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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 increases 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.

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I 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) and Papapetrou (2001) find a negative relationship between oil price shocks and aggregate stock returns for the US and for Greece, respectively. 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 future returns 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 price shocks on stock price in developed countries.

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 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

[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.

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. This paper employs the generalized autoregressive conditionally heteroskedastic in the mean (GARCH-M) model to investigate the effect of oil price return and its volatility on the sectoral stock return generation process. This framework extends the literature by allowing the investigation of the effect of changes in oil price return volatility on the first and second moments of the sectoral stock return generating process. The literature has considered the effect of oil price shocks on stock market returns. The literature has largely ignored 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. A contribution of this study is the focus on the effect of oil price return volatility on stock market return and volatility at sector level. The heterogeneity of sector response to oil price return and/or volatility can have implications for efficient portfolio diversification.[3]

[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 Yoon and Ratti (2011) and Ratti *et al.* (2011) connect oil price and volatility to firm level investment.

[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.

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 oil price return and stock price return move in opposite directions (industrials, consumer discretionary, consumer staples, health, financials, information technology, telecom, and utility), 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 (energy, materials, industrials, information technology, utilities), but significantly increases stock return volatility for the financial sector. Results are robust to consideration of the Global financial crisis in September 2008.

The organisation of the study is as flows. Section II discusses previous studies of the effect of oil price shocks on stock return. Section III discusses the data descriptive statistics. Section IV presents the GARCH-M model and the oil price volatility model. Section V presents empirical results and section VI concludes.

II Literature Review

Hamilton (2008) and Kilian (2008; 2010) note that an oil price rise reduces consumer discretionary income and raises precautionary saving and works through effects on consumer and business spending on goods and services. Kilian and Park (2009) conclude that the propagation of oil price shocks on stock prices is primarily through effects on final demands for goods and services. Important factors in the connection between oil prices and stock prices that have been identified in the literature include the sources of the oil price changes, the effect of oil prices on inflation, the dependence of the economy on oil imports, and the sector being considered. Kilian (2009) identifies the structural shocks influencing the movement of real oil price and Kilian and Park (2009) show that these factors are important in assessing the impact of oil price change on US stock prices. Ewing and Thompson (2007) find that crude oil prices lead the cycle of US consumer prices. Jimenez-Rodriguez and Sanchez (2005) argue that for oil importing countries international trade effects reinforce the negative effects of higher oil prices since these countries trade mostly among themselves. Bjornland (2009) finds that oil prices increase national income and lift stock markets for oil exporting countries.

Most of the existing literature is related to the study of the effect of oil shocks on aggregate stock market indices and this may hide diverse reactions at sector level. Industries differ with how demand for their products might vary in response to oil price shocks, with regard to oil (and energy) intensity in production, and the energy sector (and dependant sectors) in particular has a boost to revenue with an increase in oil price that might well dominate other consequences of changes in oil price. A number of papers find a positive significant relationship between oil price shocks and stock returns for the oil and gas sectors in a number countries and worldwide (Sadorsky, 2001; El-Sharif *et al.*, 2005; Boyer and Filion, 2007; Mohanty and Nandha, 2011; Dayanandan and Donker, 2011; Ramos and Veiga, 2011). Nandha and Brooks (2009) find that oil prices have a negative impact on returns in the transport sector in developed economies and insignificant effects in other countries. Arouri (2011) shows that most European stock market sectors are influenced by changes in oil prices but that responses vary widely across sectors.

For Australia, Faff and Brailsford (1999) and McSweeney and Worthington (2008) report that the oil and gas, energy and diversified resources (banking and transport) sectors have a significant positive (negative) response to oil price shocks.[4] Bowers and Heaton (2013) present evidence that crude oil returns among other factors are correlated with the systematic risk factor in the Australian stock market. Heaton et al. (2011) find that

[4] 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.

international commodities have a significant effect on the Australian stock market providing support for the view that the Australian market is commodity based. Faff and Brailsford (2000) examine the exposure of sector equity returns in Australia to an oil factor and find that industrial sector industries are significantly exposed but that resource sector industries are not. Chaudhuri and Smiles (2004) report evidence of a long-run relationship between real oil price and real stock prices. Nandha and Hammoudeh (2007) find stock markets in 15 Asia-Pacific countries are more sensitive to oil price expressed in local currency than in US dollar terms.

Several papers have directly estimated the effect of oil price volatility on stock market returns. Park and Ratti (2008) find that for many European countries, but not for the US, increased volatility of oil prices, significantly depresses real stock returns. Cong *et al*. (2008) find that increased oil volatility raises stock returns in China's mining and petrochemical sectors. 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. Choi and Hammoudeh (2010) use a Markov-Switching GARCH model to measure the switch in return volatility between high and low regimes for oil and commodities and the US stock market. 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.* (2010) examine the impact of oil prices on the stock return volatilities of US sectors and report that increases in oil prices increase the return volatility for sectors that use oil intensively.

III The Data

Data are daily indices for 10 Global Industry Classification Standard (GICS) sectors in Australian stock market and oil price from 31 March 2001 to 31 December 2010. The data start on 31 March 2001 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 (ASX) index. The sectors are energy (XEJ), materials (XMJ), industrials (XNJ), consumer discretionary (XDJ), consumer staples (XSJ), health (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 2001 to 2010. Over the period, energy, materials and financial sectors show the biggest movements in index value, and IT, telecom, and health sectors the most relative stability in index value. Reflecting the global financial crisis, the indices have big falls in 2008. The price of oil is the 1-month future prices of West Texas Intermediate (WTI) crude oil. Sadorsky (2012) 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. Oil price and oil price return are shown in Figure 2.

Descriptive statistics of daily return by sector and daily oil price return over 31 March 2001 to 31 December 2010 are reported in Table 1. 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 annualised market return is 3.84% and the annualised crude oil return is 6.72% over the period. Energy (XEJ) and materials sector (XMJ) have the highest average returns, with annualised returns of 15.24% and 13.94%, respectively. In a GICS sector the average return is small in comparison to the standard deviation of returns. The standard deviation of oil price returns exceeds the standard deviation of returns in each sector, which in turn exceeds the standard deviation of market returns.

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. Augmented Dickey and Fuller (ADF), Phillips and Perron (PP), KPSS and Zivot-Andrews tests for unit roots and stationarity are run and presented in Table 1. Under the ADF and PP tests the null hypothesis that the return series have a unit root is rejected, under the KPSS test the null hypothesis that the series is stationary is not rejected, and under the Zivot-Andrews test the null hypothesis of a unit root process against a break-stationary process where the break is endogenously calculated is rejected. Thus, all tests results are consistent with assuming that oil price and stock prices in log first differences are stationary.

IV The Model

(i) The stock return model

An asset pricing theory approach is taken to investigate the interaction between stock returns and oil price return. 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.[5] The GARCH-M model estimates conditional stock price return volatility (in the variance equation) and allows this volatility to influence stock price return (in the mean equation). The use of the GARCH-M model enables examination of the simultaneous effect of oil price

[5] Neuberger (1994) points 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.

return volatility on stock price return and return volatility over time. The model can be described as follows:

$$r_{i,t} = c_i + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{m,t} + \delta_{i3} r_{0,t-1} + \delta_{i4} \sigma_{o,t}^2 + \delta_{i5} r_{f,t} + \gamma_i \ln(h_{i,t}^2) + \varepsilon_{i,t},$$

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

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

where $r_{i,t}$ is the excess return of the sector i at time t, $r_{m,t}$ is the excess market return, $r_{f,t}$ is the log difference in US dollar/Australian dollar, $r_{o,t-1}$ 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 equation (1), conditional volatility is in logarithmic form ($\ln(h_{i,t}^2)$) as suggested by the Engle *et al.* (1987).

(ii) Oil price volatility

GARCH (1, 1) 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. Sadorsky (1999) reports that oil return volatility calculated from GARCH (1, 1) is well suited to study the relationship between oil price shocks and stock returns. Sadorsky (2006) compares various GARCH models in forecasting oil return volatility and finds that GARCH (1, 1) is the most suitable in out of sample forecast and therefore recommends this class of model in estimating oil return volatility. Lee et al. (1995) and Elyasiani et al. (2011) also apply a GARCH (1, 1) model in generating oil return 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).[6]

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

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

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

where the conditional volatility of oil price return at time t 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}.

We regress the first log difference of oil prices on its own lags one to ten and lags one and eight appear significant at the 5% level. All of the parameter estimates are statistically significant at the 1% level, and based on Ljung-Box Q statistics there is no evidence of serial correlation in the standardised residuals. The model in equations (3) and (4) is used to provide estimates of $\sigma_{o,t}^2$ over 31-3-2000 to 31-12-2010.

(iii) 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

[6] Mohammadi and Su (2010) find that oil price conditional volatility dissipates exponentially, consistent with the covariance-stationary GARCH models rather than the slow hyperbolic rate implied by the FIGARCH. Narayan and Narayan (2007) use an Exponential GARCH model to calculate oil price volatility. Kang et al. (2009) and Arouri et al. (2012) examine various GARCH models (including CGARCH and FIGARCH) and suggest that persistence or long memory may be important in the volatility of crude oil prices. We also generate oil return volatility using CGARCH (1,1) model and re-estimate the model (1) and (2) and observe little change in results from estimation of the model using GARCH(1,1).

on sector returns and the volatility of sector returns, respectively. In addition, oil price volatility may indirectly influence sector return through impact on conditional volatility of sector returns.

V Empirical Results

The results from estimating equations (1) and (2) are reported in Table 2. Model diagnostic statistics from estimating the GARCH-M model are based on the standardized residuals (ε_t / h_t). 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 indicate that the values of mean, variance, and skewness are as expected. 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. Bollerslev (1987), Lastrapes (1989), Elyasiani *et al.* (1998) and Ryan and Worthington (2004) also observe non-normality in the residuals.

The model is well specified and robust in terms of the general model performance criteria and in terms of the parameters estimated in the GARCH-M model. The LB-Q and LB-Q_s statistics signify that both mean and variance equations are robust and that there is no ARCH effect prevailing in the residuals of the model and the absence of remaining GARCH effects. The ARCH-LM tests are insignificant, with the implication that there is no serial correlation in the residuals and that the GARCH(1,1)-M model captures the serial correlation successfully.

The GARCH-M model reduces to an ARCH-M model if $\beta_i = 0$. The GARCH-M model reduces to an ARCH model if $\beta_i = \gamma_i = 0$. The null hypothesis $\beta_i = 0$ is rejected for all ten sector returns and ASX returns at the 1% level (shown in Table 2). The null hypothesis

$\beta_i = \gamma_i = 0$ is rejected for all ten sector returns and for ASX returns (shown in Table 2) at the 1% level (in results not reported). Use of a modified ARCH technique requires that in the conditional variance equation (3), the constant (ω_i), ARCH (α_i), and GARCH (β_i) parameters all be nonnegative. For all sector and the ASX returns these parameters are nonnegative in Table 2. Finally, a stationarity condition for persistence in volatility is satisfied in that the sum of the ARCH and GARCH parameters is less than unity ($(\alpha_i + \beta_i) < 1$) for all sectors and ASX returns in Table 2. Thus, the GARCH-M model is preferred over the ARCH-M and ARCH models.

(i) Results for the ASX

Results for estimating the model in equations (1) and (2) for the ASX are reported in the last column of Table 2. The world stock market index is used as market risk for the ASX, and has a coefficient of 0.7987, significantly different from zero at the 1% level of confidence as suggested by χ^2 value of 4346.15 and also significantly less than unity at the 1% level of confidence as suggested by χ^2 value of 123.62.

In the last column of Table 2 the coefficient 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. 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. 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.[7]

(ii) The Effect of Oil Price on Sector Return

In Table 2 seven out of ten sectors are responsive to oil price returns. The coefficient of oil price return (δ_3) is statistically significant at the 1% level for six sectors and at the 5% level for the consumer discretionary sector. The coefficient of oil price return is negative but statistically insignificant for health (XHJ), utility (XUJ) and telecom (XTJ) sectors. These three sectors jointly constitute about 10% of total market capitalization.

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 produce goods for which demand is sensitive to oil price shocks with the result that they are significantly negatively impacted by an increase in oil price.[8] 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%.

Our finding of a negative association between oil price returns and returns in the financial sector is consistent with those of other studies. McSweeney and Worthington (2008)

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[7] This result also implies that oil price return volatility also has an indirect effect on expected ASX returns through its influence on ASX return volatility. The positive direct effect of oil price volatility on stock price return dominates the negative indirect effect of oil price volatility on stock price (since $\hat{\delta}_4 \square -\hat{\rho}\hat{\gamma}$, where the carrot character indicates estimated value).

[8] It is important to note that consumer discretionary includes automobiles, consumer durables, leisure, textiles, diversified consumer services, retailing, distributors, hotels, restaurants, and leisure. Tourism is spread out within the consumer discretionary sector. Consumer staples include food and staples, beverage and tobacco, household and personal products. XDJ and XSJ include sub-sectors that either use significant amount of oil in production and/or produce products that use significant amounts of energy. Consistent with our results, McSweeney and Worthington (2008) find negative coefficients for retailing sector in Australian and Arouri (2011) finds negative impact of oil prices on the European consumer service sector.

note that the statistical significant response of banking stocks to oil price return may be an Australian phenomenon. However, Arouri (2011) and Elyasiani *et al.* (2011) report a strong negative relationship between oil price changes and stock returns in the European and US financial sectors, respectively. An intuitive explanation for this result is that the economic health of the financial sector reflects that of the general economy, which tends to worsen in oil importing countries when oil prices increase, because of the associated drop in consumer income. The finding that positive oil price shocks reduce stock return for most sectors is consistent with an anticipated reduction in sales following oil price increases. A decline in financial sector stock returns reflects expected decline in sector profit conditional on a worsening business outlook.

(iii) Oil Return Volatility and Sector Stock Return

The results in Table 2 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 industrials 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 when oil price is highly volatile rather than when oil price is stable.

(iv) Oil Return Volatility and Sector Return Volatility

The effect of volatility of oil return on sector volatility of excess returns is indicated by the coefficient ρ in equation (2). In Table 2, 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 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 $\alpha_i + \beta_i$ indicates that the effects of oil price shocks are highly durable. 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 least at the 10% level of confidence for eight out of ten sectors.

(v) Market Return, Exchange Rate 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 2 are statistically significant at 1% for all sectors. 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.

A rise in the Australian dollar is associated with a fall in ASX at the 10% level. The energy and material sectors rise with an appreciation of the Australian dollar (at the 10% level of confidence). This finding is similar to that by Boyer and Filion (2007) and Sadorsky (2001) for the returns of Canadian oil and gas companies. Sadorsky (2001) argues that currency depreciation increases the cost of importing drilling materials and of financing investment. A rise in the US dollar/Australian dollar rate has a negative but insignificantly effect on returns in the financial sector. The insignificance is consistent with extensive hedging of foreign exchange rate risk. The (insignificant) negative coefficient is in line with a decline in the value of foreign assets owned by the financial sector bank when the Australian dollar appreciates. Ryan and Worthington (2004) and Chi *et al.* (2010) also do not find significant effect of foreign exchange risk on Australian bank stock returns. In contrast, McSweeney and Worthington (2008) find that depreciation of the Australian dollar did significantly raise returns for banking and diversified financials.

The risk-return relationships of Australian sectors vary from sector to sector. The coefficients of conditional volatility, γ, in the return equation 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), Choudhury (1996), Ryan and Worthington (2004) and others also find a negative relationship between risk and return.

(vi) Global Financial Crisis

The sample period in this study over 31 March 2000 to 31 December 2010 embraces the Global financial crisis (GFC), 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 GFC, we include a dummy variable in the equation (1) in the GARCH-M system (1) and (2). Dummy variables with different timing will be considered in the regression equations to check the robustness of results.

The equations to be estimated are given by

$$r_{i,t} = c_i + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{m,t} + \delta_{i3} r_{0,t-1} + \delta_{i4} \sigma^2_{o,t} + \delta_{i5} r_{f,t} + \lambda_{ik} D_{kt} + \gamma_i \ln(h^2_{i,t}) + \varepsilon_{i,t},$$

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

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

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

D_{1t} has value 1 on and after 15 September, 2008, the date Lehman Brothers filed for bankruptcy protection and the stock market declined sharply, and 0 otherwise.

D_{2t} has value 1 from 6 October to 15 October, 2008 and 0 otherwise. The week of October 6–10 was the worst week for the stock market since 1933 with the S & P's 500 index losing 18.2 percent, and on 11 October, 2008 the Dow Jones Industrial Average had the highest volatility day recorded in hundred years.

D_{3t} has value 1 from 15 September, 2008 to 30 November, 2008 and 0 otherwise. The GFC appears to have stabilized by the end of November 2008 with dramatic action by the US Federal Reserve, including the pledge to purchase mortgage bonds guaranteed by Fannie Mae and Freddie Mac.

Results from estimating equations (5) and (6) are reported in Table 3 for the market index ASX (in columns 1, 2 and 3) and the financial sector XFJ (in columns 4, 5 and 6).[9] In Table 3 all coefficients of the dummy variables (λ_1, λ_2 and λ_3) are negative and statistically significant, indicating that during and immediately after the Global financial crisis returns for ASX and XFJ 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 results not reported for the other sectors, it is found that the results in Table 2 are for the most part not affected by the inclusion of dummy variables to capture the Global financial crisis.

The financial sector can be decomposed into banks, insurance, diversified financials and real estate sub-sectors. In results available from the authors, it is shown that the anomalous result for the financial sector, a positive association between oil price return

[9] The presence of a structural break in the Australian stock market during the GFC is confirmed by the Bai and Perron (1998) endogenous break test. The Bai and Perron (1998) test finds structural break on 3 October 2008 (at lower 95%, the break was on 26 September 2008 and at upper 95%, the break was on 17 October 2008).

volatility and financial sector return volatility, is founded in similar results for the bank and financial diversified sub-sectors and not in the insurance and real estate sub-sectors.

VI Conclusion

The 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. Oil price shocks can influence stock price through demand for goods that firms produce and through effects on the cost of production. We employ GARCH-M methodology to model the risk and return patterns of ten sectors in Australian stock market with daily data from 31 March 2000 to 31 December 2010. The GARCH-M model relaxes the restrictive assumption of constant conditional variance, depicts the time-varying nature of risk premia, and allows examination of the effect of oil price volatility on stock price return and volatility over time.

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 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 the variance equation, the high value of the measure of shock persistence is an indication that shock effects are highly durable. A contribution of this study is the finding that 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.

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. Information on sector vulnerability, relative immunity or strength in the face of changes in oil price returns and oil price volatility can be used to inform portfolio strategies on oil price risk. When oil price shocks are imminent or the oil price environment changes, investors and market participants can adjust or rebalance their portfolios with stocks of different sectors by looking at sensitivity of the sectors to oil price shocks.

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Table 1

The descriptive statistics and unit root results of daily GICS sector returns and oil return

	XDJ	XSJ	XEJ	XMJ	XNJ	XFJ	XIJ	XTJ	XHJ	XUJ	ASX	Oil
Descriptive statistics												
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
Unit root test												
ADF (C)	-8.12***	-9.32***	-8.76***	-8.91***	-7.81***	-8.33***	-9.40***	-8.41***	-7.96***	-7.93***	-55.32***	-8.85***
ADF (C&T)	-8.21***	-9.30***	-8.77***	-9.01***	-8.05***	-8.51***	-9.42***	-8.83***	-7.91***	-8.03***	-55.38***	-8.88***
PP (C)	-45.42***	-51.31***	46.59***	50.05***	-48.31***	-47.64***	-45.71***	-49.57***	-51.01***	-49.14***	-55.47***	-75.97***
PP (C&T)	-45.41***	-51.41***	46.58***	50.01***	-48.50***	-47.77***	-45.73***	49.73***	51.03***	-49.22***	-55.40***	-75.95***
KPSS (C)	0.10	0.13	0.10	0.08	0.29	0.23	1.29***	0.11	0.15	0.29	0.13	0.04
KPSS(C&T)	0.10	0.06	0.07	0.06	0.12	0.07	0.30***	0.09	0.14	0.25	0.11	0.04
Zivot-Andrews	-37.51**	-38.62***	-51.62**	-53.67***	-52.48***	-38.72***	-38.43***	-38.47*	-38.18**	-32.93***	-55.56***	-56.67***

Notes: The table reports summary statistics and unit root test results of GICS sectors of energy (XEJ), materials (XMJ), industrials (XNJ), consumer discretionary (XDJ), consumer staples (XSJ), health care (XHJ), financials (XFJ), information technology (XIJ), telecom (XTJ), utility (XUJ), market (ASX), and oil price. The series are return data- the first differences of the logarithm of prices. The sample runs from 31-3-2001 to 31-12-2010. By row, we report mean, median, maximum and minimum value, standard deviation (SD), kurtosis, skewness, Jarque-Bera (JB) statistics, and their p-values. Augmented Dickey and Fuller (ADF), Phillips and Perron (PP) and KPSS tests with intercept (C) and intercept and trend (C & T) are reported. Under the ADF and PP tests the null hypothesis that the return series have a unit root is rejected, under the KPSS test the null hypothesis that the series is stationary is not rejected, and under the Zivot-Andrews test the null hypothesis of a unit root process against a break-stationary process where the break is endogenously calculated is rejected. ***, **, and * represent significance at the .01, .05, and .10 levels respectively.

Table 2

Sectoral return and conditional variance equations: GARCH (1, 1)-M estimates using daily data 31-3-2001 to 31-12-2010

	XEJ	XMJ	XFJ	XDJ	XSJ	XHJ	XNJ	XIJ	XUJ	XTJ	ASX
Mean Equation											
γ	0.0617*	-0.0021***	-0.0000	0.0086	0.0004**	-0.0010**	0.0485	-0.0020	-0.0008*	-0.0006	0.0029***
	(0.0345)	(0.0006)	(0.0001)	(0.0521)	(0.0002)	(0.0005)	(0.0991)	(0.0011)	(0.0005)	(0.0005)	(0.0010)
c	0.0002	-0.0035	-0.0010	0.0004	0.0041	-0.0061	0.0000	-0.0136	-0.0060	-0.0010	0.0019
	(0.0003)	(0.0032)	(0.0013)	(0.0031)	(0.0037)	(0.0049)	(0.0043)	(0.0099)	(0.0051)	(0.0041)	(0.0020)
δ_1	0.0110	0.0159*	0.1260***	-0.0497***	0.0621**	0.0821***	0.0589**	-0.0268	0.0027	0.0875***	-0.0802***
	(0.0198)	(0.0099)	(0.0188)	(0.0129)	(0.0248)	(0.0219)	(0.0254)	(0.0187)	(0.0220)	(0.0205)	(0.0188)
δ_2	0.9409***	1.2902***	1.1542***	0.7953***	0.6151***	0.6838***	0.8678***	0.8678***	0.5984***	0.6487***	0.7987***
	(0.0156)	(0.0148)	(0.0078)	(0.0119)	(0.0299)	(0.0163)	(0.0119)	(0.0113)	(0.0365)	(0.0348)	(0.0214)
δ_3	0.1239***	0.0363***	-0.0216***	-0.0197**	-0.0222***	-0.0129	-0.0196***	-0.0310***	-0.0074	-0.0044	-0.0295***
	(0.0074)	(0.0059)	(0.0037)	(0.0089)	(0.0074)	(0.0084)	(0.0090)	(0.0099)	(0.0070)	(0.0069)	(0.0097)
δ_4	0.1698***	0.0954*	0.1921***	-0.1997	0.0219	0.2235	-0.3962**	0.1654*	0.2314*	0.1321	0.1954**
	(0.0231)	(0.0533)	(0.0318)	(0.2021)	(0.2142)	(0.6630)	(0.1415)	(0.0850)	(0.1317)	(0.2987)	(0.0849)
δ_5	0.0309*	0.0257*	-0.0118	-0.0267*	-0.0342***	-0.0077	-0.0223*	0.0020	-0.0092	0.0095	-0.0129*
	(0.0176)	(0.0152)	(0.0083)	(0.0142)	(0.0118)	(0.0172)	(0.0123)	(0.0248)	(0.0175)	(0.0169)	(0.0069)
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	0.0891***	0.0465***	0.0684***	0.0379***	0.0504***	0.0230***	0.0742***	0.0775***	0.0537***	0.0633***	0.0657***
	(0.0071)	(0.0085)	(0.0070)	(0.0039)	(0.0081)	(0.0047)	(0.0079)	(0.0140)	(0.0038)	(0.0061)	(0.0102)
β	0.8746***	0.9056***	0.9219***	0.9600***	0.9392***	0.9727***	0.8984***	0.8660***	0.8954***	0.9209***	0.9024***
	(0.0080)	(0.0105)	(0.0072)	(0.0039)	(0.0094)	(0.0053)	(0.0159)	(0.0155)	(0.0125)	(0.0062)	(0.0061)
ρ	-0.0141***	-0.0321***	0.0013***	0.0001	-0.0015	-0.0077	-0.0259***	-0.0140***	-0.0007*	0.0113*	-0.0089***
	(0.0011)	(0.0107)	(0.0004)	(0.0000)	(0.0061)	(0.0172)	(0.0069)	(0.0057)	(0.0004)	(0.0062)	(0.0021)
$\alpha + \beta$	0.9637	0.9521	0.9903	0.9979	0.9896	0.9957	0.9726	0.9435	0.9191	0.9842	0.9681
There is no effect of oil return volatility: $\delta_4 = \rho = 0$											
	54.26***	52.21***	31.62***	5.69*	4.88*	2.35	34.795***	8.21**	4.85*	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

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

$$r_{i,t} = c_i + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{m,t} + \delta_{i3} r_{0,t-1} + \delta_{i4} \sigma^2_{o,t} + \delta_{i5} r_{f,t} + \gamma_i \ln(h^2_{i,t}) + \varepsilon_{i,t},\ h^2_{i,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta_i h^2_{i,t-1} + \rho_i \sigma^2_{o,t}$$

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), exchange rate risk (δ_5) the log difference in US dollar/Australian dollar rate, 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 serial 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.

Table 3

ASX and financial sector (XFJ) with GFC dummies: 31-3-2001 to 31-12-2010

	1	2	3	4	5	6
		ASX			XFJ	
Mean equation						
γ	0.0041**	0.0043**	0.0042**	-0.0001**	0.0001*	0.0001***
	(0.0031)	(0.0032)	(0.0020)	(0.0000)	(0.0001)	(0.0000)
c	0.0043	0.0048	0.0043	-0.0012	0.0012	0.0012
	(0.0039)	(0.0030)	(0.0032)	(0.0028)	(0.0021)	(0.0021)
δ_1	-0.0613***	-0.0632***	-0.0613***	0.1280***	0.1217***	0.1192***
	(0.0193)	(0.0181)	(0.0191)	(0.0210)	(0.0120)	(0.0123)
δ_2	0.8054***	0.7992***	0.7906***	1.1513***	1.1541***	1.1328***
	(0.0148)	(0.0153)	(0.0148)	(0.0241)	(0.0410)	(0.0320)
δ_3	-0.0365***	-0.0367***	-0.0365***	-0.0217***	-0.0230***	-0.0296***
	(0.0060)	(0.0054)	(0.0060)	(0.0037)	(0.0042)	(0.0054)
δ_4	0.2109**	0.2125**	0.1890*	0.2034***	0.2033***	0.1995***
	(0.0911)	(0.1051)	(0.0995)	(0.0505)	(0.0617)	(0.0598)
δ_5	-0.0129*	-0.0130*	-0.0124*	-0.0121	-0.0129	-0.0129
	(0.0069)	(0.0068)	(0.0071)	(0.0083)	(0.0091)	(0.0088)
λ_1	-0.0070***			-0.0362***		
	(0.0004)			(0.0011)		
λ_2		-0.0171**			-0.0614**	
		(0.0078)			(0.0243)	
λ_3			-0.0020*			-0.0221***
			(0.0011)			(0.0072)
Variance equation						
ω	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	0.0781***	0.0781***	0.0771***	0.0683***	0.0692***	0.0654***
	(0.0091)	(0.0086)	(0.0098)	(0.0070)	(0.0099)	(0.0092)
β	0.9055***	0.9102***	0.9047***	0.9221***	0.9251***	0.9058***
	(0.0108)	(0.0107)	(0.0107)	(0.0073)	(0.0102)	(0.0110)
ρ	-0.0030***	-0.0024***	-0.0651***	0.0019***	0.0021***	0.0021***
	(0.0006)	(0.0006)	(0.0191)	(0.0004)	(0.0008)	(0.0006)
There is no effect of oil return $\delta_4 = \rho = 0$						
	112.24***	98.45***	102.32***	34.57***	36.21***	31.83***
Model diagnostic						
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:

$$r_{i,t} = c_i + \delta_{i1} r_{i,t-1} + \delta_{i2} r_{m,t} + \delta_{i3} r_{0,t-1} + \delta_{i4} \sigma^2_{o,t} + \delta_{i5} r_{f,t} + \lambda_{ik} D_{kt} + \gamma_i \ln(h^2_{i,t}) + \varepsilon_{i,t},\ h^2_{i,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta_i h^2_{i,t-1} + \rho_i \sigma^2_{o,t}$$

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), exchange rate risk (δ_5) the log difference in US dollar/Australian dollar rate, 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, with coefficient λ_1. 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, with coefficient λ_2. 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, with coefficient λ_3. 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.

Figure1

Price indices of S&P/ASX200 and GICS sectors from March 2001 to December 2010

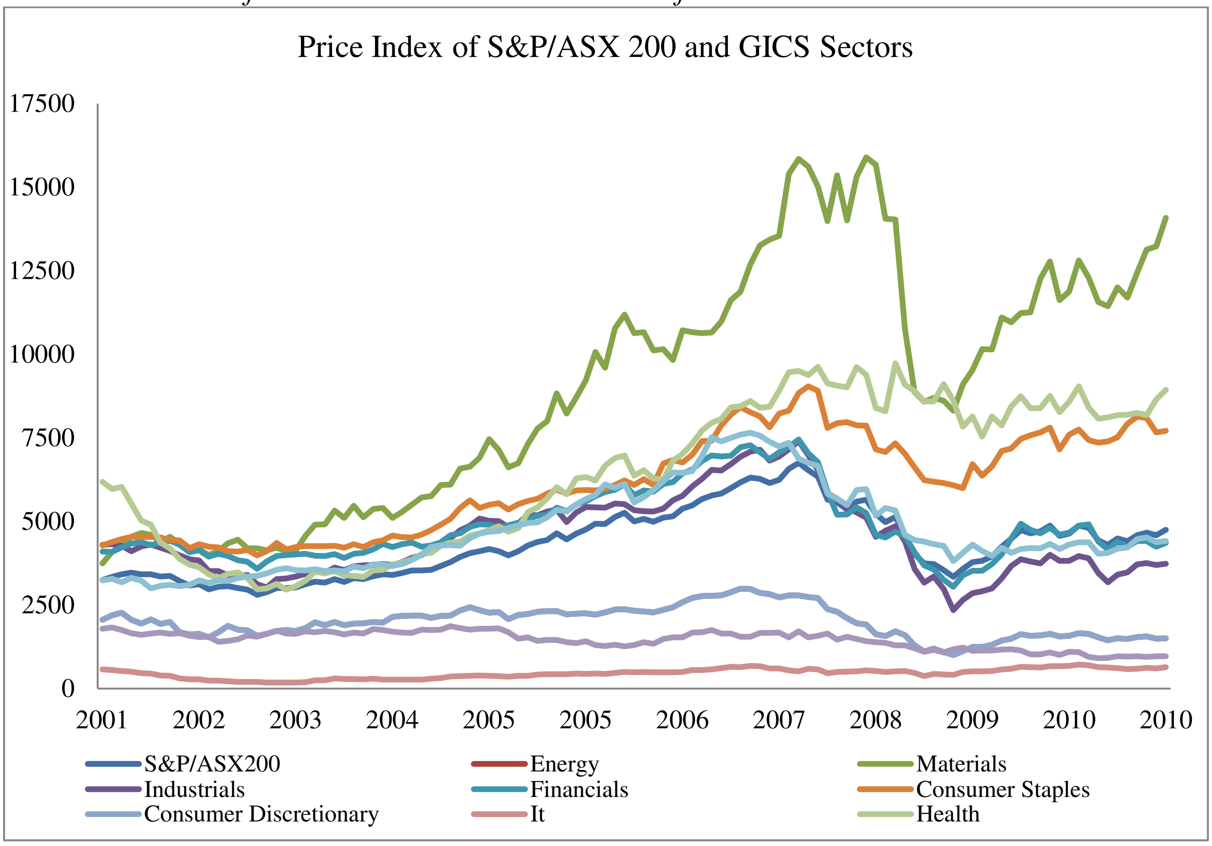

Figure 2

Crude oil price and return