Chapter 6

Conclusion

6.1 Summary of the Study

The purposes of this dissertation was: to estimate univariate and multivariate conditional volatility models and volatility spillovers models for different crude oil returns, namely spot, forward and futures returns, within and across different markets, namely Brent, WTI, Dubai and Tapis, and to examine volatility spillovers between crude oil futures returns and oil company stock returns for the major oil companies.

Econometric models, a wide range of conditional volatility models and conditional correlation models had been used to estimate and forecast volatility and volatility spillovers with symmetric and asymmetric effect, and conditional correlations in crude oil futures returns. Univariate conditional volatility models were GARCH model of Bollerslev (1986) and GJR (or TGARCH) model of Glosten et al. (1992), whereas multivariate conditional volatility models were CCC model of Bollerslev (1990), DCC model of Engle (2002), VARMA-GARCH model of Ling and McAleer (2003), and VARMA-AGARCH model (McAleer et al. (2009)).

The conclusions of the empirical results were follows. First, the univarite ARCH and GARCH components for all returns in the ARMA(1,1)-GARCH(1,1) models of the spot, forward and futures returns of all four major benchmark international crude oil markets, namely Brent, WTI, Dubai, and Tapis were statistical significant. However, in the case of ARMA(1,1)-GJR(1,1) models, only the GARCH estimates in all cases were statistically significant, and most of the estimates of the ARCH estimates and the asymmetric effect were significant. In addition, log-moment and second moment conditions were satisfied for all returns which confirmed that the QMLE were consistent and asymptotically normal.

Second, using the CCC model and the Bollerslev and Wooldridge (1992) robust *t*-ratios, the calculated constant conditional correlations across the conditional volatilities of returns within same markets were all statistically significant and high. However, in case of across different markets, the calculated constant conditional correlations across the conditional volatilities of returns were all statistically significant and range from low to high, especially conditional correlation between Tapis and other crude oil markets.

Third, the VARMA-GARCH and VARMA-AGARCH models were used to determine the volatility spillover effects between crude oil returns within markets and across markets, and also to test for the asymmetric effects of positive and negative shocks of equal magnitude. Based on the asymptotic standard errors, most of both models presented the evidence of volatility spillovers and asymmetric effects of negative and positive shocks on the conditional variance, which suggested that VARMA-AGARCH was superior to VARMA-GARCH and CCC models. However, the significant interferences in the conditional volatilities among returns were found only in some cases.

Fourth, using a rolling window technique for VARMA-GARCH and VARMA-AGARCH between crude oil returns within markets and across markets in order to forecast 1-day ahead conditional correlation, all the conditional correlations displayed significant variability, which suggested that the assumption of constant conditional correlation was not valid. Interestingly, the forecasted conditional correlations were positive for all pairs of crude oil returns and exhibit both upward trend and downward trend.

Fifth, based on the asymptotic standard errors, the estimates of the dynamic conditional correlations and the descriptive statistics for DCC across the shocks to returns in each market showed that the estimated of the two DCC parameters $(\hat{\theta}_1)$ and $(\hat{\theta}_2)$ are statistically significant, which makes it clear that the assumption of constant conditional correlation is not supported empirically.

Finally, using the VARMA-GARCH and VARMA-AGARCH models to test volatility spillover effects and asymmetric volatility spillover effects between crude oil futures returns and oil company stock returns, the empirical results showed that the conditional correlations between WTI crude oil futures returns and oil company stock returns of CCC model were very low. Surprisingly, the VARMA-GARCH and VARMA-AGARCH results show that there were no spillover effects between any pair of returns series.

6.2 Suggestions for Further Study

Since the CCC, VARMA-GARCH and VARMA-AGARCH models are assumed constant conditional correlation, which are not supported from these empirical examples, and the DCC model has some drawbacks about restrictive conditions on the parameters, so McAleer et al. (2008) proposed the Generalized Autoregressive Conditional Correlation (GARCC) model and provided completely derivation of the regularity conditions and asymptotically theory. Therefore, future improvement in volatility modelling should consider the GARCC specification, which is likely to offer the potential for more accurate model and hedge strategies.

Hedging is an instrumental financial to reduce the risk involved in holding a financial asset by taking an offsetting position, and is popularly used by the oil company, oil trade or investor to reduce its exposure to fluctuations in crude oil prices. In addition, a useful application of the volatility models is in the formulation of hedging strategies. Consequently, future research should include a more detailed consideration of the design of an optimal hedging strategy based on estimating a wider range of models yielding dynamic conditional correlations. In case of volatility spillover, alternative causality techniques should apply for testing volatility transmission and compare the results with the VARMA-GARCH or VARMA-AGARCH model.

Nowadays, because of the rising crude oil prices, concerning about limited future crude oil supply, energy security issues (such as energy prices, critical need for energy and political instability of several energy producing countries) and increased concern about the natural environment (such as climate change or global worming), other primary energy sources (such as coal and natural gas) and alternative energy sources (such as nuclear energy, biofuels (gasohol and biodiesel), hydroelectric energy, solar power, win power and wave power) become more important. Therefore, the relationship of returns and volatility for crude oil prices and alternative energy prices should be explored in the futures study, because it may be shade light on understanding of effect of crude oil price on the alternative energy industry.

In addition, because of the recent rising crude oil price and growing environmental concerns, biofuels, especially ethanol and biodiesel, has become an important alternative fuel. Consequently, the linkage of returns and volatility between the crude oil prices and four internationally agricultural inputs prices for ethanol and biodiesel production, namely sugarcane, corn, soybean and palm oil should be examined, because volatility in the crude oil prices may spillover to ethanol and biodiesel markets, which in turn may induce volatility into the agricultural market.