Cross hedging jet fuel on the Singapore spot market

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KEYWORDS: cross hedging, Singapore spot market, jet fuel

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In this paper we test for the most effective cross hedging instrument for the Singapore spot market in jet fuel over the period February 4, 1997 to August 21, 2001. Our results are mixed. We find that the heating oil contract is the best in-sample cross-hedging instrument. It has the highest correlation with the spot price and gives the best regression results. However, after correcting for serial correlation, the goodness of fit measured by R^2 is rather low. Out of sample results are weak for all models and ambiguous with respect to the heating oil contract.

1.   Introduction

The cost of jet fuel or kerosene, as it is often called, is a major concern for the airline industry. According to Co (2000), jet fuel constitutes 10-20% of airline costs and a 5% change in its price can make the difference between profit and loss. As a derivative of crude oil, the price of jet fuel is notoriously volatile,[1] which presents the airline industry with a serious risk management problem. The airlines' ability to stock large amounts of jet fuel is limited due to financing and storage costs as well as location requirements for airplane refueling. Thus, in order to manage the price risk, most airlines use the derivative markets. In fact, Nicolls (1999) finds that airline companies use the derivative markets to hedge up to 80% of their exposure while Co (2000) estimates hedging at 20-50%.

The most common hedging instrument is a futures contract but, since contracts on jet fuel itself are rare,[2] cross hedging using another petroleum or energy product is the accepted practice. Because of its high correlation with the spot price of jet fuel, the instrument of choice is often the heating oil futures contract. However, there is evidence that the heating oil contract may not always be the most effective hedge. Errera and Brown (1999), for example, show that heating oil prices are influenced by seasonal demand, which could affect the hedge. Gjolberg and Johnson (1999) emphasized that the co-

movement between price levels of crude oil and its related products, illustrated in Table 1, including jet fuel, are quite strong, thereby suggesting that the price of crude itself is a suitable candidate as a hedging proxy. Serletis and Kemp (1998) presented evidence for strong cyclical correlations between heating oil, unleaded gasoline and natural gas prices with crude oil prices in the US. Serletis and Herbert (1999) found a strong statistical relationship between Henry Hub & Transco Zone 6 natural gas prices and fuel oil prices and suggest that this can be used as an effective arbitrage mechanism for these prices across NYMEX and New York Harbor.

Table 1
List of refined products in percentages obtained from a barrel of crude oil

Product	Gallons per Barrel
Gasoline	**19.5**
Distillate Fuel Oil (includes both home heating oil & diesel)	9.2
Kerosene	4.1
Residual Fuel Oil (heavy oils used as fuels in industry, marine transport and electric power generation)	2.3
Liquefied Refinery Gases	1.9
Still Gas	1.9
Coke	1.8
Asphalt and Road Oil	1.3
Petrochemical Feedstock	1.2
Lubricants	0.5
Kerosene	0.2
Other	0.3

Figures are based on 1995 average yields for US refineries. One barrel of oil contains 42 gallons. Excess due to "processing gain"

Source: www.CommoditySeasonals.com

Given the close relationships between the different sectors of the energy market, it is clear that there are a number of potential candidates for cross hedging jet fuel on the futures markets. In this paper we take the perspective

of hedging operations based in South East Asia to test for the most effective cross hedging instrument for the Singapore spot market in jet fuel over the period February 4, 1997 to August 21, 2001. Our results are mixed. We find that the heating oil contract is the best in-sample cross-hedging instrument. It has the highest correlation with the spot price and gives the best regression results. However, after correcting for serial correlation, the goodness of fit measured by R^2 is rather low. Out of sample results are weak for all models and ambiguous with respect to the heating oil contract.

The rest of the paper is organized as follows. Section 2 discusses the minimum variance cross hedging techniques. Section 3 deals with the problems of cross hedging associated specifically with commodities. Section 4 presents the empirical results for hedging jet fuel and section 5 concludes.

2. The Evolution of Cross-Hedging Techniques

Hedging via the futures markets is not always straightforward and one has to overcome problems such as mismatch of the maturity date, the underlying asset, or both. The former leads to a delta-hedge, the latter to a cross-hedge and when both are in place to a cross delta hedge. The seminal ideas go back almost half a century and the usual approach is due to Johnson (1960), Stein (1961) and Ederington (1979). A wider perspective on cross hedging in a risk return framework is described by Anderson and Danthine (1981). It is now a common subject in textbooks such as Stoll and Whaley (1993), Ritchken (1996), and Clark (2002), to name just a few, and yet there is still an ongoing debate about what techniques are the most useful.

In this paper we are concerned with commodity cross-hedging. Although it has been shown that it is possible to cross-hedge commodities with currencies as in Sadorsky (2000) and currencies with commodities as in Benet (1990), in this paper we consider only the case of two markets from the same class, one a futures market and the other a spot market with *different* but *correlated* commodities.

The most widely used methods for calculating the optimal hedge ratio are based on regression techniques. Three types of regression models can be used: price level, price change level and percentage change level. We denote by $S(t)$ the spot price at time t of the commodity targeted for hedging and by $F_T(t)$ the futures price at time t of the proxy hedging commodity with maturity time T. The maturity of futures contracts usually comes after the hedging period. In other words if T is the exposure period for the hedge, the futures contracts used for cross hedging will have a maturity $T_2 > T_1$.

In this paper we consider only the situation of minimizing the risk of holding a portfolio of the underlying commodity and futures contracts of one

or several of its proxies. Shorting b_0 futures of one proxy for each long position in the spot leads to a cash flow at time T_1 equal to

$$S(T_1) - \beta_0 F_{T2}(T_1) + \beta_0 F_{T2}(0) \tag{1}$$

Minimizing the variance of this cash flow leads to

$$\beta_0 = \frac{\text{cov}_0(S(T_1), F_{T2}(T_1))}{\text{var}_0(F_{T2}(T_1))} \tag{2}$$

The optimal coefficient β_0 depends on the horizon of exposure to hedging T_1 and the futures maturity T_2. In practice it is often assumed that it is constant with respect to time, although some studies suggest that this is not always the case. We shall treat this assumption with caution but for the sake of simplicity we drop the index and refer to the optimal hedge ratio as simply β.

The formula given in (2) can be recovered from a simple regression model such as

$$S(t) = \alpha + \beta F_{T2(t)}(t) + \varepsilon_t \tag{3}$$

where $F_{T2(t)}(t)$ is the price of the futures contract at time t with $T_2(t)$ the nearest available maturity. The estimate of the optimal hedging ratio depends on the historical data.

In order to solve problems related to autocorrelation, many authors prefer a regression at the price change level. Thus, β is estimated from

$$S(t) - S(t-1) = \alpha + \beta (F_{T2(t)}(t) - F_{T2(t-1)}(t-1) + \varepsilon_t \tag{4}$$

There may still be problems with the regression in (4) associated with heteroscedasticity. When this is the case, a percentage change level regression is often used in the form

$$\frac{S(t)}{S(t-1)} - 1 = a + b \left(\frac{F_{T2(t)}(t)}{F_{T2(t-1)}(t-1)} - 1 \right) + \varepsilon_t \tag{5}$$

The hedge ratio is calculated from the estimated slope of this regression using the formula

where t^* is the last day in the estimation sample.

When simple linear regression methods are used, the R^2 is a measure of the efficiency of the hedging. The theoretical support is provided by Ederington (1979) and Dale (1981) but some research by Chang and Fang (1990) indicated that this measure is not always appropriate and other measures of efficiency may be more useful. However, the R^2 is still largely used in practice for its direct interpretability and ease of calculation, especially in conjunction with regression based methods.

3. Cross-Hedging Commodities

The basic principles of hedging can be used for many commodities for which no futures contract exists, because often they are similar to commodities having futures that are traded. Witt et al. (1987) compare the analytical approaches for estimating hedge ratios for agricultural commodities and discuss various issues related to regression based methods.

Our interest is jet fuel or kerosene, a commodity that could be hedged by using a number of other energy products. In energy markets, basis risk is an ever-present ingredient in hedge selection. On the one hand, the distribution of prices in the energy markets is not as unbounded as in the foreign exchange market because operating costs and constraints tend to underpin downward price movements (Moonier and Potter 1998). However, on the other hand, other economic considerations such as transfer costs, storage costs and location may lead to very interesting cross hedging problems. One good example is Woo et al. (2001) where cross hedging in power utilities markets is discussed.

Another problem outlined by Pindyck and Rotemberg (1990) is that exchange rates seem to be a factor in commodity pricing, thereby adding a potential complication to the problem of cross hedging if sensitivities vary across commodities. They found that an equally weighted index of the dollar value of British pound, German mark, and Japanese yen negatively and significantly impacts the price of crude oil in both OLS regressions and latent variable models. Sadorsky (2000) also showed that futures prices for oil related products are co-integrated with a trade-weighted index of exchange.

4. Cross-Hedging Jet Fuel

4.1 The Data
The data analysed are weekly time series from Datastream between February 4, 1997 and August 21, 2001, Tuesday continuous settlement prices for a total of 204 observations. The codes used are JET for the spot jet fuel price on the Singapore spot market, LCR for the Brent crude oil contract on the

International Petroleum Exchange (IPE), NCL for the light sweet crude oil contract on the New York Mercantile Exchange (NYMEX), NHO for the heating oil contract on NYMEX, NHU for the unleaded regular gas contract on NYMEX, and NPG for the liquid propane gas contract on NYMEX. Table 2 shows the correlations between the foregoing variables. Spot jet fuel is highly correlated with all the futures contracts with the highest correlation associated with the heating oil contract. All the futures contracts are also highly correlated among themselves.

Table 2
Price level correlations; weekly data 4th February 1997 to
26th December 2000, Tuesday Settlement Prices

Table: Price level correlation between jet kerosene and futures contracts						
	JET	**LCR**	**NCL**	**NHO**	**NHU**	**NPG**
JET	1.00					
LCR	0.92	1.00				
NCL	0.96	0.94	1.00			
NHO	0.97	0.91	0.97	1.00		
NHU	0.91	0.93	0.97	0.92	1.00	
NPG	0.90	0.90	0.92	0.94	0.86	1.00

The results of the unit root tests in Table 3 indicate that we can reject the null hypothesis of non-stationarity for all series well beyond the 1% significance level. Moreover, from the cointegration tests in Table 4 we also reject the hypothesis that the spot prices and futures prices are drifting apart in time for all futures contracts under analysis.

Table 3
The ADF statistics for random walk tests

Variable	JET	LCR	NCL	NHO	NHU	NPG
ADF statistics	-10.29*	-9.20*	-10.60*	-12.61*	-9.96*	-8.93*
*Significant at the 1% level						

4.2   *Preliminary Results*

With these results in mind, we can use ordinary least squares (OLS) in the regression model (3) to fit the data. The estimate for the slope coefficient represents the hedge ratio. The results are reported in Table 5 where we see

that the heating oil contract (NHO) is superior to the other proxies, both in terms of the significance of the hedge ratio measured by the *t*-statistic and by the overall goodness of fit measured by the R^2. However, we can see from the value of the Durbin-Watson statistic that we have problems with positive autocorrelation.

This is a typical case where researchers will often change their regression model from a price level to a price change level. Although a large group of studies (Hill and Schneeweis (1981); Park et al. (1987); Braga et al. (1989) among many others) emphasized that using price level models is wrong due to obvious statistical problems we strongly agree with Witt et al. (1987) that the statistical first difference model is not congruent to the price change model. This is because the lag operator for price (percentage) change models takes differences as the change in prices over the time interval representing the hedge exposure and, as long as this exposure is not identical to the frequency of the data under the analysis, autocorrelation may still be a problem. Moreover, the exposure is not important for price level models because the same ratio can be used whereas when price change or percentage change models are employed the hedge ratio depends on the hedging period.

Table 4
ADF tests for cointegration between jet fuel spot and futures on other oil products

Variable	LCR	NCL	NHO	NHU	NPG
ADF statistics	-4.90*	-3.96*	-3.68*	-2.84*	-3.80*
*Significant at the 1% level					

Table 5
OLS results for the simple regression model regressing the jet fuel oil on futures prices of proxy variable

Futures Contract	α	t-statistics	β	t-statistics	Adjusted R^2	Durbin-Watson statistics
LCR	2.222	3.166	1.110	32.755	0.84	0.316
NCL	0.444	0.857	1.127	47.844	0.92	0.473
NHO	1.668	3.939	39.339	55.827	0.94	0.476
NHU	0.381	0.473	37.547	30.675	0.82	0.194
NPG	5.098	7.281	48.485	28.871	0.80	0.208

Furthermore, as we mentioned above, most airline companies, although they might have some storage capacity, cannot afford to stock vast amounts of kerosene for long periods of time. Therefore, their concern is the current futures price and the ending basis and this is where price level models are relevant. If there is any problem with autocorrelation, instead of resorting to a difference model, a more appropriate solution would be to correct the estimates of the regression coefficients using a Cochrane-Orcutt procedure (see Davidson and MacKinnon, 1993, Chapter 10). Then the adjusted estimates are BLUE.

Table 6 reports the results of the Cochrane-Orcutt adjusted estimates where β represents the new hedge ratio. One of the first things to be noticed is the improvement in the Durbin Watson statistic. We can also see that the t-statistics for the hedge ratio and the R^2 have degenerated considerably. In fact, the contracts on Brent crude (LCR) and liquid propane gas (NPG) are no longer relevant proxies. Based on Table 6, the heating oil contract (NHO) is clearly statistically superior to the others.[3]

Table 6
Cochrane-Orcutt corrected estimates

Futures	ρ	β_1	t-statistics	β_2	t-statistics	Adjusted R^2	Durbin-Watson statistics
LCR	0.998	0.0424	0.466808	0.038978	0.457283	-0.00393	1.834391
NCL	0.997	0.0406	0.496997	0.416484	6.903424	0.187637	2.214941
NHO	0.994	0.0460	0.576674	19.09626	7.975026	0.236587	2.223238
NHU	0.993	0.0941	1.132133	14.98603	6.494167	0.169320	2.120128
NPG	0.997	0.0360	0.394835	5.596175	1.247208	0.002743	1.827963

4.3   Scholes Williams Estimates

Thus, we conclude that the heating oil contract is the best hedging instrument. One last problem remains, however. It is well-known that non-synchronization between spot data and futures data may affect the inference process because of a lead-lag relationship. To account for any synchronization problems in our data, we also calculate the Scholes and Williams (1977) instrumental variable estimator, suggested by Sercu and Wu (2000), for the hedge ratio for the three contracts that remain relevant. This estimator is calculated with the formula

$$SW = \frac{\hat{cov}\,(\Delta S(t), IV(t))}{\hat{cov}\,(\Delta F(t), IV(t))} \tag{10}$$

where

$$IV(t) = \Delta F(t-1) + \Delta F(t) + \Delta F(t+1) = F(t+1) - F(t-2) \qquad (11)$$

and

$$\Delta S(t) = S(t) - S(t-1) \text{ and } \Delta F(t) = F(t) - F(t-1).$$

Table 7 gives the results of the SW estimates for our data.

Table 7
Scholes-Williams instrumental variable estimates

Independent variable (Futures)	SW estimator
NCL	1.09439
NHO	32.1953
NHU	-29.75581

4.4 Out of Sample Tests

Our final step is to test the effectiveness of the relevant contracts out-of-sample using the Theil statistics. The out-of-sample testing was done over the period December 26, 2000 to December 31, 2001. Tables 8 and 9 summarize the results.

Table 8
Hedging effectiveness of OLS based estimates

	R^2	Theil-U	Theil inequal
NCL	79.8	1.12	0.69
NHO	61.1	1.00	0.98
NHU	62.8	1.12	0.64

Theil-U: Larger values indicate poor forecasting performance.
Theil inequality: lies between 0 and 1 with 0 = perfect.

In Table 8 we can see that none of the OLS based models performs very well and the heating oil contract is no longer unambiguously superior to the other models. Its R^2 and Theil inequality coefficients are the worst of the three. However, its Theil-U coefficient, which is a measure of the goodness of fit, is the best.

Table 9
Hedging effectiveness of IV based estimates

	R^2	Theil-U	Theil inequal
NCL	-39.1	1.59	0.64
NHO	-10.7	1.44	0.66
NHU	-47.4	1.64	0.79

Theil-U: Larger values indicate poor forecasting performance.
Theil inequality: lies between 0 and 1 with 0 = perfect.

When we look at the hedging effectiveness of the IV based estimates in Table 9, we can see that performance deteriorates. The R^2 are lower and the Theil-U statistics are higher. It is interesting that the Theil inequality coefficient for the heating oil contract has improved considerably, although it is still not very good.

5.   Conclusions

Jet fuel (kerosene) is a major cost for the airline companies. As a commodity linked to petroleum products its price is volatile and constitutes an important risk for these companies. Managing this risk is complicated by the fact the only futures contract traded on jet fuel is listed on the Tokyo market in Japanese yen. Thus, outside of Japan hedging on the organized exchanges requires the use of a proxy instrument to set up a cross-hedge. Numerous cross-hedging instruments have been proposed and this paper compares the effectiveness of the five major contracts suggested in the literature and used in practice - the Brent crude oil contract on the International Petroleum Exchange (IPE), the light sweet crude oil contract on the New York Mercantile Exchange (NYMEX), the heating oil contract on NYMEX, the unleaded regular gas contract on NYMEX, and the liquid propane gas contract on NYMEX -for hedging the spot jet fuel price on the Singapore spot market.

We find that the heating oil contract gives the best in-sample results. However, after correcting for autocorrelation, the fit of the new models to the data is not too good, explaining only about 24% - at best - of changes in the spot price. Since the problem may lie with the futures prices and poor synchronisation between spot data and futures data, we calculate the Scholes and Williams instrumental variable and then test out-of-sample. These tests cloud the picture. For the OLS based estimates, the Theil U and the Theil inequality coefficients suggest that none of the contracts are very effective.

Furthermore, the heating oil contract is no longer the unambiguous front runner with the lowest R^2 and the worst Theil inequality coefficient, although its Theil-U is the best. When we perform the out of sample tests with the IV based estimates, the results are worse, thereby suggesting that there is nothing to be gained by following this route, although the heating oil contract seems to have the best performance.

Endnotes

1.   In the recent past, oil prices have ranged from as low as $10/bbl in 1999 to over $35/bbl in 2000 when it caused shortages in America's Mid-Western States in the summer and fuel riots, which paralysed several European countries in September.

2.   Kerosene futures contracts are traded on TOCOM in Japanese yen. The scope of this contract is limited to Japanese based hedgers for all practical purposes because of the exchange risk and because there is no cash settlement with delivery location restricted to the Tokyo Bay area. Singapore International Monetary Exchange (SIMEX) launched fuel oil futures contracts in February 1989 but failed to attract much business. In spite of modifications to contract specification at the end of 1997 the contract lost any interest and was discontinued in 2000.

3.   There are 42 gallons per barrel. Thus, in terms of numbers of futures contracts N, $\beta/42 = 19.09626/42 = 0.45$ futures contracts per 1,000 barrels of jet fuel.

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