THE EFFECTIVENESS OF THE OPERATIONAL AND FINANCIAL HEDGE: EVIDENCE FROM THE AIRLINE INDUSTRY

By

STEPHEN DECATUR TREANOR

Bachelor of Arts
Austin College
Sherman, Texas
1996

Master of Business Administration
Texas Tech University
Lubbock, Texas
1998

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Dissertation Approved:

Dr. David A. Carter

Dissertation Adviser

Dr. Betty J. Simkins

Dr. Joel T. Harper

Dr. Jaebeom Kim

Dr. A. Gordon Emslie

Dean of the Graduate College

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CHAPTER I

INTRODUCTION

1.1 Introduction

Managers who take an active role in regulating their firm's risk have the choice of using financial hedges, operational hedges, or some mixture of both. Financial hedges are those contracts which a firm specifically engages in to reduce its risk exposure to an underlying asset. The operational hedge is where a firm uses its operations to lower its exposure to an underlying risk. Both types of hedges can effectively reduce a firm's risk.

Though operational hedges are an integral part of a firm's overall risk management program, the primary focus of the risk management literature has been on the use of financial derivatives. This is not due to a lack of interest, but to the inability to qualify and measure the operational hedges, which are at the discretion of the firm. This dissertation explicitly examines the role of both the operational and financial hedge in the airline industry. More specifically the dissertation addresses this issue in two essays. The first essay finds that airlines are exposed to jet fuel price and that operational and financial hedges are effective at lowering an airlines exposure to fuel costs. The second essay finds that operational and financial hedges complement each other. The research shows that airlines that use operational hedges are also more likely to use financial derivatives to manage their risk to fuel prices. Most surprisingly, the second essay also finds that operational hedges are destructive to an airline's value, while, the results concerning the benefits of financial hedges are mixed.

The first essay is the first, to my knowledge, to examine the operational and financial hedge in a context, in which the hedged asset is associated with the firm's costs. Tufano (1998) and Petersen and Thiagarajan (2000) examine the use of operational and financial hedges in the gold mining industry, in which gold the firms output, is the commodity being hedged. Both of these studies find that the use of financial and operational hedges is effective at reducing a gold mining firm's exposure to gold prices.

Similar to Tufano (1998), I find that airlines are exposed to the commodity being hedged, the price of fuel. Also, the first essay shows that airlines have a greater incentive to hedge as their exposure to fuel prices increases with both the level and the degree of change in fuel prices. Furthermore, I do not find that an airline's exposure to fuel prices depends on whether the volatility of the fuel prices is below or above its historical norm.

Tufano (1998) finds implicit evidence that gold mining firms use real options to manage their exposure to gold prices. Similar to Tufano finding for in the gold mining industry, my first essay finds a positive relationship between an airlines exposure to jet fuel prices and the price of jet fuel. Furthermore, as Tufano finds for a gold mining firm, there is a negative relationship between an airlines exposure to jet fuel prices and the volatility of jet fuel prices. The first essay also shows that the greater an airline's option to upgrade to a newer fuel-efficient fleet is then the greater the decline in its exposure to fuel prices as fuel price volatility rises.

Petersen and Thiagarajan's (2000) study explicitly examines the uses of real options and financial derivatives by two gold mining firms. Similar to a gold mining firms ability to adjust production, the first essay finds evidence that an airline's ability to adjust capacity through the use of a diverse fleet provides the airline an operational hedge to jet fuel prices. This result is a significant contribution to the literature as firms in other industries have similar real options to adjust their output in response to an ever-changing market. Although this study focuses on the airline industry, the results are most applicable to those industries which have an even greater level of flexibility to adjust their production.

The first essay also shows that a newer fuel-efficient fleet reduces an airlines exposure to jet fuel prices. However, I do not find evidence that the operational hedge provided by leasing an airlines fleet reduces an airlines exposure to fuel prices.

Although other studies have found that operational and financial hedges are effective at reducing a multinational corporation's exposure to exchange rates (Allayannis, Ihrig, and Weston 2001; Carter, Pantzalis, and Simkins 2006; Pantzalis, Simkins, and Laux 2001; Kim, Mathur, and Nam 2006), this dissertation focuses on the role of the operational hedge using a homogenous industry (US Airline Industry), and thus avoids any industry cross-sectional biases. In addition to using a homogenous sample, this dissertation includes an expanded number of operational hedges. The above studies have used only the foreign firm operations as their proxy for the operational hedge. This essay examines three operational hedges: the diversity of the airlines fleet, the uses of a leased fleet, and the fuel-efficiency of the fleet.

The second essay examines whether operational and financial hedges are complements or substitutes and if the use of operational and financial hedges are value enhancing to a firm. Similar to Allayannis, Ihrig, and Weston (2001) I find that operational and financial hedges are complements. That is, airlines which operate a diverse fleet are more likely to use financial derivatives to hedge next year's fuel requirements. However, I do not find evidence that a fuel-efficient fleet or a leased fleet effects an airlines decision to hedge next year's fuel requirements.

The results that operational and financial hedges are complements supports Guay and Korthari's (2003) belief that managers use the operational hedges embedded in the firm's real options to manage the majority of the firm's risk, and financial derivatives are then used to fine-tune the remaining proportion of the firm's risk management goals. This result helps explain one of the inconsistencies in the risk management literature. That is, Guay and Korthari (2003) show that financial derivatives provide little protection to a firms' cash flow from a large swing in the value of the underlying asset which is hedged. However, others find that the use of financial derivatives reduces a firm's risk exposure (Schrand 1997; Tufano 1998; Hentschel and Kothari 2001; Jin and Jorion 2006). Therefore, if firms that use financial derivatives also have a tendency to use operational hedges, then these financial derivatives reduce the firm's risk exposure, but show little protection for its cash flows.

The result that operational and financial hedges are complements is not conclusive in the risk management literature as Kim, Mathur, and Nam (2006) and Petersen and Thiagarajan's (2000) show that operational and financial hedges are substitutes. Kim, Mathur, and Nam find that multinational corporations with international subsidiaries are less likely to hedge exchange rates. Petersen and Thiagarajan find evidence that gold mining firms with greater production flexibility are less likely to use financial hedges while the opposite is true for gold mining firms with little production flexibility.

The second essay also examines if the use of operational and financial hedges are value enhancing to an airline. Contrary to the finding of both Allayannis, Ihrig, and Weston (2001) and Kim, Mathur, and Nam (2006), I do not find that operational and financial hedges increase the value of a firm. That is, a diverse fleet, a newer fuel-efficient fleet, or a leased fleet all reduce an airline's value. There is evidence that financial derivatives increase the value of the airline, however, fuel pass-through agreements actually are harmful to an airline’s value. Although Allayannis, Ihrig, and Weston and Kim, Mathur, and Nam find evidence that operational hedges enhance the firm's value, there is reason to believe their proxy is biased as they find that operational hedges are ineffective at managing a firm's exposure to exchange rates. This suggests that their proxy for the operational hedge is capturing some other aspect of the firm, one which is associated with firm value.

The structure of the dissertation is as follows: Chapter 2 (essay 1) investigates the determinants of the airlines' exposure to jet fuel prices. Section 1 of Chapter 2 briefly outlines the chapter and summarizes the results. Section 2 of Chapter 2 reviews the literature concerning a firm's exposure to an underlying asset. The Section 3 of Chapter 2 defines the three operational hedges and discusses the theoretical and anecdotal evidence concerning their benefits. The Sections 4 and 5 cover the data and methodology used to examine the effectiveness of operational and financial hedges at reducing an airline's exposure to the price of jet fuel. Section 6 of Chapter 2 presents the results, and Section 7 concludes Chapter 2.

Chapter 3 (essay 2) further investigates the role of the operational hedge and its value to the firm. The sections of Chapter 3 are as follows. Section 1 summarizes the chapter and its results. Section 2 reviews the risk management literature. Section 3 reviews the operational hedges and their proxies, which were presented in Chapter 2. Section 4, covers the methodology used to determine whether operational and financial hedges are substitutes or complements and if the use of operational and financial hedges increases a firm's value. Section 5 presents the results of Section 4. Section 6 concludes Chapter 3. Chapter 4 concludes the dissertation.

CHAPTER II:

RISK EXPOSURE AND ITS DETERMINANTS, AN EMPIRICAL STUDY FROM THE AIRLINE INDUSTRY

2.1 Introduction

The level of risk to which a firm is exposed, is directly related to the stochastic process of the underlying asset, the underlying asset's relationship with other factors affecting the firm, and the firm's ability to manage its risks. In the airline industry, the ability to manage jet fuel costs is an important component of success. For instance, according to the *Air Transport Association*[1], jet fuel costs have risen to account for 30% of the airlines' operating costs. This study finds that both the industry's and individual airline's exposure to jet fuel prices has increased as fuel prices has risen. That is, airlines tend to experience a greater level of exposure to jet fuel prices during periods when those prices are rising and are at historical highs. As the degree of an airline's exposure to fuel prices has increased, so has the importance for the firm to manage this risk with both financial and operational hedges.

This chapter examines whether airlines are indeed exposed to jet fuel prices and whether the airlines are effective at managing this exposure using both financial and

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[1] Air Transport Association (ATA). 2007. *Quarterly cost index: U.S. passenger airlines*. Air Transport Association (ATA) 2007 [cited April 24, 2007]. Available from http://www.airlines.org/economics/finance/Cost+Index.htm.

operational hedges. Financial hedges are contracts which an airline purchases to hedge against fluctuations in fuel costs. These contracts consist of, but are not limited to, futures, forwards, options, and other types of financial derivatives. On the other hand, an operational hedge is a vehicle whereby a firm seeks to manage risk directly through its operations. For an airline, the effective management of its fleet provides an operational hedge. Three operational hedges for an airline are fleet diversity, fleet fuel-efficiency, and the use of a leased fleet. A diverse and / or leased fleet provides greater flexibility to respond to changing market conditions. For instance, in 2008 during a period of record high fuel prices, airlines began cutting capacity of their mainline aircraft while at the same time increasing capacity of their regional jets. This allowed the airlines to maintain service in valuable markets while reducing their total losses. The average age of an airline's fleet is a proxy for the fuel efficiency of its fleet, as newer aircraft are more fuel efficient relative to older aircraft. An airline that is operating a newer fleet has less exposure to fuel prices than an airline with an older fleet, as the fuel-cost-to-cash-flow of a newer aircraft is less than that of an older aircraft. This is relevant, as in 2008, many airlines are choosing to mothball their older and less fuel-efficient aircraft in order to stay afloat during a period when fuel cost make it impossible for an airline to operate profitably. However, an older fleet provides investment / abandonment options which also provide an operational hedge. That is, as fuel prices increase, so do the airline's investment and abandonment options, which lower the airline's exposure to fuel price fluctuations.

I find evidence that airlines use both financial and operational hedges to manage their exposure to jet fuel price risk. The use of financial derivatives, fuel pass-through agreements, a diverse fleet, and / or a fuel-efficient fleet, all reduce an airline's exposure to fuel costs. However, a leased-fleet is ineffective at protecting an airline against its exposure to jet fuel prices.

The rest of this chapter is as follows: Section 2.2 reviews the risk management literature. Section 2.3 further develops the theoretical and anecdotal evidence for the use of operational hedges. Section 2.4 describes the data, while section 2.5 develops the models and the hypotheses for the effectiveness of both operational and financial hedges. Section 2.6 is an analysis of the airline industry's exposure to jet fuel prices and its ability the hedge its risk through the use of operational and financial hedges. Section 2.7 concludes chapter 2.

2.2 Literature Review

In this section, the literature concerning a firm's risk exposure and the determinants of such exposures is reviewed. The degree to which a firm is exposed to a particular risk is determined by (1) the nature of the underlying asset and its relationship to the firm's future cash flows, (2) the industry in which the firm operates, and (3) the operations in which the firm engages in order to manage such a risk.

2.2.a Exposure Defined & Measured

Typically, exposure is defined as the percent change in the value of the firm resulting from a percent change in the value of the underlying asset, or its rate (Bodnar, Dumas, and Marston 2002; Rajgopal 1999; Tufano 1998). In other words, a firm's risk exposure to a particular underlying asset is the firm's elasticity with respect to that asset. Adler and Dumas (1984) show that the appropriate measure of a firm's risk exposure is the regression coefficient of the firm's returns regressed against the percent change in the value of the underlying asset. Because of the co-movement between the market returns and the underlying asset, a two factor market model is used to measure a firm's exposure to an underlying risk. Specifically, the model uses the firm's returns regressed against the market returns as well as the percent change in the value of the underlying asset. The two factor market model, developed by Stone (1974), has been used extensively to estimate exposure to various risk factors (Jorion 1990; French, Ruback, and Schwert 1983; Tufano 1998; Schrand 1997) .

Unfortunately, results concerning currency exposure are not as strong as expected when industry and firm characteristics, along with the hedging activities of the firm, are not considered. In the case of exchange rate exposure, the evidence of a firm's exposure is relatively weak. For instance, Jorion (1990) finds that only 5% of multinational firms with at least 10% of their operations being foreign experience a significant exposure to exchange rate risk. Bartov and Bodnar (1994) find the value of the firm is affected by unexpected currency movements, suggesting currency exposure, but the response of investors to changes in the currency rate are not contemporaneous. Their results suggest that currency movements matter to the firm's value, but investors are unable to comprehend the significance of those movements. However, not all studies find that firms are weakly exposed to exchange-rate risk. For instance in He and Ng's (1998) study, 25% of their sample, of large multinational Japanese's firms are exposed to significant currency risk.

If a firm's exposure to particular risk factors is systematic and orthogonal to the market risk factor, then it must be priced according to APT. If a risk factor is priced, then there exists a set of firms which are exposed to the risk factor in question. However, a firm can experience exposure to an underlying asset, even though the risk factors are not priced, if the particular risk is idiosyncratic. The empirical evidence is that investors do not price inflation (Sweeney and Warga 1986) or currency risk (Jorion 1991). These results give further credence to the assertion that firms are generally not exposed to fluctuations in currency and inflation rates.

In summary, a firm's risk exposure is typically defined as the elasticity of the firm's value with respect to an underlying asset, that is, the percent change in the value of the firm with respect to a percent change in the value of the underlying asset. A firm's risk exposure to an underlying asset is measured by using a two factor model which regresses the firm's returns against the return of a market index and the percent change in value of the underlying asset. Furthermore, the studies reviewed here which did not consider a firm's or its industry's characteristics failed to find significant exposure to interest rates or exchange rates. This is not to say that a firm's exposure to any underlying asset is insignificant. Firms in which commodities account for a significant portion of their operations are likely to be exposed to price movements in those commodities. This aspect of a firm's exposure is developed in the next section.

2.2.b Determinants of Risk Exposure

2.2.b.i Firm Characteristic

For a firm to have a risk exposure to a particular underlying asset, the fluctuation in the value of that asset must be unpredictable and affect the firm's present and future cash flows and/or the value of its assets (Adler and Dumas 1984). From an operational perspective, a firm's exposure to an underlying asset originates from the inputs which are used in the production process and its outputs which are sold[2]. The degree to which a

[2] For instance, a farmer is exposed to the availability of water and the market's supply and demand for his crops.

firm is exposed to inputs and outputs associated with its line of business depends on (1) the relative correlation between input and output prices, (2) the firm's ability to adjust production, (3) and the current price and volatility of the underlying asset.

First, consider the relation between input and output prices, the relative risk exposure of the firm is negatively associated with the correlation between its input and output prices. To illustrate this point, suppose a monopoly faces an inelastic demand; then any exogenous shocks to its input prices are passed through to its customers (Allayannis and Ihrig 2001; Bodnar, Dumas, and Marston 2002). In this particular case, the firm is able to transfer some of its risk exposure to its customers. Under this circumstance, the firm possesses a natural hedge against the variability in the underlying assets. This point and the empirical evidence in support of this argument is developed later in the context of the industry characteristics.

The banking industry further illustrates the importance of the correlation between a firm's risk exposure to an underlying asset and its relationship between input and output prices. The interest that a bank receives from its loans can be viewed as the bank's output price, while funds paid to depositors can be viewed as its input price. The fact that banks typically lend money for longer maturities than the funds received from their depositors creates a risk exposure to fluctuations in the term structure spread (the difference between long term and short term interest rates). Banks have a direct relationship to fluctuations in interest rates since movements in the term structure are primarily a result of changes in expected inflation (Fama 1975; Flannery and James 1984). As Flannery and James (1984) suggest, there is a positive association between a bank's exposure to interest rates and the difference between the maturity of the bank's liabilities (deposits) and the maturity of its assets (loans). As predicted, Flannery and James (1984), Scott and Peterson (1986), Schrand (1997) and Kwan (1991) find the level of exposure to interest rates increases as the maturity gap between the short term liabilities and long term assets widens.

Consider the case where the firm's exposure is negatively related to its ability to adjust its production in response to uncertainty of the underlying asset (Dixit and Pindyck 1994; Brennan and Schwartz 1985). Brennan and Schwartz (1985) develop a model for a copper mining firm in which the firm has the option to suspend operations if the price of copper drops below a certain threshold and later to reopen the mine when conditions become more favorable. This model demonstrates that the option to suspend operations reduces the firm's risk exposure to the underlying asset because the firm can choose not to operate when conditions are unfavorable. Empirically, Kallapur and Eldenburg (2005) find that after a change in Medicare policy which increased the uncertainty concerning payment, hospitals attempted to reduce their risk by replacing high-fixed-cost / low-variable-cost equipment with high–variable-cost / low–fixed-cost equipment. That is, hospitals chose a production function that consisted of higher variable costs with the option to adjust production during unfavorable times.

Another component of the Brennan and Schwartz (1985) model is the firm's relationship to the volatility of the underlying assets. Tufano (1998) points out that as a result of the firm's option to suspend operations, the volatility of the underlying asset actually reduced the firm's risk exposure; the option to suspend operations is analogous to a call option. Since the elasticity of a call option is decreasing in volatility, the same is true for a firm with the option to suspend operations. However, this is not always the case; in a model proposed by Dixit and Pindycky (1994) where a firm can continuously adjust output, the firm's risk exposure is invariant to the volatility of the underlying asset. Tufano (1998) that finds for the gold mining industry there is a negative and significant relationship between the firm's risk exposure to gold returns and the volatility of gold returns.

If financial distress costs are significant, then the relationship between the firm's exposure and the volatility of the underlying asset can be the opposite as predicted above. That is, a firm's risk exposure to the underlying asset increases with the volatility of the underlying asset. Smith and Stulz (1985) and Stulz (1996) propose that financial distress costs are a motivating factor for a firm to engage in financial hedging. There is also empirical support for this theory (Geczy, Minton, and Schrand 1997; Graham and Rogers 2002; Nance, Smith, and Smithson 1993). The positive relationship between risk exposure and the volatility of the underlying asset can occur if the increase in volatility is associated with an increase in the probability of incurring financial distress. Though not directly testing a firm's risk exposure to the volatility of oil returns, Haushalter, Heron, and Lie (2002) find that firms that are closer to financial distress, measured by debt ratio, are more sensitive to the volatility of oil and gas returns. This result is consistent with Stulz's theory that financial distress is a motivation to use financial derivatives. The evidence of the relationship between financial distress cost and exposure is not conclusive. He and Ng (1998) find that for a sample of Japanese firms, at least 10% of whose business is foreign, the larger a firm's size and the lower its debt, the greater its risk exposure. Similarly, Tufano (1998) finds the same relationship for a firm's size, but not for debt. Since larger firms with lower debt levels are typically less financially constrained, it is surprising that these types of firms show a greater level of exposure.

In Tufano's (1998) simple model where production remains fixed, a firm's risk exposure decreases as the value of the underlying output price increases. Tufano contends that this relationship holds for a firm which has the option to suspend operations. However, according to Dixit and Pindyck's (1994) model, where the firm can continually adjust production, a firm's risk exposure is invariant to the current level of the underlying output price. Thus, the condition that a firm's risk exposure decreases as the output price increases is not a necessary one. With this said, the empirical evidence suggests a relationship between the firm's risk exposure and the current value of the underlying asset. Tufano (1998) finds that gold mining firms' risk exposure is lower when gold prices are higher. In the banking industry, Chen and Chan (1989) and Schrand (1997) find S&L's are more sensitive to interest rate movement during periods of falling interest rates. These two mentioned studies do not explicitly measure the impact that the current interest rate has on the firm's risk exposure, but for a firm to experience different levels of risk exposure during different interest rate regimes, the degree of exposure must be determined by the level of interest rates.

It should be noted that Tufano's (1998) result of a negative relationship between gold price and exposure can be construed as evidence of Froot, Scharfstein, and Stein's (1993) theory that hedging adds value if a firm's cash flows are negatively correlated with the firm's investment opportunities. When prices are low, the firm has to forgo profitable investments because cash is scarce. Yet when prices are favorable, the marginal benefit of the next investment is low, since the best investments have already been implemented. This relationship between cash flow and investment leads to the firm's being more exposed when prices are unfavorable, since the firm's best investments are lost or gained when the price is low.

2.2.b.ii Industry Characteristics

The nature of the industry in which the firm operates influences the degree of exposure the firm experiences from an underlying asset. The most obvious is the relevant importance an underlying asset has to an industry. Empirically, Tufano (1998) finds that gold mining firms are positively exposed to fluctuations in gold prices. He reports that over 50% of the estimated exposure coefficients are significantly greater than zero. Like gold mining firms' being exposed to gold prices, oil and gas companies are exposed to oil and gas prices. Jin and Jorion (2006) find that 32% of their sample of oil firms experience exposure coefficients which are significantly greater than zero. For their sample of gas firms, 87% are positively and significantly exposed to gas prices. Similarly, Rajgopal (1999) finds a positive and significant exposure to oil prices for 38% of his oil firms. For his sample of gas firms, 36% have positive and significant gas price exposure coefficients.

The importance of the industry in relation to a firm's risk exposure is not limited to those factors which are unique to the industry. For instance, interest rates theoretically affect all firms, since unexpected changes in inflation affect the value of the firm because, as described by French, Ruback and Schwert (1983) in their nominal contracting hypothesis, there is a wealth transfer between creditor and debtors as result of unanticipated movements in the inflation rate. Further, they contend that firms with varying degrees of interest rate sensitive assets and interest sensitive liability will react differently to unanticipated interest rate movements. For instance, banks are vulnerable to positive shocks in inflation, as they receive a fixed level of dollars with less purchasing power as inflation increases. In contrast, firms with fixed liabilities but whose assets prices adjust with inflation are vulnerable to unexpected deflation, as they pay a fixed dollar amount with greater purchasing power as inflation decreases. Since, the firms in an industry operate similar types of assets, a logical conclusion from the above argument is that firms in an industry will show a similar level of sensitivity to unanticipated inflation movements.

Sweeney and Warga (1986) find significant negative interest rate exposure for the utility, banking, financing and real estate, stone, clay and glass industries. They contend that firms in regulated industries, such as utilities and financial institutions are unable to adjust prices in response to unexpected increases in inflation and thus are negatively exposed. Bernard (1986) does find that certain industries experience greater interest rate exposure than others, particularly service-related industries, some of which are unregulated. However, Bernard's (1986) results do not support Sweeney and Warga's (1986) conclusion that regulated industries experience greater exposure to inflation. Choi and Elyasiani (1997) find that 47% of banks are exposed to interest rate changes and 83% are exposed to exchange rate changes. Again these studies illustrate the significance of the industry in relation to a firm's exposure to an underlying risk.

Other industry characteristics can also influence a firm's risk exposure. First, consider a monopoly. For a monopoly, the elasticity of demand for the firm's products plays a pivotal role in its exposure to an underlying asset. Since monopolies are typically not price takers, they are able to adjust their prices in response to an unexpected movement in the underlying asset. In other words, the less elastic the demand curve a monopoly faces, the greater the firm's ability to pass any negative or positive shock to its customers by adjusting the price or the markup it charges. Bodnar, Dumas, and Marston (2002) develop this concept for a duopoly. The monopoly's ability to adjust prices in response to exogenous shocks acts as a natural hedge that reduces the monopoly's risk exposure. In Allayannis and Ihrig's (2001) model, the inverse relationship between the firm's mark-up and the elasticity of the demand curve is exploited to evaluate the firm's risk exposure to exchange rates. Their model predicts that the lower an industry's markup, the greater its exposure to exchange rates. Allayannis and Ihrig's (2001) data support the argument that lower markups lead to greater exposure. Furthermore, Allayannis and Weston (1999) find that, the greater their industry's markup, the less tendency for firms to hedge. This result is predicted if (1) hedging increases with increasing exchange rate exposure and if (2) exchange rate exposure is inversely related to markup.

As mentioned in the case of a monopoly, the ability of the firm to transfer its risk exposure to its customers is directly related to the demand curve a firm faces. Also, the ability to transfer risk declines as the number of firms increases or the level of substitutability of its products increases because a firm's demand curve becomes flatter as competition increases. More simply, if a firm tries to raise prices, its customers will take their business elsewhere. Bodnar, Dumas, and Marston's (2002) model partly illustrates this concept. From the above argument, a natural conclusion is that as competition increases, a firm's risk exposure increases, since any exogenous shock to its cost structure cannot be recovered through price adjustments. However, this statement is not necessarily true for firms in highly competitive markets, where the nature of the product market forces marginal cost to equal price (i.e., supply equals demand). In this case, a homogenous, exogenous shock affects all firms in the industry similarly because firms must adjust output until marginal cost equals price. This adjustment process causes product prices to change, thus giving each firm a natural hedge against any industrial homogenous shock (Nain 2005).

Nain (2005) continues with the above argument by suggesting that in industries where hedging is common, unhedged firms have greater exchange rate exposure when compared to their hedged peers. In industries with high levels of hedging, output prices are stable as hedgers are able to keep hedged costs constant. Stable prices increase the risk exposure of the unhedged firm since output prices are no longer positively correlated with costs. Nain empirically finds that unhedged firms, in industries where hedging is common, experience higher exchange rate exposure coefficients compared to their hedged peers. In addition, firms which are unhedged in hedged industries have lower Tobin's Q (market values) than their hedged peers. He also finds that in industries where hedging is common, there is less volatility in their pass-through price. Conversely, in industries where hedging is uncommon, hedged firms are expected to experience a greater risk exposure than their unhedged peers. However, Nain does not find this to be the case. Nain's results are consistent with the notion that the greater the level of competition, the greater the industry's natural hedge and thus the lower a firm's risk exposure.

To further support the notion that greater levels of competition reduce a firm's risk exposure, there is evidence that firms in industries characterized as highly competitive are less inclined to manage their risk (Haushalter, Klasa, and Maxwell 2007). Specifically, Haushalter, Klasa and Maxwell (2007) use the Herfindahl-Herschmann index to measure the level of inter-industry rivalry and competitiveness. A highly competitive industry is one in which the number of firms is large enough that any one firm cannot influence the market price or another firm's cost function. In contrast, rivalry is defined as the ability of one firm's actions to affect another firm's profitability through market prices, its cost function, or its investment opportunities. The lower the Herfindahl-Herschmann index, the greater the level of competition in the industry and the higher the Herfindahl-Herschmann index the greater the industry rivalry. Their findings show that firms in industries with a lower Herfindahl-Herschmann index hold less cash and are less likely to use currency derivatives, which again illustrates that the greater the level of competition in the industry, the less risk exposure there is to the firm.

In his investigation of a multinational firm, Brown (2001) finds that the use of derivatives is influenced by its competitor's hedging policy. In particular, one of the goals of the firm's hedging programs is "to reduce negative impacts from currency movements on competitiveness by providing competitive information to senior management" (p. 414). This suggests the firm is exposed to a risk that is influenced by its competitors and the firm uses financial derivatives to mitigate this risk. This risk is influenced by product market rivalry and is referred to as predation risk. Predation risk is the risk a firm faces from the actions of its competitors. For instance, a firm that has limited access to external capital and is vulnerable to underinvestment runs the risk of losing investment opportunities and market share to its stronger or hedged competitors (Haushalter, Klasa, and Maxwell 2007). Mello and Ruckes (2005) show that the hedging behavior of two rival firms can influence the profitability of each firm when external capital is more costly than internal funds. They show it is beneficial for firms of similar resources to partially hedge their exposure since the rewards of being a dominant player in the industry outweigh the risks. When the firms in the industry are not similar in resources, then both the dominant and weaker firm will hedge completely. For the weaker firm, the expected benefits of becoming a dominate player by remaining unhedged do not outweigh the costs of such a gamble. Similarly, the dominant firm reaps little benefit from gaining further market share. Though Mello and Ruckes' model does not explicitly show how a firm's risk exposure is determined by its rivalry, it does illustrate a possible relationship between exposure and predation risk in that a firm which doesn't hedge experiences additional risk from its rival.

For empirical support, Williamson (2001) examines the exchange-rate exposure for automotive companies. He finds, in the early years of his sample, that when U.S. automotive makers had little competition abroad, they experienced insignificant currency exposure. During the middle portion of his sample years, when Japanese auto makers penetrated the U.S. market, U.S. automotive manufacturers began to experience significant exposure to currency fluctuations. Haushalter, Klasa, and Maxwell (2007) more specifically test the effects of product market rivalry on a firm's risk management behavior. Their findings suggest that firms with few competitors and similar technologies are more likely to use financial derivatives or maintain higher levels of cash. Furthermore, a firm with cash levels above the industry's median and in an industry characterized as having high product market rivalry is more likely to increase investment when industry investment is low. Their results further suggest that in addition to the risks a firm faces in a competitive market, firms in an industry characterized by high product market rivalry are exposed to the behaviors of their rivals. This findings implies that a firm's risk exposure to an underlying asset can be influenced by the predation risk a firm faces.

2.2.b.iii Exposure and Financial Contracts

A firm's exposure to an underlying asset is obviously affected by its risk management policies. If a firm is using financial derivatives to manage its risk, as opposed to speculating, the expectation is that the use of these contracts reduces the firm's risk exposure. In examining whether firms use currency derivatives to manage risk or speculate, Allayannis and Ofek (2001) find the absolute value of a firm's exchange-rate exposure decreases as the level of derivatives a firm uses increases. Thus, as the use of financial derivatives rises, the exposure coefficient moves closer to zero. Numerous studies find a similar relationship (Jin and Jorion 2006; Schrand 1997; Tufano 1998; Hentschel and Kothari 2001).

Guay (1999) examines whether a newly implemented hedging program reduces a firm's risk. His measures of risk are interest-rate exposure, exchange-rate exposure, total risk, firm-specific risk, and market risk. Where interest-rate and exchange-rate exposure are the coefficients from a two factor model, total risk is the firm's annualized daily standard deviation, firm-specific risk is the error terms from the market model, and market risk is the (beta) coefficient from the market model. His results show that firms implementing a risk management program experience a significant decline in all measurements of risk except for the market risk. Guay also finds firms which are new derivative users typically take a position in derivatives that reduces the firm's interest rate or exchange-rate exposure. For instance, firms that have a positive exposure to interest rates will take a short position to reduce this exposure. Therefore, Guay's study shows that firms use financial derivatives as a means to reduce risk.

An interesting question regarding a firm's hedging activity, is whether a firm's actual use of derivatives protects its cash flows. Guay and Kothari (2003) find the level of hedging activity is relatively small when compared to the overall exposure of the firm. They define hedging activity as the cash flows from the firm's derivatives that occur from a three-standard-deviation movement in the underlying asset. For instance, they find that the median firm's cash flow from derivative positions resulting in extreme movements in the underlying asset, is about 10% of the firm's operating cash flow. Thus, at best, the median firm's derivative position only protects 3% and 6% of its market value from extreme movements in interest rates and foreign exchange rates respectively. Guay and Kothari do report that their sample firms are exposed to interest rate and exchange rate movements, though the level of significance of these exposures is not reported.

Although it seems natural that firms would only use financial derivatives as a means to reduce risk, this is not necessarily the case, nor does the empirical evidence consistently bear this out. Stulz (1996) argues that when a firm has a competitive advantage in trading an asset, it is advantageous for the firm to speculate on its movements. For instance, if a financial institution gains insight into the movements of exchange rates from its daily business, it is beneficial for the firm to exploit this privileged information through speculation. Stulz (1996) refers to this type of speculation as "selective hedging." Both Adam and Fernando (2006) and Brown, Crabb, and Haushalter (2006) empirically examined this issue for gold mining firms.

Adam and Fernando (2006) find evidence of selective hedging in the gold mining industry. However, those firms that do selectively hedge are unable to generate excessive cash flows from their market-timing activities. Furthermore, Adam and Fernando find that a consistent hedging policy results in a positive cash flow to the firm from its derivative positions. This result is contrary to theory since hedging activities as a method to reduce a firm's risk exposure should generate zero net cash flows to the firm. Furthermore, their results indicate hedging does not increase a firm's systematic risk (Beta). They conclude that the positive cash flows from a firm's hedging policy is a result of gold futures' being biased predictors of the future stop price of gold. Their results suggest there are benefits to the use of financial derivatives in addition to those predicted by hedging theory. These benefits can influence a firm's exposure to the market or an underlying asset.

Brown, Crabb, and Haushalter (2006) find similar results in gold mining firms that engage in selective hedging. That is, selective hedging doesn't result in additional cash flows to the firm. They test the selective hedging hypothesis by regressing the firm's hedge ratio against the next period's percent change in gold prices. Their results suggest gold mining firms increase their hedged ratios as prices rise and reduce their hedging activity when prices fall. Thus, based on their sample, a firm's exposure to gold prices is influenced by the managers' beliefs about future prices.

In the case of bankruptcy cost, there is a direct relationship between a firm's risk exposure and its level of debt. Due to the fact that the movements in the underlying assets are directly related to the firm's future and present cash flows. Cash flows in turn are tied directly to the ability of a firm to meet its debt obligations. This relationship between risk exposure and the firm's debt obligations is only significant when there is high probability of financial distress cost. Some empirical evidence supports this hypothesis (Tufano 1998; Nain 2004). Firms are willing to accept this risk because the debt tax shield creates value for the firm as debt increases. To benefit from the debt tax shield, firms use financial derivatives to mitigate the risk of bankruptcy (Graham and Rogers 2002).

To summarize, a firm's risk exposure is defined as the effects an underlying asset has on the firm's present and future cash flows. The appropriate measure of exposure is the coefficient of the firm's returns regressed against the percent change in the underlying asset. A firm's risk exposure is a function of firm and industry characteristics, along with the actions the firm engages in to reduce or increase its exposure. More specifically, a firm's exposure is determined by its operations, the demand for its products, the level of industry competition, and its use of financial contracts.

2.3 Operational Hedges

In this section the theoretical and anecdotal evidence for the three operational hedges which an airline utilizes to manage their exposure to jet prices are discussed. The three operational hedges are: the diversity of an airlines fleet, the fuel efficiency of its fleet, and the leasing of its fleet. Both a diverse and a leased fleet provide airlines the flexibility to adjust capacity as fuel prices rise. A fuel-efficient fleet reduces an airlines exposure to fuel prices by reducing it fuel requirements.

2.3.a Fleet Composition (Diversity of Fleet)

With many industries, it is costly for a firm to exit a market and then later reenter; thus a firm will continue to operate during unprofitable periods. For instance, department stores will maintain operations during periods when costs exceed revenues in order to avoid abandonment and reentry costs. This is similarly true for an airline, which will avoid abandoning a market (route) even though the airline is incurring significant losses on the route. Abandonment costs are those costs associated with exiting the market, while reentry costs are those costs associated with reestablishing a presence in a market. Both of these costs can range from a loss in (reestablishing) customer loyalty to a loss (regain) in its overall market power. To reduce the level of losses associated with operating during unfavorable periods, and thus the incentive to prematurely exit, it is beneficial for a firm to reduce the size or scale of its operations. A diverse fleet provides an airline with this option. For instance, when fuel costs are high, an airline can reduce the level of service for a route by replacing a larger aircraft with a smaller one. This action will reduce the airline's overall losses as the total losses of smaller aircraft are less than those of a larger aircraft[3]. Appendix A contains a more formal description of this argument.

There is anecdotal evidence that some airlines use diverse fleets to protect against high fuel prices. In commenting on the Delta and Northwest merger, *The Wall Street Journal*[4] states, the two airlines are reacting to higher fuel prices by "taking steps to boost their cost-cutting and pare their capacity, with steps such as putting small planes on routes, taking aircraft out of their fleets, and reducing the number of flights per day. Ed Bastian, Delta's president and CFO, called the domestic market a "bloodbath"

[3] This argument is similar to households owning two cars, a large fuel inefficient vehicle and a smaller fuel efficient vehicle. When fuel prices are high, households tends to increase use of the fuel efficient automobile.

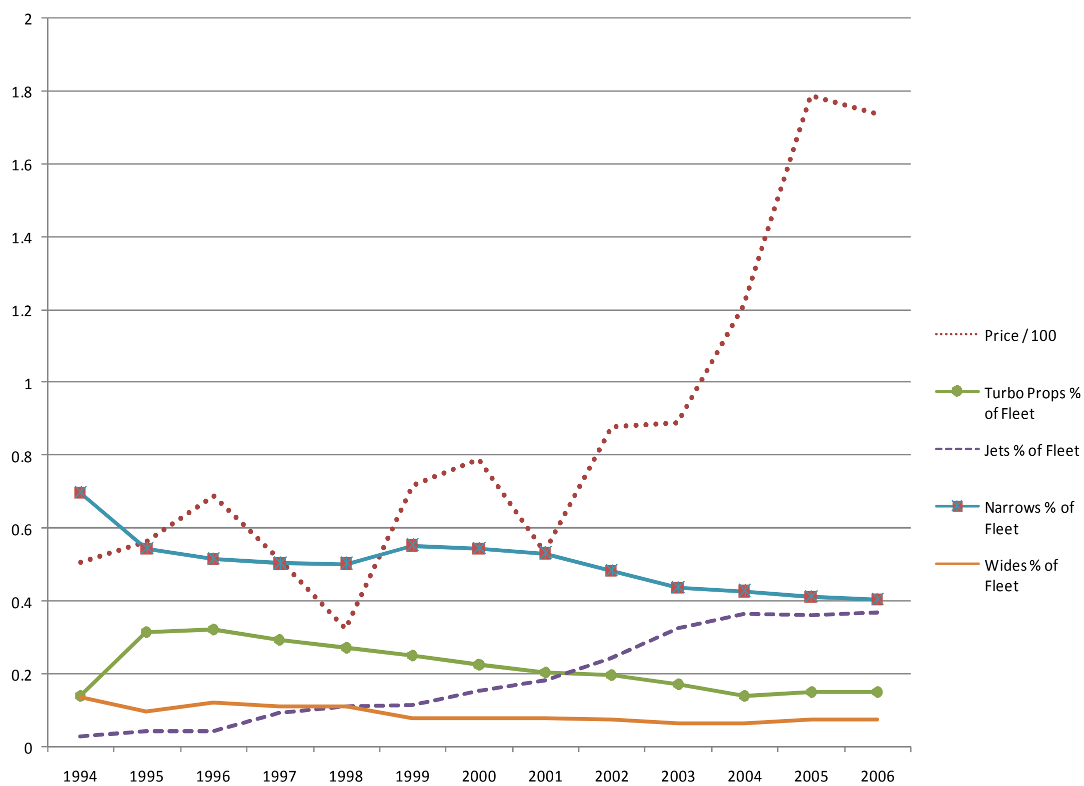
[4] Carey, Susan and Paula Prada. Delta, Northwest post losses amid big write-downs. *The Wall Street Journal.* April 24, 2008. B1.

because there are too many seats available and carriers can't raise prices quickly enough to cover surging fuel expenses."

Figure 1 illustrates the trend in the airline industry to operate smaller aircraft as fuel prices increase. Figure 1 shows a steady upward trend in the percent of the airlines' operating fleets that consist of smaller regional jets, while at the same time, the percentage of the airlines' operating fleets that consist of narrow-body or of wide-body aircraft has declined. During this same period, jet fuel prices rose dramatically. For instance, between 2001 and 2006 the percent of an airline's operating fleet that consisted of regional jets increased from 18% to 37%. During the same period, the use of narrow body aircraft decreased from 58% to 48%. Also for this period, fuel prices rose from 53.5 cents to 1.73 dollars per gallon.

Although a diverse fleet gives an airline the flexibility to adjust its capacity to higher fuel prices there are other reasons for an airline's choice of aircraft. These include the demand for which the market the airline services, the level of competition in those markets, the distance between origins and destinations, and the operational costs of the aircraft. Though these motivations are probably the major determinants to an airline's choice of aircraft, the operational hedge is still a significant contributing factor. For instance, as with aircraft size, the decision of a multinational corporation to construct a foreign manufacturing facility is not solely defined by the need to hedge (currency risk), but rather is a function of other operational needs, such as the demand for its products, labor and production costs, and political considerations, to name a few.

FIGURE 1
Price of Fuel and Fleet Makeup



Although there are many advantages to a diverse fleet, there are also disadvantages; for example, the operating costs for a diverse fleet are greater than the costs of operating a uniform fleet. The additional costs from operating a diverse fleet stem from maintaining a higher inventory of spare parts, the need for a diverse group of specialized mechanics, and higher training costs for flight crews. However, the benefits of a diverse fleet, for some airlines, might outweigh the costs.

2.3.b Fleet Fuel Efficiency

A large cost factor for airlines is jet fuel. For instance the *Air Transport Association*[5] reports that jet fuel costs account for close to 30% of an airline's operation cost. This suggests that airlines might benefit from hedging against fluctuations in fuel prices. Two possible methods of reducing jet fuel exposures are the use of financial derivatives and / or operating a fuel-efficient fleet. Thus, airlines that choose to operate a newer fleet, which is a fuel-efficient fleet, should have less exposure to fuel risk.

The popular press suggests that fuel efficiency is a major contributing factor to the decision for an airline to invest in new aircraft. *The Wall Street Journal*[6] contends that a contributing factor in AMR's decision to purchase newer Boeing 737's is fuel efficiency. The article states "The Boeing 737-800s American is expecting burn 25% less fuel per mile than the MD-80's, which account for nearly half of American's mainline fleet and average 17 years of age" (p. A12).

A newer fuel-efficient fleet reduces an airline's exposure to fuel cost, relative to an older fleet because the fuel cost of a newer aircraft is relatively less compared to its value. Recall that an airline's exposure to fuel cost is roughly defined as the change in the airline's value to a change in the price of fuel. Furthermore, a newer aircraft provides the same level of service as an older aircraft but at a lower fuel cost. This implies that a change in fuel prices is less significant for a newer aircraft than for an older aircraft.

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[5] Air Transport Association (ATA). 2007. *Quarterly cost index: U.S. passenger airlines*. Air Transport Association (ATA) 2007 [cited April 24, 2007]. Available from http://www.airlines.org/economics/finance/Cost+Index.htm.

[6] Melanie Trottman. AMR accelerates orders for fuel-efficient 737's. *The Wall Street Journal.* March 29, 2007. A12.

Another way to see this is to suppose "P" is the revenue for both the old and new planes. "αC" is the fuel cost of the new plane and "C" is the fuel cost of the old plane, where α is between zero and one. [7] Assuming an infinity and constant stream of cash flows, the value of the new aircraft is $\frac{P-\alpha C}{\delta}$ and the value of the old aircraft is $\frac{P-C}{\delta}$, where δ is the discount rate. The derivative of the new aircraft with respect to a change in the cost of fuel is $\frac{-\alpha}{\delta}$. The derivative of the older aircraft with respect to a change in the cost of fuel is $\frac{-1}{\delta}$. Thus, the value of the new aircraft changes less than that of the older aircraft, since α is less than one. This means a newer aircraft has less exposure to fuel prices than an older aircraft.

The above analysis that suggests the fuel-efficiency of the fleet is a hedge against the airline's risk to jet fuel prices. That is, airlines with an older fleet are less fuel-efficient and experience higher levels of exposure to jet fuel prices. However, an airline with an older fleet owns a real option to upgrade to a newer fleet. As fuel prices increase, the value of the airline's option to upgrade to a fuel-efficient fleet increases and thus reduces the airline's exposure to jet fuel prices. This implies that the exposure to fuel prices for an airline with an older fleet declines as fuel costs increase. The airline's exposure to fuel prices declines until the point at which it is optimal for the airline to exercise its option to upgrade to a fuel-efficient aircraft. At that point, the level of exposure for the airline with an older fleet and the option to upgrade will equal that of the airline with the newer fuel-efficient fleet. Thus, the value of the real option to upgrade

[7] The other operating costs are excluded as they are not relevant to the discussion.

reduces the difference in exposures between the airline with a fuel-efficient fleet and one with an older fleet because if there is a high probability the airline will upgrade to a new fleet in the near future, investors will price the airline as if it is operating a fuel-efficient fleet less the additional cost of the upgrade. Appendix A lays out a formal argument.

Another aspect of the real option to upgrade is that the option provides protection against the increase in the volatility of jet fuel prices. As the volatility of fuel prices increases so does the value of the option to delay investment in a new aircraft. This analysis implies that the fuel exposure for an airline with an older fleet with the option to upgrade declines as the uncertainty of fuel prices rises.

The above analysis suggests that a newer fuel-efficient fleet reduces an airline's exposure to jet fuel prices. However, the gap between the degree of exposure for a fuel efficient fleet and a fleet of older aircraft declines as fuel prices increase because the airline with an older fleet owns the option to upgrade to a newer fuel-efficient fleet.

2.3.c Operating Leases

Operating leases provide airlines the opportunity to frequently adjust their fleet to changing conditions. For instance, as the demand for a particular route changes, the airline can replace its current aircraft with those that are better suited for that market (Brigham and Ehrhardt 2005). Moreover, many airlines stagger the life of their leases so that their fleet size can adjust to changing market conditions. For instance, the 2000 America West Airlines 10-K, states:

> "The airline and travel industries are cyclical in nature. Because of this, an important element of the Company's strategy is to maintain financial flexibility as protection against a downturn in the business cycle. A key

component of this strategy is AWA's [America West Airlines] aircraft leasing plan. As of December 31, 2000, and through the end of 2004, leases for 54 aircraft will expire. As a result, if economic conditions change adversely during that period, the Airline can delay the growth of its fleet and its aircraft-related financial obligations by electing to not renew these aircraft leases." (p. 3)

In addition to staggering the life of its leases, many leasing contracts contain options clauses which allow the airline to purchase the aircraft at the end of the leasing agreement and / or cancel its leasing obligation prior to the end of the lease. Under these conditions, the leasing contract allows the airline to adjust its fleet size in response to the dynamics of the industry.

Furthermore, leasors sometimes renegotiate the terms of a lease. For instance, Southwest Airlines has been in talks with a leasor to return some of its aircraft since the airlines' growth is less than originally expected[8]. It is advantageous for the leasor to receive its aircraft because during this period of 2007, the general demand for aircraft is high and aircraft can be redeployed to earn a higher return. Thus, it is advantageous to both the airline and the leasor to restructure the original lease agreement. Further support that leasors renegotiate leases is reported in *The Wall Street Journal*[9], which states that GE restructured many of its aircraft leases so the aircraft would remain flying.

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[8] This information is based on a telephone conversation with Michael Kortschak, Manager Fleet Planning and Transactions, Southwest Airlines, in July, 2007

[9]Scott McCartney. The middle seat: one reason airlines keep flying despite huge losses: GE --- No. 1 aircraft lessor aims to avoid grounding planes; one side effect: low fares. *The Wall Street Journal*. December 14, 2004. D8.

The above discussion suggests a negative relationship between the degree to which a firm leases its fleet and its risk exposure as the airline is able to shed aircraft during unfavorable conditions and protect the firm's cash flows. Yet during favorable times when the airline is flush with cash, it renews its leases or purchases the aircraft (most likely at a higher cost). The net effect is that the airline smoothes its cash flows between favorable and unfavorable states and thus provides an operational / financial hedge.

Although operating leases provide a source of flexibility for the airline to adjust its fleet in response to changes in market conditions, however, there are other incentives for an airline to lease its fleet. Other possible motives for an airline to lease its aircraft versus buying are taxes, agency costs between shareholders and bondholders, and if the leasor's comparative advantage to the reallocation of the asset (Smith and Wakeman 1985). The leasor's comparative advantage in the reallocation of an aircraft is a result of its ability to reduce the asymmetric information concerning aircraft quality, as leasors require a damage deposit and regular maintenance overhauls from the leasees to insure the quality of the aircraft.

2.4 Data

As previously stated, three different types of operational hedges are considered in this essay, the diversity of the fleet, the fuel-efficiency of the fleet, and the use of a leased fleet. Airlines use diverse fleets along with a leased fleet to respond to changing market conditions, while a newer fleet provides airlines with greater fuel efficiency. In addition to the operational hedges, airlines use financial derivatives to hedge their risk against fuel cost.

I use a method similar to Allayannis, Ihrig, and Weston's (2001) geographic dispersion measure, to proxy the degree to which an airline uses the diversity of its fleet as an operational hedge. The proxy is referred to as the aircraft dispersion index. The construction of the aircraft dispersion index is similar to that of the Hirchman-Herfindhal concentration index, which covers the different types of aircraft that an airline uses. More specifically the aircraft dispersion index is calculated as:

$$= 1 - \sum_{j=1}^{K} \frac{\left(\text{No. of Aircraft}_{\text{j}}\right)^2}{\left(\text{Total No. of Aircraft}_{\text{i}}\right)^2} \tag{2.1}$$

where K is the total number of different models that airline "i" operates. This index range is between zero and one, with one indicating the greatest degree of diversity. If the airline operates only one type of aircraft, such as Southwest, then the index value is equal to zero. The calculation of the aircraft dispersion index is based on data obtained from the airlines' annual 10-k filings.

Operating leases allows the airline to adjust the size of its fleet to market conditions. The proxy to measure an airline's ability to use operating leases as a hedge is the percent of the airline's fleet that is leased. This proxy is calculated as the total number of aircraft the airline leases divided by the total number of aircraft owned and leased. This proxy includes those aircraft that are used for spare parts, not yet in service, and subleased to other airlines. The leasing data is obtained from the airline's annual 10-K filings.

As mentioned earlier, the hypothesis is that airlines with an older fleet experience a greater risk exposure to jet fuel costs than airlines with a newer fleet. To test this hypothesis, I include the logarithm of the total average age of the fleet. The average age of an airline's fleet is a weighted average of the age of the different aircraft the airline operates. The fleet age is reported annually and rounded to the nearest integer. The two reasons for rounding to the nearest integers are (1) many airlines only report the age of the fleet in round years and (2) it reduces possible biases created by smaller aircraft since smaller aircraft are usually younger. When the age of the fleet is not reported, the nearest / earliest possible reported age is used. For instance, Mesa Airlines reported its fleet in 1998 but not 1999. In this case the age of Mesa's fleet in 1998 is used for 1999. The average ages of the fleet is from the airline's 10-K. The average fleet age for Express Jet, Mesaba and Vanguard Airlines are not reported in their 10-K filings and thus are excluded from the sample.

Table I summarizes the major statistics for each sample airline and for the industry. The table reveals a wide range of strategies concerning the diversity of the airlines' fleets. For instance, Southwest and Pinnacle both operate only one type of aircraft in their fleets, the Boeing 737 and the CRJ regional jet respectively, while American, Delta, and United Airlines operate the most diverse fleets. Also Table I shows wide variations in the ages of the airlines' fleets. For example, Jet Blue, a newer airline, has one of the youngest fleets with an average age of 2 years. Tower Air, which filed for bankruptcy in 2000, has the oldest fleet with an average age of over 22 years. Southwest and Northwest, which are some of the oldest airlines in the industry, have an average fleet age of 9 years and 19 years respectively. Therefore the age of the airline doesn't necessarily imply the age of its aircraft. In addition, many newer airlines choose to lease older aircraft in their earlier years.

To measure the degree to which the airline uses financial hedges I use the current year's hedging activity. Another indicator to measure the degree to which an airline hedges its fuel cost is whether the airline has a fuel pass-through agreement. Fuel pass-through agreements are typically contracts between a regional airline and a mainline airline. These contracts cover a regional airline's fuel costs for the service that it provides to the mainline carrier. The percent of jet fuel costs that are hedged and the use of fuel pass-through agreements are used as proxies by Carter, Rogers, and Simkins (2006). This proxy is from the airline's 10-K filing over the period 1994 to 2006.

The sample airlines are those with a standard industry code of 4512, (scheduled air transportation). The data for measuring an airlines exposure to jet fuel prices are the airlines daily returns, an equally weighted market index, and changes in jet fuel prices. The daily airlines' returns are from CRSP, as are the returns of the equally weighted market index. Jet fuel prices are from the Department of Energy and are the U.S. Gulf Coast prices. The airlines' financial data is from COMPUSTAT. The control variables, commuters, regional airline, capacity purchase agreements are collected from the airlines 10-K fillings. The sample period is from 1994 to 2006.

TABLE I
Airlines Summary Statistics

Reports the mean, median and standard deviation for the following variables from 1994 – 2006: The Aircraft Dispersion Index, Fleet Age, Percent of Fleet Leased, Percent of Jet Fuel hedged, Commuters, and an indicator for whether has a Fuel Purchase Agreement (Fuel Pass), Capacity Agreement, or whether the airlines is an regional carrier are obtained from the airlines 10-K's. The Log of Total Asset (Size), Long Term Debt to Total Assets and Operating Cash Flow to Sales are calculated using COMPUSTAT.

	Aircraft Dispersion			Fleet Age			Leased Fleet			Percent of Fuel Hedged			Fuel Pass			Capacity Agreement		
Airline	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median
Airtran	0.31	0.17	0.36	15.27	11.19	17.00	0.48	0.36	0.47	0.17	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00
Alaska	0.72	0.05	0.72	7.85	0.69	8.00	0.65	0.15	0.65	0.22	0.18	0.25	0.00	0.00	0.00	0.00	0.00	0.00
America West	0.66	0.12	0.67	10.31	0.63	10.00	0.87	0.07	0.84	0.16	0.15	0.13	0.00	0.00	0.00	0.69	0.48	1.00
American (AMR)	0.85	0.01	0.85	9.31	1.25	10.00	0.41	0.06	0.41	0.25	0.16	0.20	0.00	0.00	0.00	0.38	0.51	0.00
ATA	0.67	0.06	0.68	12.78	5.24	16.00	0.72	0.16	0.69	0.03	0.07	0.00	0.82	0.40	1.00	0.18	0.40	0.00
Atlantic Coast Airlines	0.56	0.16	0.59	4.44	0.88	4.00	0.92	0.03	0.92	0.05	0.13	0.00	0.55	0.52	1.00	0.00	0.00	0.00
CCAIR	0.57	0.06	0.59	9.25	0.96	9.50	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Comair	0.56	0.09	0.56	4.00	0.00	4.00	0.78	0.01	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Continental	0.68	0.17	0.77	9.08	2.25	8.00	0.76	0.02	0.75	0.15	0.13	0.23	0.00	0.00	0.00	0.38	0.51	0.00
Delta	0.83	0.03	0.83	10.46	1.13	10.00	0.41	0.03	0.42	0.36	0.31	0.36	0.00	0.00	0.00	0.54	0.52	1.00
ExpressJet	0.22	0.03	0.21	N/A	N/A	N/A	1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00
Frontier Airlines	0.17	0.21	0.00	11.66	7.45	11.00	0.88	0.15	1.00	0.03	0.05	0.00	0.00	0.00	0.00	0.25	0.45	0.00
Great Lakes Aviation	0.29	0.04	0.27	7.00	2.40	6.50	0.37	0.28	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hawaiian	0.51	0.06	0.49	17.00	7.01	20.00	0.88	0.12	0.91	0.11	0.11	0.10	0.09	0.30	0.00	0.00	0.00	0.00
JetBlue	0.08	0.13	0.00	2.20	0.84	2.00	0.40	0.05	0.40	0.31	0.13	0.30	0.00	0.00	0.00	0.00	0.00	0.00
Mesa Air	0.62	0.10	0.62	4.50	0.67	5.00	0.63	0.16	0.68	0.16	0.36	0.00	0.62	0.51	1.00	0.00	0.00	0.00
Mesaba / Mair	0.50	0.08	0.54	N/A	N/A	N/A	1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00
Midway Airlines	0.50	0.05	0.51	2.50	0.58	2.50	0.81	0.05	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Midwest	0.62	0.16	0.68	20.08	0.67	20.00	0.67	0.08	0.64	0.06	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northwest	0.77	0.03	0.77	18.82	1.25	19.00	0.37	0.08	0.35	0.11	0.18	0.03	0.00	0.00	0.00	0.85	0.38	1.00
Pinnacle	0.00	0.00	0.00	2.75	0.96	2.50	1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00
Republic Airways	0.63	0.05	0.65	2.67	0.58	3.00	0.39	0.04	0.37	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00
SkyWest Inc	0.38	0.14	0.35	5.08	0.49	5.00	0.76	0.05	0.79	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00
Southwest	0.00	0.00	0.00	8.54	0.66	8.00	0.34	0.12	0.29	0.49	0.38	0.65	0.00	0.00	0.00	0.00	0.00	0.00
Tower Air	0.00	0.00	0.00	22.67	1.15	22.00	0.47	0.06	0.47	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00
Trans World	0.74	0.06	0.76	16.60	2.88	17.00	0.83	0.10	0.81	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UAL (United Airlines)	0.81	0.03	0.83	10.23	1.01	10.00	0.53	0.03	0.53	0.20	0.33	0.00	0.00	0.00	0.00	0.77	0.44	1.00
US Airways	0.80	0.02	0.79	10.45	1.04	10.00	0.56	0.07	0.53	0.11	0.12	0.06	0.00	0.00	0.00	0.64	0.50	1.00
Vanguard Airlines	0.00	0.00	0.00	N/A	N/A	N/A	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industry	0.53	0.28	0.59	10.25	5.97	9.00	0.66	0.25	0.69	0.13	0.22	0.00	0.23	0.42	0.00	0.20	0.40	0.00

TABLE I (Cont.)
Airlines Summary Statistics

Reports the mean, median and standard deviation for the following variables from 1994 – 2006: The Aircraft Dispersion Index, Fleet Age, Percent of Fleet Leased, Percent of Jet Fuel hedged, Commuters, and an indicator for whether has a Fuel Purchase Agreement (Fuel Pass), Capacity Agreement, or whether the airlines is an regional carrier are obtained from the airlines 10-K's. The Log of Total Asset (Size), Long Term Debt to Total Assets and Operating Cash Flow to Sales are calculated using COMPUSTAT.

	Size			L-Term Debt			Cash Flow to Sales			Commuters			Regional Airline		
Airline	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median	Mean	Standard Deviation	Median
Airtran	6.29	0.58	6.16	0.46	0.18	0.45	0.01	0.14	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Alaska	7.74	0.42	7.87	0.27	0.09	0.28	0.08	0.03	0.08	0.29	0.05	0.26	0.00	0.00	0.00
America West	7.58	0.58	7.36	0.27	0.14	0.24	0.05	0.07	0.07	0.02	0.05	0.00	0.00	0.00	0.00
American (AMR)	10.14	0.19	10.17	0.33	0.11	0.36	0.06	0.06	0.09	0.18	0.08	0.18	0.00	0.00	0.00
ATA	6.44	0.41	6.48	0.37	0.15	0.37	0.01	0.18	0.08	0.10	0.10	0.13	0.00	0.00	0.00
Atlantic Coast Airlines	5.40	1.08	5.68	0.22	0.13	0.17	0.04	0.15	0.09	0.50	0.36	0.46	0.91	0.30	1.00
CCAIR	3.13	0.25	3.20	0.28	0.24	0.22	0.07	0.04	0.08	1.00	0.00	1.00	1.00	0.00	1.00
Comair	6.20	0.30	6.22	0.20	0.03	0.19	0.20	0.02	0.20	0.51	0.15	0.49	1.00	0.00	1.00
Continental	8.98	0.34	9.13	0.41	0.08	0.39	0.05	0.05	0.06	0.11	0.10	0.13	0.00	0.00	0.00
Delta	9.78	0.30	9.88	0.29	0.14	0.27	0.00	0.15	0.03	0.03	0.04	0.00	0.00	0.00	0.00
ExpressJet	6.17	0.24	6.23	0.47	0.41	0.33	0.07	0.04	0.08	0.00	0.00	0.00	1.00	0.00	1.00
Frontier Airlines	5.17	1.44	5.46	0.15	0.19	0.04	-0.01	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Great Lakes Aviation	4.73	0.29	4.83	0.34	0.30	0.42	0.02	0.10	0.05	1.00	0.00	1.00	1.00	0.00	1.00
Hawaiian	5.61	0.53	5.48	0.10	0.08	0.09	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
JetBlue	7.42	0.96	7.69	0.48	0.05	0.46	0.07	0.11	0.09	0.00	0.00	0.00	0.00	0.00	0.00
Mesa Air	6.38	0.45	6.15	0.38	0.13	0.35	0.04	0.06	0.06	0.61	0.30	0.62	1.00	0.00	1.00
Mesaba / Mair	5.17	0.47	5.37	0.02	0.03	0.01	0.04	0.12	0.06	0.72	0.09	0.69	1.00	0.00	1.00
Midway Airlines	5.08	0.83	5.32	0.36	0.07	0.39	0.02	0.09	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Midwest	5.48	0.53	5.72	0.07	0.08	0.02	0.04	0.07	0.05	0.27	0.11	0.27	0.00	0.00	0.00
Northwest	9.31	0.21	9.29	0.42	0.13	0.43	0.01	0.09	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Pinnacle	5.09	0.42	5.02	0.44	0.39	0.47	0.08	0.03	0.09	0.00	0.00	0.00	1.00	0.00	1.00
Republic Airways	6.98	0.76	7.07	0.64	0.04	0.66	0.13	0.02	0.14	0.00	0.00	0.00	1.00	0.00	1.00
SkyWest Inc	6.56	1.00	6.54	0.22	0.12	0.16	0.14	0.03	0.16	0.63	0.27	0.78	1.00	0.00	1.00
Southwest	8.79	0.55	8.81	0.15	0.03	0.15	0.14	0.02	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Tower Air	5.54	0.28	5.57	0.19	0.07	0.20	0.09	0.03	0.09	0.00	0.00	0.00	0.00	0.00	0.00
Trans World	7.85	0.10	7.87	0.29	0.08	0.32	-0.03	0.04	-0.05	0.00	0.00	0.00	0.00	0.00	0.00
UAL (United Airlines)	9.84	0.29	9.94	0.21	0.13	0.25	0.02	0.50	0.06	0.00	0.00	0.00	0.00	0.00	0.00
US Airways	8.96	0.10	8.97	0.27	0.15	0.29	0.02	0.14	0.06	0.24	0.04	0.24	0.00	0.00	0.00
Vanguard Airlines	3.31	0.36	3.36	0.02	0.03	0.01	-0.19	0.16	-0.24	0.00	0.00	0.00	0.00	0.00	0.00
Industry	6.99	1.94	6.67	0.28	0.20	0.28	0.04	0.15	0.07	0.21	0.31	0.00	0.30	0.46	0.00

2.5 Model

To test the hypothesis that airlines use operational hedges to reduce their exposure to the price of jet fuel, I use a model similar to the one proposed by Stone (1974), a standard in the risk management literature. The method is a two-step procedure. First, the jet fuel risk and market risk factors for each firm are measured using a two-factor model. The jet fuel and market risk factors are the coefficient estimates from the two-factor model. The jet fuel risk factor is then regressed against the operational and financial hedging proxies. Jet fuel risk and market risk factors for each firm are the coefficients from the following two-factor model.

$$R_{i,t} = \alpha_i + \beta_{i,q}R_{mkt,t} + \gamma_{i,q}R_{jet\ fuel,t} + \varepsilon_{i,t} \qquad (2.2)$$

Where:

$R_{i,t}$ is the i[th] airline's daily return for day t,

$R_{mkt,t}$ is the return for the equally weighted market index for day t,

$R_{jet\ fuel,t}$ is the daily percent change in jet fuel prices for day t,

$\beta_{i,q}$ is the market risk factor for airline "i" for quarter q, and

$\gamma_{i,q}$ is the jet fuel risk factor for airline "i" for quarter q.

The jet fuel γ's are calculated for each airline for each quarter from 1994 to 2006.

The second step is to regress each quarterly jet fuel risk factor (γ) against the operational hedges, financial hedges, and other factors that affect the airline's risk exposure. More specifically the model is:

$$\begin{aligned}|\gamma_{i,q}| = {} & \alpha_{0+}\ \alpha_1(\text{Fleet Diversity}_{i,y}) + \alpha_2(\text{Cap}_{i,y}) + \alpha_3(\text{Leased Fleet}_{i,y}) \\ & + \alpha_4(\text{Fleet Age}_{i,y}) + (\alpha_5 + \alpha_6(\text{Fleet Age}_{i,y}))^*\ (\text{StdPrice}_{qtr}) \\ & + \alpha_7(\text{AvgPrice}_{qtr}) + \alpha_8(\text{Percent Hedge}_{i,y}) \\ & + \alpha_9(\text{FuelPass}_{i,y}) + \alpha_{10\text{-}13}(\text{Control Variables}_{i,y}) + \varepsilon_{i,q}\end{aligned} \qquad (2.3)$$

where "i" represents the firm and "y" is the year.

I use the absolute value of the airline's risk exposure to jet fuel prices, as the objective in a hedging program is to reduce the firm's exposure to the underlying risk. Furthermore, the absolute value of the risk exposure coefficient has been used by others in the risk management literature (Allayannis, Ihrig, and Weston 2001; Allayannis and Ofek 2001). I test the following eight hypotheses.

H_1: Diversity reduces exposure to jet fuel prices (α_1 <0). A diverse fleet provides an airline the flexibility to respond to changing market conditions. That is, if fuel prices are high, an airline with a diverse fleet will reduces its losses by switching to a smaller aircraft. Thus, the prediction is that α_1 is less than zero.

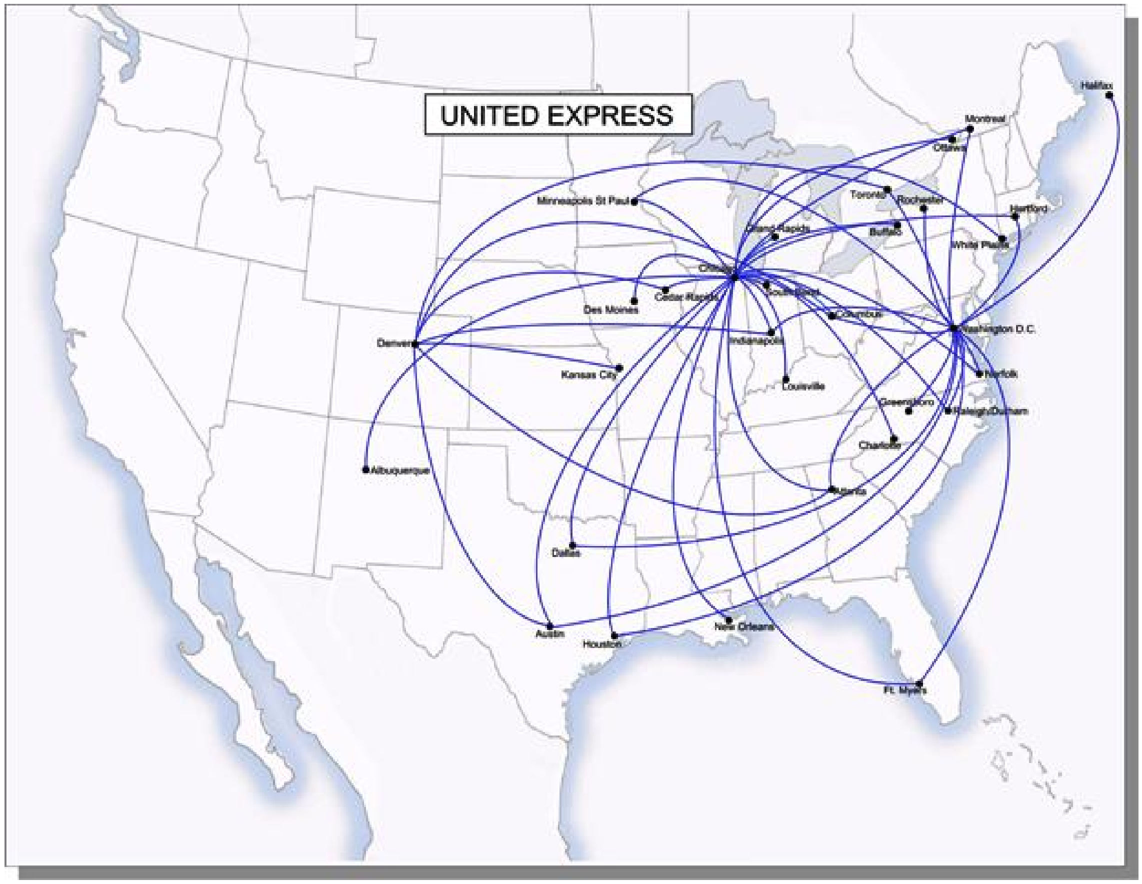
The aircraft dispersion index is biased. The first way it is biased is that smaller turbo-prop aircraft are not comparable substitutes for a larger jet aircraft. These aircraft lack the speed and nautical distance to support the routes which a typical jet aircraft serves. Furthermore, these aircraft are less fuel-efficient than their jet counterparts and thus create greater levels of exposure to fuel prices. To control for this bias, Commuter is add to the model as a control variable. This variable is the percent of the airline fleet that consists of turbo-props. In comparison, regional jets, which typically seat between 50 and 100 passengers, are smaller than the narrow body aircraft, yet have the speed and distance requirements to service many of the routes serviced by narrow body aircraft. To illustrate this point, Figure 2, shows the routes that *Republic Airways*[10] services under the name United Express. Republic Airways is a regional carrier whose fleet consists solely of regional jets. Figure 2 illustrates that this carrier services many non-feeder routes. For example, Republic Airways services many routes which are not feeders to United Airlines, but rather supplement the markets which are often serviced by larger narrow-

[10] *Republic Airways, 2006 10-K.*

and wide-body aircraft. For instance Republic Airways services the Houston to Chicago; Ft Myers, Florida to Chicago; and Denver to Toronto markets, which are neither short distance nor low traffic markets.

The second bias is associated with capacity purchase agreements. Normally under these agreements, an airline, typically a mainline airline, purchases a fixed amount of seating capacity from a regional airline. In these agreements, the mainline airline pays the regional airline a fixed profit plus a performance bonus. In return, the mainline airline is responsible for the revenue, costs, and scheduling of flights. Furthermore, the structure of the agreements is such that the mainline airline leases or subleases the aircraft to the regional carrier. With capacity purchase agreements, an airline maintains the benefits of a diverse fleet, yet still maintain profits and scheduling rights. Such agreements cause the aircraft dispersion index to be biased, as the calculation of the index excludes aircraft which are under a capacity purchase agreement. Furthermore, many mainline airlines shed their regional airlines during the unfavorable period between 2001 and 2004, yet they maintained exclusive capacity purchase agreements with their former regional carriers. This fact also causes the aircraft dispersion index to be biased, as these airlines continued to operate a diverse fleet via the regional airline. To control for this bias, a dummy variable is included (CAP) which equals one if the airline has entered into a capacity purchase agreement with a regional airline, otherwise zero.

FIGURE 2
Republic Air Routes Which are Flown Under the United Express Name



From Republic Airways 2006 10-K filling

H2: A leased fleet reduces the airline's exposure to jet fuel prices (α_3<0). A leased fleet reduces an airline's exposure to fuel price because increasing the percent of the fleet which is leased allows the airline to quickly adjust to changing market conditions.

H3: Fuel efficient fleets reduce exposure to jet fuel prices (α_4>0). The coefficient for the Fleet Age is predicted to be positive because a more fuel efficient fleet reduces an airline's exposure to jet fuel prices while an older fleet increases an airline's exposure. A newer fleet reduces an airline's sensitivity to fuel prices since fuel costs relative to the airline's cash flows are less than those of an airline with an older fleet.

H_4: Older aircraft reduce the effects of fuel price volatility (α_6<0). The coefficient for the product between the jet fuel price volatility and the age of the fleet is hypothesized to be negative. This relationship is because as the volatility of jet fuel prices increases, the sensitivity of the option to upgrade to a fuel-efficient fleet declines with respect to fuel prices. This decline in exposure is a result of the fact that an option's sensitivity to an underlying asset declining as the underlying asset's volatility increases.

H_5: Exposure declines with volatility (α_5<0). If airlines are using real options to manage their risk exposure to jet fuel prices, then the prediction is that an increase in the volatility of jet fuel prices reduces the airlines' exposure to jet fuel prices. This is similar to the prediction made by Tufano (1998), in that an increase in the volatility of gold prices reduces a gold mine's exposure to gold prices. However, as noted in the literature review, the above relationship is not a necessary one. That is, a firm using real options to manage its risk can show little or no relationship between its exposure coefficient and the volatility of the underlying asset.

H_6: Exposure increases with the price of fuel (α_7>0). The coefficient for the average jet fuel price is expected to be positive. The reason is similar to Tufano (1998), in that if production is fixed, then exposure increases with the cost of the input.

H_7: The percent of fuel cost that is hedged reduces exposure (α_8<0). For the financial hedges, the variable Percent Hedge is hypothesized to be negative, as the objective of hedging is to reduce the airline's exposure to jet fuel prices.

H_8: Fuel pass-through agreements reduce jet fuel exposure (α_9<0). FuelPass is a dummy variable indicating whether the airline has entered into a fuel pass-through agreement. FuelPass is coded as 1 if the airline has entered into a fuel pass-through

agreement and 0 otherwise. The FuelPass coefficient is hypothesized to be negative since these types of agreements lock in the airline's fuel cost.

The control variables are long-term debt to assets (LTDA), natural logarithm of total assets (Size), cash flow to sales (CFTS), and a regional airline dummy variable (REG). As Tufano (1998) contends for gold mining firms, interest payments are also a large component of an airline's fixed costs. Thus, the hypothesis is that exposure increases with firm leverage. Several studies find a positive relationship between the size of the firm and its exposure to underlying assets (He and Ng 1998; Tufano 1998). In addition, larger firms are more likely to use financial derivatives, as there is an economy of scale for a hedging program (Geczy, Minton, and Schrand 1997). The cash flow to sales ratio controls for firms' profitability. Lastly, a dummy variable is included for whether the airline is a regional airline, since regional carriers typically operate in a different market in that they provide services to the mainline airlines. In addition to the control variables, outliers of the Z-Score at the first and ninety ninth percentiles are removed from the sample because Hawaiian Airlines reported Z-Scores of -80.6 and -71.33 in 2003 and 2004 respectively.

2.6 Results

2.6.a Airline Risk Exposure (Jet Fuel)

The first question is whether airlines' exposure to fuel prices is significant enough to support the use of financial and operational hedges. Figure 3 illustrates fuel costs are a major component of the airlines' costs, typically ranging from 10% to 15% of total operating costs. According to the *Air Transport Association*[11], fuel costs currently account for 30% to 50% of an airline's operating costs. Furthermore, Carter, Rogers, and Simkins (2006) find evidence that the airline industry is exposed to fuel prices. This analysis confirms Carter, Rogers, and Simkins findings, and further finds that airlines' exposure to jet fuel prices has increased dramatically in both magnitude and statistical significance. In addition, airlines tend to exhibit higher levels of exposure to fuel price during those periods when fuel prices are high or rising.

Table II reports the results for the estimation of Equation (2.2). The columns report the average, median, standard deviation, and the percent of jet fuel risk factors (γ) that are significant at the 10% level[12]. The risk factors reported in Table II for each firm are calculated quarterly using daily returns over the sample period of 1994-2006. The sample size is 1,072 quarterly estimated airline jet fuel risk factors. The estimated quarterly airlines' risk factors with fewer than 59 observations are excluded from the sample, as there is roughly a minimum of 59 days in a quarter. The table indicates there are a number of significantly negative jet fuel price exposure coefficients. For instance 61% of JetBlue risk factors are significantly negative. The average airline's jet fuel risk factor is -0.0902, and 29% of those are significantly less than zero using a one sided t-test at the 10% significance level. Moreover 67% of the exposure coefficients are less than zero.

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[11] *Energy/Fuel*. Air Transport Association (ATA) 2008 [cited June 16, 2008]. Available from http://www.airlines.org/economics/energy/.

[12] A Seemly Unrelated Regression was also used to estimate the jet fuel risk factors. However, results are not materially different from those reported in Table II.

FIGURE 3
Percent of Operating Cost for which Jet Fuel Accounts

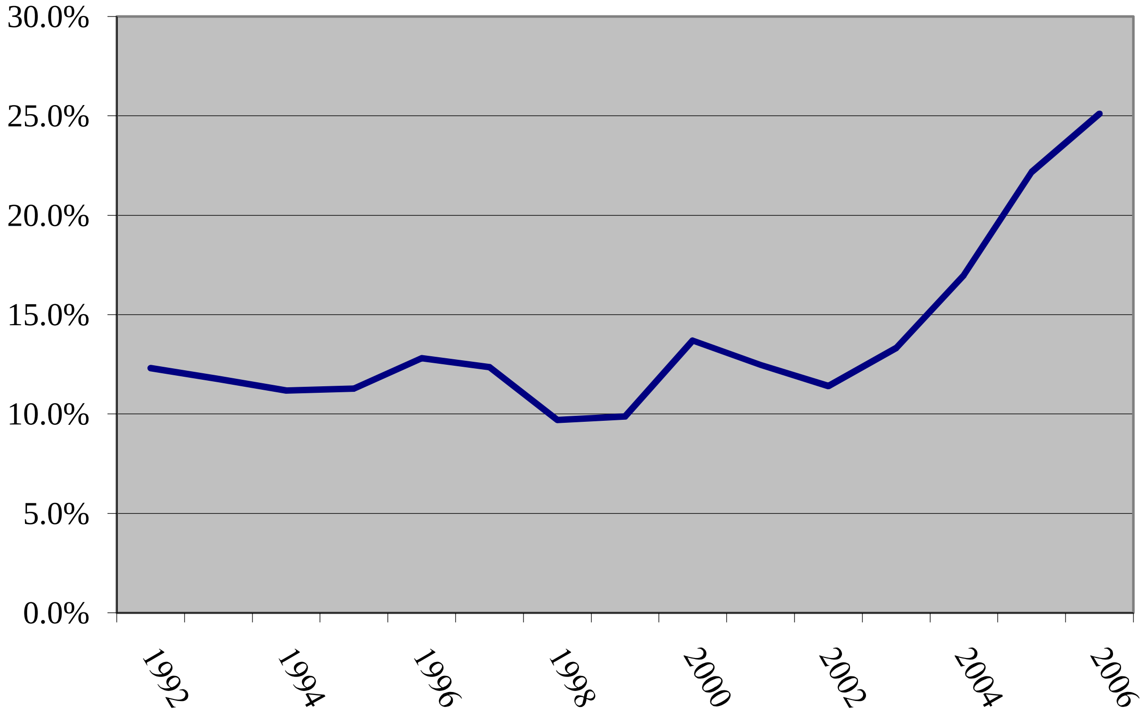


Figure 3 plots the percentage of operating cost that is attributed to jet fuel expense. The data is from the *Air Transport Association* (2007).

TABLE II
Summary Statistics of Airline Jet Fuel Exposures Coefficients

Panel A reports the average, median and standard deviation of the quarterly jet fuel risk factor (γ) for each firm over the period of 1994 to 2006. Also reported is the percentage of γ's that are significantly less than zero at the 10% level for each airline. The risk factor is calculated using equation (2.2) ($R_{i,t} = \alpha_i + \beta_{i,q}R_{mkt,t} + \gamma_{i,q}R_{jet\ fuel,t} + \varepsilon_{i,t}$). Panel B reports selected summary statistics for the airlines risk factors.

Panel A

Airline	Mean γ	Median γ	Standard Deviation γ	Percent Significant at 10%
ATA	0.02	-0.02	0.28	12%
Airtran	-0.10	-0.14	0.29	32%
Alaska	-0.10	-0.10	0.19	42%
America West	-0.15	-0.18	0.32	47%
American (AMR)	-0.22	-0.16	0.30	46%
Atlantic Coast Airlines	-0.09	-0.12	0.30	23%
CCAIR	-0.01	0.00	0.34	10%
Comair	-0.10	-0.09	0.25	25%
Continental	-0.19	-0.21	0.27	52%
Delta	-0.12	-0.09	0.18	21%
ExpressJet	-0.17	-0.13	0.20	50%
Frontier Airlines	-0.07	-0.10	0.29	24%
Great Lakes Aviation	0.00	0.05	0.58	9%
Hawaiian	-0.02	-0.04	0.27	21%
JetBlue	-0.16	-0.14	0.16	61%
Mesa Air	-0.08	-0.09	0.22	25%
Mesaba / Mair	0.02	-0.04	0.23	12%
Midway Airlines	-0.01	-0.02	0.28	7%
Midwest	-0.12	-0.09	0.26	33%
Northwest	-0.14	-0.15	0.22	39%
Pinnacle	-0.07	-0.08	0.10	17%
Republic Airways	-0.12	-0.08	0.11	30%
SkyWest Inc	-0.11	-0.10	0.21	33%
Southwest	-0.06	-0.06	0.15	37%
Tower Air	-0.01	-0.04	0.28	13%
Trans World	-0.06	-0.08	0.20	17%
UAL (United Airlines)	-0.15	-0.09	0.36	33%
US Airways	-0.05	-0.12	0.29	17%
Vanguard Airlines	-0.03	-0.04	0.26	8%

Panel B

Risk Factors	Jet Fuel
Number of Observations	1,072
Mean	-0.0902
Standard deviation	0.2762
Median	-0.0884
Minimum	-2.0397
Max	1.1805
% Negative	67%
Number significantly different from 0	
10% level	266
5% level	198
Number significantly less than 0	
10% level	312
5% level	232
Number significantly greater 0	
10% level	63
5% level	34

Figure 4 plots the percent of exposure coefficients that are less than zero, the percent of exposure coefficients that are significantly less than zero, the average magnitude of the exposure coefficients, and the average price of jet fuel. The figure shows a steady increase in the magnitude and significance of an airline's exposure to jet fuel prices. For instance, at the beginning of the sample period (1994), the average jet fuel exposure coefficient for an airline was 0.01, considerably less in magnitude than the -0.32, at the end of the sample period (2006). This change in the jet fuel exposure has economic significance. Using daily jet fuel returns from 1994 to 2006, the mean daily percent change in fuel prices is 0.08% with a standard deviation of 2.64%. Using the average fuel exposure coefficient for 1994, a one standard deviation movement in the jet fuel returns would have resulted in a 0.017% rise in the airline's stock price. This compares to with a 0.86% drop in 2006, or roughly a 0.1% rise versus a 5.38% fall in the airlines' monthly returns.

FIGURE 4
Jet Fuel Exposures

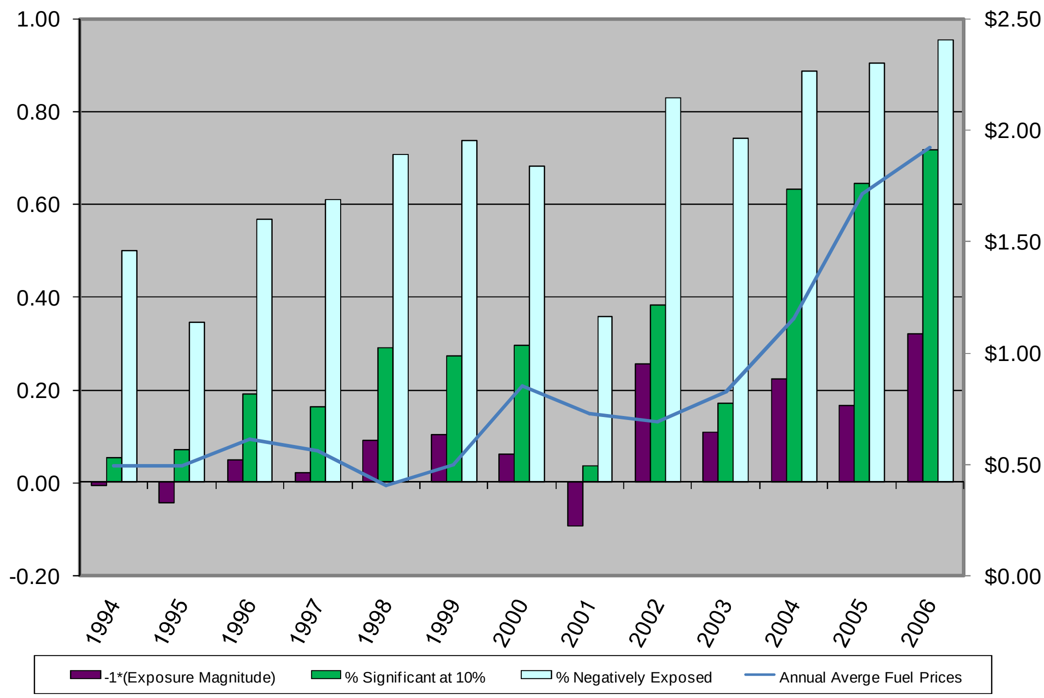
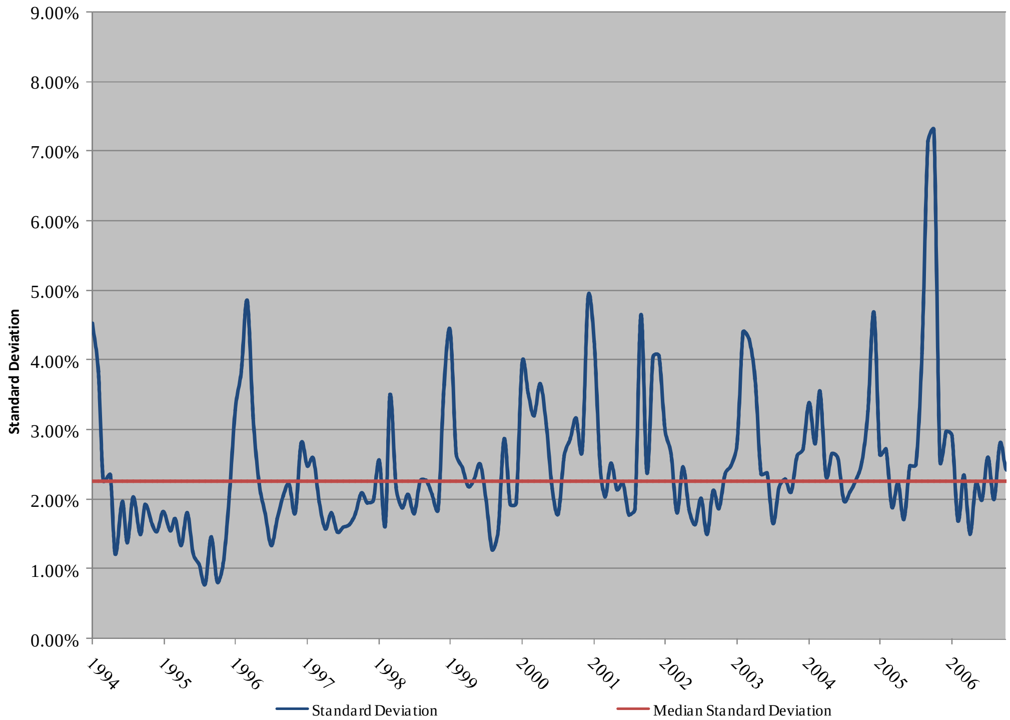


Figure 4 also indicates a possible relationship between the airlines' jet fuel exposure coefficient and the price of jet fuel. Figure 4 shows a rapid increase in jet fuel prices after 1999, and there after airlines have typically experienced a greater level of exposure to fuel prices than prior to 1999. At roughly the same time, the volatility in jet fuel prices began to increase (Figure 5). Figure 5 illustrates the increase in volatility. Between 1994 and 1999 the daily standard deviation, which is calculated monthly is above the median standard deviation of 2.25%, 27% of the time. This is compared this to the period between 1999 and 2006 when the standard deviation is above the median 64% of the time. This result is similar to Carter, Rogers, and Simkins (2006), who show a large increase in jet fuel prices post 1999. Starting in 1998 and continuing until 2006, the increase in exposure coefficients has been relatively consistent, (see Figure 4).

FIGURE 5
Daily Standard Deviation of Jet Fuel Returns / Calculated Monthly



The above analysis suggests the possibility that airlines' exposure to jet fuel prices is dependent on whether jet fuel prices are rising or falling, in a high or low price period, and in a period of high or low volatility. As discussed before, if the output for an airline is relatively fixed, then a positive relationship exists between the airline's exposure to fuel prices and the price of fuel. Furthermore, if airlines own and use real options, an inverse relationship exists between fuel price volatility and the airlines' exposure to fuel prices.

To test these hypotheses, a series of regressions are performed. In the first model, the returns of the airlines are regressed against the changes in fuel prices during periods of declining prices, rising prices, low prices with low volatility, and high prices with high volatility. The low price with low volatility period is between 1994 and 1996. The era of declining prices is from 1997 through 1998 and then again for 2001. The rising price era is between 1999 and 2000. The period of high prices with high volatility is between 2002 and 2006. These classifications are similar to those of Carter, Rogers, and Simkins (2006). Specifically the model is:

$$R_{i,t} = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 \text{Jet Fuel}_t{*}(LV) + \gamma_2 \text{Jet Fuel}_t{*}(D) + \gamma_3 \text{Jet Fuel}_t{*}(R) + \gamma_4 \text{Jet Fuel}_t{*}(HV) + \varepsilon_{i,t} \quad (2.4)$$

where LV equals one if the returns occur in periods of low fuel price and low volatility, otherwise zero; D equals one if the returns occur in periods of declining fuel prices, otherwise zero; R equals one for the periods of rising fuel prices, otherwise zero; and HV equals one for the periods of high prices and high volatility.

Table III reports the result from Equation (2.4). Column (1) of the table reports the results using OLS. Column (2) uses a firm fixed effect regression. Column (3) runs Equation (2.4) for each airline over the sample period, 1994 to 2006. The reported values for Column (3) are the mean, median, and standard deviation for the exposures during the four different price regimes. The results indicate that the airline industry exhibits insignificant exposure coefficients during periods of low prices with low volatility (LV) and periods of declining prices (D). The OLS exposure coefficients (t-statistic) for these regimes are -0.0138 (-0.94) and 0.0124 (0. 93) respectively. However, the exposure levels are negative and statistically significant during periods of high prices with high volatility (HV) and periods of rising prices (R). That is, during periods of rising prices or of high prices and high volatility, the exposure coefficients (t-statistics) are -0.086 (-6.21) and -0.172 (-17.98) respectively. Furthermore, the lower part of Table III shows the rejection of the hypothesis that exposure coefficients for regimes of low prices with low volatility are the same as those for regimes of high prices and high volatility. The same is true for the hypothesis that the exposure coefficients during periods of rising prices are the same as for periods of declining prices. The other two columns confirm the results of column one.

TABLE III
Risk Exposures During Fuel Prices Regimes

Regress the returns of the airlines on the change of jet fuel prices during periods of low price with low volatility (1994-1996), periods of declining prices (1997 – 1998, 2001) periods of increasing prices (1999 – 2000) and periods of high price with high volatility (2002-2006). The models is:

$$R_{i,t} = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 \text{Jet Fuel}_t*(LV) + \gamma_2 \text{Jet Fuel}_t*(D) + \gamma_3 \text{Jet Fuel}_t*(R) + \gamma_4 \text{Jet Fuel}_t*(HV) + \varepsilon_{i,t}$$

where $R_{i,t}$ is the daily return on airline i, $R_{mkt,t}$ is the daily market return and Jet Fuel_t is the daily percent change in the price of jet fuel. LV, D, R, and HV are dummy variables representing the price regimes of low prices with low volatility, periods of declining prices, periods of increasing prices, and periods of high prices with high volatility respectively. Column (1) reports the results using OLS. Column (2) uses a firm fixed effects regression. Column (3) reports the mean, median and standard deviation of the coefficients from model (2.4) by running each airline separately.

	Column (1) OLS	Column (2) Firm Fixed Effects	Column (3) Individual Airlines
Constant	-0.0006*** (0.0002)	-0.0003 (0.0007)	
Jet Fuel*(LV)	-0.0138 (0.0146)	-0.0137 (0.0146)	-0.0104 -0.0203 0.0736
Jet Fuel*(D)	0.0124 (0.0134)	0.0124 (0.0134)	0.0117 -0.0058 0.0686
Jet Fuel*(R)	-0.0861*** (0.0139)	-0.0857*** (0.0139)	-0.0895 -0.1153 0.0948
Jet Fuel*(HV)	-0.1731*** (0.0096)	-0.1733*** (0.0096)	-0.1489 -0.1537 0.1383
$R_{mkt,t}$	1.4500*** (0.0203)	1.4499*** (0.0203)	
sample size	68155	68155	
R square	0.0735	0.0734	
F-Statistic	1082.52***	164.57***	
Wald Test $\gamma_1 = \gamma_4$	83.15***	83.35***	
Wald Test $\gamma_2 = \gamma_3$	26.10***	25.88***	

* 10% significance (two-sided test)
** 5% significance (two-sided test)
*** 1% significance (two-sided test)

To further test the hypothesis that airlines' exposure coefficients are greater during periods of high fuel prices, the following regression is performed:

$$R_{i,t} = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 \text{Jet Fuel}_t^{(h)} + \gamma_2 \text{Jet Fuel}^{(l)}_t + \gamma_3 \text{Jet Fuel}^{(m)}_t + \varepsilon_{i,t} \qquad (2.5)$$

where Jet $\text{Fuel}^{(h)}$ is the change in jet fuel prices when the price of jet fuel is above the fourth quartile. Jet $\text{Fuel}^{(l)}$ is the change in jet fuel prices when the price of jet fuel is below the first quartile. Jet $\text{Fuel}^{(m)}$ is the change in jet fuel prices when the price of jet fuel is between the 25^{th} and 75^{th} quartile. The quartile for the price of jet fuel is determined between the years of 1994 and 2006. The first quartile price is 51.23 cents and the fourth quartile value is 94.55 cents.

Table IV confirms the results shown in Table III. That is, airlines exhibit a greater level of exposure to fuel prices during periods of high fuel prices. Column (1) of Table IV shows the results from Equation (2.5) using OLS. The Column (2) shows the results using firm fixed effects. Column (3) shows the results from running Equation (2.5) separately for each firm. The values reported in Column (3) of Table IV are the mean, median, and standard deviations for the airlines' exposure coefficients. Column (1) values reveal that the airline industry tends to exhibit higher exposure coefficients during periods when the prices are in the 75^{th} percentile. That is, the exposure coefficient during periods of high prices is three times greater than the exposure coefficient during periods of low prices. The exposure coefficients (t-statistics) for periods of high and low prices are -0.157 (-14.27) and -0.052 (-3.76) respectively. Furthermore, the table shows rejection of the hypothesis that the exposure coefficients for the two regimes are the same, thus confirming the prior analysis that airlines exhibit greater levels of exposures to fuel prices during periods when fuel prices are high.

TABLE IV
Risk Exposures During Periods of High and Low Fuel Prices

Regress the returns of the airlines on the change of jet fuel prices during periods of low, median, and high prices. The models is:
$R_{i,t} = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 \text{Jet Fuel}_t^{(l)} + \gamma_2 \text{Jet Fuel}^{(m)}_t + \gamma_3 \text{Jet Fuel}^{(h)}_t + \varepsilon_{i,t}$
where $R_{i,t}$ is the daily return on airline i, $R_{mkt,t}$ is the daily market return. Jet $\text{Fuel}_t^{(l)}$ is the daily percent change in the price of jet fuel when the price of fuel is below the 25th quartile, otherwise zero. Jet $\text{Fuel}_t^{(m)}$ is the daily percent change in the price of jet fuel when the price of fuel is between the 25th and 75th quartiles, otherwise zero. Jet $\text{Fuel}_t^{(h)}$ is the daily percent change in the price of jet fuel when the price of fuel is above the 75h quartile, otherwise zero. The quartiles are determined over the sample period of 1994 – 2006. The 25th and 75th quartiles are 51.23 and 94.55 respectively. Column (1) reports the results using OLS. Column (1) use a firm fixed regresion. Column (3) reports the mean, median and the standard deviation of the coefficients from the model by running each airline separately.

	Column (1) OLS	Column (2) Firm Fixed Effects	Column (3) Individual Airlines
Constant	-0.0007***	-0.0003	
	(0.0002)	(0.0007)	
Jet Fuel$^{(l)}$			-0.0524
	-0.0524***	-0.0524***	-0.0403
	(0.0139)	(0.0139)	0.0625
Jet Fuel$^{(m)}$			-0.0460
	-0.0578***	-0.0577***	-0.0363
	(0.0088)	(0.0088)	0.0758
Jet Fuel$^{(h)}$			-0.1046
	-0.1574***	-0.1575***	-0.1264
	(0.0110)	(0.0110)	0.2102
R_{mkt}	1.4448***	1.4448***	
	(0.0203)	(0.0203)	
sample size	68155	68155	
R square	0.0721	0.072	
F-Statistic	1325.88***	166.27***	
Wald Test / *Sign Test			
$\gamma_1 = \gamma_2$	34.92***	34.98***	0.0012

* 10% significance (two-sided test)
** 5% significance (two-sided test)
*** 1% significance (two-sided test)
* The test for the Column (3) is a Sign test with the hypothesis Low Prices > High Prices. The result is the probability of the median coefficients of low prices being larger than high prices.

Next, I determine whether airlines' exposure to fuel prices is the same when fuel prices are rising or falling. To test this hypothesis, the returns of the airlines are regressed against the returns of jet fuel prices during periods when fuel prices are rising or falling. More specifically the formula is:

$$R_{i,t} = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 \text{Jet Fuel}_t^{(r)} + \gamma_2 \text{Jet Fuel}^{(f)}_t + \varepsilon_{i,t} \tag{2.6}$$

where Jet $\text{Fuel}_t^{(r)}$ is defined as the daily jet fuel return during quarters when the average jet fuel return is positive, otherwise zero. Similarly, Jet $\text{Fuel}_t^{(f)}$ is defined as the daily jet fuel return during quarters when the average jet fuel return is negative, otherwise zero. The results indicate that the jet fuel exposure coefficients are significantly different during periods of falling fuel costs from those during periods of rising jet fuel prices. Table V reports the results of Equation (2.6). Column (1) is the result of Equation (2.6) using OLS and the arithmetic average return for the quarter. Column (2) reports the mean, median, and the standard deviation of exposure coefficients for the airlines. The Columns (3) and (4) are similar to Columns (1) and (2) except that Jet $\text{Fuel}_t^{(r)}$ is the daily change in fuel prices if the quarterly change in fuel prices is positive, otherwise zero. Jet $\text{Fuel}_t^{(f)}$ is the daily change in fuel prices if the quarterly change in fuel prices is negative, otherwise zero. As seen in Column (1), during periods when jet fuel prices are rising, the industry's exposure coefficient (t-statistic) is -0.107 (-12.89) rather than the -0.064 (-6.94) for falling jet fuel prices. Furthermore, the differences in the coefficients is statistically significant (p value = 0.001). For robustness, the summary statistics for the airlines' individual jet fuel risk exposures using Equation (2.6) are reported in Column (2). The average airline jet fuel risk factor during quarters of increasing jet fuel prices is -0.0909 (γ_1) versus the -0.0662 (γ_2) for periods of decreasing prices. Furthermore, the

Sign Test rejects the hypothesis that fuel exposures during rising fuel prices are greater than the fuel exposures during falling price periods.

TABLE V
Risk Exposures During Periods of Rising and Falling Fuel Prices

Table V regress the airline's daily returns on the change in fuel prices during periods of rising and falling fuel prices. The model is

$$Ri,t = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 \text{Jet Fuelt}^{(r)}{}_t + \gamma_2 \text{Jet Fuel}^{(f)}{}_t + \varepsilon_{i,t}$$

where $R_{i,t}$ and $R_{mkt,t}$ are the airline's and market index's daily returns. In column 1 and 2, Jet Fuel$^{(r)}$ and Jet Fuel$^{(f)}$ are the change in fuel prices during quarters when the average daily percent change in the fuel prices are positive and negative respectively. In Column 3 and 4, Jet Fuel$^{(r)}$ and Jet Fuel$^{(f)}$ are the change in fuel prices during quarters when the change in fuel prices are positive and negative respectively. Columns 1 and 3 report the results using OLS. Columns 2 and 4 are the mean, median and standard deviation for each individual airline.

	Column (1) OLS	Column (2) Individual Airlines	Column (3) OLS	Column (4) Individual Airlines
Constant	-0.0006***		-0.0006***	
	(0.0002)		(0.0002)	
		-0.0934		-0.0909
	-0.1074***	-0.1005	-0.1035***	-0.0980
Jet Fuelt$^{(r)}$	(0.0083)	0.0793	(0.0086)	0.0830
		-0.0610		-0.0662
	-0.0641***	-0.0595	-0.0715***	-0.0661
Jet Fuelt$^{(f)}$	(0.0092)	0.0665	(0.0089)	0.0628
		1.3434		
R_{mkt}	1.4497***	1.5096	1.4486***	
	(0.0203)	0.4817	(0.0203)	
sample size	68155	29	68155	29
R square	0.0715		0.0715	
F-Statistic	1751.05***		1749.11***	
Wald Test / *Sign Test Rise = Fall	12.08***	0.0012	6.67***	0.037

* 10% significance (two-sided test)
** 5% significance (two-sided test)
*** 1% significance (two-sided test)
* The test for the column 2 and 4 is a sign test with the hypothesis Falling Prices > Rising Prices. The result is the probability of the median coefficients of falling prices being larger than rising. prices.

Next, I explore the airlines' exposure to jet fuel prices during periods of high and low volatility in fuel prices. Recall that if airlines own a set of real options, then the prediction is that the exposure coefficients during high volatility periods are less than during low volatility periods. To examine this issue, a similar model to Equation (2.5) is used. Specifically, the model is:

$$R_{i,t} = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 \text{Jet Fuel}_t^{(hv)} + \gamma_2 \text{Jet Fuel}^{(lv)}_t + \gamma_3 \text{Jet Fuel}^{(mv)}_t + \varepsilon_{i,t} \tag{2.7}$$

where "hv" is the change in jet fuel prices during those quarters when the volatility of the fuel prices is above the 75^{th} percentile, "lv" is the change in jet fuel price during those quarters when the volatility of the price of fuel is in the lower quartile, and "mv" is the change in fuel prices during those quarters when the volatility of fuel prices is between the first and fourth quartiles. The volatility of jet fuel prices is the daily standard deviation of the percent change in jet fuel prices, calculated quarterly. The 25th and 75th percentiles of the volatility of jet fuel prices are 0.0198 and 0.0297 respectively. The result reported in Table VI indicates that the exposures coefficients for the airline industry during periods of high fuel price volatility are not significantly different from those in periods of low fuel price volatility.

In closing, this subsection confirms there is significant exposure to jet fuel prices for an airline. Furthermore, the results also indicate that the exposure to jet fuel prices has risen significantly, both statistically and economically. In addition, the magnitude has also increased. The indications are that the increase in an airline's exposure to fuel prices is associated with the rising price of jet fuel and the relatively high price of fuel. Lastly, this subsection does not find that the airlines' exposure to fuel prices is different during period of high and low fuel price volatility.

TABLE VI

Risk Exposures During Periods of High and Low Fuel Price Volatility

Table VI regress the airline daily returns on the change in fuel price during periods when the volatility of fuel prices is low, median, and high. The model is:

$R_{i,t} = \alpha_0 + \beta_1 R_{mkt,t} + \gamma_1 \text{Jet Fuel}_t^{(hv)} + \gamma_2 \text{Jet Fuel}^{(lv)}_t + \gamma_3 \text{Jet Fuel}^{(mv)}_t + \varepsilon_{i,t}$

Where Jet $\text{Fuel}_t^{(hv)}$ is the change in fuel prices when the quarterly volatility of jet fuel prices is above the 75th percentile. Jet $\text{Fuel}^{(lv)}_t$ is the change in fuel prices when the quarterly volatility of jet fuel prices is below the 25th percentile. Jet $\text{Fuel}^{(mv)}_t$ is the change in fuel prices when the quarterly volatility of jet fuel prices is between the 25th and 75th percentiles.

	Column (1) OLS	Column (2) Individual Airlines
Constant	-0.0007*** (0.0002)	
Jet Fuel$^{(hv)}$	-0.0570*** (0.0089)	-0.0450 -0.0465 0.0650
Jet Fuel$^{(lv)}$	-0.0831*** (0.0194)	-0.0934 -0.0874 0.0936
Jet Fuel$^{(mv)}$	-0.1251*** (0.0096)	-0.1100 -0.1228 0.1096
R_{mkt}	1.4473*** (0.0203)	
sample size	68155	29
R square	0.0717	
F-Statistic	1317.34***	
Wald Test / *Sign Test		
$\gamma_1=\gamma_2$	1.500	0.9320

* The test for the column 2 is a sign test with the alternative hypothesis High Volatility < Low Volatility Periods. The result is the probability of the coefficients of high volatility periods being more negative than low volatility periods.

* 10% significance (two-sided test)

** 5% significance (two-sided test)

*** 1% significance (two-sided test)

2.6.b Determinants of Risk Exposure

Tables VII report the results of Equation (2.3), which regresses the absolute value of the airlines' quarterly jet fuel risk factors against the previously defined operational and financial hedges. The absolute value of the airlines' risk factors is used since the analysis of the airlines' risk factors suggests that jet fuel exposure coefficients are not always negative (See Figure 4). Furthermore, the objective of a hedge is to reduce the firm's exposure to the underlying risk. Column (1) of Table VII Panel A reports the results from an OLS regression with robust standard errors. Column (2) uses a FGLS to control for heteroskedasticity. Column (3), which also uses FGLS, excludes the variables AvgPrice, StdPrice, and the product of the StdPrice and Fleet Age. Column (4) uses a firm fixed effects model. All models include a year dummy variable which is not reported. The standard errors are reported in the parentheses. The statistically significant values of interest are in bold. Table VII Panel B is included for robustness and reports Equation (2.3) with the financial and operational hedges run separately.

According to H_1, a diverse fleet reduces an airline's exposure to fuel prices. The results support this hypothesis. For columns (1-3), of Table VII Panel A, the coefficients for the Fleet Diversity are negatively statistically significant at least at the 5% level using a one-sided test (10% using a two-sided test). For instance, the Fleet Diversity coefficient for column (2) is -0.0510 and reports a Z-test statistic of -2.03. A one-sided test is appropriate since the alternative hypothesis, H_1, is that the coefficient is less than zero, not that it is different from zero. Table VII Panel B shows Fleet Diversity is negative and significant when the financial hedges are excluded from the model (Column 1).

TABLE VII
The Effectiveness of the Operational and Financial Hedges

Table VII Panel A reports the results of model (2.3)

$|\gamma_{i,q}| = \alpha_0 + \alpha_1(\text{Fleet Diversity}_{i,y}) + \alpha_2(\text{Cap}_{i,y}) + \alpha_3(\text{Leased Fleet}_{i,y}) + \alpha_4(\text{Fleet Age}_{i,y}) + (\alpha_5 + \alpha_6(\text{Fleet Age}_{i,y}))^* (\text{StdPrice}_{qtr}) + \alpha_7(\text{AvgPrice}_{qtr}) + \alpha_8(\text{Percent Hedge}_{i,y}) + \alpha_9(\text{FuelPass}_{i,y}) + \alpha_{10\text{-}13}(\text{Control Variables}_{i,y}) + \varepsilon_{i,q}$

Column (1) reports the results using OLS with robust standard errors. Column (2) and (3) results are from a FGLS model to control for heteroskedasticity. Column (4) is estimated with a firm fixed effects model with robust standard errors. All models include a year dummy variable which is not reported. The statically significant values of interest are in **bold.**

Panel A

	Column (1)	Column (2)	Column (3)	Column (4)
	OLS / Robust	FGLS / Hetero-skedastic	FGLS / Hetero-skedastic	Fixed Effect / Robust
Constant	0.0895 (0.0924)	0.1000 (0.1040)	0.1479** (0.0867)	0.3869** (0.2269)
Commuters	0.1548*** (0.0364)	0.1277*** (0.0345)	0.1169*** (0.0355)	0.0582 (0.0657)
Fleet Diveristy	**-0.0479**** **(0.0270)**	**-0.0510**** **(0.0251)**	**-0.0488**** **(0.0259)**	0.0352 (0.0645)
Leased Fleet	0.0318 (0.0369)	0.0570** (0.0337)	0.0545* (0.0348)	0.0167 (0.0699)
Fleet Age	**0.0853***** **(0.0330)**	**0.0791***** **(0.0311)**	**0.0287**** **(0.0134)**	**0.1063***** **(0.0390)**
StdPriceX(Fleet Age)	**-1.9354**** **(0.9954)**	**-1.8915**** **(1.0575)**		**-1.9425**** **(0.9590)**
AvgPrice	**0.0019***** **(0.0005)**	**0.0017***** **(0.0005)**		**0.0019***** **(0.0005)**
StdPrice	**-3.4697*** **(2.1774)**	-2.7901 (2.3228)		**-3.4755**** **(2.0922)**
Percent Hedge	**-0.0906***** **(0.0300)**	**-0.0648***** **(0.0267)**	**-0.0643***** **(0.0274)**	**-0.0826***** **(0.0340)**
FuelPass	**-0.0588***** **(0.0197)**	**-0.0478***** **(0.0196)**	**-0.0450**** **(0.0205)**	-0.0600 (0.0481)
LTDA	0.0144 (0.0549)	0.0049 (0.0379)	0.0056 (0.0394)	-0.0281 (0.0758)
Size	0.0021 (0.0064)	0.0012 (0.0060)	0.0005 (0.0062)	-0.0432* (0.0263)
CFTS	-0.1309* (0.0922)	-0.1900*** (0.0668)	-0.1907*** (0.0691)	-0.0590 (0.0875)
CAP	0.0823*** (0.0182)	0.0835*** (0.0169)	0.0837*** (0.0175)	0.0835*** (0.0245)
REG	0.0012 (0.0294)	-0.0037 (0.0287)	-0.0028 (0.0299)	-0.0071 (0.1586)
Number of observations	862	862	862	862
R^2	0.2334			0.1674
F-statistic / Wald	9.68	285.29	196.73	11.03

* 10% significance (One-Sided Test)

** 5% significance (One-Sided Test)

*** 1% significance (One-Sided Test)

TABLE VII (Cont.)
The Effectiveness of Individual Operational and Financial Hedges

Table VII Panel B reports the results of model (2.3)
$|\gamma_{i,q}| = \alpha_0 + \alpha_1(\text{Fleet Diversity}_{i,y}) + \alpha_2(\text{Cap}_{i,y}) + \alpha_3(\text{Leased Fleet}_{i,y}) + \alpha_4(\text{Fleet Age}_{i,y}) + (\alpha_5 + \alpha_6(\text{Fleet Age}_{i,y}))^* (\text{StdPrice}_{qtr}) + \alpha_7(\text{AvgPrice}_{qtr}) + \alpha_8(\text{Percent Hedge}_{i,y}) + \alpha_9(\text{FuelPass}_{i,y}) + \alpha_{10-13}(\text{Control Variables}_{i,y}) + \varepsilon_{i,q}$
The columns 1-5 of Table VII Panel B reports of the model using FGLS. Columns 1-5 exclude the financial and operational hedges. All models include a year dummy variable which are not reported. The statically significant values of interest are in **bold.**

Panel B

	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)
	FGLS / Hetero-skedastic	FGLS / Hetero-skedastic	FGLS / Hetero-skedastic	FGLS / Hetero-skedastic	FGLS / Hetero-skedastic
Constant	0.0598 (0.0759)	0.2292*** (0.0393)	0.0389 (0.0488)	0.1648*** (0.0552)	0.2420*** (0.0657)
Commuters	0.1373*** (0.0314)	0.0816*** (0.0282)	0.1323*** (0.0296)	0.0880*** (0.0269)	
Fleet Diveristy	**-0.0385*** **(0.0241)**	-0.0097 (0.0203)			
Leased Fleet	0.0549** (0.0324)			0.0170 (0.0268)	
Fleet Age	**0.0251**** **(0.0125)**		**0.0321***** **(0.0111)**		
StdPriceX(Fleet Age)					
AvgPrice					
StdPrice					
Percent Hedge					**-0.0753***** **(0.0263)**
FuelPass					**-0.0673***** **(0.0179)**
LTDA	0.0159 (0.0388)	0.0252 (0.0312)	0.0234 (0.0345)	0.0277 (0.0321)	0.0357 (0.0323)
Size	-0.0034 (0.0057)	-0.0114*** (0.0042)	-0.0019 (0.0038)	-0.0096** (0.0048)	-0.0035 (0.0042)
CFTS	-0.2219*** (0.0663)	-0.1896*** (0.0615)	-0.2506*** (0.0650)	-0.1746*** (0.0599)	-0.1541*** (0.0616)
CAP	0.0904*** (0.0171)	0.0982*** (0.0166)		0.0931*** (0.0164)	
REG	-0.0422** (0.0218)	-0.0489*** (0.0192)	-0.0422** (0.0223)	-0.0528*** (0.0195)	0.0169 (0.0182)
Number of observations	897	976	898	957	945
F-statistic / Wald	200.9	183.09	157.02	188.72	146.04

* 10% significance (One-Sided Test)
** 5% significance (One-Sided Test)
*** 1% significance (One-Sided Test)

For Column (3), the AvgPrice variable is excluded from the model because the aircraft dispersion index (Fleet Diversity) is a function of the price of fuel and the average price variable proxies for the airline's inability to adjust production. However, the aircraft dispersion index proxies for the ability to adjust production in response to different market conditions. In addition, the aircraft dispersion index measures the airline's current operating fleet, not the airline's total fleet. This analysis suggests that as the price of fuel increases, airlines will switch to a smaller fleet, which causes the dispersion index to decline. This relationship causes a correlation between the price of fuel and the aircraft dispersion index. Furthermore, the value of the real option increases with the volatility of the price of fuel, thus causing a correlation between the volatility of fuel prices and the aircraft dispersion index. This analysis suggests that the model suffers from collinearity with regards to the operational hedges, the AvgPrice, and StdPrices variables.

A common approach to correct for collinearity is to artificially orthogonalize the AvgPrice variable and the Fleet Diversity variable. The procedure is to regress the AvgPrice variable on the Fleet Diversity variable. Then for Equation (2.3), replace the AvgPrice variable with the error terms from the prior regression. The problem with this procedure is that the estimated Fleet Diversity coefficient and its standard errors are biased (Hill and Adkins 2001). Furthermore, the estimated coefficient and its standard errors for AvgPrice are the same as before. The reverse is true if the Fleet Diversity variable is regressed on the AvgPrice variable. A simpler approach is to drop the variables causing the problem (Greene 2003). Thus AvgPrice, StdPrice, and the product between StdPrice and Fleet Age are removed from the model. Column (3) reports the results. The flaw in this approach is that the estimated coefficients are biased. However, the exclusion of these variables causes the coefficient for Fleet Diversity to shift from -0.0510 to -0.0488, while the Z-test statistic decreases from -2.03 to -1.88. Furthermore, the results for the other financial and operational hedges are unaltered.

Columns (1-4) of Tables VII Panel A support the hypothesis that a fuel-efficient fleet reduces an airline's exposure to fuel prices, H_3. For Column (2), the coefficient for Fleet Age is positive (0.0791) and is significant at the 1% level using a one-sided test (5% using a two-sided test), thus indicating that an older less fuel-efficient fleet increases an airline's exposure to jet fuel prices. Furthermore, Columns (1,2 and 4) of Tables VII Panel A support hypothesis H_4 that the real option embedded in operating an older fleet provides relatively more protection to an airline when the volatility of jet fuel prices is high. That is, for Table VII Panel A of Column (2), the coefficient for the product between StdPrice and Fleet Age is -1.8915, significant at the 5% level using a one-sided test (10% using a two-sided test). The mixed partial derivatives of Equation (2.3) (see Equation (2.8) below) with respect to Fleet Age and StdPrice illustrates the benefit that the option to upgrade to a fuel-efficient fleet gives an airline. The mixed partial derivative suggests that increasing the age of an airline's fleet from 2 to 8 years will result in a decline in the airline's exposure to fuel prices by 0.01573 (-1.8915*ln(8/2)*(0.0297-0.0237)), if the daily volatility of fuel prices, calculated quarterly, increases from its median volatility of .0237 to its upper 75^{th} percentile of 0.0297[13]. This reduction in exposure is about 18% for the median airline's exposure coefficient (0.01573/0.0884). If fuel price volatility increases from its median to its upper

[13] The median age of JetBlue's fleet is 2 years. The median age of Southwest Airlines' fleet is 8 years. Both JetBlue and Southwest Airlines are discount carriers.

quartile, then an airline with an average age of 8 years will experience a decline in its exposure to fuel prices that is 18% higher than an airline with an average fleet age of 2 years.

$$\frac{\partial^2 \gamma}{\partial ln\,(age) \partial \sigma} = -1.8915 \qquad (2.8)$$

$$d\gamma \cong -1.8915 * d(lnAge) * d(\sigma)$$

$$0.01573 \cong -1.8915 * \ln\left(\frac{8}{2}\right) * (0.0297 - 0.0237)$$

Similar to Tufano's (1998) results and as predicted from the analysis of the prior section, higher fuel costs significantly increase an airline's exposure to jet fuel prices. As predicted by H_6, the coefficient for AvgPrice is positive and significant at the 1% level in all models using a one or two-sided test. The results for H_5 are not strong. That is, there is a weak and negative relationship between the standard deviation of fuel prices and the airlines risk exposure to the fuel prices. All columns of Table VII show that as the volatility of jet fuel prices increases, the sensitivity of the real options to an underlying asset declines. However, only column (1 and 4) of Table VII Panel A is significant at least at the 10% level using a one-sided test.

Confirming the hypotheses, H_7 and H_8, that airlines use financial derivatives / contracts to manage risk and not to speculate, the coefficients for the Percent Hedge and the FuelPass are negative and significant in most models. That is, increasing the percent of jet fuel hedged or entering into a fuel pass-through agreement significantly reduces an airline's risk to fuel costs by -0.0648 and -0.0478 respectively as shown in Column (2) of Table VII, Panel A. The Percent Hedge and the FuelPass variables are significant at least at the 5% level in most models using a one-sided test (5% using a two-sided test).

The Leased Fleet variable is positive and insignificant (using a one-sided test); thus, there is no support for H_2. The control variables, the REG, Size, and LTDA are insignificant in the majority of the models using a two-sided test. The variable CFTS is negative and significant in most models. The coefficient for CAP is positive and significant at the 1% level using a two-sided test.

A particular issue with model (2.3) is that the dependent variable, quarterly jet fuel gammas, are regressed against the airline's annual financial data. If the airline's estimated risk exposure reflects information concerning the airline's future financial statements, then the estimated coefficients may be biased. For instance, the airline's estimated risk exposure will reflect the delivery of new aircraft which are not in current operations or the expected spinoff of a regional subsidiary. To partly control for this bias, model (2.3) is run with both the current and next year's financial variables. The model is:

$$\begin{aligned}|\gamma_{i,q}| = {} & \alpha_0 + \alpha_1(\text{Fleet Diversity}_{i,y}) + \alpha_2(\text{Cap}_{i,y}) + \alpha_3(\text{Leased Fleet}_{i,y}) \\ & + \alpha_4(\text{Fleet Age}_{i,y}) + (\alpha_5 + \alpha_6(\text{Fleet Age}_{i,y}))^*\ (\text{StdPrice}) \\ & + \alpha_7(\text{Average Fuel Price}_{qtr}) + \alpha_8(\text{Percent Hedge}_{i,y}) + \alpha_9(\text{FuelPass}_{i,y}) \\ & + \alpha_{10\text{-}13}(\text{Control Variables}_{i,y}) + \alpha_{14}(\text{Fleet Diversity}_{i,y+1}) \\ & + \alpha_{15}(\text{Cap}_{i,y+1}) + \alpha_{16}(\text{Leased Fleet}_{i,y+1}) + \alpha_{17}(\text{Fleet Age}_{i,y+1}) \\ & + \alpha_{18}(\text{Percent Hedge}_{i,y+1}) + \alpha_{19}(\text{FuelPass}_{i,y+1}) \\ & + \alpha_{20\text{-}22}(\text{Control Variables}_{i,y+4}) + \varepsilon_{i,q}\end{aligned} \tag{2.9}$$

The model is FGLS with a year dummy variable which is not reported. The results are reported in Table VIII. The first and second columns are the estimated coefficients for the current and next year's variables. The standard errors are reported in parentheses. The third column is the sum of Column (1) and Column (2). Columns (4) and (5) report the results for the test determining whether the sum of the coefficients is equal to zero. Column (4) reports the Chi Square statistic and Column (5) reports the p-value. The results confirm H_1 and H_3, that a diverse fleet and / or a fuel-efficient fleet reduces an airline's exposure to fuel costs. That is, the sum of the coefficients for Fleet Diversity is negative and significant and the sum of the coefficients for Fleet Age is positive and significant. The results also confirm H_7, that hedging against fuel cost using financial derivatives reduces the airline's exposure to fuel prices. Table VIII shows that an airline's exposure to fuel prices increases with the price of fuel and declines as the volatility of fuel prices rises. All other hypotheses fail to reject the null hypotheses.

TABLE VIII

The Effectiveness of the Operational and Financial Hedges (Lead)

The table reports the results of equation (2.9)
$|\gamma_{i,q}| = \alpha_0 + \alpha_1(\text{Fleet Diversity}_{i,y}) + \alpha_2(\text{Cap}_{i,y}) + \alpha_3(\text{Leased Fleet}_{i,y}) + \alpha_4(\text{Fleet Age}_{i,y})$
$+ (\alpha_5 + \alpha_6(\text{Fleet Age}_{i,y}))^* (\text{StdPice}_{qtr}) + \alpha_7(\text{AvgPrice}_{qtr}) + \alpha_8(\text{Percent Hedge}_{i,y}) + \alpha_9(\text{FuelPass}_{i,y})$
$+ \alpha_{10\text{-}13}(\text{Control Variables}_{i,y}) + \alpha_{14}(\text{Fleet Diversity}_{i,y+1}) + \alpha_{15}(\text{Cap}_{i,y+1}) + \alpha_{15}(\text{Leased Fleet}_{i,y+1})$
$+ \alpha_{16}(\text{Fleet Age}_{i,y+1}) + \alpha_{17}(\text{Percent Hedge}_{i,y+1}) + \alpha_{18}(\text{FuelPass}_{i,y+1}) + \alpha_{19\text{-}22}(\text{Control Variables}_{i,y+1}) + \varepsilon_{i,q}$

Column (1) reports the results for the coefficients $\alpha_0 - \alpha_{13.}$ column (2) reports the results for the coefficients $\alpha_{14} - \alpha_{22.}$ Column (3) is the sum of Column (1 and 2). Columns (4 and 5) are the test statistics and p-values, from a Wald test, to test the null hypotheses that (Current Year + Next year) = 0. The values in the parentheses are the standard errors. The model is a FGLS controling for heteroskedasticity. The model includes a year dummy variable which is not reported

	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)
	Current Year	Next Year	Current + Next Year	Chi Sq (One Degree of Freedom)	p-value
Constant	0.0220 (0.1260)				
Commuters	0.0779 (0.1606)	0.0439 (0.1589)	0.1218	9.3900	0.002
Fleet Diversity	**0.0013** **(0.0846)**	**-0.0797** **(0.0853)**	**-0.0784**	**7.7100**	**0.0055*****
Leased Fleet	-0.0144 (0.0895)	0.0939 (0.0892)	0.0795	4.3500	0.0369**
Ln(Fleet Age)	**0.0708** **(0.0503)**	**-0.0091** **(0.0379)**	**0.0617**	**3.4400**	**0.0635***
StdPriceX(Fleet Age)	-1.1652 (1.1056)				
AvgPrice	**0.0020***** **(0.0005)**				
StdPrice	**-3.9540*** **(2.4046)**				
Percent Hedge	**-0.0182** **(0.0331)**	**-0.0477*** **(0.0315)**	**-0.0659**	**4.8300**	**0.028****
FuelPass	-0.0738** (0.0366)	0.0478 (0.0379)	-0.026	1.3700	0.242
LTDA	-0.0560 (0.0600)	0.0891** (0.0501)	0.0331	0.5200	0.470
Size	-0.0294 (0.0341)	0.0377 (0.0350)	0.0083	1.4300	0.232
CFTS	**-0.3683***** **(0.1094)**	**0.0459** **(0.0927)**	**-0.3224**	**8.8300**	**0.003****
CAP	0.0174 (0.0296)	0.0359 (0.0284)	0.0533	8.4800	0.004
REG	0.0368 (0.1056)	-0.0388 (0.1041)	-0.002	0.0000	0.953
Number of observations	749				
Wald	219.6				

* 10% significances (two-sided test)
** 5% significances (two-sided test)
*** 1% significances (two-sided test)

2.7. Summary

This essay examines the determinants of an airline's exposure to jet fuel prices. This study shows that airlines are indeed exposed to jet fuel prices. Furthermore, airlines tend to exhibit higher levels of exposure to jet fuel prices when prices are above their historical norm or rising. Second, this essay finds evidence that the use of financial and operational hedges is effective at managing an airline's exposure to the price of jet fuel.

This study shows that, for the airline industry, exposure to jet fuel costs has increased substantially over the early part of the 21st century. Moreover, an airline's exposure to the price of fuel increases with the price of fuel. In addition, airlines also tend to exhibit higher levels of exposure to fuel prices during periods when fuel prices are relatively high. Lastly, there is no evidence that airlines tend to exhibit higher or lower levels of exposure during periods when the volatility of jet fuel is above its normal level.

In the airline industry, I find evidence that the use of both financial and / or operational hedges is effective at reducing an airline's risk exposure. The flexibility that real options provide a firm is an important part of its ability to manage its risk. This essay finds evidence that a diverse fleet gives an airline the flexibility to adjust its capacity needs in order to efficiently adjust to changing market conditions. Furthermore, there is evidence that a more fuel-efficient fleet reduces an airline's exposure to fuel costs. Financial derivatives or fuel pass-through agreements are also effective at managing an airline's risk exposure.

I find evidence that the embedded option to switch to a newer fleet reduces an airline's exposure to fuel prices. That is, the evidence suggests that when the volatility of fuel prices is high, the option to replace an older fleet reduces an airline's exposure to the price of jet fuel. There is no evidence to suggest that leasing a fleet reduces an airline's exposure to the price of jet fuel.

The use of financial contracts significantly reduces an airline's exposure to fuel prices. That is, increasing the percentage of fuel which is hedged and / or entering into a fuel pass-through agreement is an effective means of reducing an airline's risk.

Appendix A

This section lays out a formal argument that a diverse fleet provides an airline an operational hedge against jet fuel costs. Though the discussion in this section focuses on the airline industry, the argument is generally applicable to other industries where exit and reentry costs are prohibitive. That is, if exit costs are such that a firm will choose to maintain operations during periods of severe losses, then the option to reduce production, which lowers overall losses, provides a valuable hedge. The simple intuition is that a firm can reduce its overall losses during adverse periods by incrementally reducing its production, while a firm without any option to adjust capacity will incur larger losses during unfavorable periods.

To illustrate, an airline servicing the Dallas to Chicago market will generally avoid exiting this route, even during periods when cost exceeds revenue. During adverse periods, the airline with a diverse fleet can reduce its level of operations by servicing the market with a smaller aircraft, which incurs proportionally fewer losses than the large aircraft. Using a smaller allows the airline to maintain a presence in the Dallas to Chicago market while reducing its overall losses. Compare this scenario to one where an airline chooses to operate a standardized fleet consisting of large aircraft. If adverse conditions occur, the airline will maintain operations and incur large losses and or prematurely exit the market. The airline with a standardized fleet incurs greater losses than an airline with a diverse fleet since larger aircraft consume a greater amount of fuel.

The argument and proof presented in this section is similar to that proposed by Dixit and Pindyck (1994). To lay out the argument, first assume, for simplicity, that abandonment costs are such that the airline will choose never to exit the market. Second, assume that for a given route an airline chooses to service all or some fraction of a fixed quantity of passengers per period. Furthermore, to focus on cost and for simplicity, assume price and demand are non-stochastic, i.e., revenue is fixed. In addition, costs follow the following Geometric Brownian Motion and have a convenience yield of δ.

$$dC = \rho C dt + \sigma C dz \qquad (1a)$$

Third, assume the airline can divide its capacity between two aircraft. The smaller of the aircraft accounts for α percent of the route's profits, while the larger aircraft accounts for the remainder of the profits. In addition, the cost (C), revenue (P), and thus profits for the smaller plane are proportional to that of the larger aircraft. Fourth, to make the problem more manageable, assume a depreciation rate of zero. Lastly, assume the airline can choose to operate all or any one of the aircraft at any particular time.

Based on the above assumptions, the profits to the airline for servicing a particular route are:

$$\Pi = \text{Max}(P\text{-}C,\ (1\text{-}\alpha)(P\text{-}C),\ \alpha(P\text{-}C))$$

$$\Pi = \text{Max}(P\text{-}C,\ \alpha(P\text{-}C)) \qquad (2a)$$

In the second line, the middle term ((1-α)(P-C)) is dropped since the profits of operating both aircraft or just the smaller one are always greater than that of operating solely the large aircraft. Thus, the airline will choose to operate only the larger aircraft in conjunction with the smaller plane. From Equation (2a), notice that the optimal cost (C*) at which the firm will switch to solely operating only the smaller aircraft is when revenue equals cost (P=C*). Thus the firm's profits are:

$$\Pi = \begin{cases} P - C & \text{if } C^* > C \\ \alpha(P - C) & \text{if } C^* < C \end{cases} \qquad (3a)$$

Compare, the above profit function to the one where exit and reentry is costless. Under this scenario, when costs exceed price, the airline will cease operations and have a loss of zero which is preferred over a loss of α(P-C). However, the fact that exit and reentry costs exist implies that the airline will not abandon the market when costs exceed price.

By creating a replication portfolio, the value of operating a route must satisfy the following ordinary differential equation.

$$0 = \frac{1}{2}\sigma^2 C^2 V'' + (r-\delta)CV' + V + \Pi \tag{4a}$$

where V is the value to the firm for operating a given route and r is the risk-free rate. The solution to the above differential equation is.

$$V = \begin{cases} V_f = AC^{\beta_1} + \dfrac{P}{r} - \dfrac{C}{\delta} & \text{if } C^* > C \\ V_p = BC^{\beta_2} + \alpha\left(\dfrac{P}{r} - \dfrac{C}{\delta}\right) & \text{if } C^* < C \end{cases} \tag{5a}$$

where β_1 and β_2 are roots to the quadratic equation which solves the general solution of Equation (4a). Thus β_1 and β_2 are:

$$\beta_1 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{\left[\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right]^2 + 2\frac{r}{\sigma^2}} > 1 \tag{6a}$$

$$\beta_2 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} - \sqrt{\left[\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right]^2 + 2\frac{r}{\sigma^2}} < 0 \tag{7a}$$

A and B are to be determined.

The term $\frac{P}{r} - \frac{C}{\delta}$ represents the value of the route if the option to switch to a different aircraft did not exist. The term AC^{β_1} represents the value of the real option to switch to the smaller plane if cost rises above the critical point. The term BC^{β_2} is the value of the real option to increase output when costs are below the critical point.

To solve for A and B, two other conditions are need, the "value-matching condition" and the "smooth pasting conditions." The "value-matching condition" states that at the critical point (C*), the value of operating at partial capacity must equal the value of operating at full capacity. The "smooth pasting condition" states that the derivative of V_p (operating a partial capacity) and V_f (operating at full capacity) evaluated at C* are equal. That is,

$$V_p(C^*) = V_f(C^*) \tag{8a}$$

$$V_p'(C^*) = V_f'(C^*) \tag{9a}$$

Using the above condition the values of A and B are determined to be:

$$A = \frac{C^{*1-\beta_1}(1-\alpha)\left(\frac{\beta_2}{r} - \frac{\beta_2 - 1}{\delta}\right)}{\beta_1 - \beta_2} \tag{10a}$$

$$B = \frac{C^{*1-\beta_2}(1-\alpha)\left(\frac{\beta_1}{r} - \frac{\beta_1 - 1}{\delta}\right)}{\beta_1 - \beta_2} \tag{11a}$$

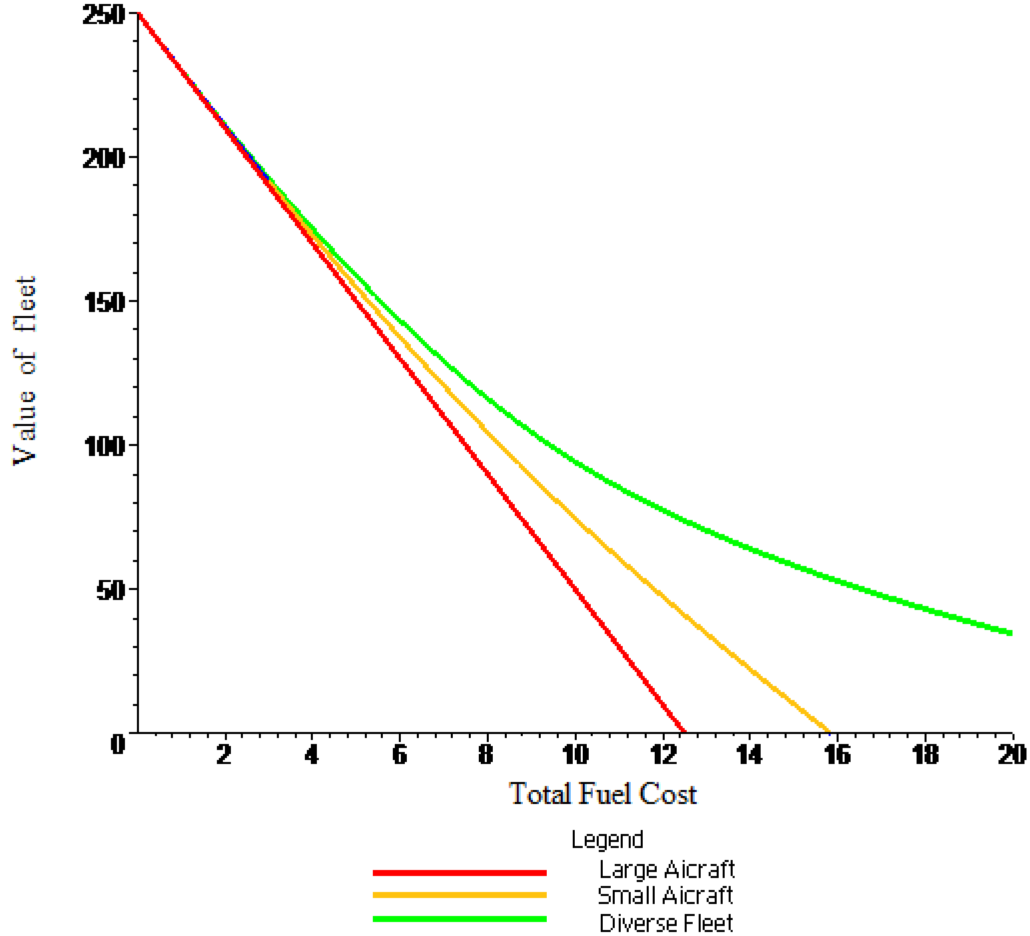
It can be shown that A and B are both positive; thus, the option to adjust capacity in response to fluctuations in fuel cost increases the value of the firm.

Further, the option to adjust capacity reduces the airline's exposure to fuel costs. More specifically, it can be shown that for all positive values of "C," the change in the value of the airline with respect to a change in the price of fuel (C) is less for an airline with a diverse fleet than it is for an airline with a uniform fleet. That is

$$\left|\frac{\partial V_d}{\partial C}\right| < \left|\frac{\partial V_u}{\partial C}\right| \qquad \forall C > 0$$

where d and u represent airlines with a diversified fleet and a uniform fleet respectively. Figure 6 shows that a hypothetical diverse fleet experiences less exposure to jet fuel prices than does the uniform fleet. Figure 6 graphs Equation (5a) at three different α's, 1.0, 0.5, and 0.1. The airline with an α of 1.0 represents an airline with a uniform fleet of one large aircraft. The α of 0.5 represents the airline with a uniform fleet of two smaller aircraft. While the α of 0.1 represents the airline consisting of one medium and one small aircraft. The other values for the parameters of Equation (5a) are, P = 100, r = 0.04, δ = 0.03, and σ = .3. The slope of the airline with a diverse fleet is always greater than or equal to that of the other two airlines. Thus, the graph and the proofs above illustrate that a diverse fleet provides an operational hedge to an airline.

FIGURE 6
The Benefits of a Diverse Fleet



Appendix B

This section lays out a formal argument that an airline with an older fleet and the option to upgrade to a more fuel-efficient fleet exhibits a decreased exposure to fuel prices as prices increase. The basic intuition is that the option to upgrade to a newer fleet caps the level of exposure to fuel prices an airline will experience. As fuel prices rise, investors increase their belief that the airline will exercise its option to invest in newer aircraft, thus pricing the firm as if it already operated fuel-efficient aircraft.

Similar to Appendix A, the argument and proof presented in this section is similar to that proposed by Dixit and Pindyck (1994). Assume that exiting from the market is so prohibitively expensive that the airline will choose never to exit. Second, assume the only difference between the old and new aircraft is their fuel efficiency. Furthermore, the fuel efficiency of the new aircraft is proportional to that of the older aircraft. To continue, assume price and demand are non-stochastic, i.e., revenue is fixed. In addition, cost (fuel costs) follow the following Geometric Brownian Motion and have a convenience yield of δ.

$$dc = \rho C dt + \sigma C dz \tag{1b}$$

To make the problem more manageable, assume a depreciation rate of zero. Lastly, the costs of operating the old aircraft are C, while the costs of operating the fuel-efficient aircraft is αC, where α are greater than zero and less than one.

Based on the above assumptions, the profits for an airline with an older fleet and the option to upgrade are:

$$\prod_{old} = P - C \tag{2b}$$

$$\prod_{new} = P - \alpha C \tag{3b}$$

where (2b) are the profits for the airline that is operating an older fleet and (3b) are the profits for the airline once it has chosen to exercise its option and upgrade to a newer fleet.

By creating a replication portfolio, it can be shown that prior to exercising its option the value of the airline operating the older aircraft is

$$V_{old} = AC^{\beta_1} + \frac{P}{r} - \frac{C}{\delta} \tag{4b}$$

while the value of the airline once it has upgraded to the newer fleet is

$$V_{new} = \frac{P}{r} - \frac{\alpha C}{\delta} \tag{5b}$$

Thus, the value of the airline is

$$V = \begin{cases} V_{old} = AC^{\beta_1} + \frac{P}{r} - \frac{C}{\delta} & \text{if } C^* > C \\ V_{new} = \frac{P}{r} - \frac{\alpha C}{\delta} & \text{if } C^* < C \end{cases} \tag{6b}$$

where β_1 is the positive root to the quadratic equation which solves the general solution of Equation (4a). The values of A and C*, the optimal fuel price at which the firm should invest, are to be determined. The term AC^{β_1} represents the option to invest in the newer aircraft.

To solve for A and C*, the "value-matching" and "smooth pasting" conditions are required. That is:

$$V_o(C^*) = V_n(C^*) - I \tag{7b}$$

$$V_o'(C^*) = V_n'(C^*) \tag{8b}$$

where I is the investment cost of purchasing the fuel efficient aircraft.

Using the above condition, the values of A and C* are determined to be:

$$C^* = \frac{-I\delta\beta_1}{(1-\alpha)(1-\beta_1)} \tag{9b}$$

$$A = \frac{-I}{(1-\beta_1)}\left(\frac{(1-\alpha)(1-\beta_1)}{I\beta_1\delta}\right)^{\beta_1} \tag{10b}$$

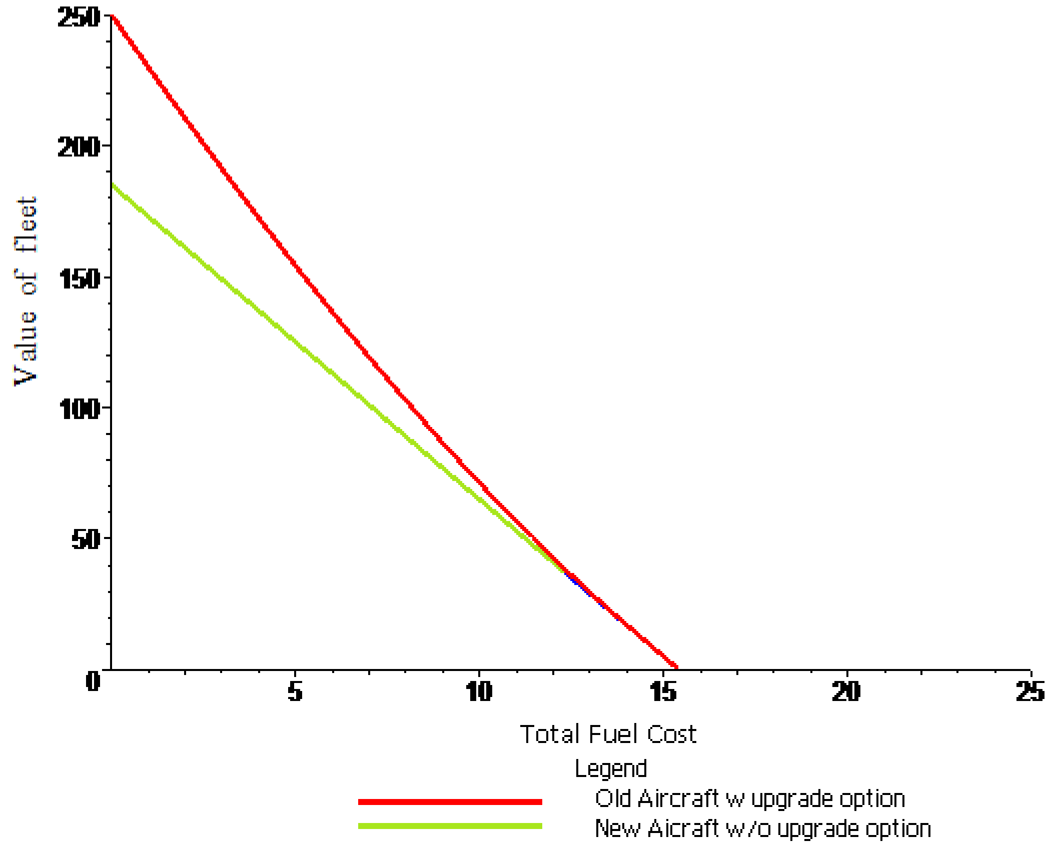
First notice that A is positive, implying that the option to upgrade to a newer fleet increases the value of the airline. Furthermore, the value of the real option is zero as fuel costs approach zero, thus implying there is little incentive to upgrade to a newer aircraft when fuel prices are low.

Next I compare the level of fuel exposure for an airline with the option to upgrade to that of an airline operating a newer fleet. The value of an airline with a newer fleet is V_{new}, implying the value of the firm changes by $\frac{-\alpha}{\delta}$, for a change in the price of jet fuel. For an airline operating an older aircraft, this value is $\beta_1 AC^{\beta_1 - 1} - \frac{1}{\delta}$. When fuel prices approach zero, the difference in the value of the two airlines is $\frac{-(1-\alpha)}{\delta}$ or the marginal fuel saving from operating a fuel-efficient fleet. As fuel prices increase, the value of the option to upgrade increases, thus reducing the level of exposure for the airline with an older fleet. The exposure for the airline with an older fleet continues to fall until the point at which the firm exercises its option to upgrade its fleet. Based on the "smooth pasting condition," Equation (8b), the exposure of the airline with the option will equal that of the airline operating a newer fleet.

Figure 7 illustrates the above argument. The lower, straight line represents the value to the old shareholders of the airline, which has exercised its option and invested in a newer fleet. The second upper curve represents the value to the old shareholders of an airline, which has yet to exercise its option. The upper curve declines rapidly when fuel prices are low. When fuel prices are high, the slope of the curve is less and eventually converges with that of the airline that has exercised its option. The point of convergence is where the airline exercises its option to upgrade.

Though this appendix has focused on the airline industry, the results are applicable to other studies gauging the effectiveness of operating hedging. That is, a firm which does not utilize an operational hedge owns the option to do so. Therefore, as the benefits from an operational hedge increase, so does the likelihood of the firm's exercising its options, thus reducing the differences in exposures between those firms that use operational hedges and those that do not.

FIGURE 7
The Real Option Embedded in an Older Fleet



CHAPTER III

OPERATIONAL AND FINANCIAL HEDGES; FRIEND OR FOE EVIDENCE FROM THE AIRLINES INDUSTRY

3.1 Introduction

There is inconsistency in the risk management literature regarding the extent to which firms use financial derivatives. Some studies indicate that the use of financial derivatives provides little protection to a firm's cash flows (Guay and Kothari 2003). Other studies show that the use of financial derivatives is value-enhancing to the firm (Allayannis and Weston 2001; Mackay and Moeller 2007; Carter, Rogers, and Simkins 2006), although this result is not conclusive (Jin and Jorion 2006). Furthermore, most studies find that the use of financial derivatives reduces the firm's overall risk exposure to the underlying asset being hedged (Allayannis and Ofek 2001; Hentschel and Kothari 2001; Schrand 1997). This inconsistency poses the question: how can an expensive risk management program reduce the overall risk of a firm and increase its value, but yet provide little protection to the firm's cash flow. Guay and Kothari (2003) suggest that the risk management program which uses both operational and financial hedges to manage a firm's risk would be consistent with their and others' findings that financial derivatives are only used to fine tune a firm's overall risk management program. Furthermore, they conclude that the inconsistency mentioned above is driven by the exclusion of the operational hedge.

This chapter examines the following: 1) if financial and operational hedges are substitutes or complements[14] and; 2) whether the use of operational and financial hedges increases the value of the firm. This chapter contributes to the literature concerning the use of operational and financial hedges, and also examines whether hedging increases the firm's value (Allayannis, Ihrig, and Weston 2001; Kim, Mathur, and Nam 2006; Carter, Rogers, and Simkins 2006; Petersen and Thiagarajan 2000; Tufano 1998; Carter, Pantzalis, and Simkins 2006; Jin and Jorion 2006). This study most closely follows Allayannis, Ihrig, and Weston (2001), who test whether the use of both financial and operational hedges protects multinational firms against exchange rate exposure. Their study finds that multinational firms' operational and financial hedges are complements rather than substitutes. Allayannis, Ihrig and Weston's conclude that a risk management policy which includes both operational and financial hedges enhances the value of the firm. However, their results is not conclusive as other studies find that operational and financial hedges are substitutes (Kim, Mathur, and Nam 2006; Petersen and Thiagarajan 2000).

This essay differs from Allayannis, Ihrig, and Weston's (2001) article in that several different operational hedges are examined, while their article examines only the firm's foreign operations as an operational hedge. Furthermore, the sample for this study is restricted to the US airline industry. Using a homogenous sample (the airline industry) controls for biases that occur when using a cross-section of industries. For instance, it is difficult to discern which currencies a multinational firm is exposed to and the degree to which a firm uses financial and operational hedges to protect against those currencies to

[14] Operational and financial hedges are substitutes if the firm uses one to manage its risks and not the other. Operational and financial hedges are complements if the firm uses both types of hedges to manage similar risks.

which it is exposed. Furthermore, as many multinational firms are conglomerates, the measurement for which Allayannis, Ihrig, and Weston (2001) use to proxy the relationship between a firm's value and its hedging activity is biased because both the hedging behavior and the firm's value vary across industries.

Similar to the Allayannis, Ihrig, and Weston (2001) study, I find evidence that financial and operational hedges are complements in the airline industry. Contrary to the finding of other studies, the use of both operational hedges and financial hedges does not increase the value of the airline (Allayannis, Ihrig, and Weston 2001; Kim, Mathur, and Nam 2006). The evidence indicating a benefit exists in financial hedges is mixed. That is financial fuel derivatives increase the airlines value, while fuel contracts which lock in the price of fuel reduce the airlines value. Furthermore, the use of operational hedges alone actually reduces the value of the airline.

I examine three operational hedges used by airlines: 1) the diversity of its fleet, 2) the airline's use of operating leases to manage its fleet, and 3) the use of fuel-efficient aircraft. The diversity of an airline's fleet and the use of a leased fleet give airlines the ability to respond quickly to changing market conditions by adjusting the number of seats flown. A newer, fuel-efficient fleet protects the airline by reducing its exposure to the price of jet fuel. I find that airlines with diverse fleets tend to exhibit a greater use of financial hedges than do their counterparts. The evidence also shows that a diverse fleet; a newer fuel-efficient fleet; and the use of operating leases all reduce an airline's value.

The rest of this chapter is as follows: Section 3.2 reviews the literature. Section 3.3 briefly reviews the operational hedges presented in chapter 2. Section 3.4 presents the methodology and the procedures used in this chapter. Section 3.5 presents the results of section 3.4. Section 3.6 concludes the essay.

3.2 Literature Review

The objectives of this section are to examine the theoretical and empirical motivations for a firm to manage its risks. The first part of this section reviews the seminal theories which show the benefits of risk management to the firm. Next, I discuss the possible ways a firm can manage its risk, specifically the use of financial and operational hedging techniques. Third, I review the empirical literature in regard to its support for and against theoretical justification for risk management. Finally, I survey the empirical literature concerning whether risk management is value-enhancing to the firm.

3.2.a Risk Management Theory

The purpose of this subsection is to review the prevailing theories concerning why firms use financial and/or operational hedges to manage their risk. To summarize, there are currently four theories related to the hedging behavior of firms. These four theories are that (1) firms exhibit a convex tax function (Smith and Stulz 1985) , (2) managers are risk averse (Smith and Stulz 1985), (3) financial distress and external capital are costly (Froot, Scharfstein, and Stein 1993; Smith and Stulz 1985), and (4) hedging reduces asymmetric information and conveys information regarding management's abilities (DeMarzo and Duffie 1995). It is important to note that these theories are not necessarily mutually exclusive. Thus, one or more hedging theories can provide possible explanations for a firm's hedging behavior. Before delving into current hedging theory, let us first understand under what circumstances corporate hedging is irrelevant to the firm's value.

3.2.a.i Hedging Irrelevances

In a perfect market, the hedging practices of a firm are irrelevant to the firm's value and hence, the current shareholder value. A perfect market, as defined by Fama and Miller (1972), is one where there are no costs resulting from portfolio adjustments; assets are infinitely divisible; firms and individuals have equal access to the capital markets; firms and individuals have no effect on the prevailing interest rate or asset prices; and investors are rational maximizing agents. Though the perfect market assumptions are all that are needed to demonstrate the irrelevance of corporate hedging, three arguments with different assumptions will be presented to arrive at the same conclusion. As the perfect market assumptions are relaxed, each argument will provide additional insight into why firms use financial derivatives to hedge their risks. The arguments are the debt irrelevance proposition (Modigliani & Miller 1958), the use of State-Pricing Theory, and the Market Equilibrium approach (Fama and Miller 1972).

The Modigliani and Miller (1958) (MM) model was initially developed to prove the irrelevance of debt, yet the implications hold for a firm's hedging strategy. The basic principle governing the MM proposition of debt irrelevance follows: If there are two similar firms, one of which is overpriced, an investor who owns the overpriced firm can sell his shares and use the proceeds, plus any additional financing, to purchase the other firm. The end result is more money at the same level of risk to the investor regardless of the outcome of the firm's earnings. However, this opportunity cannot last long since investors will move from the overpriced asset to the underpriced asset. Thus, in equilibrium, the value of the two firms must be the same.

According to the MM model, the firm and investors are believed to act in a world with the following assumptions. (1) Markets are frictionless (no transaction cost or taxes). (2) Investors and managers share the same information regarding the firm's prospects. (3) Individuals and firms can sell and buy similar claims at the same price. For instance, investors can borrow and lend at the same riskless interest rate as a firm. (4) There exist two firms with the same risk class. This assumption assumes that the earnings of the two firms are perfectly correlated and proportional to each other. (5) The firm's goal is to maximize the value of its current claimholders.

Modigliani and Miller illustrate the irrelevance of hedging in a one-period model by assuming there are two firms, one which is hedged, V_h, and the other which is unhedged, V_u. The hedged firm's value is greater than the unhedged firm's, $V_h > V_u$. The hedged and unhedged firm each have the same random operating cash flows, $\tilde{X}_h = \tilde{X}_u$. The hedged firm uses a put option with a current value of P_h to hedge its operating cash flow. A put option gives the owner of the option the right but not the obligation to sell the firm's cash flow at the expiration of the option at a predetermined strike price K. Thus, the equity holders of the hedged firm are guaranteed cash flows of $\max(\tilde{X}_h, K)$. Consequently, the cash flows of the hedged firm can be written as $\tilde{X}_h = \tilde{X}_s - \max(K - \tilde{X}_h, 0)$, where the first term is the shareholder earnings, $\max(\tilde{X}_h, K)$, and the second term is the value of the put contract at time of expiration. The investor-expected income is $\tilde{X}_s = \tilde{X}_h + \mathrm{Max}(K - \tilde{X}_h, 0)$, which is the firm's cash flows plus a put option. Thus, the current market value of the hedged firm can be written as the present value of the cash flows that will accrue to the shareholders, the stock price S_h, less the current value of a put option, $V_h=S_h-P_h$. Lastly, an investor who has α percent of the hedged firm, will be entitled to an income of $\alpha(X_s)=\alpha(\tilde{X}_h+Max(K-\tilde{X}_h,0))$. If the investor performs the following strategy, he will increase his income without incurring any additional risk. The investor sells α percent of his ownership in the hedged firm for αS_h. He buys α put contracts, αP_h. The remainder of the funds is used to purchase $\alpha(S_h-P_h)$ dollars of the unhedged firm. Recall, the value of the hedged firm is equal to the shareholder's value less the put options, so our investor owns αV_h dollars in the unhedged firm.

Continuing with the MM model, in the next period our investor's income is

$\frac{\alpha(S_h-P_h)}{V_u}\tilde{X}_u+\alpha(Max(K-\tilde{X}_h,0))$. This is the same as $\alpha((V_h/V_u)\tilde{X}_u + Max(K-\tilde{X}_h,0))$.

Notice the investor's income is greater than if he had remained in the hedged firm, since $V_h>V_u$ and the firm's cash flows are the same, $\tilde{X}_h=\tilde{X}_u$. To see this more clearly, let's compare the income from the strategy above to the income the investor would have received if he had remained in the hedged firm, $\alpha((V_h/V_u)\tilde{X}_u + Max(K-\tilde{X}_h,0))$ and $\alpha(X_h+Max(K-\tilde{X}_h,0))$ respectively. Dropping the terms α and the $Max(K-X_h,0)$ from both incomes, since they are the same, the remaining terms are, $(V_h/V_u)\tilde{X}_u$ and $\tilde{X}_h$. Observe that the income from the strategy above is greater than if the investor had not implemented the strategy, since the value of the hedged firm is greater than the value of the unhedged firm, $V_h/V_u>1$. So the income from this strategy is greater than if the investor had remained in the unhedged firm, assuming $\tilde{X}$ is never negative[15]. Similarly, it can be shown that if $V_u>V_h$, investors will sell their share in the unhedged firm to

[15] It is reasonable to assume $\tilde{X}_I$ is never negative in a one-period model, where the investor has limited liability since the investor will never be required to invest more money in the firm to make up for the firm's negative income.

purchase the hedged firm. Thus, in equilibrium, the value of the unhedged firm must equal the value of the hedged firm. In summary, since the two firms are of the same risk class, and thus have the same resulting end-of-period operating cash flow, the value of the hedged and unhedged firm must be the same or there will be arbitrage opportunities.

This same logic can be applied to futures contracts, call options, or any other tradeable contract used to hedge a firm's risk. Even further, the same analysis can be performed on parts of the firm's operating cash flows. To elaborate, in the above example, I assumed the firm was hedging all of its earning; however, a firm might want to hedge its exposure to a particular commodity or currency. Yet even under these scenarios, the firm value is independent of its hedging policy.

Another way to view the irrelevance of hedging is through State-Pricing Theory. State-Pricing Theory assumes that markets are competitive, frictionless, and complete. The assumption of competitive markets assumes that individuals and firms are price takers, and thus any one individual or firm is unable to affect the price of a primitive asset through its actions. Frictionless markets imply no transaction cost or taxes. These assumptions also imply no asymmetric information or agency cost. The complete market says the state space is spanned by the available assets.

To illustrate the irrelevance proposition under State Pricing Theory, I use a proof similar to that of Fama and Miller (1972). First, assume that the price of each Arrow-Debreu security is p_i and the firm will be liquidated in the next period with a total payout of X_i. The subscript i represents the possible states. For simplicity, let's assume that X_i is R_i dollars of revenue less $R_i\lambda$ dollars of operating cost, $X_i=(R_i(1-\lambda))$.

Under the State Pricing Theory, the current value of the firm is the price for a dollar if state i occurs multiplied by the firm's payoff for the corresponding state, summed over all states.

$$V = \sum_i p_i X_i = \sum_i p_i \left(R_i (1-\lambda)\right). \tag{3.1}$$

A firm decides to hedge against state j, which is a subset of state i. That is, the firm will buy a contract that pays a certain amount if state j occurs. For instance, suppose the firm decides to buy a put contract with a strike price of K. Then the value of the firm can be written as two parts: the value belonging to the equity holders less the put contracts.

$$V = E - P = \left[\sum_i p_i \left(R_i (1-\lambda)\right) + \sum_j p_j \left(K - R_j (1-\lambda)\right)\right] - \sum_j p_j \left(K - R_j (1-\lambda)\right). \tag{3.2}$$

$$V = \sum_i p_i X_i = \sum_i p_i \left(R_i (1-\lambda)\right)$$

Where j is the states in which K is greater or equal to the firm's income ($R_j(1-\lambda)$). From this equation, it is observed that the value of the put cancels out, resulting in the value of the hedged firm being the same as that of the unhedged firm. Obviously, this example is not restricted to put contracts but can be applied to any financial contract.

A less restrictive explanation of the irrelevance of hedging is explained by Fama and Miller's (1972) Market Equilibrium Model. Under this model, the only assumption is that markets are perfect. Perfect markets means that managers and investors are rational, information is accurate, and markets are frictionless, competitive, and efficient. Under these assumptions, there are no taxes, individuals and firms have the same financial arrangements, investors are indifferent between buying a security from a firm versus from an individual where the security is backed by the firm's assets, investors are able to protect themselves from expropriation, and managers maximize the current claimholders' wealth. Thus, the MM assumption that there is a firm with the same "business risk" and the State-Pricing Theory assumption that markets are complete is relaxed. In this model, firms, owners, and employees determine the price of labor, capital, and investment simultaneously. In this case, a firm issuing a claim against its probability distribution can be mimicked exactly by investors. For example, suppose an unhedged firm decides to hedge some of its risk. Investors who currently own the firm and who prefer the firm to remain unhedged will sell their claims against the firm such that their payoff is the same as if the firm remained unhedged. The result is that investors are indifferent to the actions of the firm's financing policies. Similarly, investors who own an unhedged firm yet desire the payoff of a hedged firm will issue claims against their ownership in the firm, such that their payoffs are the same as if the firm were hedged. The result is that investors can issue personal securities derived from the firm's assets to produce the desired payoff distribution. Thus, investors are indifferent to the firm's financing decision.

In conclusion, this subsection has shown that in a world of perfect markets, the hedging policies of a firm have no effect on the current claimholders of the company. This assertion has been demonstrated using the MM, State-Pricing Theory, and Market Equilibrium models. However, what role, if there is one, does hedging take when the assumptions of perfect markets are relaxed? Hedging can take a positive role when the assumption of taxes is relaxed, when it is costly for a particular class of claimholders or stakeholders to protect themselves from expropriation, when managers do not maximize the value of the current claimholders, and when investors and managers do not have access to the same information. More specifically, hedging can maximize the firm's value: (1) if the firm faces a convex tax regime (Smith and Stulz 1985); (2) if there exist bankruptcy costs or if access to external capital is restricted or relatively more expensive than internal funds (Froot, Scharfstein, and Stein 1993; Smith and Stulz 1985); (3) by providing a method for managers to maximize the firm's value and their personal utility (Smith and Stulz 1985); and (4) by providing valuable information about the quality of the firm's management (DeMarzo and Duffie 1995). The next section develops these theories in more detail.

3.2.a.ii Taxes

Smith and Stulz (1985) and Graham and Smith (1999) show that if a firm has a convex tax function, then it is advantageous for the firm to consider hedging some of its risk exposure. The logic is that a firm can reduce its expected taxes by paying a little more or no additional taxes when cash flow is low and significantly less taxes during periods when cash flow is abundant. The net effect is an increase in the expected value of the firm.

Grahman and Rogers (2002) illustrate this point numerically. First, assume that a firm's tax function is 0% if the firm's profits are 0 or less and 40% if the profits are greater than zero. The before tax profits are $-50 or $100 with a 50% probability. The expected profits before taxes are 25 (100*0.5 + -50*0.5). The firm's after-tax profits are -50 or 60. This leaves the firm with an expected after-tax profit of 5. If the firm decides to hedge such that its profits before taxes are always 25, then it's after-tax profits are consistently 15 (25*0.6). Obviously, any risk averse investor would prefer 15 dollars with certainty over a game with an expected outcome of 5 dollars.

Smith and Stulz's (1985) proof of this argument is as follows, assuming a two-period model: the current value of the firm is V and the risk-neutral probabilities and pretax cash flow from operations for state i are p_i, and X_i, respectively[16]. For simplicity, assume the following: (1) that the firm chooses a hedging strategy such that cash flows from its operations and its hedging strategy are equal to the expected cash flows from its operations; (2) the risk-free rate of return is zero.

The value of the firm in state i is:

$$V_i = X_i \left(1 - \tau\left(X_i\right)\right) \tag{3.3}$$

Where $\tau(X_i)$ is a convex function of income.

The first and second derivatives of the firm's end-of-period value with respect to income show that the firm's value is an increasing and concave function of income.

$$\frac{\partial V_i}{\partial X_i} = 1 - \tau\left(X_i\right) - \tau'\left(X_i\right)X_i > 0 \tag{3.4}$$

$$\frac{\partial^2 V_i}{\partial X_i^2} = -2\tau'\left(X_i\right) - \tau''\left(X_i\right)X_i < 0 \tag{3.5}$$

The first derivative is positive since it is assumed a firm would not accept an additional dollar of income if that dollar lowered the overall value of the firm. The second derivative is less than zero because τ' and τ'' are both positive.

From Jensen's inequality, the value of the hedged firm is greater than the value of the unhedged firm. This is illustrated in the equation below.

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[16] Note: the relationship between the risk neutral probabilities and state prices are $P_i = p_i / (1+r_f)$, where Pi , p_i and r_f are the risk neutral probabilities, state prices, and risk-free rate respectively. Thus, this same analysis can be performed using state prices instead of risk neutral probabilities.

$$E[V(X_i)] = \sum_i p_i[X_i(1-\tau(X_i))] \le V(E[X_i]) = \sum_i p_i X_i - \tau(p_i(X_i)) \tag{3.6}$$

From the equation above, notice that the difference between the hedged firm and the unhedged firm is the expected taxes the firm pays, with the hedged firm's expected taxes being less. Thus hedging increases the value of the firm by reducing the taxes it pays.

3.2.a.iii Financial Distress Cost

If costs are associated with financial distress, then it could be advisable for a value-maximizing firm to hedge. The logic is that when a firm is in financial distress, it experiences avoidable deadweight cost. These costs include legal fees and lost managerial and employee productivity associated with financial distress. By hedging, a firm can avoid these costs and thus increase the value of the firm.

Smith and Stulz's (1985) proof that hedging can increase the value of a firm by reducing financial distress cost is as follows: let (1) D_k be the interest paid on debt; (2) p_i, the state price for state i; (3) H_i, the hedge payoff for state i; (4) C_i, the financial distress cost for state i; and "g" ("b") represent the states where the firm is not (is) in default of its debt. That is $X_i > F$ for state "g" and $X_i < F$ for state "b" where F is the face value of debt. Assume the bond holders take possession of the firm in default. Lastly, assume a two-period model.

Smith and Stulz's proof shows that the value of a leveraged firm is:

$$V^{uh} = \sum_g p_i(X_i(1-\tau(X_i)) + \tau(X_i)D_k) + \sum_b p_i(X_i - c(X_i)) \tag{3.7}$$

If the firm hedges such that the current value of the hedge is zero, ($\sum_g p_i H_i + \sum_b p_i H_i = 0$) and $X_i + H_i > F$ for all states, then the value of the hedged firm is:

$$V^{h} = \sum_{g} p_i\left(X_i + H_i\right)\left(1 - \tau\left(X_i\right)\right) + \tau\left(X_i\right)D_k + \sum_{b} p_i\left(X_i + H_i\right)\left(1 - \tau\left(X_i\right)\right) + \tau\left(X_i\right)D_k \tag{3.8}$$

Subtracting the value of the V^h and $V^{uh,}$ results in the following equation:

$$V^{h} - V^{uh} = \sum_{b} p_i\left(\tau\left(X_i\right)\left[D_k - X_i\right] + c(X_i)\right) \tag{3.9}$$

Observe, from this equation, that the hedged firm's value is greater than the value of unhedged firm if financial distress costs are greater than the lost tax shield associated with bankruptcy. However, as Graham and Rogers (2002) observe, increasing the firm's debt results in a greater debt tax shield, which increases the benefits of hedging (D_k-X_i gets smaller as D_k rises). If it is assumed that the firm's income is still taxed in default, then the first term drops out and the value from hedging is the present value of the financial distress costs. Note, from the above analysis, the benefit of hedging is independent of the firm's investment policy.

Froot, Scharfstein, and Stein (1993) extend the argument of financial distress cost by directly incorporating this cost into the firm's cost for external capital. The significance of this argument is that it increases the incentive for the firm to use and protect internal cash for investments. The authors show how the interrelationship between a firm's cash flows and its investment opportunities create an incentive for the firm to hedge its cash flows. Intuitively, their argument consists of showing that it is advantageous for a firm to hedge if it is characterized as having to forgo its most profitable investments when its cash flows are low, yet is faced with relatively low profitable investments when its cash flows are high. From this argument, it is beneficial to the firm to transfer cash flows from those periods when cash is high and investment opportunities are low to those periods when cash flows are low but the return on investments is the highest.

Froot, Scharfstein, and Stein (1993) formally prove their argument by assuming the following: the cost of external funds is greater than the cost of internal funds (C(e)). Furthermore, the cost of external funds is increasing and convex ($C_e(e) > 0$, $C_{ee}(e) > 0$). "C(e)" is defined as the cost of external funds and "e" is the amount of external cash used. The amount invested, "I," is the sum of the firm's internal cash and external cash (I = w+e). The firm's internal cash, "w," is equal to $w_0\varepsilon$ ($w=w_0\varepsilon$), where w_0 is the last period's internal capital and ε is a normal random variable with mean 1 and a variance of σ^2. Next assume the payoff of the firm's investments (θf(I)) is an increasing, concave function with respect to the amount invested ($\theta f'(I) > 0, \theta f''(I) < 0$). "θ," which represents the relationship between the firm's investment opportunities and its cash flows, is equal to ($\alpha(\varepsilon - \bar{\varepsilon}) + 1$). "α" represents the correlation between the firm's investment opportunities and its cash flows. For instance, a positive α implies the firm's investment opportunities are high when its cash level is high. The next assumption is that the value of the firm as a function of its investments is V(I) = θf(I) – I – C(e).[17] These three pivotal assumptions concerning a firm's motivation to hedge are (1) the differential cost between external funds and internal cash; (2) the firm's increasing and concave investments function; and (3) the degree of correlation between the firm's investment opportunities and its cash level.

Froot, Scharfstein, and Stein's (1993) proof continues by first stating that the objective of the firm is to maximize its value with respect to investments. From this

[17] For simplicity, assume the discount factor and the initial internal cash (w_o) are equal to one.

assumption the first order condition is $\theta f_I(I) - 1 = C_e$. That is, the firm will continue to invest until the marginal return from its investments is equal to the marginal cost of external funds. Assume that the level of investment is decreasing with the amount of external funds used, as it is more costly for the firm to gain additional funds from the capital markets. This assumption implies that investment is increasing with the amount of internal funds available ($\frac{\partial I}{\partial w} > 0$).

Lastly, Froot, Scharfstein, and Stein's proof shows under what circumstances the firm's value is concave with respect to the random shocks to its cash flow (ε). Before continuing, note that by Jensen's equality, it is optimal for the firm to hedge (not hedge) when its expected value is concave (convex) with respect to the underlying risk. Thus, by taking the derivative of the firm's value with respect to the random shock and using the first order condition, the first derivative of the firm, evaluated at ε's mean can be written as:

$$\left.\frac{\partial V}{\partial \varepsilon}\right|_{\bar{\varepsilon}} \alpha f(I) + \left[\theta f_I(I) - 1\right] w_0 \,. \tag{3.10}$$

This equation implies that the second derivative of the firm's value with respect to the random shock is:

$$\left.\frac{\partial^2 V}{\partial \varepsilon^2}\right|_{\bar{\varepsilon}} = \alpha f_I(I)\left(w_0 + \frac{\partial I}{\partial \varepsilon}\right) + w_0 f_{II}(I)\frac{\partial I}{\partial \varepsilon} \,. \tag{3.11}$$

The second derivative of the firm's value is negative when α is non-positive since the firm's investment function is increasing and convex. This equation shows that when cash flows are negatively correlated with a firm's investment opportunities, its value is concave with respect to changes in its cash flows. Thus, hedging enhances the firm's value. Conversely, if α is positive, it is possible for the value of the firm to be convex with respect to changes in its cash flows. This result implies that hedging is detrimental to the firm's value. Note, it is assumed that investments are increasing with the firm's cash flows ($\frac{\partial I}{\partial \varepsilon} > 0$). This assumption is not true under all scenarios. Under such circumstances, when investment drops as internal cash rises, it may be optimal for the firm to overhedge.

To further understand the previous equation (the second derivative of the firm's value), the first term represents ($\alpha f_I(I)\left(1 + \frac{\partial I}{\partial \varepsilon}\right)$) the relationship between the firm's investment opportunities and fluctuations in its cash flow. To illustrate, the value of an oil company's investments decline as its cash flow declines, since both the value of the unproven oil reserves and profits from current production decline with the price of oil (Froot, Scharfstein, and Stein 1993). However, the opposite case is predicted for an airline, where the value of its investments increases with the decline in its cash holdings, since aircraft are sold below their intrinsic value during industry recessions (Pulvino 1998). The second term in the second derivative of the firm's investment function represents the benefits from hedging regardless of the correlation between the firm's investment set and its cash flows. The significance of this term is that when prices are low, the firm has to forgo profitable investments as cash is scarce. Yet when prices are favorable, the marginal benefit of the next investment is low since the best investments have already been implemented.

3.2.a.iv Managers Risk Aversion and Signaling

Managers who are unable to use the other venues such as capital markets to maximize their utility will use the firm as a vehicle to optimize their personal utility. The hedging practices of a firm are determined by the degree to which its managers are risk averse and the compensation packages of those managers. For instance, a manager whose compensation is performance based might find the firm's volatility unacceptable. This manager can use hedging as a means to reduce the volatility of his compensation plan to an acceptable level.

To understand this more fully, I use Smith and Stulz's (1985) proof to examine two scenarios. In the first scenario the manager's wealth is a concave function of the firm's value. An example is a compensation plan that is capped at a certain amount regardless of the firm's performance. Assume the manager experiences a concave utility function with respect to wealth, that is, he is risk averse. By taking the first and second derivatives of the manager's utility function with respect to the firm's value, it is observed that the manager's utility function is increasing and concave with respect to the value of the firm.

$$U'\frac{\partial w}{\partial V} > 0;\; U''\frac{\partial w}{\partial V} + U'\frac{\partial^2 w}{\partial V^2} < 0 \tag{3.12}$$

By Jensen's inequality, the manager's utility evaluated at the expected value of the firm is greater than his expected utility.

$$E[U(w(V))] \leq U(w(E[V])) \tag{3.13}$$

Therefore, the manager will optimize his utility by choosing a hedging policy such that $V_i+H_i = E[V]$, where V_i (H_i) is the value of the firm (the hedge) in each state "i."

To understand the logic to the previous analysis, suppose a manager faces a compensation plan that caps his / her wealth based on the performance of the firm.

Under this example, the manager has limited upside risk yet is completely exposed to the firm's downside risk. Thus, the manager is better off if he / she uses the firm to hedge the downside risk.

The second scenario is more interesting. Again, suppose the manager faces a concave utility function, yet his wealth is a weakly convex function with respect to the firm's value.

$$U' > 0,\ \frac{\partial w}{\partial \mathrm{V}} \geq 0;\ \mathrm{U}'' < 0,\ \frac{\partial^2 w}{\partial V^2} \geq 0 \tag{3.14}$$

By taking the first and second derivatives of the manager's utility function with respect to the firm's value, it is observed that the manager's utility function can be concave or convex with respect to the firm's value.

$$U' \frac{\partial w}{\partial V} > 0\,; \quad U'' \frac{\partial w}{\partial V} + U' \frac{\partial^2 w}{\partial V^2} \underset{>}{\overset{<}{-}} 0 \tag{3.15}$$

Thus, the manager will choose to hedge in some instances and not to hedge in other instances.

To illustrate, suppose a manager's wealth consists of the firm's stock. Under this compensation plan, the manager's wealth is a linear function of the firm's value, which implies that his utility is a concave function of the firm's value. Thus the manager will choose to hedge. Now suppose the manager's wealth consists of stock options. Under this case, the manager does not hedge if the options are deep-out-of-the-money or at-the-money. The reasoning is that the manager's utility is a convex function with respect to the firm's value. The logic is that the manager's downside risk is capped, yet he is exposed to the upside benefits. If the options are deep-in-the-money, then the manager's compensation plan becomes more linear, resembling a stock-based compensation plan. Thus, the manager will choose to implement a hedging policy.

If managers are risk averse, a firm's hedging policy can add value to the firm by leaving the optimal investment policy unchanged. A risk averse manager who is unable to hedge his risk might choose to forgo risky positive net present value projects for less risky and less valuable net present value projects. This behavior can be very costly to the firm.

DeMarzo and Duffie (1995) show that there is an incentive for managers to hedge as it conveys information to shareholders about their abilities. This information allows shareholders to develop compensation packages which reflect their manager's performance. The basic intuition of DeMarzo and Duffie's (1995) argument is that managers, through hedging, can reduce the volatility of the firm's cash flows (profits), which is not reflective of their performance.

To give a numerical example of why managers would volunteer such information concerning their performance, suppose the following: a manager has a utility function which is increasing and concave with respect to his wage. More explicitly, his utility function is equal to his wage "w" when his wage is below two. When his wage is greater than or equal to two, his utility is two. The manager's wage is a function of the firm's profits. For simplicity, assume that the manager's future wages are 80% of the firm's profits. Also, the firm's future profits are equal to the manager's ability "a" plus a random hedgeable risk "ε," the outcome of which is unknown to shareholders. The shareholders and managers know the distribution of "a," which takes on the value of 2 and 1 with equal probability. However, only the manager knows the distribution of "ε," which takes on the values of 1 and -1 with equal probability. Thus, the possible profits for the firm are (3, 2, 1, 0) with equal probability. However, since the shareholders don't know the distribution of "ε," they are unable to discern the proportions of the firm's profits that are attributed to the manager's performance and that are from the random hedgeable risk[18].

The manager wants to maximize his future expected utility, which is based on the firm's profits. The manager's expected utility when he doesn't hedge is 1.1 (0.25(2) + 0.25(1.6) + 0.25(0.8) + 0.25(0.0)). If the manager decides to hedge then his expected utility is 1.2 (0.5(1.6) + 0.5(0.8)), which is determined by his ability "a" and not the random hedgeable risk factor "ε." From the above illustration, it is obvious our manager is better off hedging, which will yield him an expected utility of 1.2 rather than 1.1. Thus, managers are willing to provide information concerning their performance, as it gives them greater utility.

3.2.b Financial vs. Operational Hedging

The previous subsection implies that hedging is a means to reduce the volatility of a firm's present and future cash flows; thus the goal of a financial or operational hedge is to meet this objective. To meet this objective, the firm uses financial hedges such as interest rates, currency, and commodity derivatives and/or operational hedges, which stem from the operating and investment activities of the firm. In this subsection, the empirical literature concerning the use of financial versus operational hedging is discussed, specifically, the financial and operational hedges available to the firm,

[18] DeMarzo and Duffie (1995) that assume the distribution of the hedgeable risk is known to shareholders but the degree to which the firm is exposed is unknown. Here "ε" captures both the hedgeable risk factor and the degree to which the firm is exposed and is assumed unknown to shareholders.

and whether the firm uses these hedges as a means to reduce risk. Lastly, this subsection discusses whether financial and operational hedges are complements or substitutes.

Many financial contracts can be used to hedge or protect against a particular risk. The most obvious is the use of derivatives; however, there are others such as the use of debt and cash (usually referred to as hedging substitutes). For example, a firm can reduce the risk of financial distress by simply reducing its debt level. However, debt provides a tax shield for the firm, which suggests that it is optimal for a firm to increase its debt tax shield through the use of debt and use other means to control the volatility of its cash flows (Stulz 1996). Graham and Rogers (2002) find just that: firms use financial derivatives as a means to increase their debt capacity.

Another example of debt used as a financial hedge when the debt is denominated in a foreign currency and is used to hedge against foreign revenue (Allayannis and Ofek 2001; Geczy, Minton, and Schrand 1997). Consistent with this notion that foreign debt is used as a hedge, Allayannis and Ofek (2001) find the percentage of a firm's foreign sales to total sales is a positive predictor of the amount of foreign debt a firm incurs. Not limited to currency hedging, the type of debt a firm chooses can protect its cash flow from interest rate risk (Faulkender 2005) by matching interest sensitive assets to similar liabilities. For instance, if the cash flow generated from a firm's assets is positively correlated with interest rates, then the firm should finance those assets with short term debt (i.e., the firm's interest payments are the highest (lowest) when cash flow from the asset is its highest (lowest)).

A firm's cash holding is a substitute for the use of financial derivatives. Recall that two motivations for the practice of risk management are to protect the firm from financial distress cost and to avoid the risk associated with lost investments. A firm can reduce the probability of financial distress and/or guarantee its investments by holding excess cash (Haushalter, Klasa, and Maxwell 2007). Almeida, Campello, and Weisbach (2004) find evidence supporting the hypothesis that financially constrained firms use cash as a means to protect their investments. The authors find that financially constrained firms increase their cash holdings in response to an increase in the firm's cash flow. While no such relationship holds for financially unconstrained firms, they also find that financially constrained firms' cash-holdings-to-total-assets are significantly greater than those of unconstrained firms. Similarly, Haushalter, Klasa, and Maxwell (2007) find that cash-heavy firms in industries characterized as having high product market rivalry increase investments during unfavorable times when their financially constrained rivals are unable to invest. The authors also find that the probability of using swap contracts declines as cash holdings increase, suggesting that cash and derivatives are substitutes.

Other financial contracts also reduce a firm's financial distress cost and hence the need to hedge. One cost associated with financial distress is the cost related to conflicts between shareholders and bondholders (agency cost). For instance, shareholders will choose highly risky projects or forgo positive net present value projects at the expense of bondholders. A firm can reduce this cost with debt covenants, convertible debt, preferred stock, and dividend policies (Nance, Smith, and Smithson 1993).

Operational hedges are a consequence of the real options a firm owns. The different types of real options are too numerous to list; however, a commonality of real options is to give the owner of the option the ability to delay decision-making until more information is available (Triantis 2000). To illustrate how a real option provides an operational hedge, consider a firm that is planning to expand into a new market. The firm has the choice to build one large plant today or construct one smaller plant with an option to expand the plant later. The larger plant, if built, would cause the firm financial distress if market conditions turned sour, thus, affecting the firm's ability to invest in profitable projects in later periods. A smaller plant would protect the firm from any such adverse conditions.

The manufacturing facilities of a multinational firm located in foreign markets is an example of a real option providing an operational hedge against currency fluctuations. The hedge is provided since production cost and revenue are denominated in the same currency. Another advantage of a firm's having multiple foreign facilities is the switching option that it provides (Triantis 2000). For instance, if the dollar increases in value relative to the foreign currency, then a US firm can switch its production from a domestic factory to the foreign facility, and thus protect itself from the appreciating dollar and at the same time exploit the cheaper foreign currency.

A firm's ability to adjust output and thus cost is another important real option that functions as an operational hedge. For instance, as describe by Dixit and Pindyck (1994), a mine owns the option to suspend operations if the price of the commodity drops below a certain threshold and later reopen when conditions improve. A firm which has this option to adjust its production, versus a firm where production is fixed (or at least its costs are), can protect its cash flows by guaranteeing a nonnegative profit.

Several studies examine whether there is empirical evidence that a firm's foreign operations provide an operational hedge against currency risk (Allayannis, Ihrig, and Weston 2001; Carter, Pantzalis, and Simkins 2006; Pantzalis, Simkins, and Laux 2001;

Williamson 2001). Williamson (2001) finds that Japanese automotive manufacturers experienced less exposure to the dollar in the latter part of his sample period. He attributes this decrease to the increase in foreign automobiles manufactured in the US. More specifically, the exposure of Japanese automakers to the dollar declines as the percent of foreign cars produced in the US increases. However, this decline in exposure is insignificant for 5 out of 7 firms. Williamson, as with most other studies, measures a firm's risk exposure as the regression coefficient from a two factor market model.

Allayannis, Ihrig, and Weston (2001) find that operational hedges do not reduce a firm's risk exposure. They hypothesize that the greater the number of geographic regions a firm's subsidiaries are located in, the greater is its operational hedge. However, the authors are unable to find a negative and significant relationship between a firm's geographic dispersion and its exposure to currency rates. Their measure of geographic dispersion is a Hirschman-Herfindahl Index. Contrary to Allayannis, Ihrig, and Weston (2001), Pantzalis, Simkins, and Laux's (2001) results show that the number of regions a firm has subsidiaries in is a significant factor in reducing a firm's risk to currency fluctuation.

Carter, Pantzalis, and Simkins (2006) examine whether multinational firms with greater geographic dispersion are less (more) exposed during adverse (favorable) conditions. Their findings suggest that widely dispersed multinational firms that are positively exposed to the appreciation of the dollar (typical of importers) do experience significant (insignificant) exposure to the dollar during strong (weak) dollar states. However, for firms with a negative exposure to currency movement (typical of exporters) geographic dispersion is not a significant determinant of their exposure in either weak or strong dollar states.

Some empirical studies show that a firm's real option to adjust its production is an operational hedge (Kallapur and Eldenburg 2005; Haushalter, Heron, and Lie 2002; Petersen and Thiagarajan 2000; Tufano 1998). Tufano (1998) finds some evidence that real options are used to lower a gold mining firm's exposure to gold prices. As mentioned above, a mine has the option to suspend production if the price of gold drops below a certain threshold. This type of real option has the characteristics of a call option. Therefore, Tufano (1998) predicts that if gold mining firms are utilizing their real options, then, their exposure to gold prices should fall as the volatility of gold prices increases. Furthermore, as with call options, a gold mining firm's exposure to gold prices increases with the gold lease rate and decreases with the 10-year Treasury Bill because the gold lease rate represents the convenience yield of gold and the 10-year Treasury Bill is the risk free rate. As predicted, Tufano (1998) finds that the volatility of gold prices and the interest rate on a 10-year Treasury Bill do significantly reduce a gold mining firm's exposure to gold prices. However, there is not a positive relationship between the lease gold rate and a mine's exposure to gold prices.

Petersen and Thiagarajan (2000) look at the hedging behavior of two distinct gold mining firms: one firm which uses financial derivatives extensively and the other that does not. They find that the operating cost of the firm which does not use financial derivatives (Homestake Mining) falls with declining gold prices. This is not true for the firm which hedges (American Barrick). They contend that Homestake Mining's ability to adjust operating costs in response to changes in gold prices is due to its ability to close mines with higher operating costs and vary the mix of ore extracted. American Barrick's ability to adjust production is more restricted.

If real options are used as operational hedges, then firms will seek risk-reducing technology if the uncertainty of their environment increases. Kallapur and Eldenburg (2005) find this to be the case. After a change in Medicare policy which increased the uncertainty concerning payment, hospitals attempted to reduce their risk by replacing high fixed cost / low variable cost equipment with higher variable cost / low fixed cost equipment. That is, hospitals chose a production function that consisted of higher variable cost with the option to adjust production during unfavorable times.

Are the uses of financial and operational hedges substitutes or complements? That is, are financial and operational hedges substitutes which a firm can use interchangeably, or do financial and operational hedges protect the firm against different risks and thus complement each other? For instance, several authors have suggested that operational hedges (financial hedges) are used to protect against long (short) term risks (Carter, Pantzalis, and Simkins 2006; Triantis 2000). The Petersen and Thiagarajan (2000) study suggests that financial and operational hedges are substitutes. More specifically, one reason Homestake chose not to use financial derivatives was its ability to adjust operating costs in response to movements in gold prices; American Barrick doesn't have this luxury. To explicitly test the question of substitutes versus complements, Allayannis, Ihrig, and Weston (2001) hypothesize that if operational and financial hedges are substitutes (complements) then the probability of a firm's using financial derivatives decreases (increases) with its geographic dispersion index because the more disperse the subsidiaries of a multinational firm, the better is that firm's operational hedge. The authors find a positive and significant relationship between the probability that a firm uses derivatives and its geographic dispersion index, thus, suggesting financial and operational hedges are complements.

3.2.c Motivation for Hedging (Empirical Results)

The previous two subsections discussed the theoretical motivations for hedging and two distinct types of hedges, financial and operational. This subsection discusses the empirical findings in support of the different theoretical motivations for hedging. More specifically, does the empirical evidence suggest that firms hedge to reduce their tax burden, reduce financial distress cost, maximize their managers utility (Smith and Stulz 1985), protect their most profitable investment opportunities (Froot, Scharfstein, and Stein 1993), and reduce the asymmetric information between managers and shareholders (DeMarzo and Duffie 1995).

3.2.c.i Taxes

Recall that hedging can enhance the firm's value if a firm experiences a convex tax function (Smith and Stulz 1985). Many authors have suggested the use of a dummy variable to indicate whether the firm incurred net operating loss carryback and carryforward (NOL) as a proxy if a firm hedges in response to the convexity of its tax function (Allayannis and Ofek 2001; Geczy, Minton, and Schrand 1997; Nain 2004; Nance, Smith, and Smithson 1993; Tufano 1996). The reason is that a firm's marginal tax rate changes when its taxable income is zero, as a firm does not pay taxes when its taxable income is nonpositive. This argument implies that firms with near zero taxable income should experience the greatest convexity in their tax functions. Since carryback and carryforward occur when the firm's taxable income is nonpositive, it is reasonable to use NOL as a proxy for the convexity of a firm's tax function. Contrary to prediction, these authors have found that a firm's decision to use financial derivatives is not significantly determined by NOL, suggesting that the convexity of a firm's tax function is not a motivating factor for the use of financial derivatives.

A problem with using NOL as a proxy for whether a firm's tax function is convex, as shown by Graham and Smith (1999), is that carryback and carryforward actually reduces the convexity of a firm's tax-function at the point where taxable income is near zero. The reason is that carryback and carryforward smooth a firm's losses over several periods, thus reducing the expected present value of a firm's taxable income. Graham and Smith (1999) show that using a firm's simulated tax liabilities, firms with a tax saving in the 90^{th} – 95^{th} percentile would save on average $134,410 from hedging. However, this number is relatively small when compared to Brown's (2001) annual estimated cost of a hedging program of $1.5 million. Further evidence against the convex-tax hypothesis is offered by Graham and Rogers (2002), who find the expected tax savings obtained from hedging are not a significant motivating factor in the firm's decision to utilize financial derivatives. The authors do find that a firm's hedging increases a firm's debt tax shield.

3.2.c.ii Financial Distress and the Underinvestment Problem

As mentioned earlier, financial distress costs are the costs that occur when a firm reaches bankruptcy. These costs can be direct or indirect, such as lawyer fees or lost employee productivity (e.g., employees using company time to seek new employment). A firm can reduce these costs by lowering its debt level or protecting its cash flow through hedging. This argument leads to the prediction that highly leveraged firms, as measured by such common ratios as debt to assets, quick ratio, and EBIT to interest, tend to hedge. However, several studies find this relationship to be insignificant to a firm's risk management decision (Allayannis and Ofek 2001; Allayannis and Weston 1999; Geczy, Minton, and Schrand 1997; Nain 2004; Nance, Smith, and Smithson 1993; Tufano 1996).

An issue with the above studies is that there is no control for the fact that a firm's hedging policy along with its degree of financial leverage are jointly determined (Stulz 1996). For instance, a firm with a high probability of bankruptcy is better off "betting the farm," as the shareholders have little to lose. Under this scenario, hedging caps the upside potential of the firm. Yet a firm with little chance of bankruptcy will choose a risk management policy that allows the firm to increase its leverage and thus exploit the debt tax shield. Graham and Rogers (2002) use a simultaneous equation regression to control for such endogeneity and find a positive relationship between a firm's hedging activity and its debt to asset ratio. Furthermore, they estimate that the median firm saves $9.8 million dollars in taxes from hedging due to the increase in debt capacity.

Another major cost associated with financial distress and external financing is agency costs, which stem from the conflicts between the different claimholders of the firms. For instance, one source of agency cost is that shareholders will forgo positive net present value projects or invest in risky projects at the expense of the bondholder (Myers 1977). To compensate bondholders for this risk, shareholders must pay a higher rate of return on borrowed funds than if those funds were from internal sources. This situation creates a differential between the cost of the funds from external and those from internal sources. This differential along with the concavity of the firm's investment function and the correlation between the value of the firm's investments and its cash flow creates a value enhancing incentive for the firm to hedge (Froot, Scharfstein, and Stein 1993)[19]. Thus, a firm with large growth opportunities and a significant cost differential between internal and external funds is characterized as having a high market to book ratio and significant R&D expenditures, as each proxy for the firm's growth potential and agency cost, respectively. Studies have found a positive relationship between a firm's propensity to hedge and its market to book ratio and R&D expenditures (Allayannis and Ofek 2001; Geczy, Minton, and Schrand 1997; Nance, Smith, and Smithson 1993; Allayannis and Weston 1999). However, other studies have found the opposite relationship. For instance, Graham and Rogers (2002) find that firms with large R&D spending tend to hedge less. Furthermore, Tufano (1996) finds an inverse relationship between the exploration activities of a gold mining firm and its level of hedging.

3.2.c.iii Manager Risk Aversion & Asymmetric information

Recall that risk averse managers will hedge the firm's cash flow if their compensation package is concave or linear with respect to the value of the firm (Smith and Stulz 1985). Thus, there should be a relationship between a firm's hedging behavior and its managers' compensation package. More specifically, managers whose wealth consists largely of the company's stock are more likely to implement a risk management policy for the firm, as these managers are unable to fully diversify their personal wealth and furthermore, their wealth is a linear function of the firm's value. Conversely, firms whose managers have a significant number of stock options are less likely to hedge as the wealth of these managers tends to be convex with respect to the value of the firm.

[19] There is a difference between the underinvestment according to Myers (1977) and to Froot, Scharfstein, and Stein (1993). With Myers (1977), shareholders choose not to invest, even when they can, since any gains will accrue to the bondholders. With Froot, Scharfstein, and Stein (1993), the underinvestment problem is that shareholders forgo profitable investments as external funds are too expensive.

However, Geczy, Minton, and Schrand (1997) find the probability that a firm uses financial derivatives is not affected by the amount of wealth its managers and directors have invested in the firm. They measure the managers' and directors' invested interest in the firm by their stock holdings and stock options. However, three problems with their proxy for the risk aversion of managers are (1) the value of the stock and options holdings which managers and directors have invested in the firm is correlated with the size of the firm, as larger firms typically have larger managing staff; (2) the hedging decision resides with the CEO of the firm and not necessarily its directors; and (3) it doesn't account for whether the options are deep in-the-money (options that are deep in the money behave more like common stock).

Tufano (1996) and Graham and Rogers (2002) address some of the above concerns regarding the Geczy, Minton, and Schrand (1997) study. They find some evidence that risk averse managers are a motivating factor for a firm's decision to hedge. In their study, Graham and Rogers (2002) use the delta and vega of the CEO's holding in the firm as proxies for how sensitive a manager's wealth is to changes in the firm's value. The delta is defined as the percent change in the value of the CEO's stocks and options to a one percent change in the firm's stock price. Vega is defined as the percent change in the CEO option holdings to a one percent change in the standard deviation of the stock returns. Their study shows a positive and significant (at the 10% level) relationship between a firm's use of derivatives and the manager's delta. This is as predicted since a delta closer to one implies that the options behave in a way similar to stocks. The vega, however, is insignificantly related to the firm's hedging decision. Tufano, using similar proxies, find that a manager's risk aversion does influence a gold mining firm's decision to hedge. Furthermore, Tufano addresses some of the concerns mentioned above (size of managerial staff). He finds, as predicted, a positive relationship between the per capita stock holding of the four top executives and the firm's decision to hedge. Furthermore, the firm's decision to hedge decreases with respect to the per capita options outstanding by all officers and directors, as predicted.

DeMarzo and Duffie (1995) theorize that firms hedge to reduce the level of asymmetric information between managers and shareholders. If this is true, then it is expected that firms which are followed by a large number of analysts should hedge less,` as analysis reduces the level of asymmetric information. Geczy, Minton, and Schrand (1997) test this hypothesis and find, contrary to prediction that, hedging increases with the number of analysts. Furthermore, Graham and Rogers (2002), find no evidence that firms with greater levels of asymmetric information tend to hedge less. Their proxy for the degree of asymmetric information is the percent of the firm owned by institutional investors. Institutional investors reduce the level of asymmetric information, as they have access to inside information concerning the firm's prospects. Contrary to the other studies mentioned, Tufano (1996) does find, as predicted by theory, that gold mining firms hedge less as the percentage of the firm which is owned by large outside block-holders increases.

3.2.d Hedging and Firm Value

The prior subsection discussed the empirical motivation for hedging. In this subsection, the question whether hedging enhances the firm's value is addressed. Allayannis and Weston (2001) examine whether the use of foreign currency derivatives increases the value of the firm. In their study, the Tobin Q of firms with foreign sales which hedge is 4.5% higher than that of nonhedging firms, the result is a premium of about $153 million (Tobin's Q is the market value of the firm divided by its replacement cost). However, an issue with their study is that their sample consists of conglomerates that operate across several different industries. The conglomerates create a sample bias as it is known that hedging varies across industries (Allayannis and Weston 1999; Geczy, Minton, and Schrand 1997) as does Tobin's Q. Thus, their result could be industry-driven rather than hedging related. When controlling for industry effects using an industry-adjusted Tobin's Q, the hedging premium drops to 3.66% and becomes insignificant.

To control for industry effects, two other studies examined the hedging benefits in a specific industry. More specifically, Carter, Rogers and Simkins (2006) examined hedging and firm value in the airline industry and Jin and Jorion (2006) addressed the question from the oil and gas industry. Carter, Rogers and Simkins found a positive and significant relationship between an airline's Tobin's Q and the percent of next year's jet fuel that is hedged. The hedging premium for the average airline's Tobin's Q is 10.2%. This roughly represents a $130 million hedging premium to an airline. Contrary to Carter and Rogers and Simkins results, Jin and Jorion did not find a positive relation between the firm's value and its hedging activities, thus, suggesting hedging does not increase the value of oil and gas firms.

As discussed in a prior subsection, financial and operational hedges are used in tandem to manage a firm's risk. Allayannis, Ihrig, and Weston (2001) examine whether the use of operational and financial hedges is value-enhancing to the firm. They do not find a positive association between the value of a multinational firm and its use of operational hedges. In their study, the operational hedge is proxied by the dispersion of the firm's subsidiaries, and the firm's value is measured by the market to book ratio. Though the use of operational hedging alone doesn't command a hedging premium, the implementation of both operational and financial hedges does account for a 16.7% premium to a firm's market to book. This result suggests that a risk management policy that uses both operational and financial hedges is value-enhancing to the firm.

If hedging does add value to the firm, then is the hedging premium associated with lower expected taxes, a reduction in financial distress cost, or an increase in investments, is it or a result of managers maximizing their utility? Allayannis and Weston (2001) believe that the hedging premium is attributed to the tax saving resulting from an increase in a firm's debt tax shield, a reduction in its bankruptcy cost, and mitigation of the underinvestment problem. Carter, Rogers, and Simkins (2006) explicitly tested the underinvestment problem for the airline industry and found that increasing the percent of the next year's jet fuel hedged by one percent increases the airline capital expenditures-to-sales ratio by 7.4%. Furthermore, they report that the hedging premium attributed to the protection of the airline's capital expenditures is 21%. This result suggests that the underinvestment problem is significant to the firm's value and commands the attention of a firm's risk management program.

In conclusion, this section discussed the theories which contend hedging adds value to the firm. First, by examining the condition in which hedging is irrelevant to the firm's value, thereby relaxing the assumption of a perfect market, it was shown that hedging increases a firm's value when there are (1) taxes, (2) financial distress costs, (3) a cost differential between the use of external and internal capital, (4) risk averse managers, and (5) informational differences between managers and shareholders. Furthermore, the empirical literature concerning the use of financial and operational hedges and the use of hedging substitutes to control a firm's risk was discussed. The empirical literature suggests that firms do not hedge as a consequence of a convex tax function. Lastly, there is some empirical evidence suggesting that risk management does increase a firm's value.

3.3 Operational Hedges / Data

As Modigliani and Miller (1958) show, in a perfect world, the use of financial derivatives to manage a firm's risk provides no additional value to the firm. This is similarly true for the operational hedge, which is defined as those operational activities which the firm engages in to mitigate its risk (Boyabaitli and Toktay 2004). To illustrate, suppose a firm has a choice between two mutually exclusive investments; the first project requires an investment today, while the second project contains an option to delay investment until the next period. Yet the difference between the investment cost of the first and second project is such that the net present value of the two projects is equal. Under this scenario, the firm is indifferent between the two projects, as both projects increase the value of the firm by the same amount. However, a firm that is choosing to manage its risk will adopt the second project, for its risk (variance) is less. The importance of this example is to illustrate the difference between the value a real option provides a firm through its investment decision and the value a real option can possibly provide by mitigating the firm's risk. Next, the justifications presented in chapter two for the operational hedges are reviewed.

3.3.a Fleet Composition (Diversity of Fleet)

A diverse fleet gives the airline the flexibility to adjust the level of its capacity to meet the condition of a dynamic market. Dixit and Pindyck (1994) analyze the choice between flexibility and scale using real option analysis. Furthermore, using real options which a diverse fleet provides acts as an operational hedge by reducing an airline's losses during unfavorable periods. To illustrate, when fuel prices are at such a level that operating a given route is unfavorable, the airline has a choice to whether quit servicing the particular route and wait until fuel prices fall or maintain service at a loss. When exit or reentry costs are prohibitively expensive, the airline will choose to maintain operations and not exercise its options to exit. Under this scenario, it is optimal for the airline to cut capacity to such a level where the airline is able to avoid the exit or reentry cost. With a diverse fleet, the airline has this option. For instance, when fuel prices are high, the airline increases the use of its smaller aircraft, resulting in a lower level of losses relative to a larger aircraft. Appendix 2.A develops the argument more formally.

I measure the diversity of an airline's fleet using a proxy similar to Allayannis, Ihrig, and Weston's (2001) geographic dispersion measure, and is referred to as the aircraft dispersion index. The construction of the aircraft dispersion index is similar to that of the Hirchman-Herfindhal concentration index, which uses the different types of aircraft that an airline uses. More specifically, the aircraft dispersion index is

$$= 1 - \sum_{j=1}^{K} \left(\frac{\text{No. of Aircraft}_{\text{j}}}{\text{Total No. of Aircraft}_{\text{i}}} \right)^2 \qquad (3.16)$$

where K is the total number of different models that airline "i" operates and "j" represents the aircraft model. This index range is between zero and one, with one indicating the greatest degree of diversity. If the airline operates only one type of aircraft, such as Southwest, then the index value is equal to zero.

3.3.b Fleet Fuel Efficiency

A large cost factor to airlines is jet fuel. This fact suggests that airlines benefit from hedging against fluctuation in fuel prices. An airline that choose to operate a newer fleet, which is a fuel-efficient fleet, have less exposure to the price of jet fuel. To measure the airline's decision to use a fuel-efficient fleet as an operational hedge, I use the average age of the airline's fleet.

The proxy for the fuel efficiency of the airline fleet is the logarithm of the average age of the fleet. The average age of an airline's fleet is a weighted average of the age of the different aircraft models the airline operates. The fleet age is reported annually and rounded to the nearest integer. The two reasons for rounding to the nearest integer are that (1) many airlines only report the age of the fleet in round years and (2) it reduces possible biases created by smaller aircraft since smaller aircraft are usually younger. When the age of the fleet is not reported, the nearest / earliest possible reported age is used. For instance, Mesa Airlines reported its fleet in 1998 but not 1999. In this case, the age of Mesa's fleet in 1998 is used for 1999. The average age of the fleet is taken from the airlines 10-K.

3.3.c Operating Leases

Operating leases provide airlines the opportunity to frequently adjust their fleet to changing conditions. For instance, as the demand for a particular route changes, the airline can replace its current aircraft with those that are better suited for that market (Brigham and Ehrhardt 2005). Moreover, many airlines stagger the life of their leases so that their fleet size can adjust to changing market conditions. In addition to staggering the life of its leases, many leasing contracts contain options clauses which allow the airline to purchase the aircraft at the end of the leasing agreement and/or to cancel its leasing obligation prior to the end of the lease. Lastly, leasors sometimes renegotiate the terms of a lease.

To proxy for the airline's ability to use operating leases as a hedge, I use the percentage of the airline's fleet that is leased. This proxy is calculated as the total number of aircraft the airline leases divided by the total number of aircraft owned and leased. This proxy includes spare parts aircraft, aircraft not yet in service, and those that are subleased to other airlines. The leasing data is obtained from the airlines' annual 10-K filings.

To proxy for the degree to which the airline uses financial hedges, I use the percentage of the airline's jet fuel hedged for next year. To capture the impact of fuel contracts which lock in an airline's fuels cost, I included an indicator variable for whether the airline has entered into a fuel pass-through agreement. Fuel pass-through agreements are typically contracts between a regional airline and a mainline airline. These contracts cover a regional airline's fuel costs for the service that it provides to the mainline carrier. The percent of jet fuel costs that are hedged and the use of fuel pass-through agreements are used as proxies by Carter, Rogers, and Simkins (2006). This proxy is from the airline's 10-K filing over the period 1994 to 2006.

Table IX reports the summary statistics used in this chapter.

TABLE IX
Summary Statistics

Table IX reports the mean, median, standard deviation, minimum and maximum for the following variables from 1994 – 2006: The Aircraft Dispersion Index, Fleet Age, Percent of Fleet Leased, Percent of Next Years Jet Fuel Hedged, Commuters, and an indicator for whether the airline has a Fuel Purchase Agreement (FuelPass), Capacity Agreement, or whether the airline is a regional carrier are obtained from the airlines 10-K's. All other variables are obtained from COMPUSTAT.

Variables	Mean	Median	Min	Max	Std Dev
Tobin's Q	0.9542	0.7815	0.0145	3.9752	0.5684
Ln(Total Assets)	6.9943	6.6746	2.6207	10.3994	1.9373
Dividend Yield	0.1571	0.0000	0.0000	5.0000	0.5551
Cash Flow / Sales	0.0448	0.0714	-1.1692	1.2287	0.1470
Capital Expenditure / Sales	0.1243	0.0778	-0.0095	2.2333	0.1845
Long-term Debt to Assets	0.2790	0.2757	0.0000	1.3005	0.1961
Z Score	1.9829	1.6945	-4.7181	7.3858	1.7552
Cash / Sales	0.1733	0.1445	0.0000	0.6830	0.1290
Next Years Percent of Fuel Hedge	0.1317	0.0000	0.0000	0.9600	0.2213
Fuel Pass-through Agreement	0.2270	0.0000	0.0000	1.0000	0.4196
Exchange Rate Derivatives	0.2366	0.0000	0.0000	1.0000	0.4257
Interest Rate Derivatives	0.2903	0.0000	0.0000	1.0000	0.4547
Aircraft Dispersion Index	0.5326	0.5946	0.0000	0.8768	0.2792
Ln(Fleet Age)	2.1486	2.1972	0.0000	3.3322	0.6264
Percent of Fleet Leased	0.6577	0.6940	0.0000	1.0000	0.2465
Regional Airline	0.3010	0.0000	0.0000	1.0000	0.4595
Capacity Purchase Agreements	0.1973	0.0000	0.0000	1.0000	0.3986
Commuters	0.2145	0.0000	0.0000	1.0000	0.3129
Annual Average Price of Fuel	84.0980	68.6959	40.2688	192.2859	47.8910
Carryforward / Carryback Dummy	0.3110	0.0000	0.0000	1.0000	0.4637

3.4 Model

3.4.a Complements vs. Substitutes

This chapter uses a model similar to that of Allayannis, Ihrig, and Weston (2001) to test whether operational and financial hedges are complements or substitutes. The model regresses the airlines' use of financial derivatives against the three operational hedges. More formally the model is defined as:

$$Hedge_{i,t} = \alpha_0 + \beta_{diversity}(\text{Fleet Diversity}_{i,t}) + \beta_{age}(Age_{i,t}) + \beta_{lease}(\text{Leased Fleet}_{i,t}) + \\ + \beta_{Dhedge}(OtherHedgeDummy_{i,t}) + \beta_{control}(\text{Control Variables}_{i,t}) + \varepsilon_{i,t}, \qquad (3.17)$$

Where:

Hedge is the percent of next year's fuel requirement hedged for airline "i" in period "t",

Fleet Diversity is the aircraft dispersion index in period "t',

Age is the logarithm of the average age of the airline's fleet,

Leased Fleet is the percent of the airline's fleet that is leased,

OtherHedgeDummy is one if the airline uses currency derivatives, interest rate derivatives or has entered into a fuel pass-through agreement, otherwise zero, and ε is the standard error term.

Table X briefly lists the predicted signs of the coefficients in the model.

The variable Hedge is defined as the airline's percentage of next year's fuel requirements hedged and is further referred to as hedge. An alternative fuel hedge variable (HedgDum) is defined as one if the airline hedges its fuel costs using derivatives, otherwise zero. The percent of fuel hedged is preferred since a dummy variable does not capture the degree to which a firm uses financial derivatives (Triki 2005). Furthermore, the decision to hedge conveys different information from the degree to which a firm engages in hedging (Haushalter 2000). For the above mentioned reasons, both the Hedge and the HedgDum variables are used to measure the airlines' financial hedging activity.

TABLE X
Complements and Substitutes (Hypotheses)

Table X reports the predicted results of model 3.17. The model tests whether operational and financial hedges are complements or substitutes. The model is:

$$Hedge_{i,t} = \alpha_0 + \beta_{diversity}(\text{Fleet Diversity}_{i,t}) + \beta_{age}(\text{Age}_{i,t}) + \beta_{lease}(\text{Leased Fleet}_{i,t}) + \beta_{Dhedge}(\text{OtherHedgeDummy}_{i,t}) + \beta_{control}(\text{Control Variables}_{i,t}) + \varepsilon_{i,t}.$$

Where: *Hedge* is the percent of next year's fuel requirement hedged for airline "i" in period "t", *Fleet Diversity* is the aircraft dispersion index in period "t', *Age* is the logarithm of the average age of the airline's fleet, *Fleet Leased* is the percent of the airline's fleet that is leased, *OtherHedgeDummy* is one if the airline uses currency derivatives, interest rate derivatives or has entered into a fuel pass-through agreement, otherwise zero, and ε is the standard error term.

	Predicted Coefficient Signs		
Variables	Complements	Substitutes	Hedging Theory
Fleet Diversity	+	-	
Ln(Fleet Age) *(Age)*	-	+	
Leased Fleet	+	-	
Long Term Debt to Assets *(LTDA)*			+
Ln(Total Assets) *(Size)*			+
Dividend Yield *(DIV)*			+
Z Score			+
Cash Flow / Sales *(CFTS)*			-
Cash To Sales *(Cash)*			-
Tobin's Q			+
Dummy(Exchange, Interest, Fuel Pass) *(OtherHedgeDummy)*			+
Regional Airline *(REG)*			?
Capacity Purchase Agreements *(CAP)*			?
Commuter			?
Annual Average Price of Fuel *(AvgPrice)*			?
Carryforward / Carryback Dummy *(NOL)*			+

If airlines are using financial and operational hedges as complements, then a positive relationship exists between the diversity of the airlines' fleets and their use of financial derivatives ($\beta_{diversity}>0$). This relationship is expected if airlines use the diversity of their fleet to hedge against the uncertainty in long-term fuel price fluctuations, against which financial derivatives provide little protection. The financial derivatives are then used to protect against short-term price fluctuations (Carter, Pantzalis, and Simkins 2006). Conversely, a negative relationship suggests that operational and financial hedges are substitutes ($\beta_{diversity}$<0). As with the diversity of the fleet, a positive (negative) relationship between the percent of the airline's fleet which is leased and the use of financial derivatives suggests that the two types are complements (substitutes).

A positive coefficient for the age of an airline's fleet (β_{age}>0) suggests that operational and financial hedges are substitutes. An airline with an older fleet has greater exposure to fuel prices and uses financial derivatives to lower this risk. Similarly, an airline with a newer fleet has lower exposure to fuel costs and has less incentive to hedge its fuel risk with financial derivatives. A negative relationship between the age of an airline's fleet and its use of financial derivatives suggests that operational and financial hedges are complements (β_{age}<0).

The OtherHedgeDummy variable is an indicator for whether the airline uses any other type of financial contract to manage its risk. The OtherHedgeDummy is 1 if the airline uses currency derivatives or interest rate derivatives or has a fuel pass-through agreement, otherwise 0. This variable is included to control for the relationships which exist between the airline's fleet and its use of financial derivatives. For instance, airlines with international operations are more likely to use both fuel and currency derivatives. Furthermore, these airlines are more likely to operate a diverse fleet, due to their greater flight distances. Thus, exclusion of this variable will cause the diversity variable to be biased.

The other control variables are the logarithm of the airline's total assets (Size), Long Term Debt Ratio (LTDA), Dividend Yield (DIV), Z-Score, Cash Flow to Sales (CFTS), Cash to Sales (Cash), Logarithm of Tobin's Q, Capital Expenditures to Sales (CAPTS), and a Net Operating Loss Carryforward and Carryback dummy variable (NOL). These variables are from COMPUSTAT. The dummy variable for whether the airline is a regional airline (REG) and the Commuter variable are gathered from the airlines' 10-K filings. The annual average price of jet fuel (AvgPrice) is from the Department of Energy and is the average of the daily Gulf Coast fuel price per year. The variable Size is used to control for the fact that larger firms tend to hedge (Nance, Smith, and Smithson 1993).

The variable LTDA is included in the model to control for the fact that hedging theory suggests that firms hedge to increase their debt capacity by reducing their chances of financial distress (Graham and Rogers 2002; Smith and Stulz 1985). Furthermore, there is a positive relationship between the extent to which a firm leases its assets and its use of debt (Ang and Peterson 1984). The Z-Score variable is included because firms near financial distress tend not to hedge so they might exploit any upside potential at the bondholders' expense (Stulz 1996). Outliers of the Z-Score at the first and ninety-ninth percentiles are removed from the sample this because Hawaiian Airlines reported a Z-Score of -80.6 and -71.33 in 2003 and 2004 respectively. The next lowest Z-Score is -6.17. Nance, Smith, and Smithson (1993) contend that firms with higher dividends have a greater incentive to hedge as a way to avoid financial distress. Furthermore, firms with greater cash flow and higher cash levels are less likely to fall under financial distress and thus have less incentive to hedge.

The logarithm of Tobin's Q and the CAPTS variables are proxies for a firm's growth potential, as firms will protect their future growth options through hedging. A dummy variable for whether the airline is a regional carrier (REG) controls for differences between mainline and regional carriers. The REG variable is coded as one if the airline provides service to a mainline airline, otherwise zero[20]. The variable NOL is predicted to be positive, as hedging increases firm value when firms face convexity in their tax schedule.

Airlines which operate turbo-props typically have a diverse fleet. However, these short haul commuter aircraft do not provide the flexibility which a regional jet does. That is, turbo-props lack the nautical distance and fuel-efficiency that a regional jet offers and which allows regional jets to act as substitutes for larger aircraft. Thus, the control variable Commuter which is the percent of an airline's fleet that is turbo-props is added to the model.

Many mainline airlines have entered into capacity purchase agreements with regional carriers. Under these contracts, the mainline airline is responsible for revenue, fuel costs, and scheduling. In return, the regional airline is guaranteed a set profit margin plus a performance bonus. Under some of these contracts, the mainline airline subleases aircraft to the regional carrier for the duration of the contract. Under these types of contracts, the mainline airline benefits from the flexibility a diverse fleet offers without actually operating one. Thus, the control variable CAP is included in the model which is coded as 1 if the mainline airline has entered into a capacity purchase agreement, otherwise 0.

[20] Alaska Airlines is not coded as a regional airline.

As the price of fuel rises, airlines will exercise their options by increasing the use of their smaller and/or more fuel-efficient aircraft. Also, there is a greater probability airlines will upgrade to a newer fuel-efficient fleet when fuel prices are high. To control for this relationship and any other relationship between the price of fuel and an airline's tendency to hedge, the AvgPrice variable is included in the model.

3.4.b Hedging and Firm Value

To test whether the use of operational and financial hedges increases the value of the firm, I use a model similar to that proposed by Allayannis, Ihrig, and Weston (2001). The model regresses Tobin's Q against the operational and financial proxies and their products. More formally, the model is:

$$\begin{aligned} \text{Log(Tobin's } Q_{i,t}) = \alpha &+ \beta_{hedge} * Hedge_{i,t} \\ &+ (\beta_{diversity} + \beta_{diversity/hedge} Hedge_{i,t}) * (\text{Fleet Diversity}_{i,t}) \\ &+ (\beta_{age} + \beta_{age/hedge} Hedge_{i,t}) * \beta_{age}(Age_{i,t}) \\ &+ \beta_{leases}(\text{Leased Fleet}_{i,t}) + \beta_{fuelpass}(FuelPass_{i,t}) \\ &+ \beta_{der\_FX}(Der\_FX_{i,t}) + \beta_{Der\_IR}(Der\_IR_{i,t}) \\ &+ \beta_{control}(Control\_Variables_{i,t}) + \varepsilon_{i,t}. \end{aligned} \tag{3.18}$$

where:

Hedge is the percent of next year's fuel requirement hedged for airline "i" in period "t",

Fleet Diversity is the aircraft dispersion index in period "t',

Age is the logarithm of the average age of the airline's fleet,

Leased Fleet is the percent of the airline's fleet that is leased,

FuelPass indicates whether the airline has entered into a fuel pass through agreement,

Der_FX and *Der_IR* indicate whether the airline uses currency or interest rate derivatives respectively, and ε is the standard error term.

The dependent variable is Tobin's Q, defined as the market value of the firm divided by its replacement cost, is used to measure the value of the firm. An approximation for Tobin's Q is used, as the true one is impossible to calculate. The calculation of the Tobin's Q is:

$$Q = \left(\frac{MVE + PS + BVINV + LTDBET + CL - CA}{TA} \right) \tag{3.19}$$

where MVE is the market value of the firm; PS is the liquidation value of preferred stock; BVINV is the book value of inventory; LTDEBT is the book value of the firm's long term debt; CL and CA are the book value of the firm's current liabilities and current assets respectively; and TA is the book value of the firm's total assets (Chung and Pruitt 1994; DaDalt, Donaldson, and Garner 2003). This approach to calculating Tobin's Q was proposed by Chung and Pruitt (1994) and is simpler than the one proposed by Perfect and Wiles (1994). Perfect and Wiles (1994) method would reduce the size of the sample to an unacceptable level (Carter, Rogers, and Simkins 2006) , so Chung and Pruitt's (1994) proxy is used for Tobin's Q.

Table XI briefly lays out the predicted signs of the coefficients of the above model and the hypotheses. The hypotheses are:

H_1: Financial hedges increase the value of the airline ($\beta_{hedge} > 0$, $\beta_{fuelpass} > 0$, $\beta_{Der_fx} > 0$and $\beta_{Der\_IR} > 0$). Hedge, FuelPass, Der_FX and Der_IR proxy for the firm's hedging activity. The predicted sign of the hedging variables is positive since hedging increases the firm's value. The variables Der_FX and Der_IR are codes as one if the airline uses foreign exchange rate derivatives (Der_FX) or interest rate derivatives (Der_IR), otherwise the variables are codes as zero.

H_2: Operational Hedges are value-enhancing to an airline ($\beta_{diversity}$ >0, β_{age} <0, β_{Fleet_Leased} > 0). The prediction is that a diverse fleet / leased fleet provides an airline an operational hedge which increases the airline's value. A newer fuel-efficient fleet reduces an airline's exposure to fuel prices and thus enhances the airline's value.

*H_3: A comprehensive hedging program that uses **both** operational and financial hedges increases an airline's value ($\beta_{diversity/hedge}$>0, $\beta_{age/hedge}$<0).* The prediction is that using operational and financial hedges together provides the airline additional value beyond the value gained by solely using an operational or financial hedge. In the case of a diverse fleet, increasing the diversity of the fleet by 0.10 increases the effectiveness of the financial hedge by 0.10*$\beta_{diversity/hedge}$[21]. In the case of the age of the fleet, reducing the age of an airline's fleet by one divided the age of its fleet increases the effectiveness of the financial hedge by $\beta_{age/hedge}$. A positive $\beta_{age/hedge}$, suggests that using financial derivates offsets the additional exposure gained by using a less fuel-efficient fleet and thus increases the value of the airline.

The control variables that are from COMPUSTAT that are similar to those proposed by Allayannis and Weston (2001) and Carter, Rogers, and Simkins (2006), are the logarithm of assets (Size), dividend yield (DIV), cash flow to sales (CFTS), cash to sales (CTS), long term debt ratio (LTDA), capital expenditures to sales CAPTS, and Z-Score. The control variables from the airlines' 10-K filings are the regional airline dummy variable (REG), capacity purchase agreement dummy variable (CAP), and the percent of the fleet which is turbo-prop (Commuter). The annual average price of fuel (AvgPrice) is from the Department of Energy.

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[21] Restated another way, increasing the percent of fuel hedged by 10% increases the effectiveness of a diverse fleet by .10*$\beta_{diversity/hedge}$

The variable Size controls for the fact that larger firms are more likely to use financial derivatives. The variable DIV controls for a firm's access to the capital markets. The predicted sign of DIV is ambiguous since firms that pay dividends might forgo profitable projects, which causes their Tobin's Q to be higher. However, firms which pay dividends due to their excess cash flow will have fewer forgone investments, causing their Tobin's Q to be lower. The variable CFTS variable measures the firm's profitability. Profitable firms have higher Tobin's Q ratios. The variable CAPTS controls for the fact that firms with greater growth prospects have higher Tobin's Q.

The variable LTDA controls for any relationship between a firm's value and the degree to which it is leveraged. The Z-Score represents the fact that firms near financial distress are more likely to incur deadweight costs associated with bankruptcy. Z-Scores in the first or the ninety-ninth percentile are removed.

The variable CAP controls for the fact that capacity purchase agreements are similar to operating a diverse fleet. The inclusion of the variable Commuter controls for the fact that turbo-props are incapable of acting as a substitute for larger aircraft. The expected sign for the coefficient of the variable AvgPrice is negative as the value of a firm declines as its input prices rise.

TABLE XI

Hedging and Airline Value (Hypotheses)

Table XI reports the predicted results of model 3.18. The model tests whether operational and financial hedges are value enhancing to the airlines. The model is:

$$\text{Log(Tobin's } Q_{i,t}) = \alpha + \beta_{hedge}*\text{Hedge}_{i,t}$$
$$+ (\beta_{diversity} + \beta_{diversity/hedge}\text{Hedge}_{i,t}) *(\text{Fleet Diversity}_{i,t})$$
$$+ (\beta_{age} + \beta_{age/hedge}\text{Hedge}_{i,t})*\beta_{age}(\text{Age}_{i,t})$$
$$+ \beta_{leases}(\text{Leased Fleet}_{i,t}) + \beta_{fuelpass}(\text{FuelPass}_{i,t})$$
$$+ \beta_{der\_FX}(\text{Der\_FX}_{i,t}) + \beta_{Der\_IR}(\text{Der\_IR}_{i,t})$$
$$+ \beta_{control}(\text{Control Variables}_{i,t}) + \varepsilon_{i,t}.$$

Where *Tobin's Q* is Chung and Pruitt's (1994) proxy for Tobin's Q, *Hedge* is the percent of next year's fuel requirement hedged for airline "i" in period "t", *Fleet Diversity* is the aircraft dispersion index in period "t', *Age* is the logarithm of the average age of the airline's fleet, *Fleet Leased* is the percent of the airline's fleet that is leased, *FuelPass* indicates whether the airline has entered into a fuel pass through agreement, *Der_FX* and *Der_IR* indicate whether the airline uses currency or interest rate derivatives respectively, and ε is the standard error term.

	Predicted values	Hypothesis
Percent of Next Year's Fuel Hedged *(Hedge)*	+	**Financial Derivatives increase firm value**
FuelPass	+	
Foreign Currency Derivative Dummy (*Der_FX)*	+	Financial Derivatives increase firm value
Interest Rate Derivative Dummy *(Der_IR)*	+	Financial Derivatives increase firm value
Aircraft Dispersion *(Fleet Diversity)*	+	**Operational Hedging increases firm value**
(Fleet Diversity)X (Hedge)	+	**Operational & Financial Hedging increase firm value**
Ln(Fleet Age) *(Age)*	-	**Operational Hedging increases firm value**
Ln(Fleet Age) X (Hedge)	-	**Operational & Financial Hedging increase firm value**
Leased Fleet	+	**Operational Hedging increases firm value**
Ln(Total Assets) *(Size)*	?	
Dividend Yield *(DIV)*	?	
Long Term Debt to Assets *(LTDA)*	?	
Cash Flow / Sales (CFTS)	+	
Capital Expenditures to Sales (CAPTS)	+	
Z-Score	+	
Cash To Sales *(Cash)*	?	
Regional Airline *(REG)*	?	
Capacity Purchases Agreements *(CAP)*	+	
Annual Average Price of Fuel *(AvgPrice)*	-	
Commuter	?	

3.5 Results

Table XII reports the results for whether operational and financial hedges are complements or substitutes. Table XIII and Table XIV presents the results for whether operational and financial hedges are value enhancing to the airline.

3.5.a Complements vs. Substitutes

Table XII reports the results from model 3.17. Model 3.17 regresses the airline's financial hedging activity against the different operational hedges. Table X reports the predicted hypotheses Panel A of Table XII reports the results of the base model 3.17 while Panel B reports the results using different combinations of the operational hedges. Column (1) of Table XII Panel A is a Tobit random effects model with the dependent variable as the percent hedged (Hedge). Columns (2) use a Logit random effects model with the dependent variable defined as is one if the airline's percent hedged is greater than zero, otherwise zero (HedgDum). All columns of Panel B use a Tobit random effects model with the dependent variable as Hedge. Each model of Panel A and B includes a year dummy variable, which is not reported.

The coefficient for Fleet Diversity is positive and significant at the 10% level in five of the columns from both Panel A and B. That is, airlines that operate a diversity fleet are more likely to use financial derivatives to hedge fuel prices. A particular counter argument of the above result is that a diverse fleet increases the risk exposure to an airline and financial hedges are used to offset this increased risk. However, Chapter 2 shows that the diversity of the airline's fleet is an effective operational hedge against jet fuel prices. Thus, the evidence from Chapter 2 suggests that the diversity of an airline's fleet and the uses of financial hedges are complements, rather than the use of financial derivatives being a means to offset any additional fuel risk associated with operating a diverse fleet.

There is no significant relationship between the fuel-efficiency of the fleet (Age) and the degree to which an airline hedges. Similarly, there is no significant relationship between the percent of the fleet which is leased (Leased Fleet) and the degree to which an airline hedges. The result that the estimated coefficient for Leased Fleet is statistically insignificant is surprising as Chapter 2 found evidence that leasing an airline's fleet increases the airline's exposure to fuel prices. This finding leads to the expectation that airlines which lease their fleet will use financial hedges to offset the increased risk exposure associated with its leasing contracts.

TABLE XII
Complements and Substitutes

Panel A reports the results of model (3.17)
$Hedge_{i,t} = \alpha_0 + \beta_{diversity}(Fleet\ Diversity_{i,t}) + \beta_{age}(Age_{i,t})$
$+ \beta_{leases}(Leased\ Fleet_{i,t}) + \beta_{Dhedge}(OtherHedgeDummy_{i,t})$
$+ \beta_{control}(Control\ Variables_{i,t}) + \varepsilon_{i,t}.$
Column (1) dependent variable (Hedge) is the Percent of Next Years Fuel Hedged. The regression is a tobit–random effects model. Column (2) uses a logit – random effects model. Column three's dependent variable (HedgDum) is 1 if the airline's percent of fuel hedged is greater than zero, otherwise 0. A year dummy is included in each model but not reported. See Table X for the description of the variable names.

Panel A		
	Column (1) Tobit / Random Effects	Column (2) Logit / Random Effect
	Hedge	HedgDum
Constant	**-1.1393** (0.5230)**	-4.8429 (5.0705)
Fleet Diversity	**0.3642* (0.2079)**	**4.9410* (2.5311)**
Age	-0.0433 (0.0715)	-0.4105 (0.8538)
Leased Fleet	-0.0963 (0.2110)	-1.2147 (2.1801)
LTDA	0.0103 (0.2641)	0.2748 (2.6987)
Size	**0.0889** (0.0425)**	0.1300 (0.4380)
DIV	-0.2470 (0.1645)	-2.2426 (2.0062)
Z-Score	0.0349 (0.0496)	-0.5835 (0.5524)
CFTS	0.0446 (0.1971)	**14.4933** (5.7243)**
Cash	0.0964 (0.3173)	5.2970 (3.9864)
Log of Tobin's Q	**0.1650* (0.0935)**	**1.7809* (1.0043)**
CAPTS	0.1674 (0.2454)	0.9830 (3.2712)
Dummy(Exchange, Interest, Fuel Pass)	**0.1542** (0.0762)**	0.5381 (0.8837)
REG	**-0.4355** (0.1804)**	**-7.4492*** (2.5428)**
CAP	**-0.1443** (0.0712)**	-0.0975 (0.8134)
Commuter	-0.1473 (0.2213)	3.2660 (2.4223)
AvgPrice	**0.0028*** (0.0011)**	**0.0387** (0.0170)**
NOL	-0.0034 (0.0680)	-0.1257 (0.7677)
Number of observations	228	228
# Censored	110	
Log Likelihood	-58.402	-84.076

* 10% significance
** 5% significance
*** 1% significance

TABLE XII (Cont.)
Complements and Substitutes with Individual Operational Hedges

Panel B reports the results of model (3.17)
$Hedge_{i,t} = \alpha_0 + \beta_{diversity}(Fleet\ Diversity_{i,t}) + \beta_{age}(Age_{i,t}) + \beta_{lease}(Leased\ Fleet_{i,t}) + \beta_{Dhedge}(OtherHedgeDummy_{i,t}) + \beta_{control}(Control\ Variables_{i,t}) + \varepsilon_{i,t}$.
The regression is a tobit–random effects model. The model includes a year dummy variable which is not reported. Columns 1-5 are different combinations of the operational hedges. See Table X for the description of the variable names.

Panel B

	Column (1) Fleet Diversity	Column (2) Age	Column (3) Leased Fleet	Column (4) Fleet Diversity & Leased Fleet	Column (5) Age & Leased Fleet	Column (6) Fleet Diversity & Age
Constant	**-1.4919*** (0.3449)**	**-1.2741*** (0.3953)**	**-1.4089*** (0.4043)**	**-1.3785*** (0.4184)**	**-1.3264*** (0.5023)**	**-1.2929*** (0.4097)**
Fleet Diversity	**0.3451* (0.1955)**			**0.3579* (0.1953)**		**0.3360* (0.1996)**
Age		-0.0052 (0.0594)			0.0009 (0.0664)	-0.0283 (0.0620)
Leased Fleet			0.0183 (0.1774)	-0.0470 (0.1837)	0.0344 (0.1957)	
LTDA	0.0642 (0.2283)	0.0541 (0.2458)	0.1003 (0.2312)	0.0349 (0.2408)	0.0584 (0.2505)	0.0389 (0.2591)
Size	**0.1061*** (0.0376)**	**0.1168*** (0.0354)**	**0.1266*** (0.0380)**	**0.1012** (0.0404)**	**0.1190*** (0.0389)**	**0.0987*** (0.0380)**
DIV	-0.2416 (0.1577)	-0.2731 (0.1776)	-0.2633 (0.1707)	-0.2399 (0.1594)	-0.2751 (0.1789)	-0.2531 (0.1657)
Z-Score	0.0323 (0.0403)	0.0160 (0.0449)	0.0183 (0.0380)	0.0347 (0.0409)	0.0161 (0.0460)	0.0294 (0.0489)
CFTS	0.0606 (0.1963)	0.0792 (0.1966)	0.0924 (0.1964)	0.0565 (0.1966)	0.0768 (0.1968)	0.0475 (0.1968)
Cash	0.1343 (0.3123)	0.0380 (0.3074)	0.0805 (0.3077)	0.1384 (0.3125)	0.0383 (0.3090)	0.1057 (0.3177)
Log of Tobin's Q	**0.1540* (0.0795)**	**0.1502* (0.0888)**	**0.1383* (0.0764)**	**0.1611** (0.0797)**	**0.1536* (0.0903)**	**0.1666* (0.0937)**
CAPTS	0.2543 (0.2313)	0.1282 (0.2303)	0.1609 (0.2291)	0.2357 (0.2326)	0.1432 (0.2434)	0.1956 (0.2365)
Dummy(Exchange, Interest, Fuel Pass)	**0.1553** (0.0754)**	**0.1708** (0.0748)**	**0.1720** (0.0753)**	**0.1540** (0.0762)**	**0.1722** (0.0751)**	**0.1583** (0.0755)**
REG	**-0.4660*** (0.1739)**	**-0.3943** (0.1706)**	**-0.4651*** (0.1691)**	**-0.4696*** (0.1724)**	**-0.3940** (0.1736)**	**-0.4191** (0.1790)**
CAP	**-0.1355* (0.0704)**	**-0.1489** (0.0703)**	**-0.1463** (0.0707)**	**-0.1456** (0.0713)**	**-0.1471** (0.0706)**	**-0.1455** (0.0711)**
Commuter	-0.0910 (0.2178)	-0.0228 (0.1986)	0.0230 (0.1977)	-0.1055 (0.2176)	-0.0181 (0.1996)	-0.1402 (0.2212)
Avg_Price	**0.0028*** (0.0010)**	**0.0026** (0.0010)**	**0.0025** (0.0011)**	**0.0027** (0.0011)**	**0.0026** (0.0010)**	**0.0027*** (0.0010)**
NOL	-0.0070 (0.0668)	-0.0025 (0.0668)	-0.0129 (0.0663)	-0.0130 (0.0672)	-0.0016 (0.0670)	-0.0009 (0.0678)
Number of observations	252	229	246	246	228	229
# Censored	134	111	128	128	110	111
Log Likelihood	-61.240	-60.162	-61.757	-59.968	-60.063	-58.594

* 10% significance
** 5% significance
*** 1% significance

The AvgPrice variable is significant in most models, at least at the 5% level. That is, airlines tend to increase their hedging activity as the price of fuel increases. This result is not surprising as Chapter 2 shows that an airline's exposure to fuel prices increases with the price of fuel. As predicted, larger airlines (Size), airlines which have greater growth potential (Logarithm of Tobin's Q), and airline that use financial hedges (OtherHedgeDummy) are more likely to hedge next year's fuel requirements. The other predicted values are insignificant.

3.5.b Hedging and Firm Value

Table XIII reports the results of model 3.18. Columns (1-4) include both the operational and financial hedges, while Column (5) excludes the operational hedges. Column (5) is included as a comparison with prior research. Column (1) reports the results using OLS with robust standard errors. Columns (2, 3, and 5) use FGLS to adjust for heteroskedasticity, while column (4) uses a fixed effects model with heteroskedastic robust standard errors. Each model includes a year dummy variable which is not reported.

Table XIV reports the results of model 3.18 using different combinations of the operational hedges. All models of Table XIV use FGLS. Panel A of Table XIV reports the result of model 3.18 using only the aircraft dispersion index (Fleet Diversity), while Panel B reports the results using only the Age variable. Panel C reports the result of model 3.18 with different combinations of the variables Fleet Diversity, Age, and Leased Fleet . The first column of Panel A and B includes all the operational hedges and is included as a comparison.

The results concerning the benefits to the airline for using financial hedges is mixed. The coefficient for Hedge is positive and significant in most models. However, the use of fuel pass-through agreements (FuelPass) significantly reduces the value of the airline, this result is significant in most models. For instance, Column (2) of Table XIII, the FuelPass coefficient is -0.3005 and significant at the 1% level. Using the mean Tobin's Q of 0.95, entering into a fuel pass-through agreement reduces the airline's Tobin's Q by about 0.29 (0.95*.30) or 30%. An argument for a negative FuelPass variable is that the variable proxies for regional airline carriers. However, the coefficient for regional airline (REG) is positive in most models and significant in the complete model of Column (2) of Table XIII, and Column (1) of Table XIV, Panel A. Further complicating the results concerning the benefits of hedging, the variable Der_IR is negative and significant in Columns (2 and 5) of Table XIII.

TABLE XIII
Hedging and Airline Value

The table reports the results of model (3.18)

$\text{Log(Tobin's } Q_{i,t}) = \alpha + \beta_{hedge}{*}\text{Hedge}_{i,t} + (\beta_{diversity} + \beta_{diversity/hedge}(\text{Hedge}_{i,t}))*(\text{Fleet Diversity}_{i,t})$
$+ (\beta_{leases} + \beta_{leases/hedge}(\text{Hedge}_{i,t}))*(\text{Leased Fleet}_{i,t}) + (\beta_{age} + \beta_{age/hedge}(\text{Hedge}_{i,t}))*\beta_{age}(\text{Age}_{i,t})$
$+ \beta_{fuelpass}(\text{FuelPass}_{i,t}) + \beta_{Der\_FX}(\text{Der\_FX}_{i,t}) + \beta_{Der\_IR}(\text{Der\_IR}_{i,t}) + \beta_{control}(\text{Control Variables}_{i,t}) + \varepsilon_{i,t}.$

Column (1) uses OLS with robust standard errors. Columns (2,3 and 5) use FGLS to control for heteroskedasticity. Column (4) uses fixed effects. Column three excludes foreign currency (Der_FX) and interest rate derivatives (IR_FX). Column (5) excludes the operational hedges. All models include a year dummy variable which are not reported. See Table XI for the description of the variable names. See Table XI for the description of the variable names.

	Column (1) OLS with Robust errors	Column (2) FGLS	Column (3) FGLS	Column (4) Fixed Effect	Column (5) FGLS
Constant	-0.7418	**-1.1325*** **	**-0.9809*** **	-1.3819	**-0.7257*** **
	(0.4547)	**(0.2790)**	**(0.2498)**	(1.0323)	**(0.1639)**
Size	-0.0065	0.0065	-0.0083	0.0809	**-0.0339** **
	(0.0288)	(0.0197)	(0.0160)	(0.1194)	**(0.0166)**
DIV	-0.0078	0.0057	-0.0023	0.0037	0.0185
	(0.0254)	(0.0225)	(0.0223)	(0.0327)	(0.0305)
LTDA	**1.3696*** **	**1.4983*** **	**1.4908*** **	**1.5107*** **	**1.5431*** **
	(0.2989)	**(0.1325)**	**(0.1214)**	**(0.4034)**	**(0.1261)**
CFTS	0.9239	**0.4583** **	**0.3792* **	**0.8174* **	**0.5503*** **
	(0.6162)	**(0.2127)**	**(0.2074)**	**(0.4519)**	**(0.2148)**
CAPTS	0.1309	**0.2714* **	**0.2440* **	0.1203	**0.3303** **
	(0.1876)	**(0.1428)**	**(0.1400)**	(0.2240)	**(0.1580)**
Z- Score	**0.2291*** **	**0.2699*** **	**0.2778*** **	**0.2109*** **	**0.2436*** **
	(0.0370)	**(0.0224)**	**(0.0220)**	**(0.0465)**	**(0.0206)**
Cash	-0.2299	**-0.3987** **	**-0.3934** **	-0.5169	-0.1127
	(0.2824)	**(0.1723)**	**(0.1669)**	(0.3707)	(0.1986)
Hedge	0.5075	**0.6566* **	**0.7417** **	-0.1300	**0.2486** **
	(0.4445)	**(0.3631)**	**(0.3534)**	(0.4707)	**(0.1037)**
FUELPASS	**-0.2899*** **	**-0.3005*** **	**-0.2833*** **	**0.6326* **	**-0.2225*** **
	(0.0655)	**(0.0611)**	**(0.0593)**	**(0.3826)**	**(0.0646)**
Der_FX	-0.0566	-0.0096		-0.0300	-0.0876
	(0.0798)	(0.0557)		(0.1144)	(0.0614)
Der_IR	-0.0099	**-0.0825** **		-0.0536	**-0.0811* **
	(0.0580)	**(0.0391)**		(0.0749)	**(0.0490)**
*Fleet Diversity	**-0.4565*** **	**-0.3237*** **	**-0.3403*** **	**-0.8111** **	
	(0.1581)	**(0.0846)**	**(0.0797)**	**(0.3427)**	
*Fleet Diversity (Hedge)	-0.2088	**-0.3442** **	**-0.3811** **	-0.3867	
	(0.2461)	**(0.1711)**	**(0.1689)**	(0.2780)	
Age	0.1004	**0.1313*** **	**0.1265*** **	0.0452	
	(0.0752)	**(0.0479)**	**(0.0477)**	(0.1212)	
(Age) X (Hedge)	-0.1045	-0.1558	-0.2011	0.2482	
	(0.2068)	(0.1690)	(0.1643)	(0.2475)	
Leased Fleet	-0.2101	-0.1530	**-0.2144** **	-0.0899	
	(0.1909)	(0.1108)	**(0.1083)**	(0.3407)	
REG	0.1432	**0.1829* **	**0.1342* **	0.1570	-0.1102
	(0.1225)	**(0.1012)**	**(0.0801)**	(0.5405)	(0.0673)
CAP	-0.0273	-0.0565	-0.0317	-0.0403	
	(0.0671)	(0.0542)	(0.0522)	(0.0766)	
AvgPrice	-0.0015	-0.0007	-0.0008	-0.0015	-0.0011
	(0.0011)	(0.0007)	(0.0006)	(0.0015)	(0.0007)
Commuter	0.0055	-0.0360		0.5326	
	(0.1436)	(0.1130)		(0.3986)	
Number of observations	236	227	227	227	258
F-Statistic / Wald	17.19	1065.31	1121.14	21.52	531.74
R-Square	0.6764				

* 10% significance (two-sided test)

** 5% significance (two-sided test)

*** 1% significance (two-sided test)

TABLE XIV
Hedging and Airline Value (Fleet Diversity)

Panel A reports the results of model (3.18)

$$\text{Log(Tobin's } Q_{i,t}) = \alpha + \beta_{hedge}{*}Hedge_{i,t} + (\beta_{diversity} + \beta_{diversity/hedge}(Hedge_{i,t})){*}(\text{Fleet Diversity}_{i,t}) + (\beta_{leases} + \beta_{leases/hedge}(Hedge_{i,t})){*}(\text{Leased Fleet}_{i,t}) + (\beta_{age} + \beta_{age/hedge}(Hedge_{i,t})){*}\beta_{age}(Age_{i,t}) + \beta_{fuelpass}(FuelPass_{i,t}) + \beta_{Der\_FX}(Der\_FX_{i,t}) + \beta_{Der\_IR}(Der\_IR_{i,t}) + \beta_{control}(\text{Control Variables}_{i,t}) + \varepsilon_{i,t}.$$

Columns one through five use FGLS to control for heteroskedasticity. Columns (2-5) is model 3.18 with the inclusion of the Aircraft Dispersion index (Fleet Diversity) and different combinations of the operational hedges. Column (1) includes all operational hedges and is included as a comparison. All models include a year dummy variable which are not reported. See Table XI for the description of the variable names.

Panel A					
	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)
	Complete Model	Fleet Diversity	Fleet Diversity X Hedge	Fleet Diversity & Lease Fleet	Fleet Diversity X Hedge & Leased Fleet
Constant	**-0.9809*** (0.2498)**	**-0.4530*** (0.1549)**	**-0.4888*** (0.1492)**	**-0.3095* (0.1881)**	**-0.3967** (0.1845)**
SIZE	-0.0083 (0.0160)	-0.0110 (0.0144)	-0.0191 (0.0141)	-0.0239 (0.0167)	-0.0258 (0.0162)
DIV	-0.0023 (0.0223)	-0.0025 (0.0363)	-0.0008 (0.0346)	-0.0082 (0.0389)	-0.0057 (0.0374)
LTDA	**1.4908*** (0.1214)**	**1.4373*** (0.1123)**	**1.4835*** (0.1105)**	**1.4158*** (0.1147)**	**1.4667*** (0.1132)**
CFTS	**0.3792* (0.2074)**	**0.4710** (0.2130)**	**0.4690** (0.2103)**	**0.4802** (0.2155)**	**0.4841** (0.2125)**
CAPTS	**0.2440* (0.1400)**	**0.2156** (0.1097)**	**0.2144** (0.1082)**	0.1690 (0.1089)	**0.1860* (0.1077)**
Z-Score	**0.2778*** (0.0220)**	**0.2112*** (0.0228)**	**0.2057*** (0.0222)**	**0.2172*** (0.0238)**	**0.2080*** (0.0234)**
Cast	**-0.3934** (0.1669)**	-0.1879 (0.1787)	-0.1455 (0.1734)	-0.1926 (0.1774)	-0.1546 (0.1732)
Hedge	**0.7417** (0.3534)**	**0.3053*** (0.0864)**	**0.5206*** (0.0997)**	**0.2343*** (0.0892)**	**0.4382*** (0.1065)**
FUELPASS	**-0.2833*** (0.0593)**	**-0.3148*** (0.0715)**	**-0.2710*** (0.0701)**	**-0.3206*** (0.0755)**	**-0.2834*** (0.0745)**
Fleet Diversity	**-0.3403*** (0.0797)**	**-0.5735*** (0.0750)**	**-0.4173*** (0.0844)**	**-0.5179*** (0.0805)**	**-0.3979*** (0.0871)**
(Fleet Diversity)X (Hedge)	**-0.3811** (0.1689)**		**-0.5984*** (0.1815)**		**-0.5529*** (0.1792)**
Age	**0.1265*** (0.0477)**				
AgeX (Hedge)	-0.2011 (0.1643)				
Leased Fleet	**-0.2144** (0.1083)**			**-0.2094** (0.1037)**	-0.1455 (0.1034)
REG	**0.1342* (0.0801)**	0.0711 (0.0767)	0.0404 (0.0758)	0.0670 (0.0805)	0.0475 (0.0793)
CAP	-0.0317 (0.0522)	-0.0398 (0.0540)	-0.0227 (0.0535)	-0.0493 (0.0531)	-0.0331 (0.0527)
AvgPrice	-0.0008 (0.0006)	**-0.0020*** (0.0007)**	**-0.0020*** (0.0007)**	**-0.0015** (0.0007)**	**-0.0016** (0.0007)**
Number of observations	227	248	248	242	242
F-Statistic / Chi2	1121.14	813.82	906.50	856.45	933.84

* 10% significance (two-sided test)

** 5% significance (two-sided test)

*** 1% significance (two-sided test)

TABLE XIV (Cont.)
Hedging and Airline Value (Age)

Panel B reports the results of model (3.18)

$$\text{Log(Tobin's } Q_{i,t}) = \alpha + \beta_{hedge}*\text{Hedge}_{i,t} + (\beta_{diversity} + \beta_{diversity/hedge}(\text{Hedge}_{i,t}))*(\text{Fleet Diversity}_{i,t}) + (\beta_{leases} + \beta_{leases/hedge}(\text{Hedge}_{i,t}))*(\text{Leased Fleet}_{i,t}) + (\beta_{age} + \beta_{age/hedge}(\text{Hedge}_{i,t}))*\beta_{age}(\text{Age}_{i,t}) + \beta_{fuelpass}(\text{FuelPass}_{i,t}) + \beta_{Der\_FX}(\text{Der\_FX}_{i,t}) + \beta_{Der\_IR}(\text{Der\_IR}_{i,t}) + \beta_{control}(\text{Control Variables}_{i,t}) + \varepsilon_{i,t}.$$

Columns (1-5) use FGLS to control for heteroskedasticity. Columns (2-5) is model 3.18 with the inclusion of the Age variable and different combinations of the operational hedges. Column (1) includes all operational hedges and is included as a comparison. All models include a year dummy variable which are not reported. See Table XI for the description of the variable names.

Panel B

	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)
	All OP's	Age of Fleet	Age & HedgeXAge	Age & Leased Fleet	Age, HedgeXAge & Leased Fleet
Constant	**-0.9809*** (0.2498)**	**-1.2522*** (0.2226)**	**-1.3515*** (0.2323)**	-0.3266 (0.2877)	-0.4381 (0.2959)
Size	-0.0083 (0.0160)	-0.0213 (0.0147)	-0.0177 (0.0148)	**-0.0685*** (0.0164)**	**-0.0636*** (0.0165)**
DIV	-0.0023 (0.0223)	0.0266 (0.0362)	0.0293 (0.0361)	0.0001 (0.0296)	0.0008 (0.0290)
LTDA	**1.4908*** (0.1214)**	**1.5702*** (0.1297)**	**1.5590*** (0.1291)**	**1.4128*** (0.1282)**	**1.3993*** (0.1279)**
CFTS	**0.3792* (0.2074)**	0.3287 (0.2090)	0.3369 (0.2096)	**0.4336** (0.2104)**	**0.4512** (0.2121)**
CAPTS	**0.2440* (0.1400)**	**0.4570*** (0.1573)**	**0.4283*** (0.1574)**	**0.2863* (0.1553)**	0.2510 (0.1574)
Z-Score	**0.2778*** (0.0220)**	**0.3151*** (0.0213)**	**0.3158*** (0.0213)**	**0.3254*** (0.0202)**	**0.3256*** (0.0203)**
Cash	**-0.3934** (0.1669)**	**-0.3710* (0.2054)**	**-0.3670* (0.2031)**	**-0.4122** (0.1897)**	**-0.4297** (0.1891)**
Hedge	**0.7417** (0.3534)**	**0.2446** (0.0981)**	**0.7234* (0.4068)**	**0.2102** (0.0907)**	**0.7008* (0.3864)**
FUELPASS	**-0.2833*** (0.0593)**	**-0.2553*** (0.0649)**	**-0.2658*** (0.0654)**	**-0.2174*** (0.0584)**	**-0.2255*** (0.0590)**
Fleet Diversity	**-0.3403*** (0.0797)**				
(Fleet Diversity)X (Hedge)	**-0.3811** (0.1689)**				
Age	**0.1265*** (0.0477)**	**0.0768* (0.0457)**	**0.1097** (0.0515)**	0.0081 (0.0482)	0.0435 (0.0544)
(Age) X (Hedge)	-0.2011 (0.1643)		-0.2250 (0.1864)		-0.2328 (0.1786)
Leased Fleet	**-0.2144** (0.1083)**			**-0.5445*** (0.1043)**	**-0.5446*** (0.1056)**
REG	**0.1342* (0.0801)**	-0.0161 (0.0781)	0.0134 (0.0809)	-0.1124 (0.0729)	-0.0736 (0.0777)
CAP	-0.0317 (0.0522)	-0.0902 (0.0568)	-0.0851 (0.0566)	-0.0252 (0.0562)	-0.0240 (0.0561)
AvgPrice	-0.0008 (0.0006)	-0.0001 (0.0008)	-0.0002 (0.0008)	-0.0002 (0.0007)	-0.0002 (0.0007)
Number of observations	227	228	228	227	227
F-Statistic / Chi2	1121.14	888.89	871.95	1071.43	1008.19

* 10% significance (two-sided test)
** 5% significance (two-sided test)
*** 1% significance (two-sided test)

TABLE XIV (Cont.)
Hedging and Airline Value (Leased Fleet)

Panel C reports the results of model (3.18)

$\text{Log(Tobin's } Q_{i,t}) = \alpha + \beta_{hedge}{*}Hedge_{i,t} + (\beta_{diversity} + \beta_{diversity/hedge}(Hedge_{i,t})){*}(\text{Fleet Diversity}_{i,t})$
$+ (\beta_{leases} + \beta_{leases/hedge}(Hedge_{i,t})){*}(\text{Leased Fleet}_{i,t}) + (\beta_{age} + \beta_{age/hedge}(Hedge_{i,t})){*}\beta_{age}(Age_{i,t})$
$+ \beta_{fuelpass}(FuelPass_{i,t}) + \beta_{Der\_FX}(Der\_FX_{i,t}) + \beta_{Der\_IR}(Der\_IR_{i,t}) + \beta_{control}(\text{Control Variables}_{i,t}) + \varepsilon_{i,t}.$

Columns (1-6)use FGLS to control for heteroskedasticity. Columns (1-6) are model 3.18 with different combinations of the operational hedges. All models include a year dummy variable which are not reported. See Table XI for the description of the variable names.

Panel C						
	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)	Column (6)
	Fleet Diversity, Age	Fleet Diversity, HedgeX(Fleet Diversity) & Age	Fleet Diversity, Age & HedgeXAge	Fleet Diversity, Age Leased_Fleet	Aircraft Dispersion, HedgeXFleet Diversity, Age Leased_Fleet	Fleet Diversity, Age, HedgeXAge & Leased_Fleet
Constant	**-1.2232*** (0.1870)**	**-1.2067*** (0.1865)**	**-1.2986*** (0.1919)**	**-0.8539*** (0.2476)**	**-0.8989*** (0.2460)**	**-0.9450*** (0.2504)**
Size	0.0096 (0.0131)	0.0045 (0.0130)	0.0133 (0.0132)	-0.0117 (0.0162)	-0.0120 (0.0160)	-0.0074 (0.0162)
DIV	0.0012 (0.0223)	0.0021 (0.0208)	0.0030 (0.0228)	-0.0061 (0.0234)	-0.0036 (0.0218)	-0.0045 (0.0240)
LTDA	**1.5270*** (0.1200)**	**1.5497*** (0.1178)**	**1.5071*** (0.1206)**	**1.4864*** (0.1224)**	**1.5130*** (0.1206)**	**1.4611*** (0.1231)**
CFTS	0.3315 (0.2053)	**0.3527* (0.2037)**	**0.3398* (0.2059)**	**0.3574* (0.2083)**	**0.3684* (0.2068)**	**0.3680* (0.2091)**
CAPTS	**0.3256** (0.1351)**	**0.3309** (0.1335)**	**0.2988** (0.1363)**	**0.2521* (0.1381)**	**0.2762** (0.1379)**	0.2189 (0.1401)
Z-Score	**0.2797*** (0.0213)**	**0.2720*** (0.0209)**	**0.2804*** (0.0212)**	**0.2848*** (0.0222)**	**0.2757*** (0.0221)**	**0.2859*** (0.0221)**
Cash	**-0.4634*** (0.1732)**	**-0.4122** (0.1686)**	**-0.4548*** (0.1724)**	**-0.4305** (0.1708)**	**-0.3960** (0.1684)**	**-0.4259** (0.1699)**
Hedge	**0.2420*** (0.0781)**	**0.3819*** (0.0908)**	**0.6848* (0.3535)**	**0.1932** (0.0806)**	**0.3253*** (0.0965)**	**0.6857* (0.3533)**
FUELPASS	**-0.3069*** (0.0571)**	**-0.2702*** (0.0567)**	**-0.3226*** (0.0582)**	**-0.2953*** (0.0588)**	**-0.2668*** (0.0581)**	**-0.3132*** (0.0601)**
Fleet Diversity	**-0.5110*** (0.0640)**	**-0.3983*** (0.0752)**	**-0.5113*** (0.0642)**	**-0.4270*** (0.0719)**	**-0.3398*** (0.0801)**	**-0.4252*** (0.0721)**
(Fleet Diversity)X (Hedge)		**-0.4341*** (0.1683)**			**-0.3995** (0.1691)**	
Age	**0.1451*** (0.0389)**	**0.1355*** (0.0393)**	**0.1707*** (0.0425)**	**0.1005** (0.0432)**	**0.0978** (0.0430)**	**0.1323*** (0.0475)**
(Age) X (Percent Hedged)			-0.2094 (0.1626)			-0.2336 (0.1638)
Leased Fleet				**-0.2485** (0.1079)**	**-0.2052* (0.1075)**	**-0.2542** (0.1086)**
Regional Airline	**0.1667** (0.0729)**	**0.1363* (0.0733)**	**0.1909*** (0.0744)**	0.1232 (0.0784)	0.1055 (0.0778)	**0.1556* (0.0803)**
CAP	-0.0653 (0.0524)	-0.0445 (0.0522)	-0.0632 (0.0524)	-0.0465 (0.0525)	-0.0308 (0.0522)	-0.0452 (0.0524)
AvgPrice	-0.0008 (0.0007)	-0.0010 (0.0006)	-0.0008 (0.0007)	-0.0006 (0.0006)	-0.0008 (0.0006)	-0.0007 (0.0006)
Number of observations	228	228	228	227	227	227
F-Statistic / Chi2	1008.49	1107.29	1005.67	1051.24	1102.60	1051.11

* 10% significance (two-sided test)
** 5% significance (two-sided test)
*** 1% significance (two-sided test)

For the operational hedges, Fleet Diversity is negative and significant at least at the 5% level in all models. To illustrate the reduction in value, an airline which does not use fuel hedges and operates a diverse fleet with a mean aircraft dispersion index of 0.53, has a Tobin's Q that is 17% (-0.3237*0.53) less than an airline operating an uniform fleet. Furthermore, if this hypothetical airline chose to hedge next years fuel requirements at the industry mean for airlines which hedge (0.30), then its reduction in value compared to a uniform fleet with similar hedging activities would be 22.6% (See Equation (3.20 below).

$$d\ln(Q) = -0.3237 \times d(\text{Fleet Diversity}) - 0.3442 * (\text{Mean hedged by hedgers}) \times d(\text{Fleet Diversity}) \tag{3.20}$$

$$\%\Delta\text{Q} = 22.6\% = -0.3237 \times (0.53) - 0.3442 * (0.30) \times (0.53)$$

The result showing that a diverse fleet reduces value is surprising since the results in the prior chapter found that the diversity and the fuel efficiency of the fleet are effective operational hedges against jet fuel costs. However, this section illustrates that though operational hedges are effective at reducing a firm's exposure, the cost of implementing such a hedge outweighs its benefits.

Column (2) of Table XIII shows Age to be 0.1313 and significant at the1% level. The positive value for the age of the fleet means that operating an older less fuel-efficient fleet increases the value of the airline. The results of Table XIII suggest that for an airline with a fleet age of 10 years (the industry average, Table I), reducing the age of its fleet by one year causes the airline's Tobin's Q to decline by 1.3% (.1331/10). The result that a newer aircraft reduces an airline value is confirmed by Table XIV Panel C column (4), which excludes the cross-products of operational hedges and the percent of fuel hedged. The cross-product of Age and Hedge is insignificant in all models (Table XIII and XIV). Thus, there is no evidence that using a fuel-efficient fleet with fuel hedges affects an airlines value.

The coefficient for Leased Fleet is negative in all models, suggesting a leased fleet is harmful to an airlines value. This result holds when the cross-products are excluded from the model (Table XIV Panel C Column (4)). To illustrate, increasing the percent of the fleet which is leased by 1% reduce the airlines Tobin's Q by 0.25% (Table XIV Panel C Column (4)).

The result that the combined use of both financial and operational hedges does not increase the value of the firm is surprising. Table XIII and Table XIV shows that is the cross-product of Fleet Diversity and Hedge is negative and the cross-product of the Age and Hedge is insignificant. This results contradicts the finding of Allayannis, Ihrig, and Weston (2001) and Kim, Mathur, and Nam (2006) who find that operational and financial hedges increase a firm's value. However, for both of these studies, their proxy of the operational hedge is ineffective at reducing the firm's exposure to currency rates. Therefore, the relationship between the firms' values and their operational hedges possibly suffers from measurement error.

3.6 Summary

This chapter analyzes three operational hedges that are at the disposal of an airline to determine if operational and financial hedges are complements or substitutes. Furthermore, the question of whether operational and financial hedges increase the value of the firm is addressed. The three operational hedges are the diversity of the airline's fleet, the leasing of the airline's fleet and the use of a newer fuel-efficient fleet. A diverse fleet and the leasing of an airline's fleet, provide the airline with the option to adjust its capacity during periods of high fuel prices. A newer fuel-efficient fleet reduces the airline's overall exposure to the price of jet fuel.

The evidence presented in this chapter shows that airlines that use operational hedges to manage their risk are more likely to also use financial hedges. That is, airlines which operate a diverse fleet are more likely to use financial derivatives. This makes sense, as changing the operations of a firm is costly and is only done once a certain threshold as been reached. For instance, it is costly for an airline to mothball an aircraft, and thus the airline will delay this decision until market conditions have deteriorated enough to justify such an action. Financial hedges are less costly to implement once the fixed cost of a hedging program has been established and thus are better suited for the fine tuning of a firm's current needs.

The findings show that financial derivatives which proxy for a firm's hedging activity underestimate the extent to which firms hedge their risk exposures. That is, other studies that focus on the extent to which hedging reduces a firm's risk exposure exclude the use of operational hedges, which are a significant component of a firm's hedging program.

A surprising result of this study shows that the use of operational hedges actually decrease the value of the firm, while there is no consistent conclusion for value that financial hedges provide an airline. In the airline industry, fuel derivatives are beneficial to the airline's value. However, the use of fuel pass-through agreements actually reduces the value of the airline. Similar to a fuel pass-through agreement, operational hedges reduce the value of the airline. That is, a diverse fleet, a newer fuel-efficient fleet and the leasing of its fleet diminishes the airline’s value.

CHAPTER IV

CONCLUSION

4.1 Conclusion

The airline industry possesses several possible venues to manage its risk exposure to the price of jet fuel. Airlines use financial hedges such as financial derivatives and fuel pass-through agreements to diminish their exposure to fuel prices. Also, airlines have the choice of utilizing the real options embedded in their operations to hedge their fuel price exposure. A few of the real options that airlines can use to manage their risk exposure to fuel prices are: the diversity of their fleets, the use of fuel-efficient fleets, and the leasing of the airline's aircraft. The diversity of an airline's fleet and the use of a leased fleet allow an airline to adjust its operating fleet to meet the needs of the dynamic market in which it operates. A fuel-efficient fleet reduces the airline's overall exposure to fuel prices.

The evidence of this dissertation is clear: first, airlines show a significant exposure to the price of fuel; second, airlines use both operational and financial hedges to reduce their risk exposure to fuel prices; third, airlines use operational and financial hedges as complements. The last and most surprising result shows, financial hedges provide mixed results concerning the benefits to the airline's value, while operational hedges are actually detrimental to the airlines' value and thus to its shareholders.

The need to use operational or financial hedges exists only if an exposure to an underlying asset also exists. The individual airlines do exhibit significant exposure to the price of jet fuel. That is, about 29% of airlines show a significant exposure to jet fuel prices. Furthermore, the airline industry exhibits greater levels of exposure to fuel prices when the price of fuel is on the rise. Similarly, the industry's exposure to fuel prices is the greatest when the price of fuel is above its historical norm. However, there is no evidence that the industry exhibits different degrees of exposure to fuel prices when the volatility of the fuel prices is above or below its historical norm. In short, airlines exhibit a significant exposure to fuel prices, which justifies the use of financial or operational hedges.

The evidence shows that airlines use financial hedges to mitigate their exposure to fuel prices. I find that the use of both financial derivatives and fuel pass-through agreements significantly reduces an airline's exposure to fuel prices. Similar to financial hedges, operational hedges lessen the effects of fuel price movements on an airline. More specifically, a diverse fleet and a newer fuel-efficient fleet are used as effective operational hedges against fuel prices. Second, there is evidence that the embedded option to switch to a newer fleet reduces an airline's exposure to fuel prices. Though a newer fuel-efficient fleet provides a higher degree of protection against fuel price movements, the option to upgrade to newer fuel-efficient aircraft from lesser fuel-efficient aircraft acts to lessen the effects of fuel price movements on an older fleet. This is significant to other studies that analyze the benefits of operational hedges, for a firm without an operational hedge always has the option to implement such a hedge. There is no evidence that airlines use or are able to use a leased fleet to reduce their exposure to fuel prices.

This dissertation findings show that airlines use financial and operational hedges as complements. That is, airlines with diverse fleets are more likely to use financial hedges. This result suggests that airlines use operational hedges to manage their long-term exposure to fuel costs and use financial derivatives to fine tune their short-term hedging needs. A critique of this argument is that airlines with a diverse fleet are more likely to use financial hedges to reduce any increased exposure to fuel prices associated with their fleet make-up. However, this s
tudy finds that a diverse fleet is an effective operational hedge for reducing an airline’s exposure to the price of fuel.

The last and most surprising result shows that there are mixed results on the benefit of hedging to an airline’s value. That is, the use of fuel pass-through agreements, a diverse fleet, a newer fuel-efficient fleet, or the leasing of an airline’s fleet, all lessen the airline's value. Furthermore, there is no evidence suggesting that both financial and operational hedges are value enhancing to the firm. However, the use of financial derivatives to hedge the airline exposure to fuel prices is value-enhancing to the airline.

In conclusion, this study shows that operational hedges are an integral part of a firm's hedging initiative. If airlines are able to use their real options to manage risk, then so can other industries with greater operational flexibility. Furthermore, this essay finds that operational and financial hedges are complements. This result confirms the finding of Allayannis, Ihrig, and Weston (2001). However, contrary to their study, this study finds that operational hedges are effective at reducing a firm's risk. Furthermore, studies which attempt to determine the motivation for hedging, the effectiveness of hedging programs, or whether hedging is value-enhancing are biased as they have excluded the operational hedge. Lastly, this study brings into question the results of prior studies which contend that a comprehensive hedging program increases the value of the firm.

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VITA

Stephen Decatur Treanor

Candidate for the Degree of

Doctor of Philosophy or Other

Thesis: THE EFFECTIVENESS OF THE OPERATIONAL AND FINANCIAL HEDGE: EVIDENCE FROM THE AIRLINE INDUSTRY

Major Field: Finance

Biographical:

Education: received Bachelor of Arts degree in Economics from Austin College, Sherman, Texas in May 1996; received Master of Business Administration from Texas Tech University, Lubbock, Texas in May 1998; Completed the requirements for the Doctor of Philosophy in Finance at Oklahoma State University, Stillwater, Oklahoma in July, 2008.

Experience: Instructor, Oklahoma State University, Stillwater, Oklahoma, 2003 – 2008; Financial Reporting Accountant, Rogue Wave Software, Boulder, Colorado, 2000-2002; Financial Analyst, Lafarge, Denver, Colorado, 1999-2000, Consultant, PrimeCo Personal Communications, Westlake, Texas, 1998.

Name: Stephen Treanor Date of Degree: July, 2008

Institution: Oklahoma State University Location: OKC or Stillwater, Oklahoma

Title of Study: THE EFFECTIVENESS OF THE OPERATIONAL AND FINANCIAL HEDGE: EVIDENCE FROM THE AIRLINE INDUSTRY

Pages in Study: 153 Candidate for the Degree of Doctor of Philosophy

Major Field: Finance

Scope and Method of Study: The purpose of this study is to examine the airline industry's exposure to jet fuel prices. Furthermore, this study tests whether operational and financial hedges are: effective at reducing an airline's exposure to the price of jet fuel, substitutes or complements, or value enhancing to an airline.

Findings and Conclusions: This research shows that both operational and financial hedges are effective at reducing an airline's risk exposure to the price of jet fuel. Furthermore, there is evidence that airlines use operational and financial hedges as complements. Lastly, and most surprisingly, the use of operational hedges destroys the airline's value. However, the evidence that financial hedges increase a firm's value is inconclusive. The findings of this research also show that an airline's exposure to the price of jet fuel is higher when the price of jet fuel is above historical norms. In additional, an airline's exposure to fuel prices increases as fuel prices rise. Lastly, the findings do not show that the airline industry experiences a greater level of exposure to the price of fuel when the volatility of the price of fuel is above or below its historical norm.

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