summarize model outputs. 
## Stargazer(coeftest(Model, vcov=sandwich), type="text") applies 
## robust standard errors 
## to the models, to account for heteroskedastic error terms. 
## Stargazer(Model, type="text") allows for extraction of R-squared 
## values and F-tests.

# Entity fixed effects discussion

```r
Fixed_entity_only <- lm(Hedge_ratio~factor(Airline),
          data=Hedge_ratio_data)

stargazer(coeftest(Fixed_entity_only, vcov=sandwich), type="text")
stargazer(Fixed_entity_only, type="text")
```

# Continents boxplots and model

```r
plot(Hedge_ratio_data$Continent, Hedge_ratio_data$Hedge_ratio,
     main="Continent boxplot", xlab="Continent", ylab="Hedge ratio")

Continents <- lm(Hedge_ratio~factor(Continent),
           data=Hedge_ratio_data)

stargazer(coeftest(Continents, vcov=sandwich), type="text")
stargazer(Continents, type="text")
```

# Currencies regression

```r
Currencies <- lm(Hedge_ratio~factor(Currency),
            data=Hedge_ratio_data)

stargazer(coeftest(Currencies, vcov=sandwich), type="text")
stargazer(Currencies, type="text")
```

# Testing year effects with same financial years

## Full year effects model

```r
year_effects <- lm(Hedge_ratio~factor(Airline)+factor(Year),
            data=Year_effects)

stargazer(coeftest(year_effects, vcov=sandwich), type="text")
stargazer(year_effects, type="text")
```

## Restricted year effects model

```r
year_effects_restric <- lm(Hedge_ratio~factor(Airline),
            data=Year_effects)

stargazer(coeftest(year_effects_restric, vcov=sandwich), type="text")
stargazer(year_effects_restric, type="text")
```

## Testing for exclusion of years
## Squared errors

Year_effects$SSE_full <- residuals(year_effects)^2
Year_effects$SSE_restric <- residuals(year_effects_restric)^2

## calculating F test statistic

\[
\frac{(\text{sum}(Year_effects$SSE_restric) - \text{sum}(Year_effects$SSE_full))/7)/
(\text{sum}(Year_effects$SSE_full)/(94-1-11))
\]

## Calculating critical value

qf(0.95, df1=7, df2=75)
qchisq(0.95, df=7)

## H0: Restricted is better

## H1: Full model is better

## Test accepts H0