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THE MARKET VALUE OF AUSTRALIAN OIL AND GAS INDUSTRY AND CLIMATE CHANGE: THE VAR, ARCH, GARCH APPROACHES

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Abstract: This study empirically examines and analyses the relationship between climate change and shareholder value in the oil and gas industry in an Australian context. This research is timely and significant, given that climate change will have a profound impact on the oil and gas industry in uncertain carbon-constrained and climate-affected economy. The oil and gas industry, whose main purpose is the production of hydrocarbons, is highly important and relevant to the Australian economy in its wealth generation and power supply. Since oil and gas companies are responsible for a substantial proportion of environmental impacts and also significantly affected by climate change, investors' perceptions and behaviour of capital market could have an enormous impact on market value of the firms according to climate change information. The study concentrates on the analysis of the Australian Oil and Gas Index and refining company Caltex Limited. The Vector Autoregressive (VAR), Autoregressive Conditional Heteroskedasticity (ARCH) and Generalised Autoregressive Conditional Heteroskedasticity (GARCH) time series models have been applied to obtain the more robust and informative results. The study concludes that some of Australia's weather–related information is value relevant. Surprisingly, the temperature does not appear to be significant. However, a weather risk hedge could enable the weather-sensitive sector to achieve weather–dependent results stabilisation.

Keywords: Climate Change, Oil and Gas Industry, Stock Prices, VAR, ARCH, GARCH, Weather Derivatives

1. INTRODUCTION

The role oil and gas play in promoting personal and national wealth puts them at the centre of great economic and socio-political issues. Our civilisation is built on oil and oil is vital to continued economic growth. In the 19th century oil was associated with the significant connection between economic development and industrial evolution. In the 20th century oil and gas have led to world domination. However, in the 21st century the peak oil and climate change concerns have altered the traditional view and point to a different future for the oil and gas industry (Lubber & Solo, 2007).

The global climate change, presented by volatile weather, new environmental regulations and worldwide public protests, creates both risks and opportunities for the oil and gas companies that could materially affect their earnings, market value and ability to compete in global markets (Wellington & Souer, 2005). On one hand, an increase in weather variability and weather extremes will have significant impact on the oil and gas industry. On other hand, oil and gas industry is a major sector of economy that significantly affects climate. It is generally accepted that fossil fuel is the main cause of increased atmospheric concentrations of greenhouse gas emissions. However, the efforts to reduce the world's reliance on carbon-polluting activities may well be the biggest single challenge — and opportunity for business since the industrial revolution. The potential impact of the new regulations and carbon constraints will have a profound impact on the oil and gas industry (The Carbon Trust).

The weather variability and weather-related disaster present a business risk for the oil and gas industry. Weather uncertainty and extremes could affect the production and also price and volume of the oil and gas. By virtue of its carbon-intensive products and long capital investment horizon, the oil and gas industry is uniquely exposed to economic, competitive and physical risks resulting from climate change. These risks are different in kind because the impact is global and the problem is long-term (Lash & Wellington, 2007).

The world ahead looks very different than world behind. Investors are also should concern about climate change, the economy-wide impact of oil and gas prices volatility and climate change's and carbon-reduction policies effect on the oil and gas industry. Today environmental performance and climate change should be relevant not just for the shareholders wishing to invest responsibly, but for any shareholder interested in the return on their investment.

The purpose of this paper is to understand how the capital market incorporates climate change information into investment decisions. The overall aim of the research is to investigate the effect on market value of the oil and gas industry arising from interaction between weather/climate and oil and gas industry. Oil and gas industry plays a key role in the world economy and is very important to Australian economy for its wealth generation and power supply.

There is a relevant scientific and research interest in the relationship between energy consumptions and weather (Valor, Meneu & Caselles, 2000; Sailor & Munoz, 1996; Boudoukh, Richardson, Shen & Whitelaw, 2005; Gabbi & Znotti, 2005). A significant body of academic research analyse the effect of environmental performance on financial performance (Dowell, Hart & Yeung, 2001; Russo & Fouts, 1998; Hart & Ahuja, 1996; Stone, Guerard, Glutekin & Adams, 2001; Blank & Carty, 2002). A number of studies compare the portfolio of companies with superior environmental performance to similarly constructed 'non-green' portfolios (Cohen, Fenn & Naimon, 1995; Early, 2000). Also, research into the casual impact of weather on security returns has been focused from a psychology perspective (Saunders, 1993; Kramer & Runde, 1997; Trombley, 1997; Pardo & Valor, 2003; Tufan & Hamarat, 2004; Loughran & Schultz, 2003; Dowling & Lucey, 2005; Cao & Wei, 2005, Worthington, 2006).

A limited number of empirical studies investigated the weather related moods and feelings on Australian stock returns (Worthington, 2006) and weather effects on Australian capital market (Cao & Wei, 2005). Also some qualitative, forecasting and scenario-building research has been done on the value relevance of world leading oil and gas companies (Wellington & Souer, 2005). However, there are no empirical multiyear studies that examined the long-term relationship between climate and weather change and market value in the context of the Australian oil and gas industry.

The empirical research used one of the different models and methodologies, for example, multi-regression analysis (Gabbi & Znotti, 2005), Worthington (2006) applied autoregressive moving average (ARMA), autoregressive conditional heteroscedasticity (ARCH, GARCH, P-GARCH) have been used by Foster (1995), Najand and Yung (1991), Susmel and Thompson (1997) and other models. While some research found a significant association between weather-related information and returns, others found an insignificant relationship.

This study contributes empirical findings on the relationship between climate change and shareholder value in the weather-sensitive oil and gas industry in the Australian context. In order to identify the value relevance of weather-related information, VAR, ARCH, and GARCH models have been applied for more robust and informative analysis. Moreover, this study compares Australia's refining company which is located and operates in Australia only, with Australia's oil and gas index which includes multinational firms which are operating around the world and, thus, affected by different weather conditions. This research, addressing the value relevance of weather and climate change in the context of the Australian oil and gas industry is timely and significant, given that climate change will have a profound impact on the oil and gas industry in uncertain carbon-constrained and climate-affected economy.

The remaining sections are arranged as follows. The following section discusses the oil and gas industry and climate change concerns. The next section presents methodology, sample and data in the paper. Another section analyses empirical results of the study, followed by a summary of the results and discussion of relevant studies and weather risk management in the oil and gas industry. The final section summarises the conclusion and suggestions for future research.

2. CLIMATE CHANGE AND OIL AND GAS INDUSTRY

Since Adam Smith, political economists have tried to relate national wealth to some national propensity or characteristic. Today, energy consumption and access may have already replaced industrialisation as a characteristic of the wealth and poverty of nations. A robust economy is marked by very large per capita energy consumption.

Moreover, ‘demand for energy does not result from wealth, but instead, promotes and generates wealth’ (Economides & Oligney, 2000, p. 10). Energy is responsible for at least half the industrial growth in a modern economy and represents less than one-tenth of the costs of production.

In 2000, the world consumed 400 quads a total energy per day and this is equivalent to 200 million barrels of oil per day. Importantly, ‘40 per cent is oil, 22 per cent is gas, 24 per cent is coal, 6 per cent is nuclear and 8 per cent comprises all other energy forms. The renewables, wind, solar and the rest comprise less than 0.5 per cent’ (Economides & Oligney, 2000, p.15).

Australian oil exploration and production began early with a reported small discovery in 1900, production increased by the 1960s, peaked in 2000 and is now set to fall steeply. Like the rest of the world, Australia relies heavily on petroleum-based fuels to meet its transport and other energy needs. Petroleum-based fuels meet more than 97 per cent of Australia’s total transport needs. At the rate of growth, the demand will increase by about 50 per cent by 2020. Australia already imports about 30 per cent of its oil and this percentage is set to pass 50 per cent by around 2015 (ASPO, 2005).

From the mid-1980s to the present, real supply and demand largely matched each other. However, oil prices have fluctuated wildly from as low as $10 per barrel to $130 per barrel. An announcement of a winter month 2 degrees warmer than usual, or just the threat of a terrorist bombing may cause a significant change in the price of oil, virtually overnight. Some political motives, such as the Arab Oil Embargo, which caused the first energy crisis of the 1970s and 1980s, revealed how panic for such a vital resource can cause considerable crises and it also established that even a very small over- or under-supply can cause price fluctuations of 50 per cent or more, wreaking havoc on oil markets (Economides & Oligney, 2000).

Oil is not a renewable resource and its supply is finite. The world’s remaining oil resources are diminishing, and supplies are located in oil fields that are smaller, more remote and more difficult to cultivate. Also, climate change is impacting the oil and gas industry both directly and indirectly. Industry is at risk from weather volatilities and extremes (McGeachie, Krierman & Krizner, 2005). In every operation, oil and gas companies engaged in exploration, development and production of oil and gas heavily depend on weather conditions (Altalo et. al., 2000). However, oil and gas industry products such as crude oil and natural gas use processes that can generate large amounts of waste and petroleum fuels and natural gas are the largest sources of carbon dioxide (CO_2) emissions (World Resources Institute, 2005).

Since the Industrial Revolution, the level of CO_2 has increased by more than 30 per cent as a result of burning fossil fuels and other human-made emissions which have amplified the natural ‘greenhouse effect’ (Keeling & Whorf, 2001). An increase in greenhouse gases is predicted to lead to changes in climate and will have a significant impact on the natural, social and economic environment (RetuTex, 2007). While scientists are still uncertain about how climate change will play out, there is no question that it will impose significant economic costs. It was estimated that, by 2050, worldwide annual costs due to climate change will be $5000 billion per year and a 1-degree Celsius increase in the average temperature could cause up to $2 trillion in damages by that time, which is a ‘real possibility for the next century, and could lead to 5–20 percent loss in global GDP’ (Stern, 2006).

In response, carbon-mitigation polices and emission trading programs have been developed at global and local levels to encourage the reduction of the global greenhouse emission. The Kyoto Protocol governs developed countries emissions. Productivity will only be maintained if the polluters seek cleaner, renewable alternative energies to replace fossil fuel (gas) energy (The Carbon Trust, 2005). The EU Emission Scheme, which commenced in January 2005, and the proposed Australian Emission Scheme, which will commence in 2010, attempt to reduce pollution caused by carbon emissions by providing incentives to reduce emissions.

Carbon reduction will likely have a dramatic impact on the way corporations conduct their business. The regulations that limit CO_2 emissions will impact oil and gas companies in two ways. Directly through capping the industry’s carbon emissions and indirectly by driving the market toward low-carbon alternatives to oil and gas (Renewable Energy Policy Network, 2005). The oil and gas companies must allocate a significant investment to environmental and carbon-constraint programs. Climate change related policies and regulations will continue to provide a growing range of new products such as low carbon fuels, and technology opportunities such as carbon capture and storage technology.

Among growing international efforts to reduce greenhouse emissions and rising public concern, shareholders could see declines in their investment in major oil and gas companies. Investors could view a clean energy future not only as a social responsibility issue, but also as an economic imperative (Dumas, 2006). But to most, oil and gas companies are still viewed as an important part of investors' portfolios for at least several decades (Anderson, 2007).

The climate change issues should become important determinants of shareholder value. Climate change factors are important sources of competitive advantage and disadvantage within the oil and gas industry. Does the capital market incorporate weather and climate change information in the stock valuation process? Reaction of the capital market could have significant impact on the market value of the oil and gas companies.

3. DATA AND METHODOLOGY

3.1. Data

Industry Selection

The industry selected is the oil and gas industry, including petroleum refining in Australia. This industry has been selected for the following reasons:

1. The oil and gas industry is highly important and relevant to the Australian economy.
2. The Australian economy depends more on fossil fuels for its wealth generation and power supply than most developed economies.
3. The oil and gas industry is one of the most weather-sensitive sectors.
4. The oil and gas industry is one of the major sectors that significantly affect climate change.
5. The growing importance of the reduction of greenhouse gases (GHG).
6. The oil and gas industry is most exposed to the risks and opportunities generated by the climate-change issues.

7. We must allocate a significant investment to environmental and carbon constraint programs.
8. It is subject to an enormous range of environmental and natural resources regulation and litigation.
9. The oil and gas companies are more likely to be affected in a material way by climate change, making this industry a subject for integrating environmental analysis into a stock's financial assessments.

Company and Index Selection

The study concentrates on the analysis and valuation of the Australian Oil and Gas Index, and on the analysis and valuation of one of the refining company Caltex Limited, with geographical focus on Australia. The Oil and Gas Index represents the leading Australian oil and gas companies and includes domestic companies and MNC that operate around the world. Caltex Limited is located and operates in Australia.

Australia has seven major operating refineries: BP Refinery (Bulwer Island) PTY, (QLD); BP Refinery (Kwinana) PTY Ltd, (NSW); Sell Refining (Geelong) Pty Ltd, (VIC); Sell Refining (Clyde) Pty Ltd, (NSW); Caltex Australia Limited (QLD, NSW) located in Brisbane and Sydney (AIP, 2005, p.5). Caltex Australia Limited is the largest refiner and marketer of petroleum products in Australia, with operations in all states and territories. Caltex is the only oil refining and marketing company listed on the Australian Stock Exchange.

Data

The weather–related temperature and pressure data are provided by the Australian Bureau of Meteorology. The maximum temperature at 3 pm has been chosen as a proxy for global warming, because Australia does not have a very cold winter. Since the changes in atmospheric pressure signal shifts in the weather, the daily pressure has been chosen as a proxy for climate change. The meteorological station has been selected to mach the weather related data and securities that are traded on the Australian Stock Exchange (ASX). The capital market data examined in the sample are daily–end closing, and weekly (Wednesday) share prices traded on the ASX are collected from DataStream's database. Since Sydney is accepted as an Australian financial capital market, the Sydney meteorological station (N066062) has been selected for the empirical analysis. All missing data have been replaced by data provided by Sydney airport meteorological station (N66037).

The study observes the change in share prices of the Australian Oil and Gas Index and weather–related data over the period from January 1973 to April 2007. This study covers the period from January 1983 to April 2007, to examine the value relevance of global warming and climate change of Caltex Limited. For comparison purposes and more robust results, a total of 8,957 Oil and Gas Index daily returns and weather-related data, as well as 6,347 Caltex Limited daily returns and temperature and pressure data, have been utilised to compare results to 1,791weekly (Wednesday) and to 1,269 weekly (Wednesday) data respectively.

3.2 Methodology

Time Series Models

A number of empirical research attempted to investigate the weather effect on the stocks' returns or futures and applied some of the time series models such as autoregressive moving average (ARMA), autoregressive conditional heteroscedasticity (ARCH, GARCH, P-GARCH) and other. The non-normality in stock returns could be attributed to the presence of heteroskedasticity. ARCH and GARCH models allow variance to evolve through time and respond to past changes.

Streeter and Tomek (1992) introduced an integrated model for volatility which was designed to simulate an ARCH (Autoregressive Conditional Heteroskedasticity) effect. Some research has been done by using GARCH specifications in modelling the impact of information flows, which is usually measured by volume. Najand and Yung (1991) concluded that the GARCH effect remains significant when volume is included in model.

Susmel and Thompson (1997) applied switching an ARCH (AWARCH) model to examine the effect of storage and regulatory change on volatility for natural gas futures. The modified model outperforms the standard GARCH by explicitly accounting for changes in markets. Periodic GARCH (P-GARCH) is the modified GARCH with time-varying coefficients introduced by Bollerslev and Ghysels (1996).

The P-GARCH could be applied to model seasonal volatility by defining the periodic cycle. This model is an extension of models applied by Najand and Yung (1991), Foster (1995), and Susmel and Thonson (1997).

The wide range of weather indicators and GJR-GARCH and ARIMA models has been applied to investigate the weather-related moods and feeling on stock market. For example, Chang Niel Yang and Yang (2005) provided empirical evidence of equity returns for the Taiwan Stock Exchange. They employed a recently developed econometric technique of the threshold model with the GJR–GARCH process on error terms.

Worthington (2006) applied a non-parametric correlation analysis and autoregressive moving average (ARMA) model. He pointed out that empirical work of this type is complicated by the strong seasonality of both equity markets and weather conditions. He concludes that all weather indicators are highly and significantly correlated. Moreover, 'given the inadequacies of the empirical techniques employed in this area, it may never be possible to confirm the influence of specific indicator as against a generic weather effect' (p13).

The aim of this study is to confirm or reject the existence of relationship returns on investment and change in the climate. The Vector AutoRegression (VAR) model is applied to investigate these relationships. In addition to the VAR estimation, Autoregressive Conditional Heteroscedasticity models (ARCH) and GARCH are also proposed. All analyses have been performed within the context of a Vector Autoregression (VAR). ARCH and GARCH are models that include past variances in the explanation of future variances and take in to account some excess kurtosis, leverage effects and volatility clustering - three important characteristics of the financial time series. All these models are useful in context as they do not require the restrictions of the more tightly structured model and allow concentration on the variables of most interest without additional variables.

Vector AutoRregression (VAR)

The Vector-regression (VAR) model has been used to capture the evolution and interdependence between multiple time series. A VAR makes minimum theoretical demand on the structure of the model and only needs to specify the variables and the largest number of lags needed to capture most of the effect that the variables have on each other. In general the VAR model can be represented as follows:

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \dots A_p y_{t-p} + e_t \quad (1.0)$$

Where c is a k x 1 vector of constant (intercept), A_i is a k x k matrix (i = 1, …p), e is a k x 1 vector of error term.

The VAR model is useful in context as it does not require the restrictions of the more tightly structured model, suggested by economic theory (Burbidge and Harrison, 1984). The results obtained by this method are, in many cases, better than those obtained from the most complex simultaneous equations models. Therefore, as in all VAR processes, each variable may be expressed as a linear combination of their lagged values and of the lagged values of all other variables in the group.

Thus, VAR lets the data determine the dynamic structure of a model. The generalized impulse response function and error variance decomposition examine the dynamic response of the capital market to change in the weather–related variables.

ARCH and GARCH models

ARCH is Autoregressive (fluctuates over time) Conditional (predictable) Heteroscedasticity (uncertain). The ARCH model introduced by Engle (1982) has been widely used in modelling financial time series. The term "conditional" implies explicit dependence on a past sequence of observations. A methodology to test for the lag length of ARCH errors using the Lagrange multiplier test was proposed by Engle (1982):

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \dots + a_q y_{t-q} + e_t \quad (2.1)$$

$$\hat{e}^2 = a_0 + \hat{a}_1 \hat{e}^2_{i-1} + \dots + \hat{a}_i e^2_{i-1} \quad (2.2)$$

Where -q is the length of ARCH lags.

The alternative hypothesis is that, in the presence of ARCH components, at least one of the estimated α_i coefficients must be significant.

The weather sensitive markets with supply and demand uncertainty and various horizon changes through time are particularly well-suited for ARCH and GARCH. Also these models are consistent with various forms of efficient market theory, which states that assets returns observed in the past cannot improve the forecasts of assets returns in the future. Moreover, the ARCH and GARCH models allow concentration on the variables of most interest without additional variables that are unavailable, especially for the daily or weekly data (i.e. profit), unobservable (i.e. risk preference) or the requirement to specify an appropriate asset pricing model. GARCH offers a more parsimonious model (i.e. using fewer parameters) that lessens the computation burden.

The GARCH (p, q) model (where p is the order of the GARCH terms and q is the order of the ARCH terms) is given by:

$$\sigma^2_t = a_0 + a_1\, \varepsilon^2_{t-1} + a_q\, \varepsilon^2_{t-q} + \beta_1\, \sigma^2_{t-1} \ldots + \beta_p\, \sigma^2_{t-p} + e_t \qquad (3.0)$$

GARCH generalizes the purely autoregressive ARCH model to an autoregressive moving average model. The weights on past squared residuals are assumed to decline geometrically at a rate to be estimated from the data.

GARCH is explicitly designed to model time-varying conditional variances. However, GARCH could fail to capture highly irregular phenomena (wild market fluctuations) and other highly unanticipated events. Several previous studies adopted the Markov switching model to capture the market, business, other cycles or seasonality and forecast future market conditions (Krolzing, 2006, Krolzig *et al*, 2002; Krolzing and Tor, 2000; Gramger and Silvapulle, 2002).

Empirical Model

The following empirical models have been applied to test the value relevance of the climate change in the oil and gas companies:

$$R_{CALT} = \beta_0 + \beta_{1TEMP} + \beta_{2PRESS} + e \qquad (4.1)$$

$$R_{O\&G} = \beta_0 + \beta_{1TEM\,P} + \beta_{2PRESS} + e \qquad (4.2)$$

where R_{CALT} and $R_{O\&G}$ are the returns of Caltex Limited refining company and Oil and Gas Index. β_{1TEMP} and β_{2PRESS} are temperature and pressure respectively.

The maximum temperature at 3 pm has been chosen as a proxy for global warming. Since the changes in atmospheric pressure signal shifts in the weather, the daily pressure has been chosen as a proxy for climate change. A series of capital market returns of the Oil & Gas index and Australian refining company, Caltex Limited, have been calculated using the discrete return formula $R_t = 100 \ln(P_t/P_{t-1})$ where P_t is the index (or company) level at the end of the day *t*.

Since Caltex is located and operates in Australia only, the Oil and Gas Index includes the large multinational companies that operate in Australia and around the world and, hence, they are affected by different weather conditions. This study expects to confirm that:

a) a significant relationship between the weather-related variables and the market value of Caltex Limited, and

b) an insignificant relationship between Australia's weather related variables and Oil and Gas Index returns on investments.

4. EMPIRICAL ANALYSES

4.1 Descriptive Statistics and Pre-estimation Analyses

Descriptive Statistics

Jarque–Bera (J-B) statistics have been used to test the null hypothesis that the data are from a normal distribution. All JB statistics are greater that than critical value 5.99

and the null hypothesis of normality is rejected. The returns' kurtosis 14.94 (Caltex) and 32.35 (O&G) considerably exceeds the value 3 of the normal distribution of being leptokurtic. However, the sample size is quite large and skewness doesn't reach ± 1.00. The descriptive statistics are presented in the following Table 1.

TABLE 1. Descriptive Statistics

	Caltex RETURN	**Caltex PRESSUR**	**Caltex TEMP**	**O&G RETURN**	**O&G PRESSUR**	**O&G TEMP**
Mean	0.000474	14.36279	21.21557	0.000350	14.44736	21.17315
Median	0.000000	14.00000	21.00000	0.000000	14.0000 0	21.00000
Std. Dev.	0.021178	4.950731	4.202440	0.014043	62.00000	4.254696
Skewness	-0.912120	0.283844	0.327627	-1.187169	0.274902	0.362494
Kurtosis	14.93368	3.635881	3.231941	32.34915	3.208832	3.350110
J –B	38530.17	192.0986	127.7337	323503.2	129.0618	241.8543

Dickey-Fuller and Phillips- Perron tests

The augmented Dickey-Fuller and Phillips–Perron tests search for a unit root in a time series sample. The null hypothesis of a unit root has been rejected. That means the variables *RETURN* and *TEMPERATURE* and *PRESSURE* series do not have the unit root problem and the series are stationary series. The Phillips–Perron Unit Root test also rejects null hypothesis of a unit root and indicates that the series area is stationary. The calculated t-statistic and adjusted–t–statistics are presented in Table 2.

TABLE 2. Unit Root Tests Results

	Return	**Pressure**	**Temperature**
CALTEX			
Augmented Dickey-Fuller test	-60.51	-8.16	-7.51
Phillips–Perron Unit Root Test	-80.82	-59.50	-70.61
OIL&GAS INDEX			
Augmented Dickey-Fuller test	52.53	-8.64	-7.88
Phillips–Perron Unit Root Test	-85.01	-71.16	-88.16
Note: Unit root based on model with constant and trend Test critical values: 1% level -3.95; 5% level -3.41; 10% level -3.127			

4.2 Empirical Results

VAR

The Vector Autoregressive Model (VAR) enables the understanding of the dynamic relationship over time among the variables and improves the accuracy of explanation by utilizing the additional information available from the related variables. To find the order of VAR, a number was guessed, and the number of lags was set at 6. The results of estimating these equations for Caltex Limited indicate that so many of the lagged variables, except one (TEMP (-6) daily, 0.000320, SE (9.2E-0.5), t-statistics [3.47]) and another (TEMP (-4) weekly, (-0.000291), SE (0.00019), t-statistics [-2.42014], are insignificant in each equation and should be left out of the model. For Oil and Gas Index on daily basis pressure appears to be significant in two equations PRESSURE (-1) (-6.89E-05), SE(2.2E-0.5), t-statistics[-3.12713] and on weekly basis TEMP (-3) (0.000317), SE(0.00010), t-statistics[3.13730] and PRESSURE (-2) (-0.000213), SE(9.1E-0.5), t-statistics[-2.34455]. All other lagged variables are insignificant.

The selection of the appropriate order of the VAR is based on various selection criteria such as the Akaike Information Criterion (AIC) and Schwarz Information Criteria (SC). Table 3 shows the VAR lag order selection criteria. AIC is 5.229, and other information criteria show that the preferred model is VAR (8) for Caltex and the Oil and Gas Index. The VAR model has been used to estimate the impulse response.

TABLE 3. Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
CALTEX						
6	16568.77	84.65919	0.038143	5.247206	5.307958*	5.268245
7	16529.39	78.49101	0.037779	5.237617	5.307962	5.261978
8	16495.42	67.67654*	0.037482*	5.229736*	5.309673	5.257419*
OIL&GAS INDEX						
7	-26490.58	114.4762	0.075986	5.936420	5.988788*	5.954245
8	-26460.12	60.74198*	0.075622*	5.931624*	5.991133	5.951879*

** indicates lag order selected by the criterion*
LR: sequential modified LR test statistic *FPE: Final prediction error*
AIC: Akaike information criterion *SC: Schwarz information*
HQ: Hannan-Quinn information criterion

The VAR allowed the data to determine the structure of a model dynamic. The generalized impulse response function and error variance decomposition allow the examination of the dynamic response of the capital market to change in the weather–related variables, and how the change in weather–related variables affect each other over time. The Caltex impulse response function indicates that the markets react slowly to small changes in the temperature and pressure within 7 days, and complete its response at the end of day 10. In regard to the Oil and Gas Index, the capital market did not react to the insignificant changes in temperature and pressure.

Table 4 reports the variance decomposition estimated over the 10 day period (10 days and 2 weeks) for the weather–related variables based on VAR. The estimating impact of the temperature and pressure on Caltex's return appears to be a small source of volatility. The temperature contributes around 0.22 percent of the volatility in returns on a daily basis and around 0.77 percent on a weekly basis. The pressure's contribution is lower on the daily (0.09 percent) and weekly basis (0.52 percent).

TABLE 4. Variance Decomposition

Variance Decomposition of RETURNS (daily):				
CALTEX				
Period	**RETURNS**	**PRESSURE**	**TEMP**	
1	0.021107	100.0000	0.000000	0.000000
2	0.021160	99.93237	0.023256	0.0443107
3	0.021160	99.93237	0.023256	0.044374
4	0.021163	99.90828	0.025534	0.066187
5	0.021168	99.88335	0.035291	0.081356
6	0.021174	99.83439	0.078904	0.086707
7	0.021189	99.70528	0.083624	0.211097
8	0.021191	99.68656	0.092611	0.220827
9	0.021191	99.68627	0.092873	0.220853
10	0.021191	99.68626	0.092874	0.220870
OIL AND GAS INDEX				
1	0.013930	100.0000	0.000000	0.000000
2	0.014029	99.89197	0.108026	5.95E-07
3	0.014041	99.87420	0.107870	0.017931
4	0.014045	99.86757	0.113947	0.018480
5	0.014047	99.86219	0.119160	0.018651
6	0.014049	99.84356	0.135719	0.020719
7	0.014052	99.82278	0.139021	0.038200
8	0.014054	99.81996	0.139044	0.040994
9	0.014055	99.81948	0.139188	0.041337
10	0.014055	99.81942	0.139210	0.041371

The impacts of temperature and pressure on the Oil and Gas Index returns are also too small. It seems that VAR captures only the trend and not fluctuations.

ARCH and GARCH

A theory of dynamic volatility could be filled by ARCH models. ARCH and their many extensions can be used to explain volatility and risk over a long term. The ARCH model has been estimated in order to explain the volatility in the returns, and where the variance depends on the last period's volatility. But in general, the variance could depend on any number of lagged volatilities, 8 in this case. The presence of hetersoscedasticity indicates that ARCH and GARCH modeling are appropriate. The optimal parameters have been estimated by ML, and daily parameters are presented in Table 5.

TABLE 5. Autoregressive Conditional Heteroscedasticity ARCH

APCH				
Q = C(4) + C(5)*(Q(-1) - C(4)) + C(6)*(RESID(-1)^2 - GARCH(-1)) GARCH = Q + C(7) * (RESID(-1)^2 - Q(-1)) + C(8)*(GARCH(-1) - Q(-1)) **Dependent Variable: RETURNS**				
CALTEX				
Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
PRESURE	-0.000126	6.06E-05	-2.086242	0.0370
TEMP	7.79E-05	7.08E-05	1.100538	0.2711
C	0.000798	0.001246	0.640482	0.5219
Variance Equation				
C(4)	0.000474	1.43E-05	33.02896	0.0000
C(5)	0.975429	0.002912	335.0104	0.0000
C(6)	0.040953	0.003270	12.52377	0.0000
C(7)	0.112967	0.011834	9.545721	0.0000
C(8)	0.394928	0.044158	8.943430	0.0000
Akaike info criterion -4.972257 Schwarz criterion -4.963740 Log likelihood 15782.49				
ARCH1				
OIL&GAS INDEX				
Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
PRESURE	4.36E-07	2.68E-07	1.625700	0.1040
TEMP	-8.02E-06	3.06E-05	-0.262554	0.7929
C	0.000535	0.000664	0.804670	0.4210

Only the *PRESSURE* appears to be significant 6.06E-05 [z= -2.086], (p=0.037), while the *TEMPERATURE* and constant appear not to be significant in the Caltex daily returns. All weather-related coefficients, including constant, are insignificant in the Oil & Gas Index daily returns. All Caltex and Oil and Gas Index weekly parameters are not significant. The error term is the cause of volatility in the returns of Caltex and the Oil and gas companies.

The generalized GARCH (1.1), GARCH (2.1), GARCH (1.2), CARCH (2.2.) models have been estimated in order to explain the high volatility in the return and value relevance of the weather–related variables. Again the only *PRESSURE* appears to be significant in the Caltex daily return. All weather-related coefficients, including constant, are insignificant in the Oil & Gas Index daily and weekly returns. However, all models show that error term is the cause of volatility. The relatively small value of error coefficient implies that large market surprises induce relatively small revisions in volatility. Constant and GARCH(-1) term, which is last period's forecast variance appear to be significant. The RESID (-1)^2 term, which describes news about volatility from the previous period and is measured as the lag of the squared residuals from the mean equation, is also significant. Even though all models produced the same result GARCH (2.1) appears to be a better model and indicates that the Caltex investors react to the change in the weather on a daily basis. The results are presented in Table 5.

TABLE 6. Generalised Autoregressive Conditional Heteroscedasticity GARCH

GARCH 21				
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*RESID(-2)^2 + C(7) *GARCH(-1) **Dependent Variable: RETURNS**				
CALTEX				
Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
PRESURE	-0.000131	6.05E-05	-2.159697	0.0308
TEMP	8.71E-05	7.04E-05	1.236532	0.2163
C	0.000650	0.001238	0.524977	0.5996
Variance Equation				
C	1.80E-05	1.08E-06	16.63559	0.0000
RESID(-1)^2	0.135680	0.010616	12.78082	0.0000
RESID(-2)^2	-0.076165	0.010384	-7.335151	0.0000
GARCH(-1)	0.901985	0.004331	208.2401	0.0000
Akaike info criterion -4.967777; Schwarz criterion -4.960324 ;Log likelihood 15767.27				
OIL &GAS INDEX				
Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
PRESURE	- 3.57E-05	3.09E-05	-1.152764	0.2490
TEMP	1.83E-05	3.65E-05	0.502378	0.6154
C	0.000772	0.000657	1.174066	0.2404

The *PRESSURE* appears to be significant 6.05E-05 (z=-2.0159), [p=0.0308], while the *TEMPERATURE* and constant are not significant in Caltex's daily return. Also, the results indicate that the capital market is efficient and incorporates the news from the last and previous periods for Caltex and the oil and gas companies included in the Oil and Gas Index**.**

5. DISCUSSION

The different models have been applied to test weather-related information and market returns relationships and the results are presented in Table 7. In general, the empirical results support the prediction of this study that Australia's weather–related information is value relevant, and investors incorporated this information for the investment in Caltex Limited refining company. However, only daily pressure that actually signals the change in the weather is significant, but the regression coefficient is too small. Surprisingly, the sensitivity of weather–sensitive company Caltex's returns to the change in the temperature doesn't appear to be significant. Moreover, weekly pressure and temperature appear to be insignificant. The empirical results support the expectation of this study that the relationship between Australia's weather-related information and the returns on the investment of the Oil and Gas Index is not significant on daily and weekly basis. The Index includes the large multinational companies that are operating around the world and which are affected by different weather conditions. The results of this study are consistent with Cao and Wei's (2005) study which examined the international weather effect and found that the temperature was not a significant factor in Australia.

TABLE 7. Summary of Results

	VAR	**ARCH**	**GARCH**
Daily data		St error in ( ), t-stat in [ ]	
	CALTEX		
PRESSURE	insignificant	6.06e-0.5 [-2.086] (0.0370)	6.05E-0.5 [-2.159] (0.0308)
TEMP	TEMP (-6) 0.00032 [3.4790] (9.2E-5) OTHER insignificant	insignificant	insignificant
	OIL &GAS INDEX		
PRESSURE	PR (-1) -6.89E-05 [-3.12713]	insignificant	insignificant

	(2.2E-050) OTHER insignificant		
TEMP	insignificant	insignificant	insignificant
Weekly data			St error in ( ), t-stat in [ ]
CALTEX			
PRESSURE	insignificant	insignificant	insignificant
TEMP	TEMP (-4) -0.000473 [-2.43014] (0.00019) OTHER insignificant	insignificant	insignificant
OLI &GAS INDEX			
PRESSURE	PR (-2) -0.000213 [-2.34455] (9.1E-05) OTHER insignificant	insignificant	insignificant
TEMP	TEMP (-3) 0.00032 [3.13730] (0.00010) OTHER insignificant	insignificant	insignificant

Also, results are consistent with Worthington's (2006) conclusion. His results indicate that there is no statistically significant relationship between the weather and Australian market returns. He pointed out that empirical work of this type is complicated by the strong seasonality of both equity markets and weather conditions. However, he concluded that weather indicators are highly and significantly correlated. Moreover, he concluded that "given the inadequacies of the empirical techniques employed in this area, it may never be possible to confirm the influence of specific indicator as against a generic weather effect" (p13). Thus, the empirical results of this study show that the temperature is not incorporated by capital markets when making decisions regarding investment in weather–sensitive companies. However, the market participants have access to weather forecasts and, more importantly, investors and oil and gas companies are hedging weather risks.

Weather derivatives

The degree to which adverse weather conditions affect a business can be expressed as the business' "weather sensitivity" (Gibbs, 2000). The Oil and gas industry is a prime example of an industry that uses knowledge of its weather sensitivity and meteorological expertise to offset its weather risk. To minimise the impact that adverse weather may have on business and to ensure a more predictable stream of income, oil and gas companies often purchase insurance and/or weather derivatives to protect themselves. Moreover, greater stability and predictable business can result in increased shareholder value.

Weather risk and financial risk are no longer considered in isolation, but are always integrated into the oil and gas companies risk management decisions. Unlike financial derivatives that are useful for price hedging, weather derivatives are used to hedge the volumetric risks. However, weather–related quantity and price are closely related to each other. As a result, companies have started to hedge the volumetric risk caused by unexpected weather conditions and price risk. A weather hedge enables weather-sensitive sectors to achieve weather–dependent result stabilisation in context of integrated risk management. The management of weather risks in oil and gas companies is usually approached in two ways. In the first, firms identify any catastrophic weather events that could adversely impact its revenue streams, and arrange appropriate insurance cover. In the second, a company can try to protect against a variation in its revenue streams arising from weather events which are not catastrophic but which do deviate from the norm by entering into weather derivative.

Non-catastrophic weather fluctuations include warm or cold periods and other events that are expected to occur reasonably frequently. Thus, the weather derivatives are a new type of securities making pre-specify payouts if some weather event occurred. Thus, the weather risks are the uncertainty in cash flows and earnings caused by non-catastrophic weather events such as temperature, humidity, rainfall, stream flows and wind. The weather derivatives contracts include any kind of weather variable, such as temperature, rain, snow, wind and other. Temperature–related protection continues to be the most prevalent, comprising more than 85 percent of all contracts (Weather Risk Management Association, WRMA, 2003). The better-quality information concerning future weather conditions could entail greater stability and predictable business, resulting in increased shareholder value.

The global impact of weather conditions has brought explosive growth in the weather derivatives' market, with a total value of over $10 billion for weather derivatives traded in the year 2002/ 2003 (Jewson & Brix, 2004). The volume of weather derivatives traded on the Chicago Mercantile Exchange jumped from $9.7 billion in 2004-2005 to more than $45 billion in 2005-2006 (Davies, 2007). The market continues to grow, including cities in other region such as London, Tokyo and Paris (Davies, 2007), although the Australian market is significantly younger and smaller than others. The catastrophe–related risks (CAT risk) caused by hurricanes, tornados, and windstorms has grown substantially, from around US $700 million in 1997 to approximately US $13.5 billion outstanding at the moment. Since 1997, the 59 'Cat' bonds issued to hedge weather risk has increased dramatically.

6. CONCLUSION

The study concludes that some weather–related information is value relevant, and investors incorporated this information for investment in Caltex Limited refining company, which is located and operates in Australia. Surprisingly, the sensitivity of weather–sensitive company Caltex's returns to the change in the temperature doesn't appear to be significant. However, only an abnormal temperature could have an impact on the returns. The relationship between Australia's weather-related information and the returns on the investment of the Oil and Gas Index is not significant due to effects on the different weather conditions around the world. The results could be explained by the fact that investors do not care at all about the climate change or capital market efficiency, which states that assets returns observed in the past cannot improve the forecast in the future. Also the inadequacies of the empirical techniques employed, or a need to control other factors, could be affected results. However, a weather hedge could enable the weather-sensitive sector to achieve weather–dependent results stabilisation. Future studies could be extended to investigation of the existence of a relationship between other weather–related variables to determine the statistical models that may be appropriate to test a relationship between weather variables and market returns. Markov-Switching Vector Autoreression model, which able to determine the speed and duration of response of market to change in weather-related variables would be appropriate.

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