Macroeconomic information and implied volatility: evidence from Australian index options

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Abstract

Purpose – The purpose of this paper is to understand that option pricing is the response of option implied volatility (IV) to macroeconomic announcements.

Design/methodology/approach – The authors use high-frequency data on ASX SPI 200 index options to examine the response of option IV, as well as higher moments of the underlying return distribution, to macroeconomic announcements. Additionally, the authors identify the response of the moments as a function of moneyness of the options.

Findings – The findings suggest that in-the-money and out-of-the money options have difference characteristics in their responses, leading to the conclusion that heterogeneity in investor beliefs and preferences affect option IV through the state price density (SPD) function.

Originality/value – The research contributes to the literature that examines whether IV captures the beliefs of market participants about the likelihood of future states together with the preferences of market participants towards these states. In particular, the authors relate changes in option IV to changes in macroeconomic announcements, through the impact of these announcements on the moments of the SPD function.

Keywords Behavioural finance, Options, Implied volatility, Macroeconomic information

Paper type Research paper

1. Introduction

In this paper, we are led to infer that out-of-the-money (OTM) options create different prospects for gains and losses as compared with in-the-money (ITM) options, and that these differences are weighted in accordance with the investor's base position as predicted by prospect theory. Thus, a behavioural understanding of investors is required to fully explain option pricing. For example, prospect theory anticipates that investors "with more to lose" (ITM option holders) are more alert to changes in economic circumstances than investors who are trading a "losing hand" (OTM option holders). In this case, ITM options are "more risk averse" than OTM options, with direct implications for explanation of the volatility smile. Option implied volatility (IV) derives the market's estimate of future volatility from traded option prices. As these option prices reflect investors' expectation of cash flows in different states of the world

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and at different time horizons, option IV can incorporate a broader information set than model-based volatility forecasts derived from realised volatility. Academic researchers and many investors consider that IV provides a superior forecast of future volatility than estimates derived from historical realised volatility. A comprehensive review of forecasting volatility in financial markets by Poon and Granger (2003) reveals that all but one of the 22 studies that used index option IV to forecast stock index volatility concluded that IV contains useful information about future volatility, and that about 50 per cent of index volatility is predictable up to a four-week horizon when actual volatility is estimated using very high-frequency intra-day returns (p. 500). Figlewski (1997) claims that both option traders and academic researchers consider IV to be of great importance.

Our research contributes to the literature that examines whether IV captures the beliefs of market participants about the likelihood of future states together with the preferences of market participants towards these states. In particular, we relate changes in option IV to changes in macroeconomic announcements, through the impact of these announcements on the moments of the state price density (SPD) function. It is well known in asset pricing that SPD's capture and summarise all information about investor preferences and economic conditions relevant to the pricing of financial assets. Earlier research by Ederington and Lee (1996) found that information releases impact on the IV of T-Bonds, Eurodollar and Deutschemark options, and that scheduled announcements lead to a decrease in uncertainty of investor concerns, and a reduction in IV, whereas unscheduled announcements lead to an increase in IV. Rosenberg and Engle (2002) identified the SPD function with a monthly pricing kernel using a cross-section of S&P 500 index option prices and the S&P 500 return density function, and found substantial evidence that the pricing kernel exhibits counter cyclical risk aversion over S&P 500 return states. In addition, they report that empirical risk aversion is positively correlated with indicators of recession (widening of credit spreads) and negatively correlated with indicators of expansion (steepening of term structure slope). Beber and Brandt (2006) examined the impact of scheduled macroeconomic announcements on the IV of at-the-money (ATM) options on the US Treasury market. They distinguished between "good news" and "bad news" announcements and whether the news content came as a "surprise", as opposed to confirming investor expectations. In addition, they test directly the sensitivity of the volatility, skewness and kurtosis of the SPD function to the impact of macroeconomic news announcements. By relating the implied risk aversion and change in risk aversion to the announcements, they argue that risk aversion varies counter-cyclically as predicted by a habit formation model. More recently, Du (2011) has proposed a general equilibrium model to explain the pricing of S&P 500 index options wherein the central ingredients are a consumption growth rate with a "peso" component and a time-varying risk aversion induced by habit formation which amplifies consumption shocks[1]. Fuherer (2000) demonstrates the ability of the habit-formation model to produce hump-shaped responses to shocks.

Although prior studies such as the above have reported confirmation of the dependence of IV on the content of macroeconomic announcements, the findings are not always consistent. This presents a need to test for their robustness in an alternative setting. The present study using a pre-global financial crisis data set (our data set ends December 2006), to enhance comparability with earlier studies, examines the response of option IV and the higher order moments (volatility, skewness and kurtosis) of the SPD function to macroeconomic announcements in the context of the Australian ASX

SPI 200 index futures options contracts. The SPI 200 futures and options on these futures are among the most liquid futures and options contracts in the world. Average daily turnover was approximately $4 billion (2008-2009) (14 per cent higher than one year previous). The features of the ASX SPI 200 futures contract include day and night trading sessions with almost 24 h access, availability through international hubs including London, Chicago, Singapore and Hong Kong, and availability for each of the next six quarterly expiry months. Our study extends the literature by differentiating between ITM, OTM and ATM options separately and in combination. In contrast with previous studies on the response of option prices to macroeconomic announcements, we separate outcomes across option moneyness (ITM or OTM). Our results, based on the relation of market response to moneyness, lend support to the belief that modern asset pricing can no longer be fully explained without reference to a behavioural understanding of investor risk taking.

Our other main findings may be summarised as follows. For ITM options, we find significant responses for the IV to macroeconomic announcements, but this is not the case for OTM or ATM options. We interpret this finding as indicating that option holders of ITM options are more sensitive to losses than holders of OTM options, in accordance with behavioural prospect theory. We note additionally that IV responds more significantly to announcements that relate directly to the broader economy, in particular the news in unemployment rate (UR) (at the 1 per cent level) (but also retail sales (RS) and dwelling starts (DS)) (for brevity, we refer to UR, RS and DS as "equity market" indicators, in contrast to "bond market" indicators, as in the following). Announcements that relate to "level of money in circulation" indicators (consumer price index (CPI), producer price index (PPI), average weekly wages (AWW) and the RBA cash target (RTC)) (which for brevity, we shall refer to as "bond market" indicators) are generally insignificant for IV (we note exceptions for PPI). These findings contrast with Beber and Brandt (2006) who in their examination of ATM options on US Treasury bonds report that UR, PPI and CPI announcements reduce the uncertainty captured by IV, but that there is no significant impact when the news is conditioned as "surprise" news. Consistent with Beber and Brandt (2006), we also report non-significant responses to "surprise" news announcements. We interpret this finding as indicating that the announcements lead of themselves to a reduction in uncertainty that cancels with the "surprise" element that itself is expected to increase uncertainty. Alternatively, it may be the IV is responsive to these surprise elements, but because their communication by government bodies is on lower frequency than our IV measures, the responses are not readily realised in our results.

A different picture emerges when we look at the second, third and fourth moments of the SPD function as embedded in the option-pricing framework. The second moment volatility of the underlying futures return probabilities does not appear to be impacted on significantly by any of the news announcements. We interpret this result as confirming a cancellation effect between the impacts of the item carried in the news, which of itself, might be expected to increase volatility, and the clarification of the item via the news announcement. In contrast, Beber and Brandt (2006) are able to report that UR, PPI and CPI announcements reduce the underlying asset volatility; however, they also find no significant impact when the news is conditioned as "surprise" news or differentiated on "good" or "bad" news. For the third and fourth moments of the SPD function, we find that the announcement for "bond market" indicators are significant (the announcements for the CPI index and RBA cash target are significant at the 1 per cent level), while the "equity markets" announcements are insignificant (with exceptions for RS). For ITM options, "good" news for these "bond market" announcements leads to more positively skewed and more fat-tailed SPD functions, while for OTM options, "bad" news for these indicators leads to less positively skewed and less fat-tailed SPD functions. Our finding contrast with Beber and Brandt (2006) who for ATM options find that the SPD becomes less (more) negatively skewed and less (more) fat-tailed in response to bad (good) news for the bond market. Thus, negatively skewed for Beber and Brandt is replaced with positively skewed in our findings. It is possible that in the Beber and Brandt studies a part of the explanation lies in the nature of a bond as a risk-free asset in combination with a put option on the firm.

2. IV and investor beliefs

Traditional static asset pricing models are characterised by investors who consume their wealth at the end of a single period, with the outcome that wealth uniquely determines consumption. In an inter-temporal setting, investors consider many periods in making their portfolio decisions and future payoffs are priced in today's money equivalent in relation to investors' inter-temporal consumption needs. A direct implication is that the IV in the Black Scholes model, in addition to capturing the volatility of the underlying asset, may also be capable of capturing investors' consumption response to such volatility. In this case, IV is a function of investors' preferences as determined by aggregate consumption, and the fundamental expression for the call premium (C_t) at time t must be written:

$$C_t = e^{-rT} \int_0^{\infty} (F_T - K)^+ q_t(F_T) dF_T \tag{1}$$

where r is the risk-free rate, and the integral is over the possible price outcomes (F_T) for the underlying asset in relation to the exercise price, K, at expiration T, and the risk neutral pricing density q_t (F_T) of underlying outcome possibilities is defined as:

$$q_t(F_T) = e^{rT} p_t(F_T) M_t(F_T) \tag{2}$$

where at time t, p_t (F_T) is the probability of attaining the underlying outcome F_T at time T, and the function M_t (F_T) represents a general stochastic discount factor that identifies the risk-neutral value of \$1 at time T. The "risk neutral pricing density" function is also referred to as the SPD function (e.g. Campbell*et al.*, 1997, p. 507) who capture M_t (F_T) in Equation (2) as $M_t(F_T) = e^{-rT} U'_T(F_t)$, where the ratio is that of the marginal utility with consumption at time T to that at the prior investment time t. Here, consistent with Beber and Brandt (2006), we shall refer to $q_t(x_T)$ in Equation (3) as the SPD function. This is consistent with Jackwerth (2000) who defines risk neutral probability as subjective probability multiplied by the risk aversion adjustment and shows how it can be derived from option prices and realised returns on assets. Expressing the integral in Equation (1) with respect to the corresponding continuously discounted rate x_T as required to achieve each outcome F_T, we express Equation (1) as:

$$C_t = e^{-rT} \int_{\ln(K/F_T)}^{\infty} (F_T - K) q_t(x_T) dx_T \tag{3}$$

The contribution of Black and Scholes (1973) is to show that provided the SPD function q_t (x_T) is normally distributed with respect to x_T (implying that the distribution of outcomes F_T is log-normally distributed with respect to x_T), C_t may be expressed as:

$$C_t = e^{-rT}[F_T N(d) - K.N(d - \sigma)] \tag{4}$$

where σ represents the standard deviation of the underlying asset's return at expiration time T, and $N(d)$ denotes the standard normal cumulative distribution function evaluated at d, where:

$$d = \frac{\ln\left(\frac{F_T}{K}\right) + \sigma_T^2/2}{\sigma_T} \tag{5}$$

In the more general case, it may be that due, for example, to investor beliefs and preferences, the SPD function q_t (x_T) is not normally distributed with respect to possible outcome returns x_T. We have, for example, the observation that the volatility smile (or smirk) for a call option is consistent with a set of probability outcomes and/or preferences for the underlying asset at the higher end of the probability spectrum that is thinner-tailed than the lognormal distribution. Thus, for a deep ITM call option, the fact that the likelihood of higher returns is reduced (compared with log-normality) is likely to be compensated by the increased likelihoods over moderately high returns, whereas for deep OTM options, moderately high returns are irrelevant. Hence, ITM options have a higher IV than OTM options. In this case, the standard deviation term, σ, in the Black Scholes model Equation (4) must be interpreted more broadly as a response to a combination of belief outcomes discounted stochastically by the preferences of investors to such outcomes.

3. Data and methodology

3.1 The Australian market

The underlying asset for an ASX SPI 200 option is the ASXSPI 200 futures contract[2]. The ASX SPI 200 futures are in turn based on the S&P/ASX 200 Index which comprises the S&P/ASX 100 plus an additional 100 stocks listed on the Australian market. The contract is recognised as the most investable benchmark for the Australian equities market and covers approximately 80 per cent of the market capitalisation of listed securities in Australia. On the last trading day (the third Thursday of the settlement month) trading for expiring contracts ceases at 12 p.m[3]. The first business day after expiry is the settlement day, when SFE Clearing publishes the final settlement price of the contract. On the second business day after expiry, SFE Clearing settles cash flows resulting from the settlement price.

The ASX SPI 200 index options have the same contract specification as the ASX SPI 200 futures on which they are traded (same unit value, contract months and trading times). The first listing date for the ASX SPI 200 index options contract was 02/05/2000. ASX SPI 200 index options (puts and calls) are available four quarter months ahead. The minimum price movement is 0.5 index point (A$12.5) and the exercise prices are set at intervals of 25 index points. New option exercise prices are created automatically as the underlying futures contract price fluctuates. The last day of trading of the underlying futures contract is the last trading day for the underlying ASX SPI 200 futures option (trading in expiring contracts ceases at 12:00 p.m. on the last trading day with non-expiring contracts continuing to trade). However, the options may be exercised on any business day up to and including the last trading day. The cash settlement price is determined by the underlying futures contract. Only "ITM" options are automatically exercised at expiry, unless abandoned. Upon exercise, the holder receives an underlying ASX SPI 200 index futures contract position at the option strike price.

3.2 Data

Our research data for call options on the SPI 200 futures are taken from the TAQTIC database which is compiled from the Reuters and SIRCA databases. The TAQTIC data include the time of transaction (in seconds), expiration date, strike price, bid and ask prices for each quote record, and trade price and size for each trade record. Thus, we have IVs reported for the quarterly expiring call options on the SPI 200 futures quoted from 31 March 2001 through to end 2006. A total of 1,992 macroeconomic announcements were collected from Bloomberg database for the period of the options data. The data on the dates, release times, actual released figures and median forecasts for the seven most important Australian macroeconomic information releases are obtained from Bloomberg covering the period from March 2001 through December 2006. Bloomberg reports the median forecast from the survey, which is made available to the market and the business press immediately after the survey is taken.

The set of seven announcements provides a comprehensive characterisation of the macroeconomy. Together, they describe the inflationary process by the CPI and PPI; the situation in the labour market by the UR and AWW; the dynamic of consumption by the RS and retail trade; the conditions of the money market by the RBA cash target (RTC) and the situation in the real estate market by DS. Most of these announcements are released widely and virtually instantaneously at a precise scheduled time. The statistical agencies impose lock-up conditions to ensure that the information is not released to the public before the scheduled time[4].

3.3 Methodology

To examine the effect of macroeconomic announcements on the IV, the log changes of IV are first calculated. From these, we construct daily time-series as the average IV changes for the options traded that day for the options in combination, and separately for ITM, OTM and ATM options. As the dependent variable, these changes are regressed on the macroeconomic announcements. The regressions are performed, first, without considering whether an announcement carries "surprise" information, or whether the announcement carries "good" or "bad" news (yielding what we term an "unconditional" response). Thereafter, we consider the "conditional" responses by distinguishing those announcements that carry "surprise" news and those that carry either good or bad news.

We run the following regression equations, each with 721,300 observations through 1,430 trading days. The "unconditional" response to macroeconomic announcements:

$$\mathrm{Ln}\left(\frac{\sigma_{IVt}}{\sigma_{IVt-1}}\right) = \beta_0 + \sum_{k=1}^{K} \beta_k \, D_{kt} + u_t \tag{6}$$

where $\ln(\sigma_{IVt}/\sigma_{IVt-1})$ is the daily log relative change in the average IV, and D_{kt} are dummy variables for the k macroeconomic announcements (CPI, PPI, UR, AWW, RS, RTC and DS) $= 1$ if announcement k is made on day t and $D_{kt} = 0$ otherwise.

We estimate the regression (7) as the conditional response to the surprise element of the macroeconomic announcements:

$$\mathrm{Ln}(\frac{\sigma_{IVt}}{\sigma_{IVt-1}}) = \alpha_k + \beta_k\ S_{kt} + e_{kt} \tag{7}$$

where $S_{kt} = A_{kt} - X_{kt}/\sigma_k$ is the standardised measure of the surprise element defined by the difference between actual (A_{kt}) and the predicted (X_{kt}) as surveyed by analysts for each announcement divided by σ_k is the (unconditional) empirical standard deviation of the innovations $A_{kt} - X_{kt}$. Thus, the standardised measure of surprise is constructed here consistent with both Balduzzi *et al.* (2001) and Beber and Brandt (2006). Equation (8) captures the conditional response to good, or bad news:

$$\mathrm{Ln}(\frac{\sigma_{IVt}}{\sigma_{IVt-1}}) = \alpha_k + \beta_{Gk}\ S_{kt}\ G_{kt} + \beta_{Bk}\ S_{kt}\ B_{kt} + e_{kt} \tag{8}$$

where for RTC, CPI and UR a positive (negative) surprise corresponds to bad (good news), whereas for PPI, AWW, RS and DS a positive (negative) surprise corresponds to good (bad news)[5].

We also relate macroeconomic news announcements to their impact on the volatility, skewness and kurtosis of the SPD as it relates to the underlying SPI 200 futures contract. The approach is based on the Gram-Charlier expansion of a function $\upsilon(\omega)$ about a "core" normal distributed function $\phi(\omega)$ as:

$$\upsilon(\omega) = \varphi(\omega) - \gamma_1 \frac{1}{3!} D^3 \varphi(\omega) + \gamma_2 \frac{1}{4!} D^4 \varphi(\omega) \tag{9}$$

where D^j denotes the jth derivative operator. Thus, the third and fourth terms, respectively, capture skewness and kurtosis departures of the function $\upsilon(\omega)$ from normality $\phi(\omega)$. As Beber and Brandt (2006), we follow the simplification advanced by Backus *et al.* (2004). These authors show that Equation (9) lends itself to an expression for the IV function in terms of an underlying normal distribution (with standard deviation equal to the underlying asset return volatility, σ) as:

$$IV\ (d) = \sigma \left[1 + \gamma_1 \frac{1}{3!} (2\sigma - d) - \gamma_2 \frac{1}{4!} (1 - d^2 + 3d.\sigma - 3\sigma^2) \right] \tag{10}$$

where d is as Equation (5). As Beber and Brandt, We solve for the coefficients γ_1 and γ_2 each day by minimising the function:

$$\sum_{i=1}^{N} [IV - IV(d_i)]^2 \tag{11}$$

where IV denotes the option daily IV from the data and $IV(d_i)$ denotes the function in Equation (10) summed over options with the same expiration date but with different strike prices, i.

Having recovered the daily coefficients σ, γ_1 and γ_2 in this way, we proceed to regress their change in value as a response to macroeconomic news announcements.

In this way, we examine the impact of macroeconomic news announcements on the second, third and fourth moments of the SPD q_t (F_T) function in Equation (3), which captures the beliefs and preferences of investors as to the underlying outcome distribution at time T.

4. Results

In this section, we report the responses of IV of the 200 SPI futures options to macroeconomic announcements, for the options combined and, separately, as ITM, OTM and ATM options. We also report the responses of the second, third and fourth moments of the SPD function to macroeconomic news announcements, for the options combined and, separately, as ITM, OTM and ATM options.

Tables I-IV present the results, respectively, for all options combined; ITM; ATM; and OTM options. Panels A, B and C relate, respectively, to (A) news announcements unconditionally (i.e. independent of whether the news is "good" or "bad"), (B) "surprise" news and (C) news distinguished as either "good" or "bad". The first row of each panel relates to the IV of the 200 SPI futures options. Allowing $\exp(1+x) \approx x$, the numbers provide the approximate fractional change in the IV at an announcement. Thus, for example, in Panel A of Table I, the numbers 0.03 in the first row imply a 3 per cent change in IV due to the announcement. The second, third and fourth rows relate to the second, third and fourth moments of the SPD function, where the numbers refer to the estimated change in the moment at an announcement. Thus, for example, in the final column of Panel A in Table I, the figure 0.48 indicates an (insignificant) increase in standard deviation of 0.48 on the day following an RTC announcement, whereas the figures of -0.35 and -0.32 in the final column indicate (significant) reductions by these numbers for skewness and kurtosis, respectively[6]. For the impact of surprise announcements in Panel B, the standardisation of the surprise element by the standard deviation allows us for the interpretation of the numbers as the change in the IV or moment components per standard deviation of the innovation surprise. Thus, in the first row of Panel B in Table I, the numbers represent the (insignificant) percentage changes in IV (0.5 per cent for UR, 1.9 per cent for RS, etc.) per standard deviation of surprise in the announcements, and the remaining rows provide the (insignificant) absolute changes in the moments per standard deviation of surprise.

In Table I, for the options combined, we observe that the IV is unconditionally (i.e., independent of whether the news is "good" or "bad") positively and significantly related to RS (at the 5 per cent level). This dependence is preserved for "good" news (at just above the 10 per cent level) but is insignificant for "bad" news. For the UR, there is again a positive and significant unconditional relation (at the 10 per cent level) and again the relation is stronger for good news (at the 5 per cent level). For DS the relation is negatively related to IV for good news (at close to the 10 per cent level). In regard to PPI, we find a negative and significant relation for bad news only (at the 10 per cent level).

For ITM options, we no longer find a dependence on RS, but PPI is now positively and significantly related (at the 10 per cent level) to the announcements "unconditionally" (notwithstanding, at close to the 10 per cent level it is negatively related for both surprise and "bad" news announcements). For UR and DS the patterns repeat the findings for all options combined with markedly increased levels of significance (UR significance is now highly significant at the 1 per cent level, and DS significance is at the 10 per cent level). For both Tables I and II, the coefficients are positive for RS and the UR implying that announcements on these items are capable of

Table I.
Daily effects of the announcements on average implied volatility and SPD higher order moments: all options combined

	α	β_{UR}	β_{RS}	β_{DS}	β_{PPI}	β_{CPI}	β_{AWW}	β_{RTC}
Panel A								
Unconditional response								
$\ln(IV_t/IV_{t-1})$	0.00	0.03* (1.72)	0.03** (1.89)	−0.03 (−1.04)	−0.02 (−0.71)	−0.02 (−0.49)	−0.04 (−1.34)	−0.02 (−1.11)
$\sigma_t-\sigma_{t-1}$	−0.028 (−0.26)	0.25 (0.53)	−0.43 (−0.88)	−0.46 (−0.56)	0.06 (0.70)	−0.43 (−0.43)	0.85 (1.03)	0.48 (0.96)
$\gamma_{1,t}-\gamma_{1,t-1}$	0.00 (0.14)	−0.07 (−0.57)	0.15 (1.23)	0.17 (0.77)	0.29 (1.3)	0.41* (1.60)	−0.17 (−0.8)	−0.35*** (−2.7)
$\gamma_{2,t}-\gamma_{2,t-1}$	0.00 (0.19)	−0.07 (−0.64)	0.18 (1.60)	0.19 (0.99)	0.26 (1.31)	0.27 (1.17)	−0.27 (−1.39)	−0.32*** (−2.75)
Panel B								
Conditional response to: surprise								
$\ln(IV_t/IV_{t-1})$		−0.005 (−0.17)	0.019 (0.72)	−0.002 (−0.06)	0.029 (1.08)	0.012 (0.45)	0.021 (0.80)	0.004 (0.15)
$\sigma_t-\sigma_{t-1}$	(−0.03)	−0.019 (−0.71)	0.015 (0.55)	0.014 (0.51)	−0.002 (−0.06)	−0.002 (−0.06)	0.011 (0.40)	−0.009 (0.35)
$\gamma_{1,t}-\gamma_{1,t-1}$	(−0.10)	0.000 (0.00)	0.011 (0.42)	−0.014 (−0.51)	0.031 (1.16)	−0.026 (−0.99)	0.000 (0.009)	0.000 (0.02)
$\gamma_{2,t}-\gamma_{2,t-1}$	(−0.08)	0.011 (0.40)	0.008 (0.31)	−0.008 (−0.29)	0.033 (1.22)	−0.012 (−0.45)	−0.007 (−0.28)	0.006 (0.21)
Panel C								
Conditional response to:								
Good news								
$\ln(IV_t/IV_{t-1})$	0.00	0.04^{**} (2.01)	0.03 (1.48)	−0.06 (−1.54)	0.04 (0.37)	−0.04 (−0.84)	−0.02 (−0.6)	−0.05 (−0.64)
$\sigma_t-\sigma_{t-1}$	−0.02 (−0.23)	0.44 (0.73)	0.04 (0.06)	0.27 (0.26)	−0.99 (−0.60)	−0.71 (−0.50)	0.76 (0.66)	1.30 (0.60)
$\gamma_{1,t}-\gamma_{1,t-1}$	0.00 (−0.28)	−0.04 (−0.25)	0.17 (0.95)	0.16 (0.95)	0.77^{*} (1.78)	0.53 (1.42)	−0.05 (−0.15)	−0.21 (−0.37)
$\gamma_{2,t}-\gamma_{2,t-1}$	0.00 (−0.22)	−0.06 (−0.45)	0.19 (1.19)	0.19 (0.79)	0.74^{**} (1.93)	0.34 (1.04)	−0.14 (−0.54)	−0.29 (−0.57)
Bad news								
$\ln(IV_t/IV_{t-1})$	0.00	0.01 (0.33)	0.03 (1.21)	0.02 (0.4)	-0.10^{*} (−1.69)	0.01 (0.35)	−0.05 (−1.19)	0.00 (0.03)
$\sigma_t-\sigma_{t-1}$	0.01 (0.13)	−0.06 (−0.07)	−0.65 (−0.91)	−1.87 (−1.35)	−0.75 (−0.46)	−0.19 (−.14)	0.92 (0.79)	−0.06 (−0.02)

(*continued*)

	α	β_{UR}	β_{RS}	β_{DS}	β_{PPI}	β_{CPI}	β_{AWW}	β_{RTC}
$\gamma_{1,t}-\gamma_{1,t-1}$	0.00 (0.06)	−0.17 (−0.72)	0.10 (0.53)	0.16 (0.44)	−0.25 (−0.59)	0.32 (0.88)	−0.31 (−1.01)	0.01 (0.02)
$\gamma_{2,t}-\gamma_{2,t-1}$	0.00 (0.08)	−0.14 (−0.70)	0.14 (0.83)	0.19 (0.57)	−0.19 (−0.51)	0.22 (0.70)	−0.39 (−1.45)	0.03 (0.04)

Notes: The table summarises responses of the IV to macroeconomic announcements: unconditional (without considering whether an announcement is "good" or "bad" news) (panel A), conditional on surprise news, (panel B) and conditional on good and bad news (panel C). The panels report the regression results for $\mu_t-\mu_{t-1}$ as the dependent variable, where in the first row, $\mu_t-\mu_{t-1}$ is the log daily change in option IV as $\ln(\sigma_{IV,t}/\sigma_{IV,t-1})$, in the second row, $\mu_t-\mu_{t-1}$ is the daily change in volatility of the underlying returns (σ_t) and in the third and fourth rows, $\mu_t-\mu_{t-1}$ is, respectively, the daily change in skewness and kurtosis as third and fourth order moments of the SPD function $q_t\,(x_T)$ of underlying returns (as it determines option prices, Equation (3)). Thus, panel A shows the parameter estimates (β_K) for the regressions as the responses to unconditional news:

$$\mu_t - \mu_{t-1} = \alpha_t + \sum_{k=1}^{K} \beta_k D_{kt} + u_t,$$

Panel B shows the parameter estimates (β_K) for the regressions as the conditional (surprises) responses:

$$\mu_t - \mu_{t-1} = \alpha_t + \beta_k S_{kt} + e_{kt}$$

and panel C shows the parameter estimates (β_K) for the regressions as the conditional (good or bad news) responses:

$$\mu_t - \mu_{t-1} = \alpha_t + \beta_{Gk} S_{kt} G_{kt} + \beta_{Bk} S_{kt} B_{kt} + e_{kt}$$

where D_{kt} are dummy variables with $D_{kt}=1$ if announcement k is made on day t and $D_{kt}=0$ otherwise. D_{kt} are from the following macroeconomic announcements: consumer price index (CPI), producer price index (PPI), unemployment rate (UR), average weekly wages (AWW), retail sales (RS), RBA cash target (RTC) and dwelling starts (DS). $S_{kt}=A_k-X_{kt}$ is the surprise element defined by the difference between actual and the predicted as surveyed by analysts for each announcement. For PPI, AWW, RS and DS a positive (negative) surprise corresponds to good (bad) news. However, for, RTC, CPI and UR a positive (negative) surprise corresponds to bad (good) news as is common in the literature. t-values are in parentheses. ***,**,*Statistical significance at the 1, 5 and 10 per cent levels, respectively

Table I.

Table II. Daily effects of the announcements on average implied volatility and SPD higher order moments: ITM options

	α	β_{UR}	β_{RS}	β_{DS}	β_{PPI}	β_{CPI}	β_{AWW}	β_{RTC}
Panel A								
Unconditional response								
$\mathrm{Ln}(IV_t/IV_{t-1})$	0.00 (−0.69)	0.03*** (2.89)	0.00 (−0.15)	−0.02 (−1.02)	−0.03* (1.71)	−0.01 (−0.55)	0.00 (−0.27)	0.00 (−0.13)
$\sigma_t - \sigma_{t-1}$	−0.028 (−0.26)	0.25 (0.54)	−0.43 (−0.88)	−0.46 (−0.56)	0.06 (0.70)	−0.43 (−0.44)	0.85 (1.03)	0.48 (0.96)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.00 (0.09)	−0.08 (−0.62)	0.15 (1.10)	0.19 (0.81)	0.43* (1.77)	0.45* (1.65)	−0.17 (−0.76)	−0.36*** (−2.60)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.00 (0.13)	−0.08 (−0.70)	0.16 (1.35)	0.21 (1.02)	0.42** (1.96)	0.28 (1.15)	−0.26 (−1.26)	−0.31*** (−2.54)
Panel B								
Conditional response to: surprise								
$\mathrm{Ln}(IV_t/IV_{t-1})$	0.00 (−0.14)	−0.003 (−0.09)	0.015 (0.57)	−0.015 (−0.55)	−0.040 (−1.49)	−0.002 (−0.07)	−0.005 (−0.19)	−0.009 (−0.34)
$\sigma_t - \sigma_{t-1}$	−0.02 (−0.23)	−0.019 (−0.71)	0.015 (0.54)	0.014 (0.51)	−0.002 (−0.06)	−0.002 (−0.06)	0.011 (0.40)	−0.009 (−0.34)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.00 (−0.09)	0.002 (0.09)	0.013 (0.47)	−0.015 (−0.57)	0.010 (0.38)	−0.035 (−1.33)	−0.010 (−0.35)	0.00 (0.00)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.00 (−0.08)	0.013 (0.49)	0.008 (0.30)	−0.010 (−0.03)	0.008 (0.31)	0.020 (−0.74)	−0.018 (−0.66)	0.005 (0.17)
Panel C								
Conditional response to:								
Good news								
$\mathrm{Ln}(IV_t/IV_{t-1})$	0.00 (−0.45)	0.04*** (3.02)	0.00 (0.10)	−0.04* (−1.61)	0.00 (−0.06)	−0.02 (−0.58)	−0.01 (−0.46)	−0.01 (−0.37)
$\sigma_t - \sigma_{t-1}$	−0.02 (−0.22)	0.44 (0.73)	0.04 (0.06)	0.27 (0.26)	−0.98 (−0.60)	−0.71 (−0.50)	0.76 (0.65)	1.31 (0.60)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.00 (−0.26)	−0.07 (−0.45)	0.18 (0.95)	0.17 (0.61)	0.74* (1.62)	0.70* (1.77)	−0.07 (−0.22)	−0.27 (−0.45)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.00 (−0.17)	−0.09 (−0.67)	0.18 (1.07)	0.20 (0.81)	0.71* (1.73)	0.46 (1.30)	−0.17 (−0.60)	−0.33 (−0.62)
Bad news								
$\mathrm{Ln}(IV_t/IV_{t-1})$	0.00 (−0.43)	0.01 (0.68)	0.00 (0.27)	0.01 (0.43)	−0.06 (1.54)	0.00 (0.23)	−0.00 (0.11)	0.03 (−0.46)
$\sigma_t - \sigma_{t-1}$	0.01 (0.13)	−0.06 (−0.06)	−0.65 (−0.92)	−1.87 (−1.35)	−0.75 (−0.45)	−0.19 (−0.13)	0.92 (0.79)	−0.06 (−0.02)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.00 (0.01)	−0.15 (−0.62)	0.09 (0.48)	0.19 (0.48)	0.16 (0.36)	0.25 (0.64)	−0.29 (−0.90)	−0.02 (−0.02)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.00 (0.00)	−0.12 (−0.57)	−0.14 (0.77)	0.20 (0.59)	0.25 (0.61)	0.16 (0.46)	−0.36 (−1.23)	−0.02 (−0.03)

Note: The definitions and caveats are as Table I

Table III. Daily effects of the announcements on average implied volatility and SPD higher order moments: OTM options

	α	β_{UR}	β_{RS}	β_{DS}	β_{PPI}	β_{CPI}	β_{AWW}	β_{RTC}
Panel A								
Unconditional response								
$\mathrm{Ln}(IV_t/IV_{t-1})$	0.00 (0.44)	−0.02 (−0.61)	−0.02 (−0.57)	−0.07 (−1.06)	−0.07 (−0.90)	−0.03 (−0.39)	−0.06 (−0.91)	0.01 (0.30)
$\sigma_t - \sigma_{t-1}$	−0.028 (−0.26)	0.25 (0.54)	−0.43 (−0.88)	−0.46 (−0.56)	0.06 (0.70)	−0.43 (−0.44)	0.85 (1.03)	0.48 (0.96)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.01 (1.18)	−0.07 (−1.40)	0.04 (0.80)	0.05 (0.54)	−0.22** (−2.43)	−0.18* (−1.80)	−0.10 (−1.13)	−0.14*** (−2.69)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.01 (0.78)	−0.06 (−1.07)	0.13** (2.01)	0.10 (0.92)	−0.11 (−0.96)	−0.07 (−0.58)	−0.21** (−1.96)	−0.21*** (−3.22)
Panel B								
Conditional response to: surprise								
$\mathrm{Ln}(IV_t/IV_{t-1})$	0.00 (0.09)	−0.004 (−0.16)	0.007 (0.24)	−0.016 (−0.58)	−0.017 (−0.62)	−0.002 (−0.08)	0.002 (0.05)	0.007 (0.25)
$\sigma_t - \sigma_{t-1}$	−0.02 (−0.23)	−0.019 (−0.71)	0.015 (0.54)	0.014 (0.51)	−0.002 (−0.06)	−0.002 (−0.06)	0.011 (0.40)	−0.009 (−0.34)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.00 (0.17)	−0.003 (−0.11)	0.018 (0.68)	−0.015 (−0.56)	0.009 (0.35)	−0.003 (−0.10)	0.061** (2.28)	0.011 (0.43)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.00 (0.05)	0.014 (0.52)	0.011 (0.43)	−0.013 (−0.49)	0.011 (0.42)	0.002 (0.07)	0.047* (1.76)	0.027 (0.99)
Panel C								
Conditional response to:								
Good news								
$\mathrm{Ln}(IV_t/IV_{t-1})$	0.00 (0.09)	0.01 (0.22)	0.01 (0.22)	−0.13 (−1.54)	−0.03 (−0.19)	−0.01 (−0.04)	−0.08 (−0.85)	−0.06 (−0.28)
$\sigma_t - \sigma_{t-1}$	−0.02 (−0.22)	0.44 (0.73)	0.04 (0.06)	0.27 (0.26)	−0.98 (−0.60)	−0.71 (−0.50)	0.76 (0.65)	1.31 (0.60)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.00 (0.08)	−0.09 (−1.54)	0.11 (1.55)	0.00 (0.03)	0.04 (0.24)	0.01 (0.09)	0.03 (0.25)	−0.18 (−0.80)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.00 (0.00)	−0.08 (−1.10)	0.17* (1.90)	0.02 (0.12)	0.16 (0.76)	0.10 (0.54)	−0.05 (−0.36)	−0.48* (−1.72)
Bad news								
$\mathrm{Ln}(IV_t/IV_{t-1})$	0.00 (0.24)	−0.10 (−1.45)	−0.06 (−1.05)	0.03 (0.27)	0.11 (0.65)	−0.05 (−0.45)	−0.04 (−0.44)	0.02 (0.10)
$\sigma_t - \sigma_{t-1}$	0.01 (0.13)	−0.06 (−0.06)	−0.65 (−0.92)	−1.87 (−1.35)	−0.75 (−0.45)	−0.19 (−0.13)	0.92 (0.79)	−0.06 (−0.02)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.00 (0.57)	−0.06 (−0.69)	−0.06 (−0.86)	0.14 (0.97)	−0.16 (−0.94)	−0.4*** (−2.80)	−0.22* (−1.83)	0.00 (0.02)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.00 (0.27)	−0.07 (−0.64)	0.06 (0.61)	0.26 (1.46)	−0.10 (−0.46)	−0.22 (−1.23)	−0.36** (−2.40)	0.03 (0.08)

Note: The definitions and caveats are as Table I

Table IV.
Daily effects of the announcements on average implied volatility and SPD higher order moments: ATM options

	α	β_{UR}	β_{RS}	β_{DS}	β_{PPI}	β_{CPI}	β_{AWW}	β_{RTC}
Panel A								
Unconditional response								
$\ln(IV_t/IV_{t-1})$	0.00 (0.055)	0.03 (0.86)	0.01 (0.33)	−0.06 (−1.02)	−0.02 (0.32)	−0.07 (−0.91)	0.00 (−0.06)	−0.02 (−0.60)
$\sigma_t - \sigma_{t-1}$	−0.028 (−0.26)	0.25 (0.54)	−0.43 (−0.88)	−0.46 (−0.56)	0.06 (0.70)	−0.43 (−0.44)	0.85 (1.03)	0.48 (0.96)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.02 (0.06)	−0.12 (0.86)	−0.07 (0.33)	−0.01 (−1.03)	−0.02 (0.32)	0.19 (−0.91)	−0.15 (−0.06)	−0.07 (−0.61)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.02 (0.89)	−0.05 (−0.51)	−0.14 (−1.59)	−0.02 (−0.12)	0.03 (0.22)	0.20 (1.06)	−0.06 (−0.50)	−0.17* (−1.80)
Panel B								
Conditional response to: surprise								
$\ln(IV_t/IV_{t-1})$	0.00 (0.06)	−0.031 (−0.86)	−0.025 (−0.72)	−0.022 (−0.61)	−0.015 (−0.43)	0.003 (0.08)	0.026 (0.74)	−0.014 (−0.38)
$\sigma_t - \sigma_{t-1}$	−0.02 (−0.23)	−0.019 (−0.71)	0.015 (0.54)	0.014 (0.51)	−0.002 (−0.06)	−0.002 (−0.06)	0.011 (0.40)	−0.009 (−0.34)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.00 (0.20)	0.002 (0.05)	−0.004 (−0.11)	0.010 (0.28)	0.037 (1.06)	0.115*** (3.28)	0.028 (0.80)	0.030 (0.84)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.00 (0.20)	0.010 (0.27)	−0.008 (−0.23)	−0.001 (−0.04)	0.020 (0.55)	0.100*** (2.83)	0.019 (0.53)	0.043 (1.21)
Panel C								
Conditional response to:								
Good news								
$\ln(IV_t/IV_{t-1})$	0.00 (0.00)	0.05 (1.04)	0.00 (−0.06)	−0.10 (−1.20)	−0.03 (−0.21)	−0.09 (−0.77)	0.00 (0.01)	0.07 (0.41)
$\sigma_t - \sigma_{t-1}$	−0.02 (−0.22)	0.44 (0.73)	0.04 (0.06)	0.27 (0.26)	−0.98 (−0.60)	−0.71 (−0.50)	0.76 (0.65)	1.31 (0.60)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.01 (0.59)	−0.06 (−0.57)	−0.10 (−0.89)	−0.20 (−1.13)	0.24 (0.79)	−0.40* (−1.75)	−0.07 (−0.40)	0.20 (0.60)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.01 (0.46)	−0.01 (−0.06)	−0.22* (−1.64)	−0.06 (−0.31)	0.22 (0.63)	−0.33 (−1.24)	0.05 (0.25)	0.08 (0.22)
Bad news								
$\ln(IV_t/IV_{t-1})$	0.00 (0.01)	−0.02 (−0.22)	0.02 (0.43)	−0.02 (−0.21)	0.04 (0.35)	−0.07 (−0.55)	0.00 (−0.05)	−0.07 (−0.33)
$\sigma_t - \sigma_{t-1}$	0.01 (0.13)	−0.06 (−0.06)	−0.65 (−0.92)	−1.87 (−1.35)	−0.75 (−0.45)	−0.19 (−0.13)	0.92 (0.79)	−0.06 (−0.02)
$\gamma_{1,t} - \gamma_{1,t-1}$	0.00 (0.27)	−0.19 (−1.26)	−0.04 (−0.34)	0.16 (0.87)	−0.11 (−0.46)	0.88*** (3.61)	−0.22* (−1.61)	0.37 (0.89)
$\gamma_{2,t} - \gamma_{2,t-1}$	0.00 (0.19)	−0.06 (−0.36)	−0.06 (−0.51)	−0.02 (−0.09)	0.00 (−0.01)	0.86*** (3.00)	−0.15 (−0.94)	0.55 (1.12)

Note: The definitions and caveats are as Table I

triggering increased uncertainty. In contrast, the coefficients on DS and the PPI are negative implying that announcements on these items are capable of reducing uncertainty.

Beber and Brandt (2006) consider ten announcement types[7]. Of these, announcements in relation to the CPI, the unemployment report and PPI appear to be the main explanatory of day-to-day changes in the average ATM IV. The coefficients are highly negatively significant, consistent with the intuition that the announcements reduce uncertainty. Our results in combination with those of Beber and Brandt therefore suggest a "damping" effect of macroeconomic announcements in that, on the one hand, the issues being raised tend of themselves to stimulate uncertainty, whereas the announcement itself tends to reduce uncertainty. This view lends interpretation to our findings (as for Beber and Brandt) that announcements with "surprise" news have little or no significance because the surprise news and the concurrent clarification of the announcement have a cancelling effect on each other.

When Beber and Brandt separate the regressions for good and bad news, their intercepts are highly significantly negative in conjunction with coefficients for CPI and NFP announcements that are significantly positive for bad news and insignificant for good news. The authors interpret their results as signifying that ATM volatility drops comparatively less when the announcements contain bad news, and conclude that good news for economic prospects leads market participants to become less risk averse. Our finding of a negative coefficient on good news for DS (for all options and ITM options) conforms to the above interpretation of Beber and Brandt. However, the positive coefficients (increased uncertainty) on good news for RS (all options combined) and more strikingly, the UR (all options combined and ITM options, with levels of significance at the 1 per cent level) contradict the Beber and Brandt hypothesis. Nevertheless, the result of increased uncertainty with employment news is perhaps not so surprising when we consider that a reduction in unemployment may be interpreted either as signalling a more prosperous economy, or alternatively as a foreshadowing of higher wage claims and skill shortages. A sharp increase in uncertainty on the announcement of unemployment figures, whose economic interpretation is itself ambiguous, may therefore be interpreted as a natural exception to the proposition that the uncertainty surrounding the issue of the news announcement tends to be mollified by the clarification of the announcement itself.

Intriguingly, we find no significant impact on IV for "bad" news in relation to the "equity" macroeconomic announcements (UR, RS and DS). Also, we find no significant impact of the macroeconomic announcements on the IV for OTM and ATM options (Table III and IV). We summarise our findings at this point with the observation that holders of ITM options are more sensitive to macroeconomic announcements than holders of OTM options and are more sensitive to economic "good" news than "bad" news.

The results for the second, third and fourth moments of the SPD in response to the macroeconomic announcements are presented in the second, third and fourth rows of the panels. The SPD is conditioned on the volatility (σ) of the underlying SPI 200 futures contract as the second moment (Equation (10)). In all cases, we observe that the announcements do not impact significantly on the volatility (σ). We again interpret this result as confirmation of a cancellation effect between the impact of the item carried in the news, which of itself, might be expected to increase volatility, and the clarification of the item via the news announcement.

The significant impacts for the change in IV were predominantly from the more direct measures of the economy (UR, RS and DS) rather than from the "level of money in circulation" orientated indicators (CPI, PPI, AWW, RTC) with the exception of PPI. Tables I and II reveal that that for all options combined as well as for ITM options, good news for PPI has a positive and significant impact on both the skewness and kurtosis of the SPDs (panels C) (but no impact for bad news). For ITM options (Table II), unconditional news for the PPI also has significant impact for skewness and kurtosis (panel A). Tables I and II also reveal that for all options combined as well as for ITM options, unconditional news for the RBA cash target (RTC) has a negative and significant impact for skewness and kurtosis (panels A); and unconditional news for CPI has a positive and significant impact on skewness (panels A). Good news for CPI also has a positive and significant impact for the third moment for ITM options (Table II, panel C).

We noted that macroeconomic announcements had no impact on IV for OTM or ATM options when taken separately (Tables III and IV, first row of all panels). For OTM options (Table III) bad news for the CPI has a negative and highly significant (at the 1 per cent level) impact on skewness (panel C) and unconditional news for CPI is also negatively and significantly related to skewness (panel A). For OTM options, unconditional news for the RTC is negatively and highly significantly (at the 1 per cent level) related to skewness and kurtosis (panel A, Table III) (as was observed for both all options and ITM options (Tables I and II). For OTM options, unconditional news for CPI is also negatively and significantly related to skewness (Table IV, panel A). For OTM options, surprise news for AWW impacts positively and significantly on skewness and kurtosis (panels B) while bad news for the AWW impacts negatively and significantly on skewness and kurtosis (panel C) with unconditional news for the AWW also impacting negatively and significantly on kurtosis (panel A). For ATM options (Table IV) both "surprise" and "bad" news for the CPI has a positive and highly significant (at the 1 per cent level) impact on the skewness and kurtosis of the SPD (panels B and C), while good news for the CPI has a negative and significant impact on the skewness of the SPD (panel C). For ATM options, unconditional news for the RTC is again negative and significantly (at the 1 per cent level) related to kurtosis (panel A).

In contrast to the impacts on the IV function directly, the direct measures of the economy (UR, RS and DS) are notably absent in their impact on the volatility, skewness and kurtosis moments of the SPD function. The only exceptions are for news on RS which (for unconditional news for all options combined) impacts positively and significantly on kurtosis (panel A, Table I), and (for unconditional and good news for ATM options) impacts negatively and significantly on kurtosis (panels A and C, Table IV).

5. Conclusion

The study has examined the impact of macroeconomic announcements on the moments of IV of option contracts on the Australian ASX SPI 200 index futures. We find evidence that ITM holders of Australian options are more sensitive to "good" news than to "bad" news (in relation to the state of unemployment at the 1 per cent level) and that ITM holders of options are more sensitive to news than are OTM holders. This suggests that ITM options are sensitive to their wealth status as "valuable" assets, whereas OTM options are akin to a lottery ticket for which investment loss is more acceptable. Thus, a behavioural understanding of investors is required to fully explain option pricing consistent with prospect theory whereby ITM investors with more to lose are more alert to changes in economic circumstances than OTM investors who are trading a "losing hand". The implication is that ITM options are "more risk averse" than OTM options, with direct implications for explanation of the volatility smile.

Nevertheless, we report no significant impact of the announcements on the volatility of the underlying futures contracts themselves. We have postulated that this may be due to a cancellation effect between the impact of the item carried in the news, which of itself, might be expected to increase volatility, and the clarification of the item via the news announcement. This is an intriguing result in that it suggests that the IV of ITM options is not only more sensitive than OTM options to economic announcements, but is more sensitive than the underlying asset itself.

In regard to the higher moments of the price density function of the futures contracts as embedded in the option price, we report that announcements relating more directly to bond holders are significant (in relation to the CPI and RBA cash target at the 1 per cent level), while announcements relating more directly to equity holders are insignificant. Again, reported asymmetries between ITM and OTM options serve to support the hypothesis that ITM and OTM options are driven by different sets of beliefs and preferences.

Notes

1. The term "peso problem" is attributed to Milton Friedman's comments about the effects of the infrequent but disastrous events on the Mexican peso market in the early 1970s.

2. These futures have been approved for trading by the US Commodities Futures Trading Commission and the UK Financial Services Authority. Contract specifications contain the commodity code (AP), contract unit (valued at A$25 per index point, e.g. A$117,500 at 4,700 index points) and contract month (March/June/September/December up to six quarter months ahead). The minimum price movement is one index point (A$25) and the exercise prices are set at intervals of 25 index points.

3. Non-expiring contracts continue to trade as per the trading hours. The cash settlement price is determined by the special opening quotation of the underlying S&P/ASX 200 index on the last trading day. The special opening quotation is calculated using the first traded price of each component stock in the S&P/ASX 200 index on the last trading day, irrespective of when those stocks first trade in the ASX trading day. This means that the first traded price of each component stock may occur at any time between ASX market open and ASX market close (including the closing single price auction) on the last trading day. Should any component stock not have traded by ASX market close on the last trading day, the last traded price of that stock will be used to calculate the special opening quotation. The trading hours are: 5:10 p.m.-7:00 a.m. and 9:50 a.m.-4:30 p.m. (during US daylight saving time) (5:10 p.m.-8:00 a.m. and 9:50 a.m.-4:30 p.m., during US non-daylight saving time).

4. With few exceptions, the announcements are timed as follows: four announcements are at 11:30 a.m. (consumer price index (CPI), DS, producer price index (PPI) and AWW), RTC is at 9:30 a.m., UR at 10:30 am, and retain sales (RS) is at 11:00 am.

5. This is the convention followed by Ederington and Lee (1996) and Beber and Brandt (2006).

6. The "material" significance of the numbers may be judged in relation to the numbers for a Gaussian distribution: standard deviation = 1, skewness = 0, kurtosis = 3.

7. These are CPI, housing starts, civilian unemployment (CUR), non-farm payrolls, PPI, RS, industrial production, consumer confidence, NAPM index (NAPM), and FOMC target (FOMC).

References

Backus, D., Foresi, S. and Wu, L. (2004), "Accounting for biases in Black-Scholes", working paper, New York University, New York, NY.

Balduzzi, P., Elton, E.J. and Green, C.T. (2001), "Economic news and bond prices: evidence from the US treasury market", *The Journal of Financial and Quantitative Analysis*, Vol. 36 No. 4, pp. 523-543.

Beber, A. and Brandt, M.W. (2006), "The effect of macroeconomic news on beliefs and preferences: evidence from the options market", *Journal of Monetary Economics*, Vol. 53 No. 8, pp. 1997-2039.

Black, F. and Scholes, M. (1973), "The pricing of options and corporate liabilities", *The Journal of Political Economy*, Vol. 81 No. 3, pp. 637-653.

Campbell, J.Y., Lo, A.W. and MacKinlay, A.C. (1997), *The Econometrics of Financial Markets*, Princeton University Press, Princeton, NJ.

Du, D (2011), "General equilibrium pricing of options with habit formation and event risks", *Journal of Financial Economics*, Vol. 99 No. 2, pp. 400-426.

Ederington, L.H. and Lee, J.H. (1996), "The creation and resolution of market uncertainty: the impact of information releases on implied volatility", *Journal of Financial and Quantitative Analysis*, Vol. 31 No. 4, pp. 513-539.

Figlewski, S. (1997), "Forecasting volatility", *Financial Markets, Institutions, and Instruments*, Vol. 6 No. 1, pp. 1-88.

Fuherer, J.C. (2000), "Habit formation in consumption and its implications for monetary-policy models", *The American Economic Review*, Vol. 90 No. 3, pp. 367-390.

Jackwerth, J.C. (2000), "Recovering risk aversion from option prices and realized returns", *The Review of Financial Studies*, Vol. 13 No. 2, pp. 433-451.

Poon, S.-H. and Granger, C.W.J. (2003), "Forecasting volatility in financial markets: a review", *Journal of Economic Literature*, Vol. 41 No. 2, pp. 478-539.

Rosenberg, J.V. and Engle, R.F. (2002), "Empirical pricing kernels", *Journal of Financial Economics*, Vol. 64 No. 3, pp. 341-372.

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