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Implied Adjusted Volatility by Leland Option Pricing Models: Evidence from Australian Index Options

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***Abstract*—**With the implied volatility as an important factor in financial decision-making, in particular in option pricing valuation, and also the given fact that the pricing biases of Leland option pricing models and the implied volatility structure for the options are related, this study considers examining the implied adjusted volatility smile patterns and term structures in the S&P/ASX 200 index options using the different Leland option pricing models. The examination of the implied adjusted volatility smiles and term structures in the Australian index options market covers the global financial crisis in the mid-2007. The implied adjusted volatility was found to escalate approximately triple the rate prior the crisis.

***Keywords*—**Implied adjusted volatility, Financial crisis, Leland option pricing models.

I. Introduction

THE Black-Scholes-Merton (BSM) option pricing model has been the cornerstone of the option pricing literature. Nonetheless, the BSM theory, particularly the constant volatility assumption, came in for criticism due to the inability of the BSM model to handle the extreme conditions, especially after the October 1987 market crash. In reality, volatility implied by those options tend to differ across both moneyness and time to maturity, which elucidates the smile or skew phenomenon, wherein failed to be explained by the BSM model.

Leland option pricing model [1] improved the BSM model by developing a hedging strategy that incorporates an adjusted volatility. Even though the idea is quite relevant, yet this model is flawed: it does not integrate the initial cost of trading into the assumptions. In response to these shortcomings in the Leland original model, [2] provided two adjustments, in which Leland explicitly considered the initial costs of trading into the assumptions that the initial portfolio consists of either all cash or all stock positions. Henceforth, this study employs [1] (hereafter referred as Leland original model) and its two variations [2] (hereafter referred as Leland cash model and Leland stock model).

With the implied volatility as a significant aspect particularly in option valuation, and given the fact that the pricing biases of Leland option pricing models and the implied volatility structure of the option are related, this study aims to investigate the implied adjusted volatility smile patterns in index options using the different Leland option pricing models. We hypothesise that the implied adjusted volatilities estimated from the different Leland option pricing models are approximately equal in value.

Until now, the use of implied volatility in option pricing is continuing to receive great attention from many academics and practitioners, despite the number of studies criticising the implied volatility. The critics are that the implied volatility induces substantial incremental information and is significantly biased in forecasting future realized volatility. As an example, [3] argued that implied-volatility-based forecast performs relatively poor compared to the forecast based on the combination of historical volatility and implied volatility. Nevertheless, the superior performance of implied volatility compared to that of historical volatility has been recognised by many researchers [4]-[9].

Although it is documented in a number of literature that volatility varies across moneyness and maturity, the reasons underlie behind this is still questionable. It is claimed that the movements in the changes of smile in option prices are very much predictable [10], [11]. Thus, this study identifies any regularity in the implied volatility structures, and thus provides a better understanding of the smile phenomena.

The subprime mortgage crisis meltdown in US which peak in mid-2007 until the end of 2008 resulted on several ripple impacts on world financial market. To the best of our knowledge, research on implied volatility surfaces within the occurrence of the recent global financial crisis is non-existence. In particular, only a small number of literature is devoted on studying the implied volatility in Australian options market so far. Thus, this study distinguishes itself from other existing literature by investigating the implied volatility smile pattern over the occurrence of the 2007 crisis in the Australian index options using the Leland option pricing models.

For that reason, the S&P/ASX 200 index options data is utilized in this paper. The sample data considered in this study covers the period from April 2001 until the end of 2010, which covers the global financial crisis period.

Furthermore, this study distinguishes itself from previous studies in which an option implied adjusted volatility is examined, instead of merely option implied volatility. The fluctuating market conditions and possible risk aversions can be further expounded by assessing the volatility surfaces, thus provides an avenue for future research.

The remainder of this article is structured as follows.

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Section II provides a review of several previous studies on implied volatility structures conducted on different markets and derivatives, followed by the description of Leland option pricing models in Section III. The data utilization and methodology is then described in Sections IV and V, respectively. The empirical results and the analysis are presented in Section VI, followed by the conclusion in Section VII.

II. Literature Review

Volatility surface is the blend effect of both maturity and strikes on volatility, and hence can be simply considered as the term structure of the volatility skewness. It provides an effective snapshot that captures volatility in the context of both dimensions.

Primarily, each literature is conducted on different set of market and derivative, which explain the fact of deviation in results. Reference [12] denoted that the volatility smile patterns tend to differ across markets, underlying assets and time to maturity. A number of literatures have shed some light on the study of volatility smiles across different markets and derivatives.

To date, there are several literature dedicated on studying the volatility smiles pattern across different classes of underlying assets. For instances, [13], [14] are among those that studied on foreign currency options; [15]-[21] are on individual stocks and stock index options; [22], [23] are on futures options.

In brief, the following synthesises some of the similar findings sought from previous literature. Index option smile is highly skewed since the 1987 market crash [18], [21], [24], whereby a more intensified negative incline is experienced in US, mainly by options on S&P 500 [19], [25], [26]. The same is applied in the case of futures options [20], [23].

On the other hand, the volatility implied by options particularly prior to the 1987 crash was reported to be originally having symmetric U-shaped smiles in almost all markets over different assets, independent of the options maturity [13], [18], [23], [27], [28]. Ultimately, in many option markets, the smile shows negative skewness [17], [26], [29], whereby mature markets tend to exhibit negative asymmetric profiles [30].

Further, changes in implied volatility in one market is discovered to be likely to spread to other markets, especially major markets, thus, demonstrate the existence of a sturdy global correlation across volatility markets [31], [32]. In fact, this finding is supported by [33] in which, the economic and stock markets in Japan and US, were intensified by all crises in a severe and collective manner. Hence it was believed that implied volatility would move substantially during crisis and shocks.

Additionally, volatility implied on call options is revealed to decline in slope as the call options go deep-out-of-the-money, and on the same token with put options, i.e. as put options go deep-in-the-money, the implied volatility descends monotonically. This is found to be recurrent on other index options since the 1987 market crash [21], [22].

Apart from that, there are several literatures that studied the degree of the intensification of volatility curvature. The studies identified that the volatility skewness is more pronounced for short options maturity as well as for increased volatility; and tapers off for longer maturity and reduced volatility which is due to the fact that short-dated volatility involves more jumps than long-dated volatility [20], [34].

From the literature reviewed above, there seems to be little consensus on the structure of implied volatility across different markets, but it is unequivocally believed as a function of the underlying assets. Intensified skewed is recurrently observed on index options, with higher implied volatility realised for lower strikes and lower implied volatility for higher strikes [35]; which is vice versa in the case of commodities. On the other hand, a more symmetrical curve is normally realised for currency options. The following part reviews on previous studies which highlighted on the different patterns of volatility implied by options returns conducted across various derivatives written on options. However, to study on different assets underlying the options requires broader data which is insufficient in this study. This paves the way for further research.

Following [36], [37], the features of implied volatility surface can be characterized into two. First, the implied volatility surface can be observed to be systematically changing with moneyness and time to maturity. This explains the generally observed non-flat surface which gives rise to the emergence of the sneer or smile in most implied volatility surface profiles. Second, the implied volatility surface is changing with time, reflected by the level of option prices that change to accommodate new information in the market. This provides us an insight on how we will investigate the volatility surface implied on the S&P/ASX 200 index options traded on the floor of Australian Stock Exchange (ASX).

III. Leland Option Pricing Models

Following the pricing biases in the BSM model, Leland original model [1] initiated a study to include transaction costs in valuing option prices. The modified option replicating strategy, which is a function of size of transaction costs and frequency of revision, originates from the idea that the accentuation of option price fluctuate movement can be modeled by volatility adjusted for trading costs,

$$\sigma^* = \frac{\sigma\left(1+k\sqrt{\frac{2}{\pi}}\right)}{\sqrt{\sigma\sqrt{\Delta\tau}}} \tag{1}$$

where σ is the volatility of the underlying asset, k is the round-trip transaction cost rate per unit dollar of transaction and $\Delta\tau$ is the time between hedging adjustment.

One of the assumptions in [38] is that the stock pays no dividend. However, dividends on some stocks may be substantial and can have a significant effect on the valuation of options whose stocks make such payments during the life of the options. Therefore, a dividend adjustment must be allowed for in the option pricing formula.

Reference [39] generalized [38] model by relaxing the assumption of no dividend. Reference [40] allowed for a constant continuous dividend yield on the stock and stock index. Replacing S_0 by S_0e^{-qT} in the BSM model, the prices of call, c, and put, p, on an index providing a dividend yield at rate q are as follows:

The Leland original model [1]:

$$c = S_0e^{-qT}N(d_1^*) - Ke^{-rT}N(d_2^*) \quad (2)$$

$$p = Ke^{-rT}N(-d_2^*) - S_0e^{-qT}N(-d_1^*) \quad (3)$$

The d_1^* and d_2^* are obtained as in (4) and (5) respectively, by replacing σ with the adjusted volatility, σ^*, and after adjusting for dividend yield at rate q. The function $N(.)$ is the cumulative probability distribution function for a standardised normal distribution.

$$d_1^* = \frac{\ln\left(\frac{S_0}{K}\right)+\left(r - q + \frac{\sigma^{*2}}{2}\right)T}{\sigma^*\sqrt{T}} \quad (4)$$

$$d_2^* = \frac{\ln\left(\frac{S_0}{K}\right)+\left(r - q - \frac{\sigma^{*2}}{2}\right)T}{\sigma^*\sqrt{T}} = d_1^* - \sigma^*\sqrt{T} \quad (5)$$

The following illustrates the Leland cash model and Leland stock model in [2].

The Leland cash model [2]:

$$c_{cash} = \left(1+\frac{k}{2}\right)S_0e^{-qt}N(d_1{}^*) - Ke^{-rT}N(d_2{}^*) \quad (6)$$

$$p_{cash} = Ke^{-rT}N(-d_2{}^*) - \left(1+\frac{k}{2}\right)S_0e^{-qt}N(-d_1{}^*) + \left(\frac{k}{2}\right)S_0e^{-qt} \quad (7)$$

The Leland stock model [2]:

$$c_{stock} = \frac{k}{2}S_0e^{-qt} + \left(1-\frac{k}{2}\right)S_0e^{-qt}N(d_1{}^*) - Ke^{-rT}N(d_2{}^*) \quad (8)$$

$$p_{stock} = Ke^{-rT}N(-d_2{}^*) - \left(1-\frac{k}{2}\right)S_0e^{-qt}N(-d_1{}^*) \quad (9)$$

The use of the adjusted volatility introduced by [1] and the following modification of the strategy to include initial costs of trading into the option pricing model are, in fact, found to be significantly improve the option pricing performance [40].

IV. Data

This paper utilises the data of call options on the S&P/ASX 200 index (XJO) traded daily on ASX during the period of April 2001 to December 2010. This almost ten-year data allows us enough observations to conduct a significant analysis. The sample covers the period from April 2001 until December 2010 and is divided into three groups which represent the pre-crisis, during-crisis and post-crisis period. The pre-crisis period covers from 2 April 2001 until 30 June 2007, whereas the post-crisis period is identified from 1 January 2009 until the end of the sample period.

The underlying asset price and the actual price of the index option are obtained from the closing price of the S&P/ASX 200 index and the closing price of the S&P/ASX 200 index option, respectively. The Australian 90-day Bank Accepted Bill (BAB) rate is taken as a proxy for the riskless interest rate. The transaction costs, k, are extracted from [41] for empirical purposes. Expiry-day, *T*, is measured by the number of trading days between the day of trade and the day immediately before expiry day divided by the number of trading days per year. We employ 252 days as the number of trading days in a year for Australian stock market. The moneyness of the S&P/ASX 200 index options is calculated by *Delta* (Δ), whereby delta for call and put is denoted by Δ_c and Δ_p, respectively [23], [29].

The sample data is chosen to include the recent US subprime mortgage crisis that began on 1 July 2007 and lasted until about the end of 2008. Therefore, the sample period is divided into 3 different periods. The pre-crisis period covers from 2 April 2001 until 30 June 2007, crisis period is from 1 July 2007 and ended at the end of 2008; and post-crisis period is from 1 January 2009 until the end of the sample period.

In order to obtain an error-minimized sample for the study, we adopt several sampling procedures from previous studies. The following filtering procedures are applied so that any offending daily option prices are excluded, which are:

1) All observations that unable to adhere to both upper and lower bound of arbitrage constraint, are omitted [12], [21], [35], [41], [42];
2) All observations with less than 6 days left to maturity are excluded from the sample;
3) All observations that subject to zero exercise price, i.e. options that require no payment upon exercise, are removed; and
4) Options with absolute deltas greater than 0.98 or less than 0.02 are excluded [23], [28].

Sample statistics for the whole data set are reported in Table I. The average maturity recorded for call options is 60.08 days. The sample data covering the period of April 2001 until December 2010 account for 41,622 call options with most options concentrated on the pre-crisis period. Both deep-out-of-the-money and out-of-the-money options are recorded to be the most actively traded options which accounts for 52.93 per cent of the total sample. In addition, long term and deep-in-the-money options are the least frequent options observed throughout the sample period.

TABLE I
SAMPLE PROPERTIES OF S&P/ASX 200 INDEX CALL OPTIONS

Moneyness	Time to Maturity in days (T)			
	Pre-Crisis			
Delta (Δ_c)	T < 30	30 ≤ T < 90	T ≥ 90	Total
DOTM (0.02 < Δ_c≤ 0.125)	4.64	3.07	1.44	3.09
	(531)	(1004)	(491)	(2026)
OTM (0.125 < Δ_c≤ 0.375)	16.99	17.98	12.17	15.95
	(1387)	(3724)	(2392)	(7503)
ATM (0.375 < Δ_c≤ 0.625)	52.64	75.70	76.28	71.90
	(1137)	(3542)	(1929)	(6608)
ITM (0.625 < Δ_c≤ 0.875)	127.89	215.28	330.82	211.18
	(473)	(968)	(296)	(1737)
DITM (0.875 < Δ_c≤ 0.98)	209.27	412.42	554.69	373.60
	(164)	(293)	(86)	(543)
	During Crisis			
Delta (Δ_c)	T < 30	30 ≤ T < 90	T ≥ 90	Total
DOTM (0.02 < Δ_c≤ 0.125)	16.85	24.02	52.75	20.70
	(201)	(281)	(55)	(1037)
OTM (0.125 < Δ_c≤ 0.375)	56.58	80.03	119.12	71.39
	(1543)	(1113)	(277)	(2933)
ATM (0.375 < Δ_c≤ 0.625)	149.92	222.60	327.13	207.88
	(1205)	(1424)	(410)	(3039)
ITM (0.625 < Δ_c≤ 0.875)	274.73	459.13	777.61	381.72
	(373)	(224)	(57)	(654)
DITM (0.875 < Δ_c≤ 0.98)	419.27	937.90	1908.33	637.69
	(116)	(59)	(6)	(181)
	Post Crisis			
Delta (Δ_c)	T < 30	30 ≤ T < 90	T ≥ 90	Total
DOTM (0.02 < Δ_c≤ 0.125)	11.35	22.62	51.32	24.35
	(1368)	(1179)	(735)	(3282)
OTM (0.125 < Δ_c≤ 0.375)	38.84	68.89	132.82	70.92
	(1982)	(2172)	(1098)	(5252)
ATM (0.375 < Δ_c≤ 0.625)	96.10	162.19	299.80	166.62
	(1547)	(1792)	(879)	(4218)
ITM (0.625 < Δ_c≤ 0.875)	173.79	280.03	507.94	246.17
	(1030)	(663)	(199)	(1892)
DITM (0.875 < Δ_c≤ 0.98)	285.38	497.49	1195.88	453.30
	(449)	(177)	(91)	(717)

Sample Average			
Delta (Δ_c)	Maturity (days)	Volume	Open Interest
0.376	61.41	114.1126327	1100.59

The table presents the average price for call options over different moneyness and maturity categories over the three periods, with inclusion of sample average of option moneyness, option maturity, volume and open interest in the presence of the 2007 crisis consideration. Those in parentheses correspond to the number of call options. The maturity is divided into three categories: (i) short term (<30 days), (ii) medium term (30-90 days) and (iii) long term (≥90 days). The pre-crisis period is from 2 April 2001 to 30 June 2007, during crisis period is from 1 July 2007 to 31 December 2008 and post-crisis period is from 1 January 2009 to 31 December 2010. DOTM, OTM, ATM, ITM and DITM stand for deep-out-of-the-money, out-of-the-money, at-the-money, in-the-money and deep-in-the-money, respectively. Moneyness is tabulated based on delta (Δ). Delta for call is $\Delta_c = e^{-qT}N(d_1^*)$.

V. METHODOLOGY

The implied adjusted volatility is obtained by utilising the Visual Basic for Applications (VBA) function in which an iterative bisection loop is employed. In particular, the implied adjusted volatility is calculated by equalising both the theoretical, $X_{theoretical}$, which depends on security price (S), strike price (K), option expiry period (τ), risk-free interest rate (r), adjusted volatility (σ^*) and dividend yield (q), along with the market-observed option price, X_{market} of the S&P/ASX 200 index, i.e.,

$$X_{market} = X_{theoretical(S,K,\tau,r,\sigma^*,q)} \quad (10)$$

where X is call option price.

A 3-dimensional graph is then plotted in order to better illustrate the different implied volatility surfaces resulted from different moneyness and time to maturity. The effect of volatility sneer within the occurrence of the recent global financial crisis is additionally investigated in this part. Owing to that, the sample data is subdivided into several different options moneyness and time to maturity groupings, and the average is taken out of each group.

Since this study considers the crisis period in the sample data, we conduct a test for the existence of data break. By using Chow Breakpoint test, there exists a structural break at 1 July 2007 and 31 December 2008.

TABLE II
AVERAGE OF CALL OPTIONS IMPLIED ADJUSTED VOLATILITIES DERIVED FROM THE DIFFERENT LELAND OPTION PRICING MODELS ACROSS BOTH MONEYNESS AND OPTION'S TIME TO MATURITY OVER THE WHOLE SAMPLE PERIOD 2001-2010

	Leland original		Leland cash		Leland stock	
	Average	SD	average	SD	average	SD
PANEL A: Time to Maturity						
T≤29	1.212	0.645	1.209	0.650	1.199	0.670
30≤T<49	1.098	0.681	1.098	0.681	1.095	0.687
50≤T<69	0.907	0.668	0.907	0.668	0.905	0.670
70≤T<89	0.799	0.607	0.799	0.607	0.799	0.608
90≤T<109	0.784	0.571	0.784	0.571	0.783	0.572
110≤T<129	0.803	0.639	0.803	0.639	0.802	0.640
T≥130	0.877	0.641	0.877	0.641	0.873	0.645
Total	**1.020**	**0.669**	**1.019**	**0.670**	**1.014**	**0.678**
PANEL B: Delta-Moneyness						
DOTM	0.772	0.485	0.772	0.485	0.742	0.537
OTM	0.998	0.615	0.998	0.615	0.996	0.617
ATM	1.184	0.752	1.184	0.752	1.184	0.752
ITM	0.984	0.695	0.983	0.695	0.984	0.695
DITM	0.797	0.601	0.755	0.640	0.797	0.601
Total	**1.020**	**0.669**	**1.019**	**0.670**	**1.014**	**0.678**

This table displays the average implied adjusted volatility of the different Leland's models, namely the Leland original model, Leland cash model and Leland stock model. The standard deviation (SD) is reported next to the average implied adjusted volatility. The maturity is divided into three categories: (i) short term (<30 days), (ii) medium term (30-90 days) and (iii) long term (≥90 days). The pre-crisis period is from 2 April 2001 to 30 June 2007, during crisis period is from 1 July 2007 to 31 December 2008 and post-crisis period is from 1 January 2009 to 31 December 2010. DOTM, OTM, ATM, ITM and DITM stand for deep-out-of-the-money, out-of-the-money, at-the-money, in-the-money and deep-in-the-money, respectively. Moneyness is tabulated based on delta (Δ). Delta for call is $\Delta_c = e^{-qT}N(d_1^*)$.

TABLE III
CALL OPTIONS IMPLIED ADJUSTED VOLATILITIES DERIVED FROM THE DIFFERENT LELAND OPTION PRICING MODELS WITH TOTAL AVERAGE ACROSS BOTH MONEYNESS AND OPTION'S TIME TO MATURITY OVER THE WHOLE SAMPLE PERIOD 2001-2010

Delta-Moneyness		DOTM	OTM	ATM	ITM	DITM	Total
PANEL A: Leland original model							
Time to Maturity in days (T)	T≤29	0.868	1.220	1.450	1.240	1.057	1.406
	30≤T<49	0.769	1.109	1.284	0.930	0.694	1.273
	50≤T<69	0.663	0.891	1.068	0.724	0.565	1.162
	70≤T<89	0.731	0.765	0.878	0.710	0.743	1.120
	90≤T<109	0.617	0.727	0.916	0.687	0.417	1.001
	110≤T<129	0.618	0.739	0.978	0.665	0.386	0.935
	T≥130	0.681	0.813	1.062	0.936	0.544	0.994
	Total	0.707	0.895	1.091	0.842	0.629	1.005
PANEL B: Leland cash model							
Time to Maturity in days (T)	T≤29	0.868	1.220	1.450	1.239	0.956	**1.147**
	30≤T<49	0.769	1.109	1.284	0.930	0.694	**0.957**
	50≤T<69	0.663	0.891	1.068	0.724	0.565	**0.782**
	70≤T<89	0.731	0.765	0.878	0.710	0.743	**0.765**
	90≤T<109	0.617	0.727	0.916	0.687	0.417	**0.673**
	110≤T<129	0.618	0.739	0.978	0.665	0.386	**0.677**
	T≥130	0.681	0.813	1.062	0.936	0.544	**0.807**
	Total	**0.707**	**0.895**	**1.091**	**0.841**	**0.615**	**0.830**
PANEL C: Leland stock model							
Time to Maturity in days (T)	T≤29	0.821	1.213	1.450	1.240	1.057	**1.156**
	30≤T<49	0.746	1.109	1.284	0.930	0.694	**0.953**
	50≤T<69	0.647	0.891	1.068	0.724	0.565	**0.779**
	70≤T<89	0.727	0.765	0.878	0.710	0.743	**0.764**
	90≤T<109	0.604	0.727	0.916	0.687	0.417	**0.670**
	110≤T<129	0.611	0.739	0.978	0.665	0.386	**0.676**
	T≥130	0.657	0.813	1.062	0.936	0.544	**0.802**
	Total	**0.687**	**0.894**	**1.091**	**0.842**	**0.629**	**0.829**

DOTM, OTM, ATM, ITM and DITM stand for deep-out-of-the-money, out-of-the-money, at-the-money, in-the-money and deep-in-the-money, respectively. DOTM is defined by 0.02<Δ≤0.125; OTM by 0.125<Δ≤0.375; ATM by 0.375<Δ≤0.625; ITM by 0.625<Δ≤0.875; and DITM by 0.875<Δ≤0.98. Moneyness is tabulated based on delta (Δ). Delta for call is $\Delta_c = e^{-qT}N(d_1^*)$. The time to maturity is written as: less than or equal to 29 days is short-term, 30 to 89 days is medium-term and greater than or equal to 90 days is long-term.

VI. Empirical Results on Implied Adjusted Volatility Smile Pattern

This section discusses the implied adjusted volatility surfaces sought from the S&P/ASX 200 index options covering the period April 2001 until December 2010. We consider two different data sets: whole data set from 2001-2010; and, the crisis-considered data set.

The sample data covers the period from 2001-2010, is divided into three groups which represent the pre-crisis, during crisis and post-crisis period respectively. The pre-crisis period covers from 2 April 2001 until 30 June 2007; the crisis period starts from 1 July 2007 until 31 December 2008; and the post-crisis period is identified from 1 January 2009 until the end of the sample period.

Options are categorized into three levels based on option's time to maturity, (i.e., short-term options are for option's time to maturity less and equal to 29 days; medium-term options are for time to maturity between 30 and 89 days; and long-term options are for option's maturity more than 90 days), and five levels of moneyness.

A. 2001-2010 Data Set

Based on the adjusted volatility, we sought different adjusted volatility implied on the S&P/ASX 200 index options on the basis of the three different Leland's framework, namely Leland original model, Leland cash model and Leland stock model.

This subsection separately presents the data in terms of option's time to maturity and option's delta-moneyness. Both average implied adjusted volatility and the standard deviation from the different Leland option pricing models are reported in Table II.

Table II reports the average of call options implied adjusted volatility against the option's time to maturity and moneyness. In order to assess the size of data variation, the standard deviation (SD) is provided. Strikingly, all three models produce almost equivalent results of implied adjusted volatility in term of both moneyness and time to maturity. All Leland models considered produce approximately the same value in term of both average implied adjusted volatility as well as SD over the whole sample period 2001-2010. This in fact supported our hypothesis that the implied adjusted volatilities derived from the different Leland option pricing models are approximately equal in value.

The effect of both moneyness and option's time to maturity on the adjusted volatility implied on the S&P/ASX 200 index options for the whole sample set is further investigated by considering a three-dimensional assessment. Table III represents the respective implied adjusted volatility across the different moneyness and option's maturity levels.

Fig. 1 exhibits the respective adjusted volatility surfaces implied on the S&P/ASX 200 index options after alleviating for the full sample period interval, derived from the different Leland models.

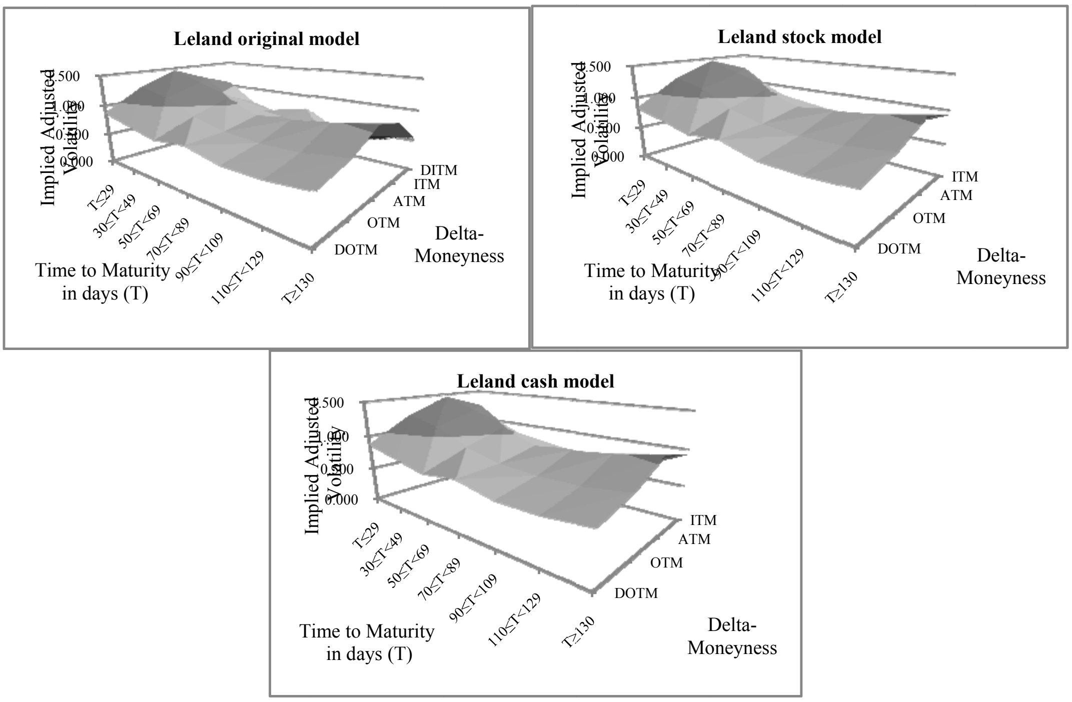

Fig. 1 Implied adjusted volatility surfaces on S&P/ASX 200 index call options of 2001-2010 derived from the different Leland option pricing models

The volatility adjusted based on the different Leland models implied on the call options display a downward sloping skewness, which is illustrated in Fig. 1. The in-the-money (ITM) call options are traded at higher volatility compared with those of out-of-the-money (OTM) call options.

In the context of term structure, at-the-money (ATM) options accounted for almost flat pattern. Otherwise, the term structure increases from long-term options to short-term options. Those options with short-term maturity happen to be significantly higher than the medium-term options. Furthermore, the implied adjusted volatility decreases from deep in-the-money (DITM) to deep-out-of-the-money (DOTM) options.

B. Crisis-Considered Data Set

This section also presents the results of the volatility adjusted based on the three Leland models which is implied on the S&P/ASX 200 index options, by considering the three different intervals period. The crisis period is, in particular, taken into account to reflect the subprime mortgage crisis meltdown in US which peak in mid-2007 until the end of 2008. Therefore, we investigate and analyze the implied adjusted volatility surface of S&P/ASX 200 index options specifically on different intervals, marked by the pre-, during- and post-crisis periods.

Tables IV and V describe the average implied adjusted volatility against the option's time to maturity and moneyness. Accordingly, the standard deviation (SD) is provided to reflect the size of data variation. The bold values reported in the table represent the total average of the implied adjusted volatility. The implied adjusted volatility in each table is reported based on the three Leland option pricing models. The three panels represent the results of both average implied adjusted volatility as well as the respective SD from the pre-, during- and post-crisis period, respectively.

TABLE IV
AVERAGE OF CALL OPTIONS IMPLIED ADJUSTED VOLATILITIES DERIVED FROM THE DIFFERENT LELAND OPTION PRICING MODELS ACROSS BOTH MONEYNESS AND OPTION'S TIME TO MATURITY OVER THE DIFFERENT PERIODS: PRE-, DURING AND POST-CRISIS

Time to Maturity	Leland original model		Leland cash model		Leland stock model	
	average	SD	average	SD	average	SD
PANEL A: Pre-Crisis						
T≤29	0.430	0.084	0.421	0.106	0.409	0.128
30≤T<49	0.413	0.064	0.413	0.064	0.413	0.064
50≤T<69	0.417	0.061	0.417	0.061	0.417	0.061
70≤T<89	0.412	0.065	0.412	0.065	0.412	0.065
90≤T<109	0.409	0.062	0.409	0.062	0.409	0.062
110≤T<129	0.395	0.058	0.395	0.058	0.395	0.058
T≥130	0.383	0.056	0.383	0.056	0.383	0.056
Total	**0.412**	**0.068**	**0.410**	**0.074**	**0.407**	**0.080**
PANEL B: During Crisis						
T≤29	1.767	0.259	1.767	0.259	1.757	0.286
30≤T<49	1.858	0.186	1.858	0.186	1.858	0.186
50≤T<69	1.891	0.186	1.891	0.186	1.891	0.186
70≤T<89	1.752	0.227	1.752	0.227	1.752	0.227
90≤T<109	1.650	0.236	1.650	0.236	1.650	0.236
110≤T<129	1.916	0.252	1.916	0.252	1.916	0.252
T≥130	1.916	0.099	1.916	0.099	1.916	0.099
Total	**1.806**	**0.237**	**1.806**	**0.237**	**1.802**	**0.253**
PANEL C: Post-Crisis						
T≤29	1.350	0.532	1.350	0.532	1.343	0.576
30≤T<49	1.456	0.489	1.456	0.489	1.446	0.516
50≤T<69	1.512	0.488	1.512	0.488	1.503	0.511
70≤T<89	1.501	0.471	1.501	0.471	1.498	0.481
90≤T<109	1.403	0.462	1.403	0.462	1.398	0.476
110≤T<129	1.501	0.472	1.350	0.472	1.497	0.483
T≥130	1.370	0.509	1.456	0.509	1.358	0.534
Total	**1.411**	**0.510**	**1.411**	**0.510**	**1.403**	**0.541**

This table displays the average implied adjusted volatility of the different Leland's models, namely the Leland original model, Leland cash model and Leland stock model. The standard deviation (SD) is reported next to the average implied adjusted volatility. The time to maturity is written as: less than or equal to 29 days is short-term, 30 to 89 days is medium-term and greater than or equal to 90 days is long-term.

TABLE V
AVERAGE OF CALL OPTIONS IMPLIED ADJUSTED VOLATILITIES DERIVED FROM THE DIFFERENT LELAND OPTION PRICING MODELS ACROSS BOTH MONEYNESS AND OPTION'S MONEYNESS OVER THE DIFFERENT PERIODS: PRE-, DURING AND POST-CRISIS

Delta-Moneyness	Leland original model		Leland cash model		Leland stock model	
	average	SD	average	SD	average	SD
PANEL A: Pre-Crisis						
DOTM	0.373	0.059	0.373	0.059	0.344	0.113
OTM	0.401	0.068	0.401	0.068	0.398	0.075
ATM	0.431	0.068	0.430	0.068	0.430	0.068
ITM	0.428	0.056	0.427	0.058	0.428	0.056
DITM	0.417	0.057	0.356	0.159	0.417	0.057
Total	**0.412**	**0.068**	**0.410**	**0.074**	**0.407**	**0.080**
PANEL B: During Crisis						
DOTM	1.735	0.281	1.735	0.281	1.705	0.352
OTM	1.827	0.217	1.827	0.217	1.825	0.224
ATM	1.868	0.180	1.868	0.180	1.868	0.180
ITM	1.614	0.284	1.614	0.284	1.614	0.284
DITM	1.546	0.293	1.546	0.292	1.546	0.292
Total	**1.806**	**0.237**	**1.806**	**0.237**	**1.802**	**0.253**
PANEL C: Post Crisis						
DOTM	0.713	0.183	0.713	0.183	0.683	0.341
OTM	1.389	0.231	1.389	0.231	1.388	0.235
ATM	1.961	0.064	1.961	0.064	1.961	0.064
ITM	2.000	0.000	2.000	0.000	2.000	0.000
DITM	2.000	0.000	2.000	0.000	2.000	0.000
Total	**1.411**	**0.510**	**1.411**	**0.510**	**1.403**	**0.541**

This table displays the average implied adjusted volatility of the different Leland models, namely the Leland original model, Leland cash model and Leland stock model. The standard deviation (SD) is reported next to the average implied adjusted volatility. DOTM, OTM, ATM, ITM and DITM stand for deep-out-of-the-money, out-of-the-money, at-the-money, in-the-money and deep-in-the-money, respectively. DOTM is defined by $0.02<\Delta\leq 0.125$; OTM by $0.125<\Delta\leq 0.375$; ATM by $0.375<\Delta\leq 0.625$; ITM by $0.625<\Delta\leq 0.875$; and DITM by $0.875<\Delta\leq 0.98$. Moneyness is tabulated based on delta (Δ). Delta for call is $\Delta_c = e^{-qT}N(d_1^*)$. The time to maturity is written as: less than or equal to 29 days is short-term, 30 to 89 days is medium-term and greater than or equal to 90 days is long-term.

In terms of the average implied adjusted volatility assessed in the context of time to maturity, the Leland original model is recorded to produce the highest implied adjusted volatility of 0.412 in pre-crisis interval. However, Leland stock option pricing model is documented to result in the highest SD during that period with 8.0 per cents compared to the Leland original model with 6.8 per cent.

During the crisis period interval, the highest average implied adjusted volatility in term of time to maturity is recorded by both Leland original model and Leland cash model of 1.806. In particular, the long-maturity call options of range $T\geq 110$ days have the highest implied adjusted volatility for all three Leland models. Strikingly, this period interval of crisis lead to enormous deviation in its sample data with the smallest is recorded to be 9.9 per cent, which is much bigger than the highest average SD in pre-crisis period, and the maximum is 28.6 per cent recorded from the Leland stock model. Consequently, Leland stock model results the biggest SD average of 25.3 per cent compared to other Leland models in the during-crisis interval.

Both of the Leland cash and stock models are reported to have the average implied adjusted volatility of a total average of 1.170, which is much higher than that recorded for Leland original model with average implied adjusted volatility of 0.291. Accordingly, both of the Leland cash and stock models resulted in the biggest SD recorded over the post-crisis period, which is 18.3 per cent. The SD over the post-crisis period is much smaller than those documented in the during-crisis period. However, the SD value is still bigger than that of the pre-crisis period.

Surprisingly, when implied adjusted volatility is averaged in term of moneyness, the results is recorded to be the same in the context of the average implied adjusted volatility and the respective SD. For all three interval periods, the Leland stock model reports the highest SD compared to the other two Leland models. The ATM options for all Leland models are documented to have the lowest SD value for during- and post-crisis. This explains the fact that ATM option is a stable option, thus may appropriately serve as an unbiased benchmark.

The investigation on the implied adjusted volatility pattern or structure over the different interval periods is proceed by considering both option's moneyness and time to maturity, simultaneously. The corresponding implied adjusted volatility, derived from the different Leland option pricing models are described in Tables VI, VII, and VIII, respectively. The results of all three Leland models are reported as the average implied adjusted volatility, averaged in terms of both time to maturity and moneyness. The bold values reported in the table are referred to as the total average of the implied adjusted volatility. The three panels show the results of implied adjusted volatility from the pre-, during- and post-crisis period, respectively.

TABLE VI
CALL OPTIONS IMPLIED ADJUSTED VOLATILITIES DERIVED FROM THE LELAND ORIGINAL MODEL WITH TOTAL AVERAGE ACROSS BOTH MONEYNESS AND OPTION'S MONEYNESS OVER THE DIFFERENT PERIODS: PRE-, DURING AND POST-CRISIS

Delta-Moneyness		DOTM	OTM	ATM	ITM	DITM	Total
PANEL A: Pre-Crisis							
Time to Maturity in days (T)	T≤29	0.382	0.433	0.456	0.425	0.404	**0.430**
	30≤T<49	0.373	0.403	0.435	0.422	0.384	**0.413**
	50≤T<69	0.374	0.405	0.436	0.429	0.437	**0.417**
	70≤T<89	0.363	0.401	0.428	0.438	0.447	**0.412**
	90≤T<109	0.363	0.394	0.430	0.441	0.417	**0.409**
	110≤T<129	0.358	0.386	0.405	0.447	0.396	**0.395**
	T≥130	0.372	0.368	0.398	0.419	0.431	**0.383**
	Total	**0.373**	**0.401**	**0.431**	**0.428**	**0.417**	**0.409**
PANEL B: During Crisis							
Time to Maturity in days (T)	T≤29	1.662	1.801	1.846	1.624	1.581	**1.703**
	30≤T<49	1.891	1.872	1.874	1.675	1.603	**1.783**
	50≤T<69	1.953	1.970	1.917	1.462	1.420	**1.744**
	70≤T<89	1.927	1.728	1.801	1.440	1.526	**1.684**
	90≤T<109	1.483	1.585	1.750	1.291	-	**1.527**
	110≤T<129	2.000	1.980	1.974	1.341	0.240	**1.507**
	T≥130	1.883	1.877	1.954	1.947	1.565	**1.845**
	Total	**1.829**	**1.830**	**1.874**	**1.540**	**1.323**	**1.682**
PANEL C: Post-Crisis							
Time to Maturity in days (T)	T≤29	0.650	1.318	1.945	2.000	2.000	**1.583**
	30≤T<49	0.723	1.443	1.952	2.000	2.000	**1.624**
	50≤T<69	0.791	1.495	1.994	2.000	2.000	**1.656**
	70≤T<89	0.804	1.460	1.999	2.000	2.000	**1.653**
	90≤T<109	0.781	1.265	1.956	2.000	-	**1.501**
	110≤T<129	0.842	1.547	1.957	2.000	-	**1.587**
	T≥130	0.749	1.382	1.973	2.000	-	**1.526**
	Total	**0.763**	**1.416**	**1.968**	**2.000**	**2.000**	**1.606**

DOTM, OTM, ATM, ITM and DITM stand for deep-out-of-the-money, out-of-the-money, at-the-money, in-the-money and deep-in-the-money, respectively. DOTM is defined by 0.02<Δ≤0.125; OTM by 0.125<Δ≤0.375; ATM by 0.375<Δ≤0.625; ITM by 0.625<Δ≤0.875; and DITM by 0.875<Δ≤0.98. Moneyness is tabulated based on delta (Δ). Delta for call is $\Delta_c = e^{-qT}N(d_1^*)$. The time to maturity is written as: less than or equal to 29 days is short-term, 30 to 89 days is medium-term and greater than or equal to 90 days is long-term.

Firstly, we discuss the implied adjusted volatility resulted from the Leland original option pricing model after alleviating the results for the different moneyness and time to maturity groupings over the three intervals considered. During the pre-crisis interval, the implied adjusted volatility recorded to be the highest in the case of short-term ATM options of 0.456, whereas the minimum value is recorded by the DOTM options of 0.358 with time to maturity ranging from 110 to 129 days. The implied adjusted volatility increases from long-term maturity to short-term maturity options. On the other hand, the implied adjusted volatility averaged in term of moneyness shows increasing in value as it moves from the OTM, to ITM and to ATM options.

In the during-crisis course of interval, the implied adjusted volatility is documented to be ranging from 0.240 to 2.000, with the maximum value is obtained from the DOTM options of long-term time to maturity and the minimum is recorded by DITM options with time to maturity of 90-130 days. This leads the respective options to be valued with low implied adjusted volatility. In view of total average of implied adjusted volatility, the values are found to be increasing as they move from OTM options, to ITM options, and to ATM options. On the other hand, in term of time to maturity, the implied adjusted volatility values increases as their time to maturity become smaller.

The post-crisis interval documented that the optimum values of implied adjusted volatility, averaged in terms of both moneyness and time to maturity is observed in ITM and DITM options. However, in this post-crisis period, after the data filtering procedure, the sample does not include long-term DITM options. The implied adjusted volatility of post-crisis period is discovered to be more stable than the other two intervals based on the resulted range after controlling the effect for the unavailability of data. The implied adjusted volatility is found to move in better manner along the different moneyness levels. The value escalates from OTM options, to ITM options and to ATM options. This is consistent with the discussion made for the during-crisis period. Despite that, the dynamics of implied adjusted volatility in term of time to maturity in this particular period is less-pronounced as in the during-crisis case.

TABLE VII
CALL OPTIONS IMPLIED ADJUSTED VOLATILITIES DERIVED FROM THE LELAND CASH MODEL WITH TOTAL AVERAGE ACROSS BOTH MONEYNESS AND OPTION'S MONEYNESS OVER THE DIFFERENT PERIODS: PRE-, DURING AND POST-CRISIS

Delta-Moneyness		DOTM	OTM	ATM	ITM	DITM	Total
PANEL A: Pre-Crisis							
Time to Maturity in days (T)	T≤29	0.382	0.433	0.456	0.423	0.201	**0.379**
	30≤T<49	0.373	0.403	0.435	0.422	0.384	**0.404**
	50≤T<69	0.374	0.405	0.436	0.429	0.437	**0.416**
	70≤T<89	0.363	0.401	0.428	0.438	0.447	**0.415**
	90≤T<109	0.363	0.394	0.430	0.441	0.417	**0.409**
	110≤T<129	0.358	0.386	0.405	0.446	0.396	**0.398**
	T≥130	0.372	0.368	0.397	0.419	0.431	**0.397**
	Total	**0.369**	**0.399**	**0.427**	**0.431**	**0.388**	0.403
PANEL B: During Crisis							
Time to Maturity in days (T)	T≤29	1.662	1.801	1.846	1.624	1.581	**1.703**
	30≤T<49	1.891	1.872	1.874	1.675	1.603	**1.783**
	50≤T<69	1.953	1.970	1.917	1.462	1.420	**1.744**
	70≤T<89	1.927	1.728	1.801	1.440	1.526	**1.684**
	90≤T<109	1.483	1.585	1.750	1.291	-	**1.527**
	110≤T<129	2.000	1.980	1.974	1.341	0.240	**1.507**
	T≥130	1.883	1.877	1.954	1.947	1.565	**1.845**
	Total	**1.829**	**1.830**	**1.874**	**1.540**	**1.323**	**1.682**
PANEL C: Post-Crisis							
Time to Maturity in days (T)	T≤29	0.650	1.318	1.945	2.000	2.000	**1.583**
	30≤T<49	0.723	1.443	1.952	2.000	2.000	**1.624**
	50≤T<69	0.791	1.495	1.994	2.000	2.000	**1.656**
	70≤T<89	0.804	1.460	1.999	2.000	2.000	**1.653**
	90≤T<109	0.781	1.265	1.956	2.000	**-**	**1.501**
	110≤T<129	0.842	1.547	1.957	2.000	**-**	**1.587**
	T≥130	0.749	1.382	1.973	2.000	**-**	**1.526**
	Total	**0.763**	**1.416**	**1.968**	**2.000**	**2.000**	**1.606**

DOTM, OTM, ATM, ITM and DITM stand for deep-out-of-the-money, out-of-the-money, at-the-money, in-the-money and deep-in-the-money, respectively. DOTM is defined by 0.02<Δ≤0.125; OTM by 0.125<Δ≤0.375; ATM by 0.375<Δ≤0.625; ITM by 0.625<Δ≤0.875; and DITM by 0.875<Δ≤0.98. Moneyness is tabulated based on delta (Δ). Delta for call is $\Delta_c = e^{-qT}N(d_1^*)$. The time to maturity is written as: less than or equal to 29 days is short-term, 30 to 89 days is medium-term and greater than or equal to 90 days is long-term.

The values of implied adjusted volatility derived from both of the Leland cash and stock models are found to have approximately the same results. Thus, we discuss the results of both of the models together. Next, we discuss on the possible dynamic pattern resulted from the implied adjusted volatility in terms of both moneyness and time to maturity.

The implied adjusted volatility values from both of the Leland cash and stock models are discovered to be the highest in the case of short-term ATM options with 0.456. However, the results differ in the case of minimum implied adjusted volatility, in which the Leland cash model recorded the short-term DITM with 0.201, while the Leland stock model with short-term DOTM option with 0.273 as the minimum implied adjusted volatility.

For during-crisis interval, the maximum and minimum values of implied adjusted volatility derived from the Leland stock and cash models are reported to be recorded by the long-term DOTM and long-term ITM options, respectively. In the case of post-crisis interval, both models produce the same results, with the maximum implied adjusted volatility is retrieved from the long-term DITM options, while the minimum implied adjusted volatility is documented by the long-term ITM options.

In general, all of the Leland models recorded almost similar results of implied adjusted volatility corresponding to each interval considered.

Following that, the dynamics of implied adjusted volatility derived from the three Leland models on the S&P/ASX 200 index options over the different intervals are measured in terms of root mean square error (RMSE) as well as standard deviation (SD). These results are recorded in Table IX. The implied adjusted volatility from all three models considered revealed to be consistent throughout the study, despite the findings of during-crisis implied adjusted volatility to be unusually high. This is supported by the significant increase in values of both RMSE and SD over the during-crisis interval.

TABLE VIII
CALL OPTIONS IMPLIED ADJUSTED VOLATILITIES DERIVED FROM THE LELAND STOCK MODEL WITH TOTAL AVERAGE ACROSS BOTH MONEYNESS AND OPTION'S MONEYNESS OVER THE DIFFERENT PERIODS: PRE-, DURING AND POST-CRISIS

Delta-Moneyness		DOTM	OTM	ATM	ITM	DITM	Total
PANEL A: Pre-Crisis							
Time to Maturity in days (T)	T≤29	0.273	0.418	0.456	0.425	0.403	**0.395**
	30≤T<49	0.373	0.403	0.435	0.422	0.384	**0.404**
	50≤T<69	0.374	0.405	0.436	0.429	0.437	**0.416**
	70≤T<89	0.363	0.401	0.428	0.438	0.447	**0.415**
	90≤T<109	0.363	0.394	0.430	0.441	0.417	**0.409**
	110≤T<129	0.358	0.386	0.405	0.446	0.396	**0.398**
	T≥130	0.372	0.368	0.397	0.419	0.431	**0.397**
	Total	**0.354**	**0.397**	**0.427**	**0.431**	**0.416**	**0.405**
PANEL B: During Crisis							
Time to Maturity in days (T)	T≤29	1.617	1.797	1.846	1.624	1.581	**1.693**
	30≤T<49	1.891	1.872	1.874	1.675	1.603	**1.783**
	50≤T<69	1.953	1.970	1.917	1.462	1.420	**1.744**
	70≤T<89	1.927	1.728	1.801	1.440	1.526	**1.684**
	90≤T<109	1.483	1.585	1.750	1.291	-	**1.527**
	110≤T<129	2.000	1.980	1.974	1.341	0.240	**1.507**
	T≥130	1.883	1.877	1.954	1.947	1.565	**1.845**
	Total	**1.822**	**1.830**	**1.874**	**1.540**	**1.323**	**1.681**
PANEL C: Post-Crisis							
Time to Maturity in days (T)	T≤29	0.626	1.315	1.945	2.000	2.000	**1.577**
	30≤T<49	0.681	1.443	1.952	2.000	2.000	**1.615**
	50≤T<69	0.753	1.495	1.994	2.000	2.000	**1.649**
	70≤T<89	0.791	1.460	1.999	2.000	2.000	**1.650**
	90≤T<109	0.753	1.265	1.956	2.000	-	**1.494**
	110≤T<129	0.827	1.547	1.957	2.000	-	**1.583**
	T≥130	0.711	1.382	1.973	2.000	-	**1.517**
	Total	**0.735**	**1.415**	**1.968**	**2.000**	**2.000**	**1.600**

DOTM, OTM, ATM, ITM and DITM stand for deep-out-of-the-money, out-of-the-money, at-the-money, in-the-money and deep-in-the-money, respectively. DOTM is defined by 0.02<Δ≤0.125; OTM by 0.125<Δ≤0.375; ATM by 0.375<Δ≤0.625; ITM by 0.625<Δ≤0.875; and DITM by 0.875<Δ≤0.98. Moneyness is tabulated based on delta (Δ). Delta for call is $\Delta_c = e^{-qT}N(d_1^*)$. The time to maturity is written as: less than or equal to 29 days is short-term, 30 to 89 days is medium-term and greater than or equal to 90 days is long-term

TABLE IX
THE AVERAGE OF CALL IMPLIED VOLATILITY RETRIEVED FROM THE DIFFERENT LELAND OPTION PRICING MODEL OVER PRE-, DURING- AND POST-CRISIS PERIOD

	Pre-Crisis		During-Crisis		Post-Crisis	
	Average	RMSE	Average	RMSE	Average	RMSE
Leland original model	0.409 (0.0682)	0.0191	1.682 (0.2369)	0.2243	1.606 (0.5097)	0.3815
Leland cash model	0.402 (0.0736)	0.0337	1.682 (0.2369)	0.2243	1.606 (0.5097)	0.3815
Leland stock model	0.405 (0.0803)	0.0287	1.681 (0.2528)	0.2252	1.600 (0.5411)	0.3879

RMSE is root mean square error. The values in parentheses are the standard deviation (SD).

In the case of Leland cash model, the maximum average of implied adjusted volatility is reported to be those of from the during-crisis interval, whereas the minimum is those of from the pre-crisis interval, with the value of 1.682 and 0.402, respectively. The value of the implied adjusted volatility from the during-crisis period is reported to increase approximately three folds from that of the pre-crisis. The value is observed to be decreasing from the during-crisis to the post-crisis period by 30 per cent. Similar findings are discovered in the case of Leland original model.

In term of SD, the results are approximately the same for all three models. The SD increases from the pre-crisis to during-crisis by an unusually high rate, followed by a brief drop on the value during the post-crisis period. The largest SD value is reported from the implied adjusted volatility derived from the Leland stock model for all three periods considered. Both of the Leland original and Leland cash models result in similar SD values especially in case of during- and post-crisis intervals.

VII. CONCLUSION

The call options for all models result in relatively the same pattern of implied volatility across both maturity and moneyness, thus realizing the put-call parity relationship. This confirms our hypothesis that the implied adjusted volatilities estimated from the different Leland option pricing models is approximately equal in value. The implied volatility escalate approximately triple the rate prior the crisis as a result of high levels of uncertainty about the future market movements. However the implied volatility reduces after the crisis, which possibly resulted from the improved market after the crisis in Australia, particularly over the course of 2009 until 2010. For future research, the volatility surfaces can be further assessed to expound the fluctuating market conditions and possible risk aversions in Australia market.

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