Fine-Tuning a Corporate Hedging Portfolio: The Case of an Airline

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The firm here is now a large body of academic research that attempts to explain why companies hedge the risks arising from volatility in commodity prices, foreign exchange, interest rates, and other such “financial prices.” In recent years, there has also been a number of academic papers on how companies should hedge, including discussions of optimal corporate hedging practices involving the use of linear futures-like contracts as well as nonlinear option-like contracts. But because actual corporate hedging practices are typically confidential, these theoretical studies have generally been of limited use to practitioners. Studies of airline industry hedging activities, for example, have been forced to rely on information from publicly available sources, such as 10-K reports. And most academic studies of corporate hedging have focused primarily on the question of whether there is a discernible relationship between the firm’s hedging activities and its value.2

In this paper, we provide a case study involving in-depth analysis of an international air carrier’s actual jet-fuel price hedging strategy and compare it with an optimized mix of derivatives. We also explain how the airline’s financial strength, fuel price-and-quantity correlations, and risk profile relate to that optimal mix of derivatives. With this air carrier’s specific objectives in mind, we recommend a hedging strategy that proposes the use of a specific customized derivative: annually-settled Asian options. We show how this derivative can be used to protect the airline against jet-fuel price fluctuations at reasonable cost while also preserving the corporate liquidity that can be jeopardized by some hedging instruments.3

The Airline’s Hedging Strategy

Airlines are heavily exposed to fluctuations in jet fuel prices. Moreover, there are several factors that complicate strategies for hedging such exposures. Although major commodity exchanges such as ICE and NYMEX have listed futures and options on crude oil and various refined products, these do not include futures on jet fuel. As a result, many airlines, including the one in this case study, use derivatives based on crude oil or heating oil. There may also be a discrepancy between a firm’s desired hedging horizon and the maturities available for standardized derivative contracts. Finally, exchanges require hedgers to post cash-variation margin for futures and short options positions, and this requirement can be onerous for cash-strapped airlines.

For all those reasons, airlines often find over-the-counter (“OTC”) derivatives offered by financial institutions preferable to standard exchange-traded contracts. The high degree of flexibility inherent in OTC derivatives—especially those that provide payoffs based on average prices during a specific delivery month—allows airlines to match their financing requirements and hedging objectives.

We found that four major considerations influence the airline’s hedging decision:

1. The firm’s financial strength and current credit rating;
2. The correlations between the volumes of fuel it consumes and the prices it pays;
3. Its fixed and variable transaction costs; and
4. Its internal risk profile.

While these four considerations cannot easily be translated into quantitatively measurable rules, the overall hedging

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1. For example of such papers, see “On the Optimal Mix of Corporate Hedging Instruments: Linear Versus Nonlinear Derivatives,” by Gerald Gay, Joaunh Nam and Marian Turac in the Journal of Futures Markets, 23(3), 217-239, 2003; and “Managing Long and Short Price-and-Quantity Exposure at the Corporate Level,” a Working Paper at the University of Texas at Austin by Sergey Kolos and Ehud Ronn.
4. Jet-fuel is a kerosene-like middle distillate. The prices of crude oil, home heating oil and jet-kerosene are highly correlated as the latter two are derived physically from the former in the refining process.
strategy recognizes these factors. And since management does not have a specific quantitative optimization framework, it relies instead on experience and rules of thumb.

An airline’s credit rating heavily influences the kinds of hedges it can obtain in the OTC market as well as the cost of those hedges. A high credit rating allows the firm to choose from a broad range of hedging instruments, some of which—for example, a “collar” involving the purchase of a call and sale of a put—are likely to involve the financial institution accepting some credit exposure to the airline.

Airlines also have to contend with a somewhat uncertain relationship between fuel prices and the quantities of fuel they will consume at those different prices. During strong economic conditions, both the demand for flights and the prices for jet fuel tend to increase, while the reverse typically holds during a recession. While both the passenger and the cargo sectors face similar fluctuations of prices and quantities, it is generally easier to pass fuel price increases on to the mostly industrial cargo customers than to the more price-sensitive passengers. As a consequence, the cargo and passenger business segments may require substantially different hedge ratios.

The firm’s fixed and variable transaction costs, for reasons that are fairly self-evident, also influence the airline’s choices of jet fuel price hedging tools.

Finally, the fourth major consideration is the airline’s internal “risk profile.” This factor reflects the firm’s airfare ticket sales strategy, and its desire for flexibility in adjusting to changes in market conditions. The airline we studied seeks to make gradual adjustments to changes in fuel costs, particularly to increases in such costs, thereby giving it sufficient time and cash flow to make the necessary operating changes.

Such a gradual approach, which is illustrated in Figure 1, begins with the airline hedging volumes equal to 5% of its expected fuel consumption 24 months in the future. With each passing month, the airline hedges another 5% of expected volumes until the hedged position amounts to approximately 85%-90% of the total six months prior to the actual consumption. This 24-month time horizon corresponds to the airline’s confidence in its ability to forecast flight schedules for the next two years with a reasonable degree of certainty. To minimize the risk of overhedging, it limits hedges to 85%-90% of the expected jet fuel consumption.

This figure shows the layered hedging approach employed by the airline in relative terms. The firm starts trading derivative contracts with a volume of 5% of the expected consumption 24 months before the actual date of usage and then continually adds another 5% per month.

Demand varies seasonally, especially within the passenger sector, with peak consumption during June, July and August. Hedge volumes are adjusted to reflect such expected variation. Figure 2 projects the seasonal pattern of expected fuel consumption and hedging volumes (in barrels of crude oil) for the two-year period (2007 - 2008) as perceived by management at the end of 2006 (see also Table 1). As can be seen in the figure, the hedge ratio projected for the first six months (from January to July 2007) stays at 85-90% of the expected consumption, but then drops off in an almost linear fashion thereafter, finishing at a level of 5% by the end of 2008.

This figure shows the layered hedging approach employed by the airline in absolute terms. The graph accentuates the

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5. The airline in question has an investment grade with A-3 from S&P and currently Ba1 from Moody’s.
seasonal variations in hedging volume, as measured in barrels of crude oil. For example, note the significantly higher hedge volume for Jul-07 relative to Jan-07.

**The Firm’s Use of Derivatives**

To benefit from customized terms and less onerous margin requirements, all of our airline’s hedges are financial contracts that are traded over the counter (OTC) with major investment banks as counterparties. The airline’s ability to trade OTC, as noted, depends on its credit rating; without an investment grade rating, the OTC market would be either inaccessible or available only at substantial credit costs.

Moreover, instead of using “linear” instruments such as futures, forwards or swap contracts, our airline used only options (“non-linear”)—and of a type known to industry participants as “Asian” options. The payoffs from Asian options depend on the monthly-averaged crude oil price instead of the price at the end of the month or other settlement date. This is attractive to airlines because they purchase fuel ratably (at the same rate each day) over the month.

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6. The results shown for the “Expected Consumption” are estimates based on the hedge ratio presented in Figure 1, i.e., the expected consumption in July 2007 is the product of the total amount hedged during this month multiplied by the hedge ratio. The ratio is in this case at roughly 90% at t-7 (July 2007) for time t (December 2006).
Additionally, the averaging feature of the option dampens the volatility of the underlying asset, thereby reducing the premiums hedges must pay for Asian options.

This figure shows the Premium Collar structure most commonly applied by the firm. The costs of an unhedged physical short position (dashed black line) is compared with the airline gross exposure (solid gray line) trading a long call and a short put option.

The airline’s standard hedge, which is shown graphically in Figure 3, consists of a long call and short put. Because the strike of the call purchased is closer “to-the-money” than the put sold, the hedge requires the airline to pay cash “up-front.” For that reason it is referred to as a “premium collar” (as distinct from a “zero cost collar”). The net premium paid for the lower call option strike effectively provides higher pay-offs for the airline if and when oil prices rise.

In a commonly used structure, the firm’s collar consists of an out-of-the-money (OTM) call struck at 110% of the relevant futures price together with a short position in an OTM put struck at 80% of the relevant futures prices. This derivative structure has the effect of limiting the airline’s net exposure (as reflected in the solid gray line in Figure 3) to increases in jet fuel prices while also allowing the airline to benefit to some extent from falling fuel prices.

But the airline does not simply follow this strategy every month in a mechanical fashion. Sometimes it alters its hedges based on its own price expectations. Depending upon those expectations and the prices for fuel options, it might, for example, sell another Asian call struck at 125% of the relevant futures price, or purchase another OTM put option with a strike price lower than 80% of the relevant futures price.

In the case of the 125% call, this would provide cash to the airline if prices rose above 110% of the initial futures price but stop paying out if prices averaged more than 125% of strike. By selling a higher strike option, the airline would reduce the net premium it would have to pay the option dealer up-front. The potential problem is that it would be exposed to massive increases in fuel prices (i.e. of more than 25%). Similarly, the purchase of the lower strike puts increases the net premium required of the airline but permits it to benefit if prices drop precipitously. This latter effect can be quite important in a market where certain airlines cannot afford to hedge, and thus benefit if oil prices drop sharply. A financially strong airline can afford to hedge, but would not wish to find itself locked into higher prices in the event of a 2008-style oil-price crash.8

The airline’s preference for option-like rather than futures-like hedging tools is a fundamental strategic issue. Its willingness to pay a net premium to be long further OTM puts reflects its strategic preference to cap its exposure to fuel price increases while enjoying a proportionately greater upside from price decrease. (By preserving this upside, our airline may “protect itself” against any windfall experienced by financially weaker or less sophisticated competitors in the event of a precipitous drop in fuel prices.) The variability of, and resulting uncertainty about, the correlations between the price the airline pays for fuel and the quantities it consumes also encourages use of option-type hedging tools. And since the airline thus has a non-linear exposure to fuel prices, the non-linear option pay-offs are likely to be more attractive than the linear payoffs of futures, forwards and swaps.

**Annual Asian Options**

Asian options are settled according to the arithmetic mean (or average) of the underlying price. These options are more difficult to value than standard stock options, however,9 and the academic literature provides three different ways of pricing them. (For details of our derivation of annual-average option values using observable futures and listed-options data, see Appendix A.)

**Fine-Tuning the Hedge**

As noted in the earlier study by Brown and Toft, in cases where the “correlation between price and quantity is positive, exotic derivatives offer additional gains over forwards or options alone,” and the size of such gains increases with quantity risk but falls with price risk.

To see this, consider the airline’s hedging portfolio as of December 31, 2007 for the next 12 months—that is, from January to December 2008. For simplicity, we assume all option contracts are acquired on December 31, 2007 (in fact, they were acquired gradually each month, as mentioned earlier) and also assume constant crude oil consumption for each month in 2008 (of 3.5 million barrels).

We assume the airline uses the same premium collar hedge of buying a monthly Asian OTM call with a strike at 110% of the crude oil futures price for month t, while

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7. A zero-cost collar represents the combination of long call and short put strikes an option dealer would sell for no net premium up-front.
8. The airline’s decision to sell more OTM options can also be affected by the so-called volatility “smiles” characteristic of OTM options. The “smiles” in question are graphic representations of option implied volatilities shown over a wide range of strikes from OTM puts to OTM calls. If the price of the OTM call seems high (or price of the OTM put seems low) to the airline, it will be more inclined to sell that call (or buy the OTM put). The hedger’s view of the optimal collar structure, therefore, strongly depends on the effective transaction costs associated with putting on the hedge, and to a lesser extent, on future price expectations.
9. The classic closed-form Black-Scholes option formula assumes the distribution of underlying price changes is LogNormal. However, the arithmetic mean of a series of price changes depends on the sum of LogNormal distributed random variables, which is not itself LogNormal. Hence, we must rely on approximate solutions rather than closed-form ones.
The firm’s annual exposure for each oil price scenario considering the standard collar position is calculated as follows: The airline’s total consumption in 2008 sums up to 42,000,000 barrels. The firm hedges 32,156,890 barrels with its option structure. Hence, the airline total exposure is the payoff of the hedge portfolio plus the unhedged amount of 9,843,110 barrels. Consequently, the amount fully exposed to the spot price depends on the oil price scenario considered—with spot prices ranging from $10 to $200.

Figure 4 shows the airlines costs with a “Benchmark Portfolio” structure under each of the oil price scenarios (x-axis), including option premium costs. This figure shows how the premium collar portfolio (“S”-curve) compares with a completely unhedged position where the airline buys all its 2008 consumption on the spot market (the 45-degree line).

In what follows, the benchmark “S”-curve serves as our baseline when assessing alternative hedging portfolios. That is, we take the firm’s own “S”-curve depiction of risk and return, which uses the implicit assumption of a specific variable price (from $10 to $200) throughout the year. Taking this objective function as a given, we then aim to optimize and fine-tune the combinations of derivatives to achieve better expected results (measured in dollars per barrel of Brent oil) for each and every oil price scenario from $10 up to $200 in 2008.

Incorporating Annual Asian Options

Replacing the monthly settled options with annual ones requires an estimate of annual volatility. Using Appendix A’s Equation (6) to calculate average annual crude oil volatility for 2008, we derive an annual averaged volatility of 14.07% (see Table 3), which is significantly lower than the individual monthly averages (compare Table 2).

Table 1 shows the futures price curve and the calculated strike prices for the monthly call and put options. The prices for the strip of annually settled call and put options can now easily be calculated applying the standard Black framework with the following information: (1) futures prices on Brent crude oil \( F_t \), (2) strike prices for the call and put options \( K_{\text{Call}}^t \), \( K_{\text{Put}}^t \), (3) an interest rate of 3% p.a., and (4) the “blended volatility” \( \Sigma_T \), calculated based on Appendix A’s equation (2) using the implied volatilities for plain vanilla options. These prices are reported in Table 2.

We can see that for calendar-year 2008, the airline spends roughly $85 million on call option premiums and receives about $20 million from sales of OTM put options. The net premiums of $65 million per year mean that the firm spends approximately $2.02 on variable hedging costs for each barrel of oil consumed (see Table 3).

To evaluate the airline’s hedge portfolio, we consider a range of oil price outcomes over calendar year 2008. There are 20 different scenarios, with average annual prices ranging from $10 to $200 per barrel of oil.

This figure shows the airline crude oil exposure—in $ per barrel of oil consumed—applying the “Benchmark Portfolio” (dotted blue line) compared to an unhedged position (solid line) assuming twenty different oil price scenarios in 2008 (x-axis).

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The other inputs needed to estimate the annual Asian option values are publicly available: (1) the annual averaged (dotted blue line) compared to an unhedged position (solid line) assuming twenty different oil price scenarios in 2008 (x-axis).

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Asian options with annually-settled options on the 1,807,000 barrels common across all months. This gradually shifts the hedge portfolio from monthly-settled to annually-settled over calendar year 2008. The resulting “Alternative Portfolio” then includes a mix of both monthly and annual Asian call and put options (see Figure 5).

The firm’s seasonally-adjusted hedge volume is 1,807,000 barrels of oil (see Table B.1) for December 2008. So, month-by-month, we replace the monthly-settled

futures price (mean of the twelve contracts from January to December 2008) is $92.37, and (2) the strikes are 110% of the underlying for the calls and 80% for the puts, $101.76 and $74.01 respectively. The firm’s seasonally-adjusted hedge volume is 1,807,000 barrels of oil (see Table B.1) for December 2008. So, month-by-month, we replace the monthly-settled

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### Table 2

<table>
<thead>
<tr>
<th>Volatilities and Option Prices (as of 12/31/2007)</th>
<th>Option Prices (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implied Plain Vanilla Volatility</td>
<td>Plain Vanilla Call</td>
</tr>
<tr>
<td>Plain Vanilla Put</td>
<td>Asian Put</td>
</tr>
<tr>
<td>Jan 2008</td>
<td>32.72%</td>
</tr>
<tr>
<td>Feb 2008</td>
<td>31.43%</td>
</tr>
<tr>
<td>Mar 2008</td>
<td>28.96%</td>
</tr>
<tr>
<td>Apr 2008</td>
<td>26.89%</td>
</tr>
<tr>
<td>May 2008</td>
<td>25.67%</td>
</tr>
<tr>
<td>Jun 2008</td>
<td>25.19%</td>
</tr>
<tr>
<td>Jul 2008</td>
<td>24.69%</td>
</tr>
<tr>
<td>Aug 2008</td>
<td>24.31%</td>
</tr>
<tr>
<td>Sep 2008</td>
<td>24.04%</td>
</tr>
<tr>
<td>Oct 2008</td>
<td>23.70%</td>
</tr>
<tr>
<td>Nov 2008</td>
<td>23.08%</td>
</tr>
<tr>
<td>Dec 2008</td>
<td>21.61%</td>
</tr>
</tbody>
</table>

### Table 3

**Input Values for the Black (1976) Framework to Calculate the Annual Call and Put Option Prices**

<table>
<thead>
<tr>
<th>Futures Price (100%)</th>
<th>Call Strike (110%)</th>
<th>Put Strike (80%)</th>
<th>Arithmetic Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 92.37</td>
<td>$ 101.76</td>
<td>$ 74.01</td>
<td>14.07%</td>
</tr>
</tbody>
</table>

Figure 4  Firm’s Exposure Applying the “Benchmark Portfolio” (Premium Collar)
This figure shows the mix of derivative instruments in each month in 2008 applying the “Alternative Portfolio” measured in barrels of crude oil (y-axis). Two different options are considered: a constant layer of annual Asian options (dark blue area) and a variable layer of monthly Asian option (blue area). The remaining unhedged volume (light blue area) is assumed to be purchased at the spot market.

We can now compare the “Alternative Portfolio” structure to the “Benchmark Portfolio” in terms of option premium costs during 2008. Table B.2 presents the hedging amount and the actual costs or benefits of each short and long position on an aggregated basis. Using annual Asian options saves 30 cents per barrel of oil hedged. And as a result, the firm now needs to spend only $1.72 per barrel on option premiums, roughly a 15% savings over the benchmark.

This figure shows the cost savings (in $ per barrel of oil consumed by the airline) from applying the “Alternative Portfolio” in comparison to the currently established “Benchmark” considering twenty different [$10, $200] oil price scenarios in 2008 (x-axis).

We can also see the firm’s gross exposure under different oil price scenarios and whether it is better off under each oil price between $10 and $200. Figure 6 shows the incremental advantage provided by the Alternative Portfolio on a per barrel basis. Consequently, reduced hedging costs are realized under all oil price scenarios in 2008.

**Option Strike Optimization**

Next, we see whether the airline can further improve its hedged results by changing the strike prices (i.e. 110% and 80% of underlying futures). We begin the optimization process by varying the call
option strike between $0.01 and $200.00 while keeping the stroke of the put at the previous $73.94 price level. Alternatively, we vary the put strike while holding the call strike fixed at $101.67. This allows us to define the following two optimization problems to find the optimal strike prices:

$$\min_{K^C} \sum_{i=1}^{20} \left[ M_i - \max \{0, K_i^{opt} - M_i \} + \max \{0, M_i - K_i^{bench} \} \right]$$

$$+ P_C(K_i^{opt}) - P_C(K_i^{bench})$$

s.t. 

$$M_i - \max \{0, K_i^{opt} - M_i \} + \max \{0, M_i - K_i^{bench} \}$$

$$+ P_C(K_i^{bench}) \leq C_i^{bench}$$

$$K_i^{bench} = 73.94,$$ 

$$0.01 \leq K_i^{opt} \leq 200.00.$$ 

When developing the optimized put strike portfolio, the restrictions (9) and (10) are replaced with:

$$K_i^{bench} = 101.67,$$ 

$$0.01 \leq K_i^{opt} \leq 200.00.$$ 

Our optimal strikes will be the ones that give us better expected outcomes under each scenario. The results are perhaps a bit surprising. We find, first of all, that the optimal call strike for the firm is $99.93, lower than the previously used 101.76. The lower strike does mean the airline has to pay higher premiums for the calls. The “Optimized Call Portfolio” requires an additional 2.02 per barrel of oil hedged, or 9,507,620 more in total.

In the second optimization, the optimal put strike turns out to be 0.01 (the lowest value possible in our optimization framework), which means that the optimal decision for the airline is not to sell puts at all. The benefits to airline of being able to buy fuel when prices fall below 74.01 (the initial strike price of the annual put option) are greater than the roughly 6 million it would receive from put sales (see Table B.3 for comparison of the capital inflow due to the sold put options). The overall spending on option premiums in 2008 is then roughly 61 million for average hedging costs of 1.91, representing a reduction of 5.5% relative to the firm’s currently-utilized Benchmark Portfolio.

Despite the significantly higher net option premiums it must pay, the airline is better off under both the “Optimized Call Portfolio” and the “Optimized Put Portfolio.” The slightly lower call strike price provides an additional average profit of 0.87 per barrel of oil consumed in 2008 under all the scenarios between 110 and 200 a barrel. For those scenarios when prices are below 110, the results are the same as for benchmark case (see Figure 2). Not selling any annual Asian put options, however, allows the airline to benefit significantly under oil-price scenarios of 74.01 and lower. This is especially important strategically because competing airlines, particularly the financially weak ones who had been unable to deal in options, would be reaping significant benefits of prices below 74.01.

This analysis demonstrates, first of all, that the airline could be better off than it is now by switching from monthly-settled to annually-settled options when establishing its collars. Second, it shows that the airline could improve its situation even more by purchasing more expensive, lower-strike calls or not selling any puts.

Cash Management and Corporate Hedging

The interaction between a firm’s cash management, its leverage and its hedging activities is critical. A number of academic studies have found that companies with lower returns on assets and high borrowing costs typically hold more liquid assets, as do both small companies and firms with volatile assets, as do both small companies and firms with volatile assets. A study on hedging in the U.S. airline industry found that “the most active hedgers of fuel costs among airlines are the larger firms with the least debt and highest credit ratings.” Clearly, there is a trade-off between financing and commodity price risk management.

The airline needs to maintain a certain cash position (or have credit lines) to buy physical jet-fuel. While an annually-settled option won’t pay off until the end of the year, owning such an option would make the airline more creditworthy to its lenders.

The simulations above that showed the advantage of the
the beginning (December 31, 2007); (2) the midpoint (June 30, 2008), and (3) the end (December 31, 2008).

Table 4 shows how the firm’s financial condition would have changed over 2008 under the “Benchmark Portfolio” and the “Alternative Portfolio.” The Benchmark Portfolio cost $67 million while the Alternative Portfolio cost only $57 million. It is true that under the “Benchmark Portfolio,” the airline receives cash from its monthly-settled options throughout the year; but the annual option also increases in mark-to-market value even if it does not pay out until year’s end. Given the Brent mid-year average spot price on June 30, 2008 of $109.75, the average of the six outstanding

Alternative Portfolio were based upon a very wide range of oil prices. Of course, one should not draw strong conclusions about the soundness of a hedging strategy in just one year, but it is reasonable to ponder how the two portfolios would have performed under the specific circumstances that unfolded in 2008.

In that particular case, it turns out the existing Benchmark strategy would have come out ahead. The situation in 2008 was particularly unusual as oil prices peaked around the Fourth of July, almost exactly mid-year, and then fell precipitously during the next six months. We evaluate the firm’s hedging and cash position at three points in time: (1) the beginning (December 31, 2007); (2) the midpoint (June 30, 2008), and (3) the end (December 31, 2008).

Figure 7  Development of the Spot Brent Price in 2008

Table 4  Cash Position of the Airline Comparing the “Benchmark Portfolio” and the “Alternative Portfolio”

<table>
<thead>
<tr>
<th></th>
<th>12/31/2007 (million $)</th>
<th>06/30/2008 (million $)</th>
<th>12/31/2008 (million $)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BENCHMARK PORTFOLIO</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Options Premiums</td>
<td>$67</td>
<td>$67</td>
<td>$67</td>
</tr>
<tr>
<td>Expenses Hedged Volume</td>
<td></td>
<td>$1,777</td>
<td>$3,041</td>
</tr>
<tr>
<td>Annually hedged</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Monthly hedged</td>
<td>$1,777</td>
<td>$3,041</td>
<td>$822</td>
</tr>
<tr>
<td>Expenses Unhedged Position</td>
<td></td>
<td>$337</td>
<td>$822</td>
</tr>
<tr>
<td>Liquidity Cushion due to Monthly Options</td>
<td></td>
<td>-$236</td>
<td>$0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$1,945</td>
<td>$3,929</td>
<td></td>
</tr>
<tr>
<td><strong>ALTERNATIVE PORTFOLIO</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Options Premiums</td>
<td>$57</td>
<td>$57</td>
<td>$57</td>
</tr>
<tr>
<td>Expenses Hedged Volume</td>
<td></td>
<td>$1,883</td>
<td>$3,128</td>
</tr>
<tr>
<td>Annually hedged</td>
<td>$1,184</td>
<td>$2,100</td>
<td>$1,028</td>
</tr>
<tr>
<td>Monthly hedged</td>
<td>$699</td>
<td>$1,028</td>
<td>$822</td>
</tr>
<tr>
<td>Expenses Unhedged Position</td>
<td></td>
<td>$337</td>
<td>$822</td>
</tr>
<tr>
<td>Liquidity Cushion due to Annual and Monthly Options</td>
<td></td>
<td>-$526</td>
<td>$0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$1,750</td>
<td>$4,006</td>
<td></td>
</tr>
</tbody>
</table>
futures prices of $141.43, and assuming unchanged implied volatilities, the annual Asian option would have increased in value by approximately $468 million. This would have significantly increased the airline’s borrowing capacity. Because of the mark-to-market gain, the “Alternative Portfolio” on June 2008 is more valuable than the Benchmark. Under the Alternative Portfolio, total fuel purchase costs mid-year 2008 were $1.75 billion versus $1.95 billion for the Benchmark Portfolio.

However, the performance of the two portfolios changes during the latter half of 2008. Because the average price for 2008 was $96.94, the annual Asian call options expired out of the money (their strike price was $101.67). This meant that the airline simply purchased fuel at the spot price throughout the year and enjoyed no payout from options it owned. It benefited from the collapse in prices at the end of the year, but this was not enough for the Alternative strategy to win in 2008. With the Benchmark portfolio, the airline spent roughly $80 million less ($3.929 billion versus $4.006 billion) than it would have under the Alternative.

The airline recognizes the importance of its liquidity in its annual reports. It holds liquid assets of $5 billion, mentions its good corporate credit rating, and notes that it has short-term credit lines totaling $2.5 billion. This matters in the hedging context because liquidity enables the airline to use more economic annually-settled Asian options rather than monthly-settled. As long as the firm owns valuable annual options, it should be able to draw on its bank credit lines to satisfy any intra-year need for cash.

This case study of a real airline shows how a major corporate hedging program actually works. There is no one calculation that can lead a firm to an optimal hedging strategy, but the four factors this firm used to guide its strategy would seem pretty universally applicable: (1) the firm’s financial strength and credit rating, (2) the relationship between fuel prices and volumes consumed, (3) the fixed and variable costs of hedging, and (4) the firm’s internal risk profile. Given all those considerations, we also believe that annually-settled Asian options offer great economic benefits to corporate risk management programs.

**Appendix A—Monthly Settled Average Rate Options**

To value the annually settled Asian options we recommend, it is first necessary to understand the more commonly used monthly-settled options, in which the averaging takes place only in the final month prior to expiration.

We calculate the average volatility ($\Sigma_t$) in a two-step process using the implied volatilities ($\delta_t$) of the plain vanilla options on Brent crude of the Intercontinental Exchange (ICE) in London.

(1) We first calculate the volatility, $\delta_t$, during the option’s last month, which is lower than the implied plain vanilla one, $\delta_t$, due to the “volatility-dampening” effect of averaging:

$$\delta_t = \frac{1}{t} \ln\left(\frac{2e^{\delta_t^2} - (1 + \delta_t^2)}{\delta_t^2}\right)$$  \hspace{1cm} (1)

(2) We then compute the effective “blended variance,” $\Sigma_t^2$, which combines the variance of the non-averaging period and the variance during the averaged period (with $T = (T - t) + t$):

$$\Sigma_t^2 = \frac{(T - t)\delta_t^2 + \delta_t^2}{T}$$

the standard deviation of which is:

$$\Sigma_t = \sqrt{\frac{(T - t)\delta_t^2 + \delta_t^2}{T}}$$  \hspace{1cm} (2)

where $T$ represents the length of the non-averaging period and $t$ the averaging period. By using $\delta_t$ the “blended volatility” $\Sigma_t$, we are able to value a monthly-settled option applying the standard Black formula for European style options on futures contracts:

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Ehud I. Ronn is a professor of Finance at the McCombs School of Business, University of Texas at Austin. Dr. Ronn received his Ph.D. from Stanford University in 1983. During 1991–’93, Dr. Ronn served as Vice President, Trading Research Group at Merrill Lynch & Co., and from January 2010 to February 2011 as Commodity Market Modeling practice area manager at Morgan Stanley & Co. Dr. Ronn was the founding director of the University of Texas Center for Energy Finance 1997–2009. Dr. Ronn’s research, teaching and consulting have focused primarily on energy finance issues since 1997.
Call_{Asian} = e^{-rT}[FN(d) - KN(d - \Sigma_r\sqrt{T})]

Put_{Asian} = e^{-rT}[KN(\Sigma_r\sqrt{T} - d) - FN(-d)]

where \( F \) denotes the current price of the futures contract, \( N(.) \) stands for the cumulative normal distribution function, \( r \) denotes the risk-free rate of interest, \( T \) is the time to option expiration, \( \Sigma \) represents the “blended standard deviation,” and

\[
d = \frac{\log\left(\frac{F}{K}\right)}{\Sigma\sqrt{T}} + \frac{\sqrt{2}}{2}\Sigma_r\sqrt{T}
\]

The “Annual Asian Option”

While we like Asian options for the same reasons many hedgers already do, we think companies should consider using annually settled instead of monthly settled Asian options. An annual settlement would involve a 12-month long averaging period, further dampening the measured volatility and therefore requiring even lower option premia from the hedgers. Additionally, the standard time period in terms of financial or accounting purposes commonly also involves 12 months—the firm’s financial year. So, using a financial hedging instrument that averages price effects over the whole financial year would seem quite practical. Therefore, we recommend using annually settled options in place of the commonly used strip of twelve successive, monthly-settled options.

To illustrate annually settled option pricing, let us consider one with a maturity of one year (\( T = 1 \)). We have 12 successive crude oil futures prices to observe, but we need to estimate the volatility of the annual average.

We do have the implied volatilities of plain-vanilla options (\( \delta_i \)) listed on the ICE. These implied volatilities could be converted into their last-month-averaged counterparts, \( \Sigma_r \). As we do so, recall the computation of \( \delta_i \) in Equation (1). We now add the subscript \( T \) to \( \delta_i \) to denote the averaged volatility for month \( T \), \( \delta_{AT} \), which can differ across the months due to \( \delta_i \neq \delta_j \) for \( i \neq j \). Hence, the only required inputs are the sequence of twelve monthly futures prices \( (F_1, F_2, \ldots, F_{12}) \) and the corresponding implied volatilities of the plain vanilla options \( (\delta_1, \delta_2, \ldots, \delta_{12}) \), all of which are publicly available.

Applying Equation (2) and using \( d_{AT}, t, \) and \( T \), the first two moments can be calculated as following:

\[
M_1 = \frac{1}{N} \sum_{T=t}^{T} F_T
\]

\[
M_2 = \frac{1}{N^2} \sum_{T=t}^{T} \sum_{t=1}^{T} F_T F_{T-t} e^{\frac{e^{2t}}{2}} + \frac{1}{N^2} \sum_{T=t}^{T} \sum_{t=1}^{T} F_T F_{T-t} e^{\frac{(e^{2t}-e^{2T})}{2}}
\]

We computed the requisite correlations \( \rho_{T} \) between the twelve futures contracts using the following formula:

\[
\rho(\Delta t, t_{min}) = A + (1 - A) e^{\frac{-t_{min}}{\Delta t}}
\]

where

\[
A = e^{-b|\Delta|}
\]

\( a, b = \) two positive coefficients
\( \Delta t = \) time span between two futures contracts (in years)
\( t_{min} = \) time to maturity of the earlier of the two contracts

Finally, the one-year-averaged option volatility, denoted \( \Sigma_r \), is then obtained from the two moments \( M_1 \) and \( M_2 \) using \( \tau = 1 \):

\[
\Sigma = \sqrt{\frac{\frac{1}{\tau} - \frac{M_2}{M_1}}{M_1}}
\]

With the futures price sequence and the estimated average volatility, we can now apply the Black commodity futures option model to value the Annual Asian Option. For a given strike price \( K \), and an interest rate \( r \), the option can be valued with \( 1 \) the futures price \( F \) set to \( \frac{M_1}{\tau} \), \( 2 \) the time to expiration set to \( \tau = 1 \), and \( 3 \) the volatility set to \( \Sigma \).

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18. This cost reduction is computed relative to the “Benchmark Portfolio” (in %).
### Appendix B

#### Table B.1  Volume of Barrels Oil Hedged Under “Alternative Portfolio”

<table>
<thead>
<tr>
<th>Year 2008</th>
<th>Expected consumption</th>
<th>Monthly Asian Hedged</th>
<th>Unhedged Spot Purchases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>3,500</td>
<td>1,807</td>
<td>594</td>
</tr>
<tr>
<td>Feb</td>
<td>3,500</td>
<td>1,807</td>
<td>745</td>
</tr>
<tr>
<td>Mar</td>
<td>3,500</td>
<td>1,807</td>
<td>480</td>
</tr>
<tr>
<td>Apr</td>
<td>3,500</td>
<td>1,807</td>
<td>411</td>
</tr>
<tr>
<td>May</td>
<td>3,500</td>
<td>1,807</td>
<td>435</td>
</tr>
<tr>
<td>Jun</td>
<td>3,500</td>
<td>1,807</td>
<td>477</td>
</tr>
<tr>
<td>Jul</td>
<td>3,500</td>
<td>1,807</td>
<td>483</td>
</tr>
<tr>
<td>Aug</td>
<td>3,500</td>
<td>1,807</td>
<td>818</td>
</tr>
<tr>
<td>Sep</td>
<td>3,500</td>
<td>1,807</td>
<td>988</td>
</tr>
<tr>
<td>Oct</td>
<td>3,500</td>
<td>1,807</td>
<td>1,134</td>
</tr>
<tr>
<td>Nov</td>
<td>3,500</td>
<td>1,807</td>
<td>1,579</td>
</tr>
<tr>
<td>Dec</td>
<td>3,500</td>
<td>1,807</td>
<td>1,692</td>
</tr>
</tbody>
</table>

#### Table B.2  Volume of Barrels Oil Hedged Under “Alternative Portfolio”

<table>
<thead>
<tr>
<th>Year 2008</th>
<th>Expected consumption</th>
<th>Annual Asian Hedged</th>
<th>Monthly Asian Hedged</th>
<th>Unhedged Spot Purchases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>3,500</td>
<td>1,807</td>
<td>1,097</td>
<td>594</td>
</tr>
<tr>
<td>Feb</td>
<td>3,500</td>
<td>1,807</td>
<td>946</td>
<td>745</td>
</tr>
<tr>
<td>Mar</td>
<td>3,500</td>
<td>1,807</td>
<td>1,212</td>
<td>480</td>
</tr>
<tr>
<td>Apr</td>
<td>3,500</td>
<td>1,807</td>
<td>1,280</td>
<td>411</td>
</tr>
<tr>
<td>May</td>
<td>3,500</td>
<td>1,807</td>
<td>1,257</td>
<td>435</td>
</tr>
<tr>
<td>Jun</td>
<td>3,500</td>
<td>1,807</td>
<td>1,215</td>
<td>477</td>
</tr>
<tr>
<td>Jul</td>
<td>3,500</td>
<td>1,807</td>
<td>1,208</td>
<td>483</td>
</tr>
<tr>
<td>Aug</td>
<td>3,500</td>
<td>1,807</td>
<td>873</td>
<td>818</td>
</tr>
<tr>
<td>Sep</td>
<td>3,500</td>
<td>1,807</td>
<td>704</td>
<td>988</td>
</tr>
<tr>
<td>Oct</td>
<td>3,500</td>
<td>1,807</td>
<td>558</td>
<td>1,134</td>
</tr>
<tr>
<td>Nov</td>
<td>3,500</td>
<td>1,807</td>
<td>112</td>
<td>1,579</td>
</tr>
<tr>
<td>Dec</td>
<td>3,500</td>
<td>1,807</td>
<td>0</td>
<td>1,692</td>
</tr>
</tbody>
</table>
## Table B.3 Aggregated Hedging Costs in Terms of Option Premiums and Gross Exposure Per Barrel of Oil Consumed

<table>
<thead>
<tr>
<th>Hedging Instruments</th>
<th>Benchmark Portfolio</th>
<th>Alternative Portfolio</th>
<th>Optimized Call Portfolio</th>
<th>Optimized Put Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aggregated Premiums (in Mil. $)</td>
<td>Volume Hedged (Mil. barrels)</td>
<td>Aggregated Premiums (in Mil. $)</td>
<td>Volume Hedged (Mil. barrels)</td>
</tr>
<tr>
<td>Monthly Call (long)</td>
<td>$84.549</td>
<td>32.156</td>
<td>$24.640</td>
<td>10.469</td>
</tr>
<tr>
<td>Annual Call (long)</td>
<td>-</td>
<td>-</td>
<td>$41.817</td>
<td>21.687</td>
</tr>
<tr>
<td>Annual Put (short)</td>
<td>-</td>
<td>-</td>
<td>-$6.025</td>
<td>21.687</td>
</tr>
<tr>
<td>Total cost</td>
<td>$65.047</td>
<td>$55.307</td>
<td>$64.719</td>
<td>$61.332</td>
</tr>
<tr>
<td>Gross Exposure /barrel consumed</td>
<td>$2.02</td>
<td>$1.72</td>
<td>$2.01</td>
<td>$1.91</td>
</tr>
<tr>
<td>Cost reduction19</td>
<td>-</td>
<td>14.9 %</td>
<td>-</td>
<td>0 %</td>
</tr>
</tbody>
</table>

Table B.3 shows the aggregated option premiums of the “Benchmark Portfolio” currently established by the airline and the three alternative portfolio including annual Asian options. The gross exposure (total cost) in $ per barrel of oil consumed is shown based on the derivatives’ payoff traded and the remaining spot market purchases.

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19. This cost reduction is computed relative to the “Benchmark Portfolio” (in %).