The flexibility and benefits of operating a diverse fleet: an analysis using real options

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Abstract

Purpose – The purpose of this paper is to develop a simple model illustrating the benefits of operating a diverse fleet of aircraft.

Design/methodology/approach – The paper is theoretical. It describes how real options are beneficial to the firm in both capital budgeting and risk management. It illustrates the use of real options in the airline industry, and how real options are used as a risk management tool. Then the model is developed which illustrates how a diverse fleet can provide an airline protection against fuel price risk.

Findings – The results of the model show that a diverse fleet is value enhancing to an airline during periods when fuel prices are high or uncertain. Furthermore, this paper shows that a diverse fleet provides an airline with an operational hedge to jet fuel prices. Though the paper focuses on the airline industry, the results are applicable to those industries vulnerable to volatile input costs, and prohibitive abandonment and re-entry costs.

Originality/value – The paper uses real option analysis to show the benefits for an airline deriving from operating a diverse fleet of aircraft.

Keywords Airlines, Risk management, Fleet management, Airline industry, Real options, Hedging

Paper type Research paper

1. Introduction

In the summer of 2008 the high price of jet fuel placed a significant constraint on the airline industry. During this period many airlines began reducing their exposure to fuel prices through the use of financial hedges, retiring old fuel inefficient aircraft, and cutting seating capacity. Many analysts during this period believed that airlines would reduce a significant portion of their excess seating capacity through the elimination of their smaller regional jets[1]. Furthermore, many believed that the high price of fuel would bring about the end of the era of the regional jet. However, the actions of the airlines told a different story. Though the airlines were reducing their seating capacity, they were eliminating capacity in their larger mainline aircraft by more than their smaller regional jets. In fact, several airlines were actually increasing the number of seats flown by their regional jets. For instance, *The Wall Street Journal* commented that Delta and Northwest were:

> […] 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 (Carey and Prada, 2008).

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Other airlines were taking similar actions; United Airlines was expecting to reduce their 2009s mainline aircraft seating capacity by 12.5 percent, while increasing the seating capacity of their express jets by 11.0 percent[2]. Similarly, US Airways was expecting to decrease seating capacity of their mainline aircraft by 6 percent while increasing their express jet seating capacity by 2 percent in 2009[3].

This paper explains the surprising actions of the airlines by developing a simple model using real option analysis, which illustrates the benefits of operating a diverse fleet of aircraft that differ in seating capacity. Although the discussion in this paper focuses on the airline industry, the argument is generally applicable to other industries where exit and reentry costs are prohibitive and the firm's input costs are highly volatile. More specifically, if exit/reentry costs are such that a firm will choose to maintain operations during periods when high input costs are causing severe losses, then the option to reduce production, which lowers overall losses, provides a valuable hedge.

Simple intuition tells us that a firm can reduce its overall losses during periods of high input costs by incrementally reducing its production, while a firm without any option to adjust capacity will incur larger losses during the unfavorable periods.

To illustrate this point, an airline servicing the Dallas to Chicago market will generally avoid exiting this route, even during periods when costs exceed 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 aircraft allows the airline to maintain a presence in the Dallas to Chicago market while reducing its overall losses. Compare this scenario to one in which 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.

Although, the literature regarding real option analysis is quite broad, this paper brings three new insights to the literature. First, we examine a real option in which the underlying asset is an input into the firms operations, rather than an output such as copper or oil which is typical in the literature (Dixit and Pindyck, 1994; Brennan and Schwartz, 1985). Second, we examine an environment in which exit and reentry costs are prohibitively expensive, which is common in the service industry where customer loyalty is a significant component of a firm's success, unlike mineral extraction where exit and reentry is a viable option (Tufano, 1998; Petersen and Thiagarajan, 2000). Lastly, this paper discusses the implications of a firm managing its risk with real options. More specifically, it explains how a diverse fleet can reduce an airline's exposure to fuel prices.

The rest of the paper is as follows: Section 2 describes how real options are beneficial to the firm in both capital budgeting and risk management. It illustrates the use of real options in the airline industry, and how real options are used as a risk management tool. In Section 3 the model is developed which illustrates how a diverse fleet can provide an airline protection against fuel price risk. Section 4 contains the conclusion.

2. Overview of the benefits of real options

Real options analysis (ROA) is used as a capital budgeting tool and as a risk management tool. The focus of this paper is on the latter. In both cases, capital budgeting and risk management, ROA incorporates both the value of waiting until more information is available, and the value of flexibility (Dixit and Pindyck, 1994). To illustrate these two points it is best to examine how ROA is used as a capital budgeting tool.

ROA as a capital budgeting tool has its roots in financial options. The value of waiting and the value of flexibility is demonstrated by comparing a financial call option to that of a similar type of real option, the option to delay or defer. A call option gives the owner of the option the right but not the obligation to buy a share of common stock before the expiration date, at a predetermined price (Damodaran, 2000). The predetermined price is known as the strike price or exercise price. If the stock price is greater than the strike price then the option will be exercised and investment in the stock will occur at the strike price, otherwise the option will expire and investment will not occur. With a call option, the investor is able to delay his decision to purchase the stock until more information is revealed and he has the flexibility to change his investment decision, i.e. invest if the price is greater than the strike price otherwise let the option expire.

Similar to a call option the option to delay determines the value of the firm's ability to defer the investment choice until a later date. The option to delay the present value of the project's cash flows and the investment cost at or before the expiration date is analogous to a call option's stock price and strike price, respectively. Namely, at the expiration date investment will occur if the project's value is greater than the investment cost, otherwise the project is rejected (Damodaran, 2000). With the option to delay, as with the call option, the value to wait until more information is known is encapsulated into the value of the project by allowing the firm to delay the investment decision to a later date. Furthermore, the option to delay values the inherent flexibility in a project by valuing the ability to forgo a project if continuing with the project is no longer in the best interest of the firm.

Real option analysis is not foreign to the airline industry. Miller and Clarke (2005) use ROA to evaluate the timing and size of an airport expansion project. Stonier (2001) uses ROA in fleet purchasing, fleet delivery, and fleet planning. He describes how purchasing an aircraft instead of using a long-term lease provides the airline flexibility in abandoning a market if it turns out to be unprofitable. He discusses the benefits of the purchasing options which aircraft manufacturers extend to the airlines, such as the aircraft delivery option which allows the airline to cancel the purchasing agreement by a specified date. This option allows the airline to opt out of purchasing the aircraft if demand for air travel no longer justifies the use of the aircraft. Another type of option that manufacturers offer airlines is the switching option. The switching option allows the airline to change the type of aircraft that will be delivered after the purchase agreement has been made. This gives the airline the flexibility to choose the optimal size of the aircraft needed to service its markets at the time the option expires. This option is of value as it allows the airline to maintain the frequency of flights on highly contested routes or maintain higher customer satisfaction by giving customers more choices when the demand for air travel has changed (Stonier, 1999; Lapre and Scudder, 2004).

Just as financial options are used for hedging so are real options. Several studies find evidence that multinational firms use their foreign operations to hedge against exchange rate movements (Allayannis *et al.*, 2001; Pantzalis *et al.*, 2001; Kim *et al.*, 2006). When the domestic currency is stronger than the foreign currency a multinational corporation will move production to the foreign country. Such actions allow the corporation to produce goods for the domestic or foreign markets at a lower cost. Tufano (1998) and Petersen and Thiagarajan (2000) find that gold mining firms use real options to hedge gold prices. Such as, when gold prices fall below a certain threshold the firm has the option to cease operations of the mine until prices rise. Empirically Tufano shows that gold mining firms share similar characteristics to those of a call option; confirming that gold mining firms are able to minimize their downside risk while maintaining their upside potential. Petersen and Thaigarajan examine two gold mining firms and find that the firm that does not hedge uses real options to adjust its costs in response to gold prices.

Carter *et al.* (2006) were the first to examine the use of financial hedges in the airline industry. They find that hedging fuel cost is an important component to the airline's value. They conclude that airlines hedge fuel cost to protect their investment opportunities when capital financing is tight. Weiss and Maher (2009) and Treanor *et al.* (2011) examine the use of real options as an operational hedge in the airline industry. Contrary to the predictions of this paper and Stonier (1999) Weiss and Maher suggest and find evidence that a uniform fleet provides an operational hedge to the airline. Treanor *et al.* arrive at the opposite conclusion after controlling for the fact that, as this paper suggests, as fuel prices rise the airline's operational fleet, those aircraft used in service, will become more uniform as the airline switches to smaller aircraft and conversely will become more diverse as fuel prices fall.

Similar to the use of real options described in this section a diverse fleet provides an airline the ability to wait until more information is known and the flexibility to react to such information, such as periods of high or low fuel prices. In the next section the model is developed which shows how a diversified fleet can protect against fuel price risk.

3. Model

The model presented in this section is similar to that proposed by Dixit and Pindyck (1994). For simplicity in laying out the model, it is assumed that abandonment/reentry costs are such that the airline will choose never to exit the market. One must also assume that the airline services only one route, and that the airline chooses to service all or some fraction of a fixed quantity of passengers per period. Furthermore, to focus on cost and simplicity, one must assume price and demand are non-stochastic, i.e. revenue is fixed. In addition, fuel costs (C) is assumed to be the only cost, and follows the following Geometric Brownian Motion which has a convenience yield of δ:

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

The airline in this paper 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. Since α represents the smaller aircraft, its value is greater or equal to 0.0 and less than 0.5. In addition, the cost (C), the revenue (P), and thus profits for the smaller plane are proportional to that of the larger aircraft. Therefore, the profits from the smaller plane are $\alpha(P - C)$ and the profits from the larger plane are $(1 - \alpha)*(P - C)$. This implies the total profit of the airline operating at full capacity is $(P - C)$. Furthermore, to make the problem more manageable one must assume a depreciation rate of zero. Lastly, one must 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:

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

$$\Pi = \mathrm{Max}(P - C, \alpha(P - C)) \tag{2}$$

The first term at the top of the equation inside the max function represents the airline's profits when it is operating both the larger and smaller aircraft. The second and third term in the max function represent the airline's profits when solely the larger aircraft or smaller aircraft are in operation. The airline will choose to operate either both aircraft or just the smaller aircraft. In the second line, the middle term $((1-\alpha)(P - C))$ is dropped since the profits of operating both aircraft or just the smaller one are always greater than that of operating only the large aircraft. More specifically, when fuel costs are below the aircraft revenue (P), then it is optimal for the airline to operate both aircraft $((P - C) > (1-\alpha)(P - C) > \alpha(P - C))$. When fuel costs are above the aircraft revenue (P), then it is optimal for the airline to operate just the smaller aircraft $(\alpha(P - C) > (1-\alpha)(P - C))$, since α is less than 0.5. Thus, the airline will choose to operate only the larger aircraft in conjunction with the smaller plane. Figure 1 shows the profits of the smaller, larger, and diverse fleet. Equation (2) implies the cost (C^*) at which point it is optimal for the airline to switch to solely operating the smaller aircraft. At this point revenue equals cost $(P = C^*)$. Thus, the firm's profits are:

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

Before continuing it is important to note that if fuel costs are constant and always below the revenue, then an airline would be indifferent between operating a diverse fleet consisting of a small and larger aircraft or a uniform fleet consisting of the largest aircraft. In this scenario the airline is always profitable and thus there are no benefits to operating a diverse fleet. If there are any additional costs to operating a diverse fleet, which there are, then it would be optimal to operate the largest aircraft possible since they are more fuel efficient than a smaller aircraft. This analysis suggests that if fuel costs were non-stochastic, which they are obviously not, then it would be optimal to operate a uniform fleet consisting of the largest aircraft available.

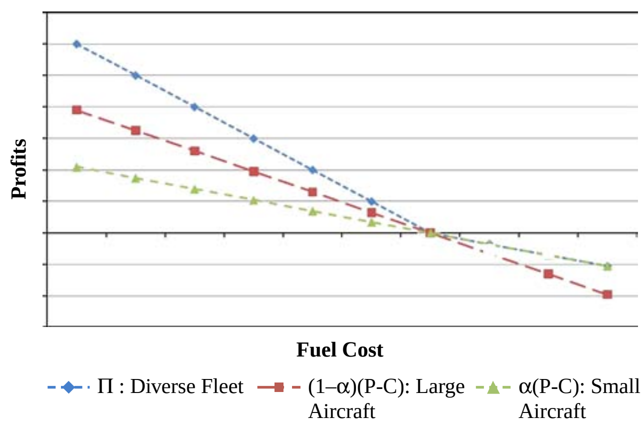

Figure 1.
Aircraft profits to fuel cost

If an airline is free to exit and renter a market without incurring any additional cost, then the airline would be indifferent between a uniform fleet and a diverse fleet. Also, if there are additional costs to operating a diverse fleet the airline would prefer a uniform fleet. In this scenario, when costs exceed revenue the airline will cease operations and have a loss of zero which is preferred over a loss of $\alpha(P - C)$. However, abandon and reentry costs do exist in the airline industry, and airlines typically do not abandon routes as soon as those routes become unprofitable.

Using the same technique as Dixit and Pindyck (1994), we determine the value of the airline with a diverse fleet. We will then compare this value to the value of an airline that operates only one large aircraft. To find the value of an airline with a diverse fleet we begin by creating a replicating portfolio (π). As is common in most finance text books, the investor creates a replicating portfolio by purchasing the airline (V) and shorting V' units of the airline's fuel costs (C). The equation for the replicating portfolio is:

$$\pi = V - \frac{\partial V}{\partial C} C$$

Using Ito Lemma and adjusting for the profits of the airline (Π), and the convenience yield of fuel (δ), the change in value of the portfolio over a small period of time is:

$$d\pi = \frac{1}{2}\sigma^2 C^2 V'' - (\delta) C V' + \Pi$$

From the above equation both the drift rate (ρ) and the random variable (dz) fallout of the equation[4]. The lost of the random variable implies the portfolio has no risk and it must earn a risk free rate of return (r). Thus, the value of operating an airline must satisfy the following ordinary differential equation:

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

The general solution to the differential equation is $A_i C^{\beta_1} + B_i C^{\beta_2}$, where i represents full (f) or partial (p) capacity. The particular solution to the above differential equation is:

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

The term $((P/r) - (C/\delta))$ is a perpetuity of the airline's profits (Π) where the revenue (P) is discounted at the risk free rate and fuel cost (C) is discounted at the convenience yield (δ)[5].

Terms B_f and A_P are zero for the particular solution in order to satisfy the condition that the airline's value is not infinite when fuel cost rise or fall. The terms β_1 and β_2 are derived by plugging the solution ACs^{β} into equation (4) and arriving at:

$$AC^{\beta}\left(\frac{\sigma^2}{2}\beta^2 + \left(r - \delta + \frac{\sigma^2}{2}\right)\beta + 1\right) \tag{6}$$

Solving the roots to the quadratic equation (6) gives:

$$\beta_1 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{\left[\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right]^2 + 2\frac{r}{\sigma^2}} > 1 \tag{7}$$

$$\beta_2 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} - \sqrt{\left[\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right]^2 + 2\frac{r}{\sigma^2}} < 0 \tag{8}$$

The terms A and B are to be determined from the boundary conditions.

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

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

or:

$$B_p C^{*\beta_2} + \alpha\left(\frac{P}{r} - \frac{C^*}{\delta}\right) = A_f C^{*\beta_1} + \frac{P}{r} - \frac{C^*}{\delta}$$

from equation (5), and:

$$V_p'(C^*) = V_f'(C^*) \tag{10}$$

which by equation (5) is:

$$B_p \beta_2 C^{\beta_2 - 1} - \alpha\left(\frac{1}{\delta}\right) = A_f \beta_1 C^{\beta_1 - 1} - \frac{1}{\delta}.$$

Using the above conditions and solving the equations (9) and (10) simultaneously the values of A_f and B_p are:

$$A_f = \frac{C^{*1-\beta_1}(1-\alpha)((\beta_2/r) - ((\beta_2 - 1)/\delta))}{\beta_1 - \beta_2} \tag{11}$$

$$B_p = \frac{C^{*1-\beta_2}(1-\alpha)((\beta_1/r) - ((\beta_1 - 1)/\delta))}{\beta_1 - \beta_2} \tag{12}$$

In Dixit and Pindyck's (1994, p. 189) book, shows that A_f and B_p are both positive. Thus, the option to adjust capacity in response to fluctuations in fuel cost increases the value of the firm. The term $A_f C^{\beta_1}$ represents the value of the real option to switch to the smaller plane if cost rises above the critical point. The term $A_f C^{\beta_1}$ is increasing in value as the price of jet fuel rises:

$$\frac{\partial A_f C^{\beta_1}}{\partial C} = \beta_1 A_f C^{\beta_1 - 1} \geq 0$$

giving the airline a hedge against the price of fuel. The term $B_p C^{\beta_2}$ is the value of the real option to increase output when costs are below the critical point.

If we define an airline's exposure to fuel prices as the change in the value of the airline with respect to a change in the price of fuel, then the option to adjust capacity reduces the airline's exposure to fuel costs relative to a standardized fleet of a large aircraft. More specifically, consider the case of an airline with a diverse fleet consisting of two aircraft, one medium aircraft and one smaller aircraft. The smaller aircraft represents α percent of the airline's capacity and $1-\alpha$ represents the medium aircraft's capacity. The other airline's fleet consists of one large aircraft, such that its seating capacity is equal to that of the medium and smaller aircraft, i.e. α is equal to 1. Consider this case when the price of fuel is below the critical point and both airlines are operating at full capacity. In this scenario, the change in the value of the airline with a diverse fleet is:

$$\frac{\partial V_d}{\partial C} = \beta_1 A_f C^{\beta_1 - 1} - \frac{1}{\delta} \tag{13}$$

and that of a uniform fleet is:

$$\frac{\partial V_u}{\partial C} = -\frac{1}{\delta}. \tag{14}$$

Where "d" represents the value of a diverse fleet and "u" represents the value of a uniform or standardized fleet. Subtracting equation (14) from equation (13), and realizing that the option to switch to a smaller aircraft ($A_f C^{\beta_1}$) increases in value as fuel costs rise ($\beta_1 A_f C^{\beta_1 - 1} \geq 0$), shows that:

$$\frac{\partial V_d}{\partial C} \geq \frac{\partial V_u}{\partial C}$$

The above formula indicates that a diverse fleet's exposure to fuel prices is less than that of a uniform fleet when fuel prices are below the critical point[6].

Now, consider the case when the price of fuel is above the critical point. The change in the value of the airline with a diverse fleet is equal to:

$$\frac{\partial V_d}{\partial C} = \beta_2 B_p C^{\beta_2 - 1} - \alpha\left(\frac{1}{\delta}\right). \tag{15}$$

Similarly the change in the value of the airline with a standardized fleet is:

$$\frac{\partial V_u}{\partial C} = -\left(\frac{1}{\delta}\right). \tag{16}$$

If a diverse fleet is less exposed to fuel prices than a standardized fleet then:

$$\frac{\partial V_d}{\partial C} \geq \frac{\partial V_u}{\partial C}.$$

By comparing equations (15) and (16) it is observed that the equality holds when C is greater than the critical value C*. That is:

$$\beta_2 B_p C^{*\beta_2 - 1} \geq -\frac{1}{\delta}(1-\alpha). \tag{17}$$

Substituting in the value of B_p, equation (12), and dividing both sided by $(1-\alpha)$ gives:

$$\beta_2 \frac{((\beta_1/r) - ((\beta_1 - 1)/\delta))}{\beta_1 - \beta_2} \left(\frac{C^*}{C}\right)^{1-\beta_2} \geq -\frac{1}{\delta}. \tag{18}$$

It is important to note from equation (18) that the LHS goes to zero as $C \rightarrow \infty$, this implies that if the inequality hold for $C^* = C$ then it holds for all C larger than C^*:

$$\beta_2 \frac{((\beta_1/r) - ((\beta_1 - 1)/\delta))}{\beta_1 - \beta_2} \left(\frac{C^*}{C}\right)^{1-\beta_2} \geq \beta_2 \frac{((\beta_1/r) - ((\beta_1 - 1)/\delta))}{\beta_1 - \beta_2}(1) \geq -\frac{1}{\delta}$$

Multiplying both sides by δ, r and $(\beta_1 - \beta_2)$ and then rearranging terms gives:

$$\beta_2(r - \delta) \geq r. \tag{19}$$

Dixit and Pindyck's (1994, p. 189) book, shows that the above inequality holds.

In concluding the proof, it has been 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 for an airline with a uniform fleet. That is:

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

Figure 2 shows that a hypothetical diverse fleet experiences less exposure to jet fuel prices than does the uniform fleet. Figure 2 graphs equation (5) 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

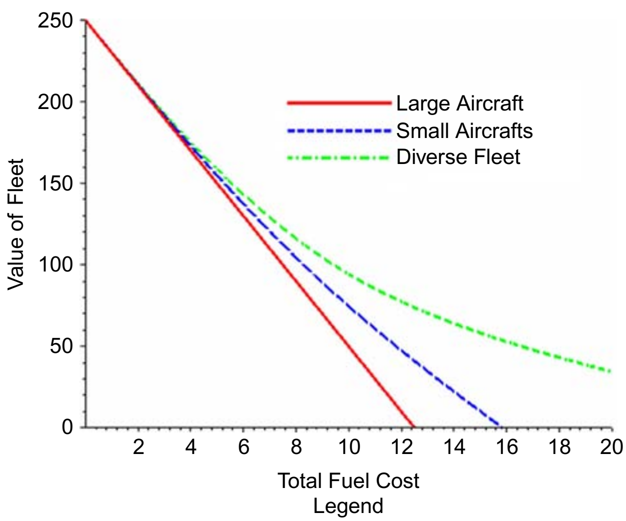

Figure 2.
The benefits of a diverse fleet

small aircraft. The other values for the parameters of equation (5) are, $P = 100$, $r = 0.04$, $\delta = 0.03$, and $\sigma = 0.3$. The slope of the equation for an 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.

4. Conclusion

We develop a simple model that illustrates the additional value to an airline by operating a diverse fleet of aircraft when fuel prices are uncertain. Furthermore, this paper shows that a diverse fleet provides an airline with an operational hedge by reducing its exposure to the price of jet fuel. Our paper also helps explain the regional jets' persistent nature during periods when fuel price uncertainty has increased. Although this paper focused on the airline industry; the results are applicable to those industries in which exit and reentry costs are prohibitively expensive, and there is significant exposure to input costs.

Notes

1. The Boyd Group in Evergreen Colorado, March 2008.
2. UAL, press release, June 4, 2008.
3. USAir, press release, June 12, 2008.
4. The drift rate (ρ) and the random variable dz drop out of the equation because the first derivative of the change in the value of the airline (V'dC) cancels out the short position (V'dC) (Hull, 2005).
5. The convenience yield is equal to the required return for jet fuel less its capital appreciation (ρ).
6. The stochastic process "C" restricts it from being less than zero. Since airlines are negatively exposed to fuel prices, a positive inequality means that the airline with a diverse fleet is less exposed to feel prices.

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