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Oil price shocks and volatility in Australian stock returns

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Oil price shocks and volatility in Australian stock returns

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Abstract

This paper examines the effect of oil shocks on return and volatility in the sectors of Australian stock market and finds significant effects for most sectors. For the overall market index, an increase in oil price return significantly reduces return, and an increase in oil price return volatility significantly reduces volatility. An advantage of looking at sector returns rather than a general index of stock returns is that sectors may well differ markedly in how they respond to oil price shocks. The energy and material sectors (as expected) and the financial sector (surprisingly) are out of step (in different ways) with results for the other sectors and for the overall index. A rise in oil price increases returns in the energy and material sectors and an increase in oil price return volatility reduces stock return volatility in the financial sector. Explanation for the negative (positive) association between oil return (oil return volatility) and returns (volatility of returns) in the financial sector must be based on the association via lending to and/or holdings of corporate bonds issued by firms with significant exposure to oil price fluctuations and their speculative positions in oil related instruments.

JEL Classifications: G12, G15, Q4

Keywords: oil price shocks, Australian stock market, global financial crisis

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1. Introduction

A great deal of research has been directed toward identifying the interaction between oil prices and stock prices.[1] In an early paper, Chen et al. (1986) use oil risk factor in explaining stock returns in US stock market. Jones and Kaul (1996) in an investigation of the effect of oil prices on stock returns in Canada, Japan, UK and US, establish a link through changes in cash flows on stock prices in Canada and US. Sadorsky (1999) finds a negative relationship between oil price shocks and aggregate stock returns for the US. In contrast to Huang et al. (1996) who find no significant effect, Ciner (2001) finds a negative connection between real stock returns and oil price futures when nonlinear effects are introduced. Recent work reporting that oil price increases lead to reduced stock returns includes O'Neil et al. (2008) for US, UK and France, Park and Ratti (2008) for US and 12 European oil importing countries, and Nandha and Faff (2008) for global industry indices (except for extractive industries). Driesprong et al. (2008) find that oil price change predicts stock prices in many economies. Apergis and Miller (2009) however, do not find a large effect of structural oil market shocks on stock price in eight developed countries. Basher and Sadorsky (2006) that the changes in oil prices are significant in determining the returns of many emerging stock markets.

Oil price shocks influence stock prices through affecting expected cash flows and/or discount rates. Oil price shocks can affect corporate cash flow since oil is an input in production and because oil price changes can influence the demand for output at industry and national levels. Oil price shocks can affect firm value by influencing the discount rate for

[1] This research on the effect of oil prices on stock prices has been influenced and runs in parallel to a larger literature on the connection of oil price shocks with real activity. Much of this research has been influenced by Hamilton's (1983) connection of oil price shocks with recession in the US Hamilton's finding has been elaborated on and confirmed by Mork (1989), Lee et al. (1995), Hooker (1996), Hamilton (1996, 2003) and Gronwald (2008), among others.

cash flow through affecting the expected rate of inflation and the expected real interest rate. Higher volatility in oil prices also increases uncertainty at firms and in the economy with associated effects on firm value. Bernanke (1983) and Pindyck (1991) argue that changes in energy prices create uncertainty about future energy prices, causing firms to postpone irreversible investment decisions in reaction to the outlook for profits.[2]

In this paper we study the effect of oil price return and volatility on the return and the volatility of return in the sectors of Australian stock market. The literature has considered the effect of oil price shocks on stock market returns, but has not focused on the effect of oil return volatility on the volatility of stock market returns. In addition, most studies on the effects of oil price shocks are of national country indices or on specific sectors such as oil and gas and transportation. Results for aggregate indices may mask interesting effects of oil price shocks at the sector level. This may be particularly true for the influence of oil price volatility on sectoral volatility since the standard deviation of sector stock returns usually exceeds the standard deviation of aggregate market returns (in Australia with the only exception is the consumer staple sector). The heterogeneity of sector response to oil price return and/or volatility can have implications for efficient portfolio diversification.[3]

It is found that for the overall market index, an increase in oil price return significantly reduces return, and an increase in oil price return volatility significantly reduces volatility. The latter result follows since increased oil price volatility is associated with oil price changes that tend to move most stocks in a particular direction. For eight out of ten sectors (significantly so for six sectors) oil price return and stock price return move in

[2] Recent papers that connect oil-related volatility and investment decisions include Kellogg (2010) who uses oil prices as a measure of uncertainty, Stein and Stone (2010) who use oil prices as an instrument for a stock-price based uncertainty measure, and Henriques and Sadorsky (2011) and Yoon and Ratti (2011) who connect oil price and energy price volatility to firm level investment decisions.

[3] Fama and French (1997) find substantial differences in factor sensitivities across US industries. Both returns and volatility at the industry level provide significant information about the return and volatility process at the aggregate market level. Hong et al. (2007) identify the significance of industry level return to provide information about the movements of aggregate stock market. Thus, studying the return and volatility at the sector or industry level has significance in understanding the market.

opposite directions, but for the energy and materials sectors increased oil price return increases sector returns. An increase in oil price return volatility significantly reduces stock return volatility for five sectors (including the energy and materials sectors), but significantly increases stock return volatility for the financial sector. The negative link between oil return and returns and the positive association between oil return volatility and volatility of returns in the financial sector must be based on the association via lending to and/or holdings of corporate bonds issued by firms with significant exposure to oil price fluctuations and their speculative positions in oil related instruments. Results are robust to consideration of the Global financial crisis in September 2008.

We use the GARCH-in-mean (GARCH-M) methodology to model the stock return behaviour of the sectors of the Australian market and to examine the effects of oil return and oil return volatility. The GARCH-M methodology allows an examination of whether stock return volatility is a significant factor in the determination of sector risk premia.[4] In the GARCH-M model estimated, oil price return and oil return volatility can influence sector return directly and also indirectly through oil return volatility influencing sector return conditional volatility. This provides a potentially rich set of oil price influences on sector return and volatility of returns. Data are daily from 31 March 2000 to 31 December 2010.

The organisation of the study is as flows. Section 2 discusses previous studies of the effect of oil price shocks on stock return. Section 3 discusses the data descriptive statistics. Section 4 presents the GARCH-M model and the oil price volatility model. Section 5 presents empirical results and section 6 concludes.

[4] Neuberger (1994) point out that investors cannot ignore volatility when the risk premia required by the investors changes with volatility in asset returns. Bauwens et al. (2006) argue that second order moments of asset returns is important for many issues in financial econometrics.

2. Literature Review

This literature review is necessarily selective and will focus, beyond those papers already mentioned as examining the connection between oil price returns and country level stock price returns, on research on the influence of oil price returns on sectoral stock price returns, on research on the influence of oil price volatility on stock price returns, and on research on the influence of oil price volatility on stock price returns and volatility.

A number of papers have focused on the effect of oil price shocks on the returns of the oil and gas sector. Sadorsky (2001) and Boyer and Filion (2007) find a positive significant relationship between oil price shocks stocks returns for Canadian oil and gas companies, El-Sharif et al. (2005) report the same result for UK oil and gas companies as does Mohanty and Nandha (2011) for US oil and gas companies. Dayanandan and Donker (2011) report that oil price increases have a positive and statistically significant impact on the accounting profits of oil and gas companies in North America. Ramos and Veiga (2011) analyse the returns of the oil and gas sector in 34 countries and find that sector returns are significantly influenced by oil price returns.

Nandha and Faff (2008) examine thirty-five global industrial sector indices and find that oil price increases negatively impact all sectors except the oil and gas sectors. In an analysis of transport sector in thirty-eight countries, Nandha and Brooks (2009) find that oil prices have a negative impact on returns in developed economies and insignificant effects on returns in Asian and Latin American countries. Arouri (2011) investigates the response of sectors of European stock market indices to oil price changes and finds that most European stock market sectors are influenced by changes in oil prices but that responses vary widely across sectors. Faff and Brailsford (1999) report that across 25 Australian sectors the oil and gas and diversified resources industries have a significant positive response to oil price shocks in contrast to a significant negative response to oil price shocks in the paper and packaging and banking and transport sectors. McSweeney and Worthington (2008) consider nine sectors in the Australian stock market find that higher oil prices have a positive effect on energy sector returns and a negative effect in the banking, retailing, and transportation sector.[5]

Several papers have directly estimated the effect oil price volatility on stock market returns. Sadorsky (1999) shows that oil price shocks volatility generated by a GARCH process plays a role in explaining the US real stock returns. Park and Ratti (2008) find that for many European countries, but not for the US, increased volatility of oil prices, measured by monthly the sum of squared first log differences in daily spot crude oil price, significantly depresses real stock returns.

Only a few papers in the area address the effect of oil price volatility on the volatility of the stock price sector returns. Sadorsky (2003) considers oil price volatility and finds it as a significant factor in determining stock return volatility of the US technology sector. Hammoudeh et al. (2004) find that crude oil price volatility is associated with volatility of the S&P oil sector indices. Hammoudeh et al. (2010) examine the impact of oil prices on the stock return volatilities of 27 sectors in the US and report that increases in oil prices increase the return volatility for sectors that use oil intensively. Choi and Hammoudeh (2010) use a Markov-Switching GARCH model to measure the switch in return volatility between high and low regimes for commodities (including Brent oil and West Texas Intermediate oil) and the US stock market. Elyasiani et al. (2011) find that oil price fluctuations are important in determining excess stock returns in 9 out of 13 US stock market sectors over December 1998 to December 2006.

[5] With regard to work on volatility of the Australian stock market, Kearns and Pagan (1993), Kearney and Daly (1998) and Nicholls and Tonuri (1995) examine the impact of non-oil factors on stock market volatility. Kearney and Daly (1998) relate stock market volatility to the volatility of financial and economic variables.

3. The Data

Data are daily indices for 10 Global Industry Classification Standard (GICS) sectors in Australian stock market and oil price from 31 March 2000 to 31 December 2010. The data start on 31 March 2000 because the GICS classification, developed by Standard and Poor and Morgan Stanley Capital International, became effective in Australia from that day. There are 2543 daily observations. A market benchmark is provided by the S&P/ASX 200 index. The sectors are energy (XEJ), materials (XMJ), industrials (XNJ), consumer discretionary (XDJ), consumer staples (XSJ), health care (XHJ), financials (XFJ), information technology (XIJ), telecom (XTJ), and utility (XUJ). All data are collected from Datastream.

Figure 1 displays the index value of S&P/ASX 200 and 10 GICS sectors from 2000 to 2010. Over the period, energy, materials and financial sectors show the biggest movements and IT, telecom, and health sectors the most relative stability. The market index S&P/ASX 200 reflects the global financial crisis in 2008 has a big fall in 2008. Energy, material and financial sector have the biggest falls in value at this time. The daily excess return series for each sector are displayed in Figure 2. Return is defined as the first difference of the natural log of price. Excess stock return is calculated as daily return in excess of the yield on Australian 90 day bank accepted bill continuously compounded. The return series for each sector shows volatility clustering in that large increases and large decreases in return tend to bunch together.

The price of oil is the 1-month future prices of West Texas Intermediate (WTI) crude oil. Sadorsky (2011) notes the WTI crude oil futures price contract is the most widely traded futures contract and serves as a world-wide standard in the oil market. Boyer and Filion (2007) favour futures price rather than spot price because spot prices are more affected by random noise and by transitory shortages and supplies. The oil price level and oil price return are shown in Figure 3.

Descriptive statistics of daily return by sector and daily oil price return over 31 March 2000 to 31 December 2010 are reported in Table 1. The annualised market return is 3.84% and the annualised crude oil return is 6.72% over the period. Most of the GICS sectors have positive monthly mean return with the exceptions being consumer discretionary, telecom and information technology. Energy (XEJ) and materials sector (XMJ) have the highest average returns, with annualised returns of 15.24% and 13.94%, respectively. The average return in a GICS sector is small in comparison to the standard deviation of returns in a GICS sector and the average oil price return is also small relative to standard deviation of oil price returns. The standard deviation of oil price returns is over twice the standard deviation of market returns and exceeds the standard deviation of returns in each sector. The standard deviation of daily returns in each sector exceeds the standard deviation of daily market returns in Australia.

The return series of the GICS sectors and oil price are not normally distributed. Skewness is not close to zero and kurtosis is much higher than 3 for the return series. All return series are negatively skewed. The Jarque-Bera test (J-B) statistics reject the null hypothesis of normality in the distribution of the sample return series. As normality is the underlying assumption of the asset pricing models, modelling is challenging when the distributions of the return series are not normal. Given this limitation of the return distribution, ARCH and GARCH type models are attractive vehicles for analysis. The condition of non-normality of thick tails can be modelled by assuming a conditional normal distribution of returns. ARCH and GARCH class models can efficiently manage this non-normality condition.

The results of unit root test statistics for the data are provided in Table 2. The results indicate that GICS sector indices and oil price data are non-stationary in levels and are stationary as returns (first log differences). The ADF and PP tests do not reject the null hypotheses of a unit root when the data are in levels and reject the null hypothesis of a unit root data when the series are in return form. However, the value of KPSS test reject the null hypothesis of a unit root for data in both levels and first log differences implying the stationarity of the oil price return.

4. Model

The objective of this study is to investigate the effect of oil price return and oil price return volatility on return and the volatility of return on the sectors in the Australian stock market. An asset pricing theory approach is taken to investigate the interaction between stock returns and oil price return and is used to establish a relationship between risk and return and to identify the significant factors in determining stock returns.

4.1. The stock return model

We use the GARCH-M methodology to model the stock return and conditional volatility of stock returns. This methodology improves the specification of asset pricing theories, as Bollerslev et al. (1992) contend, since the GARCH-M model allows for time varying conditional variances of asset returns and a time varying risk premium.

The model consists of a return equation that includes the market return, oil price return and oil price return volatility, and the conditional volatility measure of returns, and a volatility equation that includes the oil price return volatility factor. Analytically, the model can be described as follows:

$$r_{i,t} = c_i + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{m,t} + \delta_{i3} r_{0,t-1} + \delta_{i4} \sigma_{o,t}^2 + \gamma_i \ln(h_{i,t}^2) + \varepsilon_{i,t},$$

$$\varepsilon_{i,t} \left| \psi_{t-1} \sim N\left(o, h_{i,t}^2\right), \; i = 1, 2...., J \right. \qquad (1)$$

$$h_{i,t}^2 = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1}^2 + \rho_i \sigma_{o,t}^2 \qquad (2)$$

where $r_{i,t}$ is the excess return of the sector i at time t, $r_{m,t}$ is the excess market return, $r_{o,t-1}$ is oil price return at time $t-1$, $\sigma_{o,t}^2$ is conditional oil return volatility based on information available at time $t-1$, and J is the number of sectors. The volatility of sector i stock returns at time t is measured by conditional variance $h_{i,t}^2$, which is a function of the squared values of the past residuals, $\varepsilon_{i,t-1}^2$, an autoregressive term, $h_{i,t-1}^2$, and oil return volatility, $\sigma_{o,t}^2$. The error term, $\varepsilon_{i,t}$, is a random variable with a zero mean and conditional variance h_t^2 and is dependent on the information set ψ_{t-1}. The parameters α_i and β_i in equation (2) are required to satisfy stationarity conditions $\alpha_i > 0$, $\beta_i > 0$, $(\alpha_i + \beta_i) < 1$, $i = 1, 2...., J$.

In the equation for sectoral return, equation (1), conditional volatility is in logarithmic form ($\ln(h_{i,t}^2)$) as suggested by the Engle et al. (1987). Elyasiani et al. (1998) and Ryan et al. (2004) use log of conditional variance in their GARCH-M models. In the GARCH-M model in equations (1) and (2), oil price return and oil return volatility can influence sector return directly and also indirectly through oil price return volatility influencing sector return conditional volatility. This provides a potentially rich set of oil price influences on sector return and volatility of returns. The measure of oil price return volatility will be discussed below.

4.2. Oil price volatility

A generalized autoregressive conditional heteroskedasticity (GARCH) model will be used to generate measures of conditional variance to serve as approximations for oil return volatility. Univariate GARCH models have wide application in modelling volatility in oil prices. Kang et al. (2008) use various GARCH models to calculate the volatility of crude oil price. Narayan and Narayan (2007) use an EGARCH model to calculate oil price volatility across various sub samples. Sadorsky (2006) studies the appropriateness of various statistical models to capture oil price volatility and conclude that univariate GARCH model outperforms multivariate models in modelling of oil price volatility. Bollerslev et al. (1992) recommends the use of low-order GARCH models and the GARCH (1, 1) model in particular for a data series in which the sample autocorrelation function dies out slowly (as it does for oil prices). Sadorsky (1999) notes that volatility calculated from GARCH (1, 1) is well suited to study the relationship between oil price shocks and stock returns.

We estimate the following GARCH (1, 1) model:

$$r_{o,t} = \gamma_0 + \sum_{i=1}^{i=p} \gamma_i r_{o,t-i} + \xi_t, \qquad \xi_t \left| I_{t-1} \sim N\left(o, \sigma_{o,t}^2\right), \qquad t = 1,....,T \right. \tag{3}$$

$$\sigma_{o,t}^2 = \omega_0 + \omega_1 \xi_{t-1}^2 + \omega_2 \sigma_{o,t-1}^2 \tag{4}$$

where $r_{o,t}$ is the oil price return at time t, the volatility of oil price return at time t is measured by conditional variance $\sigma_{o,t}^2$, which is a function of the squared values of the past residuals and an autoregressive term. The error term, ξ_t, is a random variable with a zero mean and conditional variance $\sigma_{o,t}^2$ dependent on the information set I_{t-1}.

Table 3 reports estimates from the GARCH (1,1) model. All of the parameter estimates are statistically significant at the 1% level and based on the Ljung-Box Q statistics, there is no evidence of serial correlation in the standardised residuals. The model in Table 3 is used to provide estimates of oil price return volatility, $\sigma_{o,t}^2$, over 31-3-2000 to 31-12-2010 in estimation of the GARCH-M model in equations (1) and (2).

4.3. Hypotheses on the effects of oil prices

An advantage of looking at sector returns rather than a general index of stock returns is that sectors may well differ markedly in how they respond to oil price shocks. In equation (1) the coefficient δ_3 identifies the effect of oil price return on Australian sectors' returns. In equations (1) and (2) the coefficients δ_4 and ρ capture the effect of oil price return volatility on sector returns and the volatility of sector returns, respectively. Overall, there is no effect of oil return volatility on sector returns and/or conditional volatility of sector returns if the null hypothesis, Ho: $\delta_4 = \rho = 0$, is rejected.

The parameter γ provides an estimate of the relationship between a sector's return and its own conditional volatility of sector returns and provides an estimate of the degree of intertemporal trade off between expected return in a sector and conditional volatility of return in that sector. Oil price volatility may indirectly influence sector return through impact on conditional volatility of sector returns.

In the GARCH class of models, the sectors' excess returns conditionally depend on market return, oil price return, and own volatility. In this case, the sectors' returns are also dependent on their own lagged return. The graphical presentation of returns in the different sectors in Figure 2 shows that the return in one sector depends on its previous period's return. This supports the inclusion of autoregressive lag of one in mean equation.

5. Empirical Results

The results from estimating equations (1) and (2) with no dummy variable to capture the effect of the Global financial crisis and results with a dummy variable to capture the effect of the Global financial crisis are reported in Tables 4 and 5, respectively. Model diagnostic statistics from estimating the GARCH-M model are based on the standardized residuals $\left(\varepsilon_t / h_t\right)$. Under the null hypothesis of normality, the conditional mean and variance are expected to be zero and unity, respectively, and the variance is to be serially uncorrelated and homoskedastic. The diagnostic statistics presented in Tables 4 and 5 indicate that the values of mean, variance, and skewness are as expected. For ASX and all the sectors, the mean is close to zero and the variance is 1. The skewness is negative for most of the sectors and the overall market, however; the value is close to zero. The GARCH-M process reduces the sample kurtosis, but fails to fully account for leptokurtosis. In most of the cases, the value of the kurtosis is more than 3. The J-B statistics for normality test suggests that the residuals are not normally distributed. The studies of Bollerslev (1987), Lastrapes (1989), Elyasiani et al. (1998) also observe non-normality in the residuals.

Our model is well specified and robust. The LB-Q and LB-Q_s statistics are used to evaluate the specifications of mean equation and variance equation respectively. The insignificant LB-Q and LB-Q_s statistics indicate an absence of remaining ARCH effect, so does the insignificant LM statistics. The LB-Q and LB-Q_s statistics signify that both mean and variance equations are robust and that there is no ARCH prevailing in the residuals of the model. For all the sectors estimated, the LB-Q and LB-Q_s are insignificant. The ARCH-LM tests are insignificant, with the implication that there is no serial correlation in the residuals and that the GARCH-M model captures the serial correlation successfully. Overall, the diagnostic statistics for the model indicate that that the GARCH-M model performs well.

5.2. Results for the ASX

Results for estimating the model in equations (1) and (2) with no dummy variable to capture the effect of the Global financial crisis for the ASX market index are reported in the last column of Table 4. The world stock index is used as market risk for the ASX. In the last column of Table 4 the coefficients δ_3 is negative and statistically significant at the 1% level of confidence indicating that an increase in oil price return reduces stock return. The coefficient δ_4 is statistically significant at the 5% level of confidence and indicates an increase oil price return in volatility raises stock return. An increase in oil price return volatility is associated with decreased ASX return volatility at the 1% level of confidence. This could well happen, if greater error in predicting oil price returns which increases conditional oil price volatility also causes most sector returns to move in the same direction.

The parameter γ in the mean equation is positive and statistically significant at the 1% level, indicating a positive risk premium for expected ASX return for increased conditional volatility of ASX returns. This result also implies that oil price return volatility also has an indirect affect on expected ASX returns through its influence on ASX return volatility. The positive direct effect of oil price volatility on stock price return clearly dominates the negative indirect affect of oil price volatility on stock price (since $\hat{\delta}_4 \; \square \; -\hat{\rho}\hat{\gamma}$, where the math superscript carrot character indicates estimated value). For the ASX index, the null hypothesis of no effect of oil return volatility on either returns and/or volatility of returns (H_o: $\delta_4 = \rho = 0$) is rejected at the 1% level of confidence.

5.3. The effect of oil price on sector return

The objective in this study is to identify the effect of oil price return and oil return volatility on the return and the volatility return in the sectors of the Australian stock market. The oil return volatility also evaluates its effect on the volatility of the sectors. All sectors are not equally exposed to oil price risk factors i.e. some sectors are affected by oil shocks significantly and some sectors do not responsive to the oil price shocks. Industries differ with regard to oil (and energy) intensity in production, and in how demand for their products might vary in response to oil price shocks, and the energy sector in particular has a boast to revenue with an increase in oil (and energy) price that might well dominate other consequences of changes in oil price. Results from estimating equation (1) and (2) are reported in Table 4.

In Table 3 all sectors except information technology (XIJ) and telecom (XTJ) are responsive to oil price shocks. The coefficient of oil price return (δ_3) is statistically significant at the 1% level for six sectors, at the 5% level for the consumer discretionary sector (XDJ), and at the 10% level for the heath sector (XHJ). Oil price return is statistically insignificant for utility and telecom sectors. In the sectors other than energy and materials, increased oil price return reduces sector returns. Industrials (XNJ), consumer discretionary (XDJ) and consumer staples (XSJ) sectors use energy intensively in production and are significantly negatively impacted by an increase in oil price. Significant negative effects of oil price increases are also found for the financial, health, industrials and information technology sectors.

Increased oil price return significantly raises returns in the energy and materials sectors (XEJ and XMJ), sectors in which oil is a source of revenue. The materials sector includes chemicals (including petro chemicals). and mining (including coal). For the Australian energy sector we find that a 1% increase in oil price raises return by about 0.138%. The result is consistent with and analogous to findings that oil price returns are positively associated with the returns of oil and gas companies (a narrower classification than that of XEJ in this study). Sadorsky (2001) and Boyer and Filion (2007), for example, find that a 1% increase in oil price raises the return of Canadian oil and gas companies by about 0.300%. Mohanty and Nandha (2011) report that a 1% increase in oil price raises return in the US oil and gas sector by between 0.207% and 0.378% depending on time period. Ramos and Viega (2011) report a smaller effect (about 0.144%) of oil price returns on returns in the oil and gas sector worldwide.

Faff and Brailsford (1999) found for Australia (for sectors not strictly comparable to the GICS) that oil and gas and diversified resources have a statistically significant positive sensitivity to the oil price return. They found that oil price return had a statistically significant negative effect on paper and packaging, transport and banks. McSweeney and Worthington (2007) utilize a multifactor model to examine the role of crude oil as a pricing factor in Australian excess industry returns over the period January 1980 to August 2006 for nine industries (banking, diversified financials, energy, insurance, media, property trusts, materials, retailing and transportation). McSweeney and Worthington (2007) find that oil price return has a statistically significant negative effect for the banking, retailing transportation industries, and a statistically significant positive effect for the energy industry.

These studies are consistent with our findings, particularly the positive association between oil price returns and returns in the energy sector and the negative association between oil price returns and returns in the financial sector. McSweeney and Worthington (2007) note that the statistical significant response of banking stocks to oil price return may be an Australian phenomenon. However, in a recent study Arouri (2011) report a strong negative relationship between oil price changes and stock returns in the European Financials sector. Explanations for the negative association between oil prices and excess returns in the financial sector may be based on the fact that oil price shocks are recognized as playing a role in the business cycle and that bank stocks are important in investor portfolios. Elyasiani et al. (2011) also find a similar result for the financial sector in the US and contend that even though the financial sector is not directly related to oil production and consumption, association with oil occurs via lending to and/or holdings of corporate bonds issued by firms with significant exposure to oil price fluctuations and their speculative positions in oil related instruments.

Arouri (2011) examines the effect of oil price returns on (twelve) European sector indices for Automobile & Parts, Financials, Food & Beverages, Oil & Gas, Health Care, Industrials, Basic Materials, Personal & Household Goods, Consumer Services, Technology, Telecommunications, and Utilities. Besides the result for Financials already noted, they report statistically significant negative effect of oil price returns for Automobile & Parts, Food & Beverages and Consumer services. These latter results are consistent with our significant findings for industrial industrials, consumer discretionary and consumer staples. Arouri (2011) also finds a statistically significant positive link between oil price increases and returns for the Oil & Gas sector and for Basic Materials. These findings are also consistent with our finds for the energy and materials sectors in Australia.

5.4. The effect of oil return volatility on sector stock return

The sectors in the Australian stock market are also exposed to conditional oil return volatility. The results in Table 4 show that returns in the energy (XEJ), materials (XMJ), financial (XFJ), information technology (XIJ) and Utility (XUJ) sectors significantly increase with an increase in oil price volatility. The exception here is the finding that returns in the industry sector (XNJ) fall with an increase in oil price volatility. These results are consistent with the finding by Elyasiani et al. (2011) that energy, material, and financial sector in US are positively related to oil return volatility. Elyasiani et al. (2011) contend that sector returns and conditional oil return volatility are positively related in sectors that may increase prices to customers when oil price is highly volatile rather than when oil price is stable. Returns in the consumer staples, consumer discretionary, health and technology sectors do not react significantly when oil return volatility increases.

5.5. The effect of oil return volatility on sector return volatility

The volatility of oil return is included to the variance equation (equation 2) to identify its effect on the sectors' volatility of excess returns. It is measured by and indicated by the coefficient ρ in Table 4. Oil return volatility significantly influences sector volatility of returns at the 1% level of confidence for six out of ten sectors. An increase in oil price return volatility significantly reduces stock return volatility for five sectors (energy, materials, industrials, information technology, utilities), but significantly increases volatility stock return volatility for the financial sector (and the telecom sector, although this result is not robust as shown later). The positive association between oil return volatility and volatility of returns in the financial sector may be due to association with firms with significant exposure to oil price fluctuations and their speculative positions in oil related instruments. In the variance equation, the high value of the measure of shock persistence, $\alpha_i + \beta_i$, is an indication that the effects of oil price shocks are highly durable. For the remaining sectors, the oil return volatility does not have any significant effect, suggesting the oil return volatility does not induce further volatility to those sectors. For the sector indices, the null hypothesis of no effect of oil return volatility on either sector returns and/or volatility of sector returns (Ho: $\delta_4 = \rho = 0$) is rejected at the 10% level of confidence for eight out of ten sectors.

5.6. The effect of market return and risk-return trade off

The estimated coefficient of market return represented by δ_2 indicates the response of sector return to market return in the Australian stock market. The coefficients of market return in Table 4 are statistically significant at 1% for all sectors. The results are consistent with theory and empirical results. The values of the coefficient, δ_2, range from 0.5984 to 1.2541. Energy, materials and financials are the sectors most responsive to market movement, and consumer staples, telecom and utilities are the least responsive sectors to market movement.

The risk-return relationships of Australian sectors vary from sector to sector. In equation (1), the coefficient γ shows the trade off between sector return and conditional volatility of h_t^2, allowing time varying risk premium to affect sector returns. As the expectations of investors and the sectors are heterogeneous, the trade off relationship between risk and return is not same for all sectors. The coefficients of conditional volatility, γ, are statistically significant for energy, consumer staples, materials, health and utilities. For energy and consumer staples the coefficient is positive, consistent with conditional volatility being compensated by additional return. For materials, health and utilities the trade off is negative, suggesting an adverse risk return trade off over time. Glosten et al. (1993), Ryan et al. (2004) and others also find a negative relationship between risk and return. Chowdhury (1996) mentions that when this risk-return trade off parameter is negative, the investors are penalized rather than rewarded for undertaking risk.

5.7. Global Financial Crisis

The sample period in this study over 31 March 2000 to 31 December 2010 embraces the global financial crisis, during which the financial system was thrown into turmoil. To assess whether the effect of the distribution of oil price returns continues to have the same impact on sector returns pre and post global financial crisis, we include a dummy variable in the equation (1) in the GARCH-M system (1) and (2). Dummy variables with different timing to capture the role of the global financial crisis will be considered in the regression equations estimated to check the robustness of results

The equations to be now estimated are given by

$$r_{i,t} = c_i + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{m,t} + \delta_{i3} r_{0,t-1} + \delta_{i4} \sigma^2_{o,t} + \lambda_{ik} D_{kt} + \gamma_i \ln(h^2_{i,t}) + \varepsilon_{i,t},$$

$$\varepsilon_{i,t} | \psi_{t-1} \sim N\left(o, h^2_{i,t}\right), \; i = 1, 2...., J, \quad k = 1, 2, 3 \qquad (5)$$

$$h^2_{i,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta_i h^2_{i,t-1} + \rho_i \sigma^2_{o,t} \qquad (6)$$

where $D_{kt}, k = 1, 2, 3$ is a dummy variable defined as follows:

D_{1t} is a dummy variable with value 1 on and after 15 September, 2008, the date Lehman Brothers filed for bankruptcy protection and the stock market declined sharply, and 0 before 15 September, 2008.

D_{2t} is a dummy variable with value 1 from 6 October to 15 October, 2008 and 0 otherwise. The 6 - 15 October, 2008 includes some of the most extraordinary stock market behaviour in history. The week of October 6–10 was the worst week for the stock market since 1933 with the Standard & Poor's 500 index losing 18.2 percent, and on 11 October, 2008 the Dow Jones Industrial Average had the highest volatility day ever recorded in over hundred year history.

D_{3t} is a dummy variable with value 1 from 15 September, 2008 to 30 November, 2008 and 0 otherwise. The global financial crises appeared to have stabilized by the end of

November 2008 with dramatic action during November by the US Federal Reserve, including the pledge to purchase mortgage bonds guaranteed by Fannie Mae and Freddie Mac.

Results from estimating equations (5) through (6) are reported in Table 5 for the market index ASX (in columns 1, 2 and 3) and the financial sector XFJ (in columns 4, 5 and 6). In Table 5 all coefficients of the dummy variables are negative and statistically significant. λ_1, λ_2 and λ_3 are negative indicating that during and immediately after the global financial crisis market returns Australia and returns in the financial sector in Australia are lower than in the period 31 March 2000 to 31 December 2010 overall. What is interesting is that the results concerning the effect of oil price returns and volatility are unchanged by the inclusion of the dummy variables. A rise in oil prices depresses returns in the ASX and the XFJ significantly, and a rise in oil price volatility reduces volatility in the returns to the ASX and increases volatility in the returns in the financial sector at the 1% confidence level in all cases.

In Table 6 results from estimating equations (5) through (6) for all sectors are reported for the inclusion of the dummy variable D_{1t}. In Table 6 the coefficient of D_{1t} is negative and statistically significant for six sectors. λ_1 is not statistically significant for the consumer staples, health, information technology and telecom sectors indicating that in these sectors returns are not lower over on and after September 15 2008 than over the period 31 March 2000 to 31 December 2010 overall. An examination of Table 6 compared to the results in Table 4 (that do not include D_{1t}) reveals that the impact of oil price return and volatility on sector return and volatility are not for the most part affected by the inclusion of the dummy variable. In particular, the results on oil price shocks for the energy, materials and financial sectors are robust to inclusion of dummy variables to capture the global financial crisis.

6 Conclusion

The main objective of this study is to measure the effect of oil price return and oil return volatility on the return and volatility of the sectors of Australian stock market respectively. The research also studies the risk-return trade off of these sectors. To facilitate the research, we consider conditional volatility as a measure of oil price risk and total risk of sectors' return and employ GARCH-M methodology to model the risk and return patterns of ten sectors in Australian stock market. The GARCH-M methodology advances this research by allowing estimation of conditional volatility of stock returns and by estimating the effect of oil return and oil return volatility on return and volatility of return in the stock market sectors. Data are daily from 31 March 2000 to 31 December 2010.

It is found that for the overall market index, an increase in oil price return significantly reduces return, and an increase in oil price return volatility significantly reduces volatility. The latter result follows since increased oil price volatility is associated with oil price changes that tend to move most stocks in a particular direction. For eight out of ten sectors (significantly so for six sectors) oil price return and stock price return move in opposite directions, but for the energy and materials sectors increased oil price return increases sector returns. In the energy and material sectors higher oil prices increase positive cash flows with resultant increases in sector returns.

In variance equation, the high value of the measure of shock persistence is an indication that shock effects are highly durable. An increase in oil price return volatility significantly reduces stock return volatility for five sectors (including the energy and materials sectors), but significantly increases volatility stock return volatility for the financial sector. The negative link between oil return and returns and the positive association between oil return volatility and volatility of returns in the financial sector must be based on the association via lending to and/or holdings of corporate bonds issued by firms with significant exposure to oil price fluctuations and their speculative positions in oil related instruments. Results are robust to consideration of the Global financial crisis in September 2008. The results obtained from this study are of potential significant interest to investors and financial market participants. Since all sectors in Australia are not uniformly sensitive to oil price shocks, risk diversification possibilities across industries arise.

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Table 1: The descriptive statistics of daily GICS sector returns and oil return

The table reports summary statistics of the return of GICS sectors: energy (XEJ), materials (XMJ), industrials (XNJ), consumer discretionary (XDJ), consumer staples (XSJ), health care (XHJ), financials (XFJ), information technology (XIJ), telecom (XTJ), utility (XUJ), and market (ASX). The sample runs from 2000:03 through 2010:12. By row, we report mean, median, maximum and minimum value, standard deviation (SD), kurtosis, skewness, Jarque-Bera (JB) statistics and their p-values. The returns are the first differences of the logarithm of prices.

	XDJ	XSJ	XEJ	XMJ	XNJ	XFJ	XIJ	XTJ	XHJ	XUJ	ASX	Oil
Mean	-0.0003	0.0003	0.0006	0.0005	0.0001	0.0001	-0.0006	-0.0004	0.0003	0.0001	0.0001	0.0003
Median	0.0000	0.0000	0.0008	0.0006	0.0003	0.0001	-0.0005	0.0000	0.0001	0.0000	0.0002	0.0002
Maximum	0.0901	0.0681	0.0921	0.0933	0.0574	0.0881	0.1237	0.0718	0.1150	0.0519	0.0563	0.1405
Minimum	-0.1257	-0.1085	-0.1258	-0.1274	-0.0880	-0.0899	-0.2760	-0.1085	-0.0720	-0.0799	-0.0870	-0.1318
SD	0.0143	0.0129	0.0145	0.0162	0.0113	0.0119	0.0192	0.0129	0.0119	0.0106	0.0104	0.0223
Skewness	-0.4002	-0.6971	-0.4816	-0.4695	-0.5463	-0.4816	-1.050	-0.6971	-0.0710	-0.3310	-0.5561	-0.0815
Kurtosis	8.4526	8.1818	9.2756	9.0108	7.7206	10.1371	21.7339	8.1818	10.1371	7.1751	9.9997	5.6999
JB-statistics	3549.70	3365.48	4711.33	4325.63	2743.97	5955.82	4156.25	3365.48	5955.82	2088.54	5870.94	855.04
JB-P Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2: Unit root statistics of the sector, market and oil price returns

Three measures of unit root are considered both at level and at first difference. Energy (XEJ), materials (XMJ), industrials (XNJ), consumer discretionary (XDJ), consumer staples (XSJ), health care (XHJ), financials (XFJ), information technology (XIJ), telecom (XTJ), and utility (XUJ). The series of first difference is represented by Δ. Also, two specification of with intercept (C) and intercept and trend (C & T) are considered. Here, ***, **, and * represent significance at the .01, .05, and .10 levels respectively.

	ADF		PP		KPSS	
	C	C & T	C	C & T	C	C & T
lnASX	-1.13	-1.08	-1.04	-0.07	181.77***	62.80***
ΔlnASX	-8.14***	-8.25***	-51.15***	-51.22***	0.141	-1.21
lnXDJ	-1.42676	-1.48	-1.34	-1.40	240.85*	-7.18*
ΔlnXDJ	-8.18***	-8.20***	-45.47***	-45.46***	-1.30	-0.27
lnXSJ	-1.48	-0.82	-1.43*	-1.04*	166.99***	100.40***
ΔlnXSJ	-9.32***	-9.39***	-51.34***	-51.44***	0.99	-0.96
lnXEJ	-1.14	-1.98	-1.14	-2.03	88.76***	109.68***
ΔlnXEJ	-8.76***	-8.77***	-46.59***	-46.58***	1.01	-0.38
lnXFJ	-1.30	0.51	-1.27	0.40	207.09***	44.33***
ΔlnXFJ	-8.25***	-8.49***	-47.61***	-47.78***	0.06	-2.03
lnXHJ	-1.47	-1.47	-1.39	-1.31	204.50***	43.52***
ΔlnXHJ	-7.90***	-7.92***	-50.97***	-50.98***	0.84	-0.56
lnXNJ	-0.93	0.56	-0.89	0.90	193.31***	41.87***
ΔlnXNJ	-7.86***	-8.09***	-48.39***	-48.50***	-0.10	-2.24
lnXTJ	-4.40	-4.62	-4.42	-4.62	258.58***	-47.86***
ΔlnXTJ	-9.44***	-9.46***	-45.52***	-45.57***	-1.70	1.60
lnXMJ	-1.31	-1.22	-1.27	-1.25	93.46***	96.39***
ΔlnXMJ	-8.99***	-9.03***	-50.04***	-50.05***	0.67	-0.76
lnXTJ	-1.23	-0.57	-1.18	-0.46	32.11***	-86.33***
ΔlnXTJ	-8.44***	-8.82***	-4.55***	49.69***	1.30	1.24
lnXUJ	-1.20	-0.36	-1.15	-0.10	159.40***	60.53***
ΔlnXUJ	-7.95***	-8.04***	-49.11***	-49.19***	0.48	-1.24
lnOIL	-1.27	-1.90	-1.43	-2.12	5.44***	1.53***
ΔlnOIL	-8.80***	-8.80***	-75.89***	-75.88***	0.07	0.65

Table 3: GARCH (1, 1) estimation of conditional oil return volatility

Parameter	Estimate	Standard error
c	-0.0006*	0.0003
γ_1	-0.0476**	0.0193
γ_2	-0.0497***	0.0190
ω_0	0.0035***	0.0010
ω_1	0.0472***	0.0136
ω_2	0.9412***	0.1025
Ljung-Box Q-statistics (residuals) for serial correlation		
$Q(6)$: P-value = 0.89		
$Q(12)$: P-value = 0.96		
$Q(24)$: P-value = 0.98		
Ljung-Box Q-statistics (residuals) for serial correlation		
$Q^2(6)$: P-value = 0.49		
$Q^2(12)$: P-value = 0.78		
$Q^2(24)$: P-value = 0.88		
$\overline{R}^2 = 0.1248$ S.E.E = 0.0222	D.W = 2.04	

Notes: The GARCH (1, 1) model:

$$r_{o,t} = c + \gamma_1 r_{o,t-1} + \gamma_2 r_{o,t-8} + \xi_t \text{ , } \zeta_t / I_{t-1} \approx N(0, \sigma^2_{o,t}) \qquad t = 1, \ldots.., T, \quad \sigma^2_{o,t} = \omega_0 + \omega_1 \xi^2_{t-1} + \omega_2 \sigma^2_{o,t-1}$$

is estimated, where $r_{o,t}$ is the oil price return at time t, $\sigma^2_{o,t}$ is the conditional volatility of oil price return at time t, and the error term, $\xi_{i,t}$, is a random variable with a zero mean and conditional variance $\sigma^2_{o,t}$ and is dependent on the information set I_{t-1}. All of the reported parameter estimates are statistically significant at the 1% level and based on the Ljung-Box Q statistics, there is no evidence of serial correlation in the standardised residuals. Therefore, the model appears adequate. *, **, and *** represents the significance of the coefficients at 1%, 5%, and 10% level.

Table 4: Sectoral return and conditional variance equation: GARCH (1, 1)-M estimates using daily data 31-3-200 to 31-12-2010

Notes: This table reports the results estimating equations (1) and (2) for daily data:

$$r_{i,t} = c_i + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{m,t} + \delta_{i3} r_{0,t-1} + \delta_{i4} \sigma^2_{o,t} + \gamma_i \ln(h^2_{i,t}) + \varepsilon_{i,t},\ h^2_{i,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta_i h^2_{i,t-1} + \rho_i \sigma^2_{o,t}$$

The dependent variable is the monthly excess returns of the GICS sectors. Explanatory variables include one lag of sector's own return (δ_1), market excess return (δ_2), oil price return (δ_3), oil return volatility (δ_4) in mean equation, sector's conditional risk (γ), ARCH term (α), GARCH term (β), and conditional oil return volatility (ρ). Here, energy (XEJ), materials (XMJ), industrials (XNJ), consumer discretionary (XDJ), consumer staples (XSJ), health care (XHJ), financials (XFJ), information technology (XIJ), telecom (XTJ), and utility (XUJ). J-B refers to the Jarque-Bera's normality test statistics for the regression residuals. LB-Q (20) is the Ljung-box test statistics for residual serial correlation at lag 20 and LB-Q^2 (20) is the test statistics for squared residual correlation. ARCH-LM is the non heteroskedasticity statistics. The standard errors are in parentheses. ***, **, and * denote the significance of the coefficients at 1%, 5%, and 10% level.

	XEJ	XMJ	XFJ	XDJ	XSJ	XHJ	XNJ	XIJ	XUJ	XTJ	ASX
Mean Equation											
γ	0.0648**	-0.0004***	-0.0000	0.0021	0.0004**	-0.0010**	0.0000	-0.0020	-0.0008*	-0.0006	0.0021***
	(0.0288)	(0.0001)	(0.0001)	(0.0003)	(0.0002)	(0.0005)	(0.0003)	(0.0011)	(0.0005)	(0.0005)	(0.0003)
c	0.0002	-0.0040	-0.0010	0.0038	0.0041	-0.0058	0.0008	-0.0136	-0.0060	-0.0010	0.0023
	(0.0003)	(0.0030)	(0.0013)	(0.0022)	(0.0037)	(0.0046)	(0.0040)	(0.0099)	(0.0051)	(0.0041)	(0.0033)
δ_1	0.0203*	0.0150*	0.0953***	-0.0521***	0.0621***	0.0841***	0.0586**	-0.0268	0.0027	0.0875***	-0.0802***
	(0.0113)	(0.0104)	(0.0210)	(0.0133)	(0.0120)	(0.0259)	(0.0249)	(0.0187)	(0.0220)	(0.0205)	(0.0188)
δ_2	0.9742***	1.2541***	1.0941***	0.7990***	0.6412***	0.7014***	0.8740***	0.8521***	0.5984***	0.6002***	0.7633***
	(0.0159)	(0.0541)	(0.0156)	(0.0214)	(0.0299)	(0.0325)	(0.0258)	(0.0412)	(0.0365)	(0.0321)	(0.0110)
δ_3	0.1384***	0.0400***	-0.0175***	-0.0254**	-0.0214***	-0.0120*	-0.0259***	-0.0330***	-0.0074	-0.0044	-0.0278***
	(0.0078)	(0.0061)	(0.0029)	(0.0074)	(0.0071)	(0.0065)	(0.0090)	(0.0119)	(0.0070)	(0.0069)	(0.0052)
δ_4	0.1514***	0.1337*	0.2102***	-0.1994	0.0221	0.2985	-0.3962**	0.1858**	0.2314*	0.1452	0.2001**
	(0.0190)	(0.0752)	(0.0414)	(0.2201)	(0.3012)	(0.4108)	(0.1415)	(0.0850)	(0.1317)	(0.4011)	(0.0899)
Variance Equation											
ω	0.0000***	0.0000***	0.0000**	0.0001**	0.0000***	0.0000***	0.0000***	0.0000***	0.0000****	0.0001***	0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
α	0.0512***	0.0321***	0.0332***	0.0523***	0.0662***	0.0305***	0.0742***	0.0421***	0.0537***	0.0633***	0.0413***
	(0.0071)	(0.0032)	(0.0062)	(0.0098)	(0.0102)	(0.0040)	(0.0079)	(0.0075)	(0.0038)	(0.0061)	(0.0041)
β	0.8210***	0.8271***	0.8952***	0.8554***	0.9001***	0.8548***	0.8984***	0.9025***	0.8954***	0.9209***	0.9464***
	(0.0080)	(0.0320)	(0.0081)	(0.0050)	(0.0095)	(0.0040)	(0.0159)	(0.0155)	(0.0125)	(0.0062)	(0.0055)
ρ	-0.0205***	-0.0213***	0.0010***	0.0001	-0.0010	-0.0004	-0.0259***	-0.0029*	-0.0007*	0.0113*	-0.0093***
	(0.0010)	(0.0099)	(0.0003)	(0.0000)	(0.0063)	(0.0003)	(0.0069)	(0.0016)	(0.0004)	(0.0062)	(0.0029)
$\alpha+\beta$	0.8722	0.8592	0.9184	0.9077	0.9663	0.8853	0.9726	0.9446	0.9491	0.9842	0.9877

There is no effect of oil volatility $\delta_4 = \rho = 0$	54.26***	52.21***	31.62***	5.69*	4.88*	2.35	34.795***	8.21**	6.85*	2.22	112.24***
Log likelihood	10215.39	18542.21	10411.12	113612.27	8253.42	7895.36	7001.21	11245.36	11420.98	12547.25	10214.86
Model diagnostic statistics											
Mean	0.00	0.00	-0.01	-0.02	0.00	0.00	-0.01	0.00	0.00	-0.02	0.001
Variance	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000
Skewness	-0.10	-0.29	-0.73	0.75	-0.18	-0.47	0.00	0.29	-0.06	0.87	-0.4687
Kurtosis	4.80	6.49	15.99	12.04	5.59	8.46	4.22	6.77	7.08	23.23	4.5860
J-B	398.33***	1985.21***	3981.07***	1525.31***	1485.14***	668*.26***	329.52***	130.19***	362.19***	412.29***	598.43***
LB-Q (20)	30.10	18.55	41.82	36.24	21.71	38.78	25.77	47.05	29.58	19.04	29.63
LB-Q_s (20)	35.68	29.62	49.21	19.18	36.39	13.75	26.12	29.15	19.73	22.80	35.36
LM	0.81	0.98	0.44	0.90	1.11	1.24	0.74	0.82	1.02	0.43	1.10

Table 5: ASX and financial sector (XFJ) with GFC dummies
GARCH (1, 1)-M estimates using daily data 31-3-200 to 31-12-2010

	1	2	3	1	2	3
	ASX			XFJ (Financial)		
Mean equation						
γ	0.004131**	0.0042**	0.0042**	-0.0001**	0.0002**	0.0001***
	(0.0031)	(0.0032)	(0.0020)	(0.0000)	(0.0001)	(0.0000)
c	0.0041	0.0040	0.0043	-0.0011	0.0011	0.0012
	(0.0031)	(0.0031)	(0.0032)	(0.0018)	(0.0021)	(0.0021)
δ_1	-0.0613***	-0.0613***	-0.0613***	0.1255***	0.1217***	0.1192***
	(0.0191)	(0.0191)	(0.0191)	(0.0189)	(0.0120)	(0.0123)
δ_2	0.7903***	0.7901***	0.7906***	1.1512***	1.1523***	1.1328***
	(0.0148)	(0.0150)	(0.0148)	(0.0241)	(0.0354)	(0.0320)
δ_3	-0.0365***	-0.0365***	-0.0365***	-0.0217***	-0.0229***	-0.0296***
	(0.0060)	(0.0060)	(0.0060)	(0.0037)	(0.0041)	(0.0054)
δ_4	0.2162**	0.2271**	0.1887*	0.2034***	0.2033***	0.1995***
	(0.0911)	(0.1046)	(0.0995)	(0.0505)	(0.0618)	(0.0598)
λ_1	-0.0070***			-0.0351***		
	(0.0004)			(0.0099)		
λ_2		-0.0163**			-0.0621**	
		(0.0078)			(0.0243)	
λ_3			-0.0021*			-0.0221***
			(0.0011)			(0.0072)
Variance equation						
α	0.0000***	0.0000***	0.0000***	0.0000**	0.0000**	0.0000**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
α	0.0773***	0.0772***	0.0773***	0.0683***	0.0691***	0.0685***
	(0.0087)	(0.0086)	(0.0087)	(0.0070)	(0.0099)	(0.0092)
β	0.9047***	0.9049***	0.9047***	0.9221***	0.9251***	0.9047***
	(0.0107)	(0.0106)	(0.0107)	(0.0073)	(0.0102)	(0.0110)
ρ	-0.0030***	-0.0029***	-0.0613***	0.0019***	0.0024***	0.0021***
	(0.0006)	(0.0006)	(0.0191)	(0.0004)	(0.0008)	(0.0006)
$\alpha+\beta$	0.9820	0.9821	0.9820	0.9904	0.9942	0.9732
Model diagnostic						
Mean	0.00	0.00	0.00	0.02	0.02	0.02
Variance	1.00	1.00	1.00	1.00	1.00	1.00
Skewness	-0.09	-0.09	-0.09	0.05	0.05	0.05
Kurtosis	3.65	3.86	3.73	4.41	4.42	4.41
J-B	125.89***	126.39***	126.72***	234.32***	233.98***	235.01***
LB-Q (20)	27.54	28.11	28.31	23.06	23.06	23.06
LB-Q_s (20)	19.58	19.10	19.46	16.51	16.05	16.93
LM	0.98	1.03	0.99	0.44	0.47	0.43

Notes: This table reports the results estimating equations (5) and (6) for daily data:

$$r_{i,t} = c_i + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{m,t} + \delta_{i3} r_{0,t-1} + \delta_{i4}\sigma^2_{o,t} + \lambda_{ik} D_{kt} + \gamma_i \ln(h^2_{i,t}) + \varepsilon_{i,t},$$

$$h^2_{i,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta_i h^2_{i,t-1} + \rho_i \sigma^2_{o,t}$$

The dependent variable is the excess returns of the ASX and the financial sector (XFJ). Explanatory variables include one lag of sector's own return (δ_1), market excess return (δ_2), oil price return (δ_3), oil return volatility (δ_4) in mean equation, sector's conditional risk (γ), ARCH term (α), GARCH term (β), and conditional oil return volatility (ρ). D_1 is a dummy variable equal to 0 before 15 September 2008 and equal to1 on and after 15 September 2008. D_2 is a dummy variable equal to 0 before 6 October 2008 and after 15 October 2008 and equal to 1 from 6 October to 15 October 2008. D_3 is a dummy variable equal to 0 before 15 September 2008 and after 30 November 2008 and equal to 1 from 15 September to 30 November 2008. The standard errors are in parentheses. ***, **, and * denote the significance of the coefficients at 1%, 5%, and 10% level.

Table 6. Sectoral return and conditional variance equation with GFC dummy: GARCH (1, 1)-M estimates using daily data 31-3-200 to 31-12-2010

	XEJ	XMJ	XFJ	XDJ	XSJ	XHJ	XNJ	XIJ	XUJ	XTJ	ASX
Mean Equation: Dependent variable $r_{i,t}$											
γ	0.0648**	-0.0004***	-0.0001**	0.0015*	0.0002**	-0.0013**	0.0002	-0.0012	-0.0002	-0.0006	0.0041**
	(0.0288)	(0.0001)	(0.0000)	(0.0008)	(0.0001)	(0.0006)	(0.0003)	(0.0009)	(0.0004)	(0.0005)	(0.0031)
c	0.0031	-0.0041	-0.0011	0.0004	0.0020	-0.0008	0.0021	-0.0120	-0.0020	-0.0062	0.0041
	(0.0045)	(0.0030)	(0.0018)	(0.0022)	(0.0032)	(0.0044)	(0.0034)	(0.0083)	(0.0042)	(0.0051)	(0.0031)
δ_1	0.0115**	0.0613***	0.1255***	-0.0441***	0.0502***	0.0645***	0.0775***	-0.0248	0.0213	0.1006***	-0.0613***
	(0.0058)	(0.0191)	(0.0189)	(0.0161)	(0.0185)	(0.0169)	(0.0186)	(0.0177)	(0.0188)	(0.0192)	(0.0191)
δ_2	0.9409***	1.2903***	1.1512***	0.7975***	0.6266***	0.7215***	0.8665***	0.9683***	0.5491***	0.5763***	0.7903***
	(0.0157)	(0.0148)	(0.0241)	(0.0121)	(0.0115)	(0.0174)	(0.0111)	(0.0069)	(0.0150)	(0.0178)	(0.0148)
δ_3	0.1241***	0.0365***	-0.0217***	-0.0110**	-0.0134**	-0.0266***	-0.0191***	-0.0348***	-0.0057	-0.0052	-0.0365***
	(0.0073)	(0.0060)	(0.0037)	(0.0037)	(0.0052)	(0.0074)	(0.0051)	(0.0129)	(0.0071)	(0.0084)	(0.0060)
δ_4	0.1627***	0.2162**	0.2034***	-0.1716	0.1298	0.1952	-0.4125*	0.1024**	0.3068*	0.2271	0.2162**
	(0.0321)	(0.1030)	(0.0505)	(0.6429)	(0.5415)	(0.8302)	(0.2357)	(0.0492)	(0.6418)	(0.7960)	(0.0911)
λ_1	-0.0140***	-0.0196***	-0.0351***	-0.0012*	0.0021	0.0015	-0.0059**	-0.0023	-0.0110**	-0.0026	-0.0070***
	(0.0052)	(0.0071)	(0.0099)	(0.0007)	(0.0125)	(0.0327)	(0.0029)	(0.0059)	(0.0052)	(0.0236)	(0.0004)
Variance Equation: Dependent variable $h_{i,t}^2$											
ω	0.0000***	0.0000***	0.0000**	0.0000**	0.0000***	0.0000***	0.0000***	0.0000***	0.0000****	0.0001***	0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
α	0.0957***	0.0773***	0.0683***	0.0401***	0.0413***	0.0229***	0.0379***	0.0385***	0.0219***	0.0908***	0.0773***
	(0.0091)	(0.0087)	(0.0070)	(0.0041)	(0.0052)	(0.0018)	(0.0079)	(0.0033)	(0.0028)	(0.0085)	(0.0087)
β	0.8634***	0.9046***	0.9221***	0.9573***	0.9523***	0.9214***	0.9519***	0.9292***	0.9736***	0.8790***	0.9047***
	(0.0141)	(0.00107)	(0.0073)	(0.0041)	(0.0060)	(0.0021)	(0.0159)	(0.0028)	(0.0030)	(0.0107)	(0.0107)
ρ	-0.0029***	-0.0030***	0.0019***	0.0002	-0.0013	-0.0002	-0.0115***	-0.0098***	-0.0005***	-0.0005	-0.0030***
	(0.0011)	(0.0006)	(0.0004)	(0.0003)	(0.0025)	(0.0003)	(0.0038)	(0.0017)	(0.0002)	(0.0010)	(0.0006)
$\alpha + \beta$	0.8722	0.8592	0.9184	0.9077	0.9663	0.8853	0.9726	0.9446	0.9491	0.9842	0.9877
There is no effect of oil return	54.31***	49.32***	34.55***	5.67*	4.30*	2.08	36.81***	18.21***	19.85***	1.88	112.24***

$\delta_4 = \rho = 0$

Log likelihood	9157.99	9591.98	11216.49	9537.64	10245.66	7895.36	10245.19	8412.61	8542.85	7028.10	9852.47
Mean	0.02	-0.02	0.02	-0.01	0.00	-0.02	0.01	-0.02	0.00	-0.01	0.00
Variance	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Skewness	0.05	-0.05	0.05	0.02	0.05	0.42	-0.26	0.79	-0.23	-0.81	-0.09
Kurtosis	4.41	3.96	4.41	4.92	3.91	11.87	5.37	10.60	6.36	9.63	3.65
J-B	234.32.33***	108.53***	234.32***	430.84***	1485.14***	9288.27***	689.89***	7055.42***	1347.06***	5458.43***	125.89***
LB-Q (20)	20.18	14.61	23.06	21.92	23.51	14.78	19.28	22.95	22.35	22.77	27.54
$LB\text{-}Q_s$ (20)	16.97	19.61	16.51	16.53	25.05	7.73	12.92	14.11	9.71	10.75	19.58
LM	0.62	1.02	0.44	0.12	0.29	0.30	2.31	0.62	0.36	0.06	0.98

Notes: This table reports the results estimating equations (5) and (6) for daily data:

$$r_{i,t} = c_i + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{m,t} + \delta_{i3} r_{0,t-1} + \delta_{i4}\sigma^2_{o,t} + \lambda_{ik} D_{kt} + \gamma_i \ln(h^2_{i,t}) + \varepsilon_{i,t},\; h^2_{i,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta_i h^2_{i,t-1} + \rho_i \sigma^2_{o,t}$$

The dependent variable is the monthly excess returns of the GICS sectors. Explanatory variables include one lag of sector's own return (δ_1), market excess return (δ_2), oil price return (δ_3), oil return volatility (δ_4) in mean equation, sector's conditional risk (γ), ARCH term (α), GARCH term (β), and conditional oil return volatility (ρ). D_1 is a dummy variable equal to 0 before 15 September 2008 and equal to1 on and after 15 September 2008. This table reports the results estimating the equation (3.4) and (3.5) for daily data. Here, energy (XEJ), materials (XMJ), industrials (XNJ), consumer discretionary (XDJ), consumer staples (XSJ), health care (XHJ), financials (XFJ), information technology (XIJ), telecom (XTJ), and utility (XUJ). J-B refers to the Jarque-Bera's normality test statistics for the regression residuals. LB-Q (20) is the Ljung-box test statistics for residual serial correlation at lag 20 and $LB\text{-}Q^2$ (20) is the test statistics for squared residual correlation. ARCH-LM is the non-heteroskedasticity statistics. The standard errors are in parentheses. ***, **, and * denote the significance of the coefficients at 1%, 5%, and 10% level.

Figure 1: Price indices of S&P/ASX200 and GICS sectors from March 2000 to December 2010

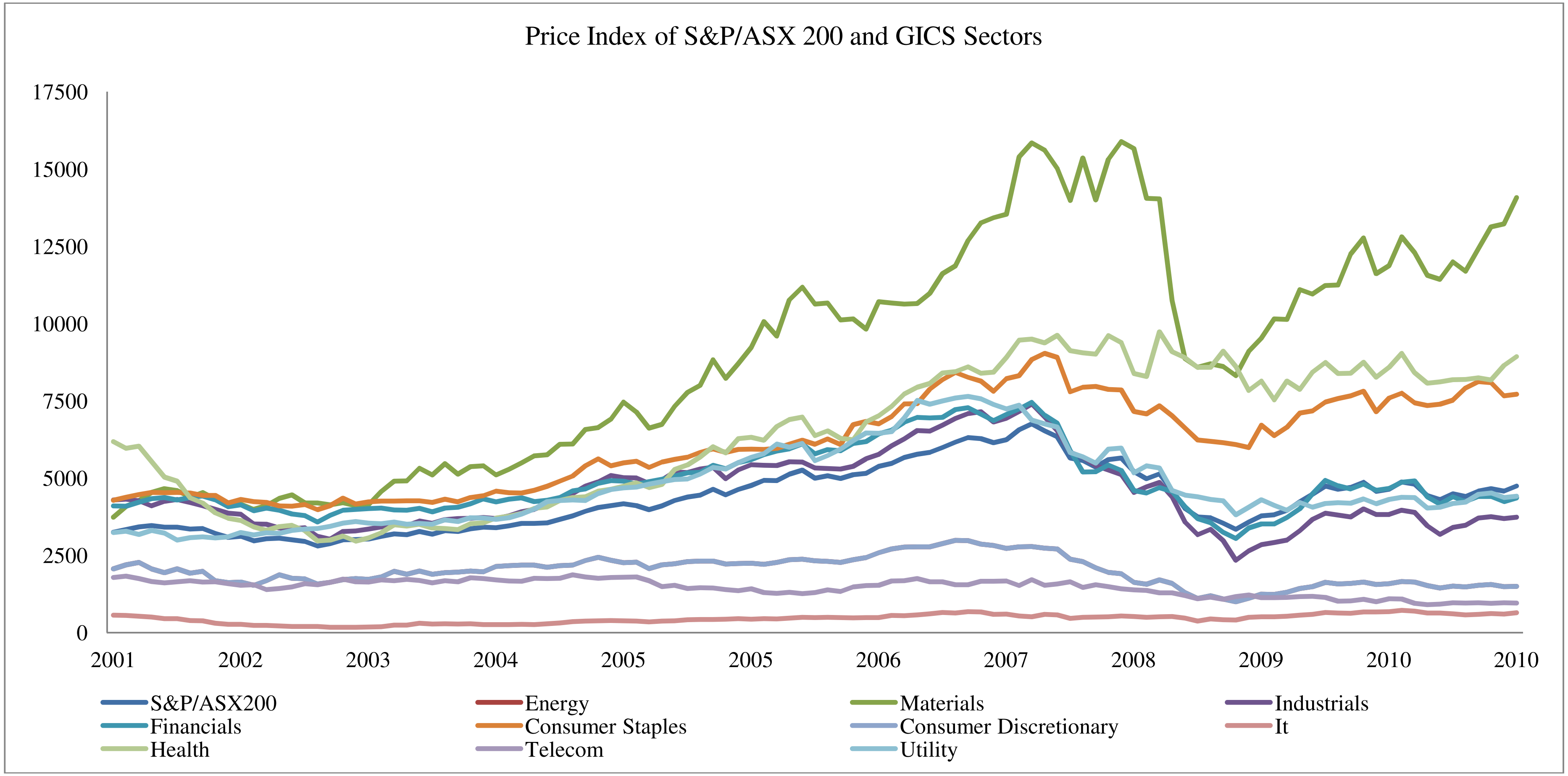

Figure 2: Daily return of ten sectors from 31 March 2000- 31 December 2010

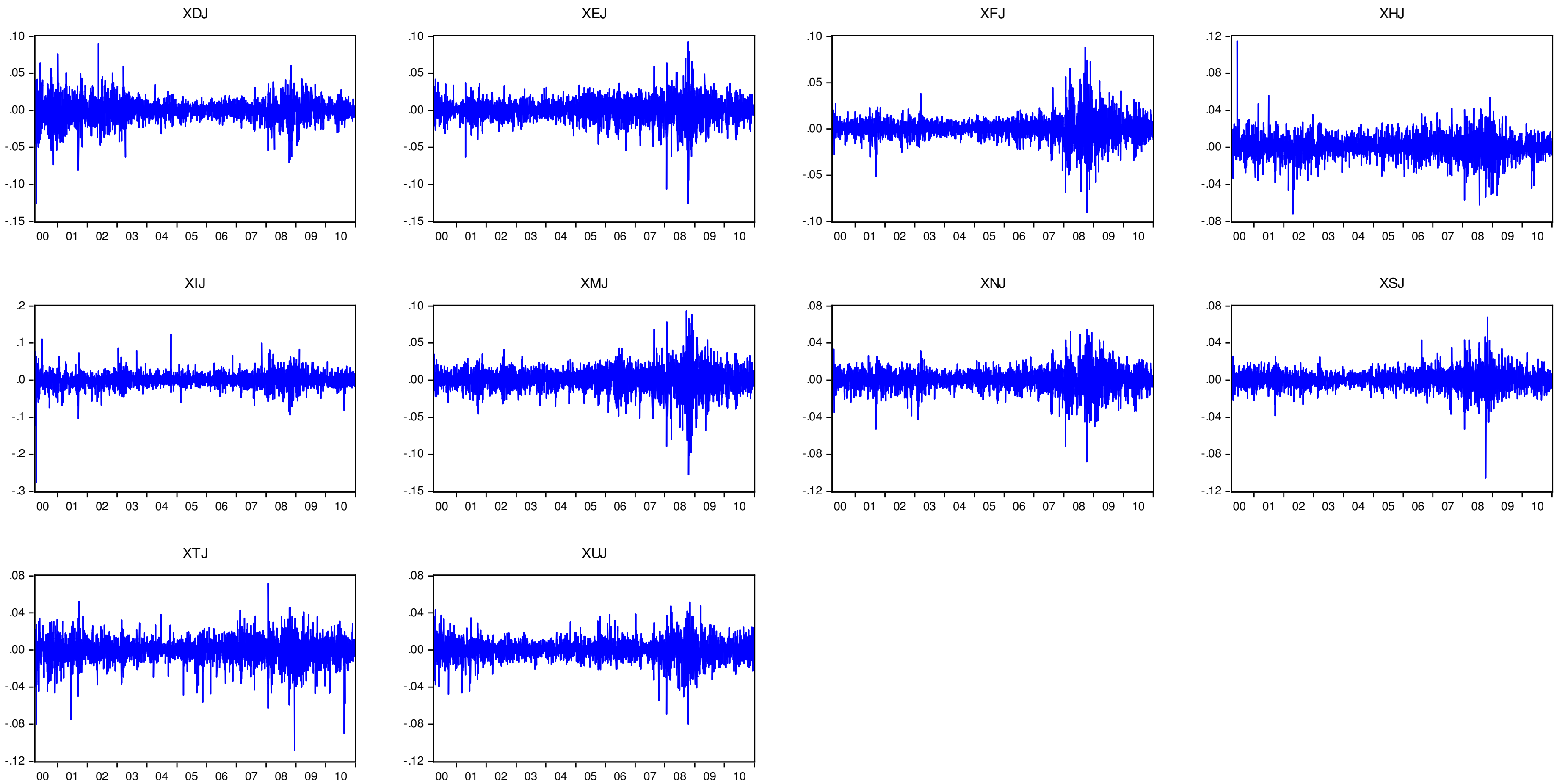

Figure 3: Crude oil price and return