IMPACT OF HEDGING PRESSURE ON IMPLIED VOLATILITY IN FINANCIAL TIMES AND LONDON STOCK EXCHANGE (FTSE) MARKET

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ABSTRACT

This paper examines the impact of net buying pressure and the event of 9/11 on the implied volatility of the U.K. FTSE 100 (Financial Times and the London Stock Exchange) index options. Our findings indicate that when effects such as financial leverage, information flow and mean reversion are held constant, the net buying pressure of the out-of-the-money put options plays a dominant role in determining the shape of the implied volatility function. Further, the event of 9/11 has a transitory influence on the implied volatility change. Our results also support the notion that hedging pressure can help explain the difference between implied volatility and realized volatility.

JEL: G11, G15

INTRODUCTION

The concept of implied volatility has received considerable attention from researchers in the past few decades. This research has addressed such questions as what drives the evolution of implied volatility and what contributes to the difference between implied volatility and realized volatility? Implied volatility is an inverse function of the option pricing models given the underlying spot asset price, exercise price, the risk-free rate of return, the remaining time to expiration, and the price of the option. Market participants such as arbitrageurs, speculators, and hedgers often treat implied volatility as market expectations in making their decisions. Arbitrageurs focus on implied volatility to profit from their actions, while hedgers pay attention to implied volatility to transfer risk to speculators. Thus, implied volatility is useful for traders to price and hedge their positions.

It is widely known that implied volatility observed in the market violates the constant volatility assumption of the Black-Scholes Option-Pricing Model (BSOPM). Many researchers have presented empirical evidence to support the notion that implied volatility exhibits persistent patterns of volatilities varying by strike, known as "volatility smile or sneer". For example, implied volatility exhibited a pattern known as "a smile" (Bollen and Whaley, 2004) in both the index option markets and the individual stock option markets prior to the market crash in October 1987. After the crash however, the pattern changed to exhibit a sneeze or skewed curve (see Dumas et al., 1998; Bollen and Whaley, 2004; Chan et al., 2004). The assumption of constant volatility in the BSOPM is relaxed in studies using deterministic models (Scott, 1987; Dupire, 1994), the GARCH generalized autoregressive conditional heteroskedasticity models (Heston and Nandi, 2000; Lehnert, 2003) and stochastic models (Hull and White, 1987; Bates, 1996, 2000). However, empirical research has shown that these models fail to explain the implied volatility smile in the global market (see Lamoureux and Lastrapes, 1993; Bates, 1996; 2000; Zhi and Lim, 2002).

Other factors such as time-varying volatility, a jump in stochastic volatility, market imperfections, and hedging pressure, have been used to explain the implied volatility pattern. However, Dumas et al., 1998; Bates, 2000; Szakmary et al., 2003 show that the time-varying, jump diffusion, and stochastic volatility models also fail to explain the implied volatility smile. From the market participants perspective, the

hedging pressure theory proposed by Bollen and Whaley (2004) and documented by Chan et al. (2004), suggests that the net buying pressure of index put options caused by the limits to arbitrage mainly drives the index options premium to higher levels against a potential market crash. The result is non-constant volatility.   This explanation of the volatility smile appears to be consistent with the empirical evidence observed in the US and Hong Kong markets.

This paper follows the Bollen and Whaley (2004) framework to examine whether the net buying pressure of put options influences implied volatility based on the U.K. FTSE 100 index options.   In addition, we investigate whether the difference between implied volatility and realized volatility can be due to hedging pressure and the effects of the event of 9/11.   Since the large demand in index put options is for the purpose of hedging portfolios from market crashes, the unexpected tragedy of the event of 9/11 could enhance hedging demand and therefore affect implied volatility.   The remainder of this paper is organized as follows.   The next section describes the data followed by the research methodology.   The empirical results section discusses the impact of net buying pressure and the event of 9/11 on the implied volatility of the U.K. FTSE 100 index options.   The last section concludes the paper.

REVIEW OF RELATED LITERATURE

Studies on the U.K. FTSE 100 (Financial Times and the London Stock Exchange) index options serve as an example. By comparing the stochastic volatility, the GARCH and the BSOPM based on the FTSE 100 index options, Lehar et al. (2002) find that the performance of the GARCH, unambiguously dominated both the BSOPM and the stochastic volatility models in terms of in-sample forecasts.   However, the out-of-sample forecasts among these models showed significant differences.   The predictions from most of the models showed sizable biases.

Other research on the phenomenon of the implied volatility smile focuses on the options market microstructure (Henstchel, 2003; Bollen and Whaley, 2004 and Chan et al., 2004).   Market imperfection suggests that the small measurement error caused by finite quotations, bid-ask bounce effects, and non-synchronous prices between the index options and index value, result in large changes in the implied volatility (Henstchel, 2003).   However, Guan and Ederington (2005) show that biased implied volatility in terms of forecasting is not attributed to measurement error.   An asymmetric trading price around a bid-ask midpoint can only partially mitigate the smile of implied volatility when using the traded price to replace the bid-ask midpoint (Norden, 2003).

Shleifer and Vishny (1997) argued that the ability of professional arbitrageurs to explore mis-specified underlying financial assets is subject to the limitation of digesting the short or intermediate term loss. Liu and Lonstaff (2000) argued that margin requirements undermine the size of the potential profit taken by investors.   These examples imply that market supply and demand are imbalanced without the market makers and that the prices of options will evolve with the dynamic supply, likewise, the implied volatility.

Bollen and Whaley (2004) argue that the buying pressure stems from the large demand of institutional investors in a particular index put option.   This net buying pressure pushes market makers to increase the risk premium to hedge their increasing positions and risks.   The findings of Chan et al. (2004) on the Hang Seng Index (HIS) options support the relationship between net buying pressure and the implied volatility proposed by Bollen and Whaley (2004).   The authors discovered that net buying pressure is mainly from the demand in the OTM (out-of-the-money) put options.   Guan and Ederington (2005) empirically discuss the information frown (the information content pattern of the implied volatility is a rough image of the implied volatility smile) in the S&P 500 index options.   They find that the biased and inefficient implied volatility derived from the OTM put options can be due to hedging pressure instead of market imperfections.   This evidence also supports the net buying pressure argument in the Bollen and Whaley (2004) study.

METHODOLOGY

Data

We obtained tick-by-tick data of the options on the FTSE 100 index for the year 2001 from EURONEXT. The options on the FTSE 100 index traded on the London International Financial Futures and Options Exchange (LIFFE) are of the European style and expire on the third Friday of the contract delivery month or the last trading day preceding the third Friday, when the third Friday is not a business day. The time-stamped options transaction data contain trading time (year, month, hour, minute and second), options premiums, types (puts or calls), trading volume, strike price and expiry date. The options premium and exercise price are quoted in index points. The contract multiplier is £10 per index point (see http://www.euronext.com for more details of tick-by-tick data)

The daily data on the London inter-bank offer rates (LIBOR) was obtained from the Yahoo Finance website with the term-to-maturity ranging from overnight to three months as a proxy for the risk-free interest rate. We obtained the annualized daily dividend rates from the FTSE 100 Group as a proxy of the dividend rates. The close values of the FTSE 100 index were obtained from the http://www.econstats.com website to form the daily continuously compounded return of the underlying asset series as follows:

$$R_t = \ln(\frac{S_t}{S_{t-1}}) \tag{1}$$

where S_t and S_{t-1} are the close values of the FTSE 100 index on day t and day $t-1$ respectively. Further, we obtained data for the trading volume variable (V_t) from the UK Yahoo Financial website. We formed the trading volume of the FTSE 100 index as the sum of the trading volumes of the 87 constituents of the FTSE 100 index. Finally, to form a series of realized volatility, we obtained the price of the FTSE 100 index futures from the EURONEXT Company.

Given the above data set and the Black-Scholes (1973) formulae, we can back out the implied volatility as our dependent variable in examining the impact of net buying pressure on the implied volatility. To avoid the problems with thin trading and price distortion due to time decay, we excluded options with more than two months time remaining and options with less than four trading days remaining. The time decay effect is the phenomenon that options with a shorter time remaining until expiry deteriorate in value rapidly when holding other things constant. We also excluded options with a calculated implied volatility of more than 600% or less than 5%.

To obtain the net buying pressure on the implied volatility function, we classify the options into five different categories of moneyness for each option style—call and put respectively. Following Lehnert (2003), and Guan and Ederington (2005), we define moneyness as the ratio of the current index value to the option's strike price (i.e. moneyness = S/K, where S is the current index value and K is the option's strike price). The moneyness categories used in this study are shown in Table 1.

We obtain the realized volatility from the intraday prices of the FTSE 100 index futures based on the inverse function of the future fair price of $S = Fe^{-(R-D)T}$, where, F is the FTSE 100 index future's trading price at the trading time; R is the risk-free rate of interest; D is the dividend yield; and T is the time remaining to the expiration of the future contract which is less than three months. To be consistent with the options trading hours (8:00 to 17:30 GMT), we only use the data where trading hours range from 8:00 to 16:30 GMT. Further, the index value backed out from the index future price is preferred over the index price on the equity market for two reasons. One is that the future's price will converge to the value of the corresponding underlying expiration. The other is that relative to the cash market, the index

futures market is more likely to be chosen by the traders to hedge their option positions. I n the cash market, the FTSE 100 index value is only recorded once every fifteen minutes due to lags in reporting the transactions of the constituents in the index. Therefore, the index value from the cash market is relatively stale owing to it lagging the futures price by a few minutes.

General Framework

We adopt the Bollen and Whaley (2004) framework to evaluate the impact of net buying pressure on implied volatility, based on the UK index options market. The general model is specified as follows:

$$\Delta\sigma_t = \beta_0 + \beta_1 R_t + \beta_2 V_t + \beta_3 NBPP_t + \beta_4 NBPC_t + \beta_5 \Delta\sigma_{t-1} + \beta_6 D_{1t} + \beta_7 D_{2t} + \varepsilon_t, \qquad (2)$$

where $\Delta\sigma_t$ is the change in the average implied volatility in a moneyness category from the close on day t-1 to the close on day t, R_t is the FTSE 100 index return from the close on day t-1 to the close on day t, V_t is the trading volume on the FTSE 100 index on day t in millions of pounds, $NBPP_t$ and $NBPC_t$ are the net buying pressure on the put and call option respectively, D_{1t} takes the value of one from 11 to 30 September 2001 and zero otherwise, and D_{2t} takes value of one after 10 September 2001 and zero otherwise.

The dependent variable in equation (2) measures the change in implied volatility, $\Delta\sigma_t$. In measuring the implied volatility, the bid-ask bounce effect (i.e. the trading option's price could occur either at the bid or ask) may result in calculated implied volatility shifting between the high and the low values and hence can potentially introduce measurement error. One way to avoid the bid-ask bounce effect in computing the implied volatility is to use the option's bid-ask mid point (see Corrado and Su, 1998; Bollen and Whaley, 2004). To avoid the bid-ask bounce effect and take into account the asymmetric trading price, we compute the implied volatility using the trading price for each traded option contract within a day by using the tick-by-tick data, which are time-stamped to the second. Following this, the average implied volatility based on all the calculated implied volatilities obtained from each traded option contract within the day will serve as our proxy of the day's implied volatility.

The independent variable, R_t, detects the relationship between the implied volatility and the underlying asset return. Following Bollen and Whaley (2004) and Chan et al. (2004), we employ the return on the underlying asset as our control variable. Theoretically, the movement in implied volatility negatively correlates with the returns of the underlying asset due to the leverage effect (see Black, 1976; Christie, 1982; Fleming et al., 1995).

We include the trading volume of the FTSE 100 index, V_t, as a control variable to reflect the information flow generated jointly from the implied volatility and trading volume. The expected sign of the trading volume variable is unclear. In general, the more new information introduced into the market, the greater the trading volume and the implied volatility (see Bollen and Whaley, 2004; Chan et al., 2004).

The variable, $\Delta\sigma_{t-1}$, which is lagged behind implied volatility by one period, is included to examine mean reversion as opposed to a random walk process. If the implied volatility is mean reverted, it will be forced back to its long-run mean by either known or unknown factors whenever it moves too far away from its mean. A one lagged change in the implied volatility ($\Delta\sigma_{t-1}$) is used in our study to control the effect of the mean reversion on the change in implied volatility. However, the expected sign on this variable is unclear. Bollen and Whaley (2004) argue under the case of the limits to arbitrage, the options risk premium will converge on the long run mean risk premium when market makers gradually rebalance their positions. In this case, the coefficient of $\Delta\sigma_{t-1}$ ($\beta5$) should be negative. However, if the impact of the net buying pressure on the options risk premium is caused by the learning process (referred to as the

trading activities, which follows the market expectation of future volatility), the option price and implied volatility should behave stochastically. Hence, the change in the implied volatility caused by the change in market expectations would be independent of the previous level of implied volatility and the coefficient of $\Delta\sigma_{t-1}$ (β_5) should be zero (see Bollen and Whaley, 2004; Chan et al., 2004).

Net buying pressure is defined as the difference between the number of buyer-motivated traded contracts and the number of seller-motivated traded contracts. Bollen and Whaley (2004) define the buyer-motivated (seller-motivated) contracts as the option contracts with a trading price higher (or lower) than the middle point of the prevailing bid-ask spread. Therefore, the midpoint of the prevailing bid-ask is preferred for obtaining the observations for the net buying pressure variables in our study.

Framework for the Impact of Net Buying Pressure on IVF

In this section, we transform the general framework in equation (2) into four different models according to the option's moneyness:

$$\Delta\sigma_{all,t} = \beta_0 + \beta_1 R_t + \beta_2 V_t + \beta_3 NBPP_{all,t} + \beta_4 NBPC_{all,t} + \beta_5 \Delta\sigma_{all,t-1} + \varepsilon_t \tag{3}$$

$$\Delta\sigma_{otmc,t} = \beta_0 + \beta_1 R_t + \beta_2 V_t + \beta_3 NBPP_{otm,t} + \beta_4 NBPC_{otm,t} + \beta_5 \Delta\sigma_{otmc,t-1} + \varepsilon_t \tag{4}$$

$$\Delta\sigma_{otmp,t} = \beta_0 + \beta_1 R_t + \beta_2 V_t + \beta_3 NBPP_{otm,t} + \beta_4 NBPC_{atm,t} + \beta_5 \Delta\sigma_{otmp,t-1} + \varepsilon_{1t} \tag{5}$$

$$\Delta\sigma_{otmp,t} = \beta_0 + \beta_1 R_t + \beta_2 V_t + \beta_3 NBPP_{otm,t} + \beta_4 NBPP_{atm,t} + \beta_5 \Delta\sigma_{otmp,t-1} + \varepsilon_{1t} \tag{6}$$

Equation (3) evaluates the overall effect of the explanatory variables on the change in the implied volatility. If net buying pressure significantly affects the change in implied volatility, the coefficients, β_3 and β_4, should be significantly greater than zero. The large demand in the OTM index puts mainly drives the index options risk premium to higher levels against the potential stock market decline (Bollen and Whaley, 2004). We use equations (4) to (6) to examine the impact of the OTM puts' net buying pressure on the change in the implied volatility.

Equations (4) and (5) assess the effect of net buying pressure on both implied volatilities of the call and put options across different moneynesses, respectively. The net buying pressure of the OTM put should affect the OTM put itself and subsequently on the overall change in implied volatility regardless of option type (put or call). If these are true and can be applied to the FTSE 100 index options, β_3, the coefficient of the net buying pressure of the OTM puts in equation (4), must be significantly different from zero or greater than β_4 for the OTM calls. Conversely, β_3, the coefficient for the OTM index puts in equation (5), should be greater than β_4 since the impact of the net buying pressure on the implied volatility comes from the OTM puts instead of calls. Equation (6) determines whether the net buying pressure from the OTM puts drives the evolution of the implied volatility when controlling the effects of the net buying pressure for the ATM puts which replaced the ATM calls in equation (5).

Impact of 9/11 Event On Implied Volatility

To examine the impact of the 9/11 event on the changes in the implied volatility, we adopt the following specifications, analogous to those discussed above.

$$\Delta\sigma_{all,t} = \beta_0 + \beta_1 R_t + \beta_2 V_t + \beta_3 NBPP_{all,t} + \beta_4 NBPC_{all,t} + \beta_5 \Delta\sigma_{all,t-1} + \beta_6 D_{1t} + \beta_7 D_{2t} + \varepsilon_t \tag{7}$$

$$\Delta\sigma_{otmc,t} = \beta_0 + \beta_1 R_t + \beta_2 V_t + \beta_3 NBPP_{otm,t} + \beta_4 NBPC_{otm,t} + \beta_5 \Delta\sigma_{otmc,t-1} + \beta_6 D_{1t} + \beta_7 D_{2t} + \varepsilon_t \tag{8}$$

$$\Delta\sigma_{otmp,t} = \beta_0 + \beta_1 R_t + \beta_2 V_t + \beta_3 NBPP_{otm,t} + \beta_4 NBPC_{atm,t} + \beta_5 \Delta\sigma_{otmp,t-1} + \beta_6 D_{1t} + \beta_7 D_{2t} + \varepsilon_t \tag{9}$$

$$\Delta\sigma_{otmp,t} = \beta_0 + \beta_1 R_t + \beta_2 V_t + \beta_3 NBPP_{otm,t} + \beta_4 NBPP_{atm,t} + \beta_5 \Delta\sigma_{otmp,t-1} + \beta_6 D_{1t} + \beta_7 D_{2t} + \varepsilon_t \tag{10}$$

The dummy variable D_{1t} is designed to examine whether the implied volatility has signal to the salient event as well as the succeeding market shock, whereas the dummy variable, D_{2t} is designed to examine whether the effect of the 9/11 event is transient.

The impact of the 9/11 event transferred to the implied volatility via the net buying pressure could vary in the pre-9/11, post-9/11, and during the period of 9/11. For example, if the market is more volatile during the period of 9/11 which is [9/9, 9/30], then the coefficient, β_6, should be significantly different from zero. If the impact of the net buying pressure caused by the event of 9/11 is transient, then β_7 should not differ from zero.

Bias between Implied Volatility and Realized Volatility

To determine whether the hedging pressure causes the bias between implied volatility and realized volatility, we follow Szakmary et al. (2003), Bollerslev and Zhou (2004), and Guan and Ederington (2005) information content method with the following equations:

$$RV_t = \gamma_0 + \gamma_1 IV_t + \varepsilon_t \tag{11}$$
$$RV_t = \gamma_{01} + \gamma_{11} IV_{1t} + \varepsilon_t \tag{12}$$
$$RV_t = \gamma_{011} + \gamma_{111} IV_{11t} + \varepsilon_t \tag{13}$$

where RV_t is the realized volatility, IV_t is the implied volatility before isolating the effects of hedging pressure, IV_{1t} is the implied volatility after isolating the effects of hedging pressure, and IV_{11t} is the implied volatility after isolating the effects of market imperfections.

In equations (11) to (13), the actual daily realized volatility is defined as the annualized standard deviation of the natural logarithm of the FTSE 100 index return change as:

$$RV_t = \sqrt{365 \times [\frac{1}{N-1} \sum (R_t - \overline{R})^2]} \tag{14}$$

where $R_t = \ln(\frac{S_t}{S_{t-1}})$.

Guan and Ederington (2005) argue that under the case of market efficiency, the realized volatility (RV_t) fluctuates around the market expectation (EV_t) and specifies as:

$$RV_t = EV_t + \varepsilon_t \tag{15}$$

Further, if assumptions made in Black and Scholes (1973) are true, implied volatility would be completely consistent with market expectations and hence the following equation holds:

$$IV_t = EV_t \tag{16}$$

As noted by Guan and Ederington (2005), combining equation (11) with (15) and (16), the coefficient in equation (11), γ_1, which exhibits the ability of the implied volatility to capture the information before

isolating the effect of hedging pressure, should be equal to one. The expected value of R^2 equals $\dfrac{Var(EVt)}{Var(EVt)+Var(\varepsilon t)}$ (where R^2 is the fraction of the sample variance of the dependent variable explained by the independent variable). However, Guan and Ederington (2005) further argue that implied volatility is influenced by factors other than market expectation, and hence equation (16) should no longer hold, but instead:

$$IV_t = EV_t + \eta_t \tag{17}$$

Suppose one of the factors influencing implied volatility is hedging pressure. According to Guan and Ederington (2005), the estimated coefficient of IV_t in equation (11), γ_1, which is equivalent to $\dfrac{Var(EVt)}{Var(EVt)+Var(\eta_t)}$, would be downward biased from one if the variances of η_t were different cross-sectionally. The R^2, which is equivalent to $(\dfrac{Var(EVt)}{Var(EVt)+Var(\eta_t)})(\dfrac{Var(EVt)}{Var(EV_t)+Var(\varepsilon_t)})$, is also downward biased from $\dfrac{Var(EVt)}{Var(EVt)+Var(\varepsilon t)}$.

Accordingly, if the impact of hedging pressure on implied volatility is true, the calculated implied volatility with the effects of the net buying pressure from the index puts will not converge to one unless the market makers completely rebalance their position. In other words, the ability of the implied volatility contaminated by the hedging pressure is weakened in terms of capturing the market information. We adopt the following two-stage least squares technique to estimate the information content in implied volatility. Firstly, we regress the contaminated implied volatility equation on the instrumental variable (Z_t) as follows:

$$IV_t = \gamma_0' + \gamma_1' Z_t + \varepsilon_{t3} \tag{18}$$

Secondly, we use the problem-free estimators $(\gamma_0' + \gamma_1' Z_t)$ to proxy for the variable of the contaminated implied volatility, IV_t, in equation (11). Since the contaminated part has been isolated, the expected value of the coefficient of the variable (IV_{t1}), γ_{11} in equation (12), is greater than γ_1 in equation (11). In general, it is unrealistic to expect γ_{11} to be one because only the impact of the hedging pressure is isolated. It is possible that the implied volatility is influenced by other factors than the hedging pressure, such as market imperfections caused by non-synchronous prices, bid-ask bounce effect, and other unknown factors.

The instrumental variables method can also be used to examine the impact of market imperfections on implied volatility via equation (13). We use the averaged implied volatilities from the OTM and DOTM calls as our instrumental variable (i.e. $Z_t = 1/2(IV_{OTMC, t} + IV_{DOTMC, t})$) when examining the impact of net buying pressure on the implied volatility (see Bollen and Whaley, 2004; Guan and Ederington, 2005). For the impact of market imperfections on the implied volatility, we follow Guan and Ederington (2005) using the one-lagged implied volatility $(Z_t = IV_{t-1})$ as the instrumental variable.

EMPIRICAL RESULTS

Summary of Data

Table 1 reports the average implied volatilities and the daily net buying pressure of the FTSE 100 index options over the year 2001 in terms of the moneyness category. The results show the IVF index of the puts is decreasing monotonically across the S/K-ratio categories. On the contrary, the IVF index of the calls is increasing monotonically across the same categories. Table 1 also shows that the index IVF, regardless of the option type, decreases from Category 1 to the lowest point of Category 3. From this point onward, the IVF increases to the level of Category 5, similar to Category 1. The implied volatility of the Category 1 options (DOTM puts and DITM calls) is 112.42%, which is 160.38% higher than the average implied volatility of Category 3 (DITM puts and DOTM calls) 42.82%. In general, the three different patterns in the shapes of the FTSE 100 index options can be due to the more expensive calls corresponding to the lower strikes and the more expensive puts corresponding to the higher strikes. As a result, the IVF of puts skewed more rightward, but the calls skewed more leftward in terms of categories based on the S/K-ratio.

In addition, the data in Table 1 shows that the daily net buying pressure of the put options is about 14% higher than that of call options. Among the put options, the more out-of-the money, the greater the net buying pressure. The OTM put option (Category 4) has the highest daily average net buying contracts at 91, and the highest net purchase ratio of 8.4%. That is, 52% of total net buying pressure of put options is due to the OTM put options.

Further, Table 1 also demonstrates that the net buying pressure of both put and call options correlate with the change in the implied volatility of all options. There is also an intriguing outcome, where the net buying pressure positively correlates with the change in the implied volatility for all the moneneyness put options except Category 1. On the contrary, the net buying pressure negatively correlates with the change in the implied volatility for most of the call options. Furthermore, the OTM put options (Categories 4 and 5) show greater correlation between net buying pressure and the change in implied volatility than do the ITM put options (Categories 1 and 2), while the opposite is true for the call options. For example, the correlation for the OTM put options is 0.193 but only 0.0733 for the ITM put options; inversely, the figure is 0.0091 for the OTM call options but -0.2652 for the ITM call options. Furthermore, when combining the last three columns of Table 1, it is interesting to note that for the call options, the greater the net buying pressure, the less the correlation between net buying pressure and the change in the implied volatility.

Empirical Evidence of Impact of Net Buying Pressure on Implied Volatility

Table 2 shows the signs of coefficients for the control variable (R_t) are mixed and most of them are not significant. Only the sign of the coefficient for the variable R_t in equation (3) is negative at the less than 1% level of significance. These findings are consistent with the Figlewski and Wang's (2000) results but inconsistent with the results of Bollen and Whaley (2004) and Chan et al (2004). Thus, our evidence suggests that financial leverage had no relationship with the change in implied volatility for the FTSE 100 index during the sampling period in the year 2001. One possible explanation for these empirical results is that the leverage effect on the return volatility is asymmetrical (Dumas, Fleming and Whaley, 1998). The higher ratio of equity to debt has a powerful effect on return volatility, while the lower ratio of equity to debt affecting return volatility is weak. Since Bollen and Whaley (2004) used a long period sampling data (June 1988 through December 2000) and the S&P 500 index value tended to increase during this period, the financial leverage with the higher ratio of equity to debt severely affected the return volatility. Chan et al (2004) also adopted a long sampling period of 1993 to 2000 and the HSI experienced an upward trend. Their results are similar to Bollen and Whaley's (2004) findings. On the contrary, our

sampling period is only one year and as the FTSE 100 index value tended to decrease dramatically, the financial leverage with the lower ratio of equity to debt had almost no affect on the change in the implied volatility.

Table 1: Average Implied Volatility, Daily Net Buying Pressure and Correlation between Net Buying Pressure and Change in Implied Volatility across Different Moneyness

S/K-Ratio Interval	Code	Options Type	Moneyness	Abbreviation	Average Implied Volatility	NBP Contracts	NBP Ratio (%)	ρ
<0.925	1	c	Deep-out-of-the-money	DOTM	23.561	47	4.34	-0.0106
		p	Deep-in-the-money	DITM	201.28	7	0.64	-0.0091
		All Option Types			112.42	54	4.99	
[0.925, 0.975)	2	C	Out-of-the-money	OTM	30.668	65	6.00	0.0091
		P	In-the-money	ITM	84.698	-1	0.09	0.0733
		All Option Types			57.683	64	5.91	
[0.975, 1.025]	3	c	At-the-money	ATM	41.409	19	1.75	-0.0846
		p	At-the-money	ATM	44.239	57	5.26	0.2494
		All Option Types			42.824	76	7.02	
(1.025, 1.075]	4	c	In-the-money	ITM	85.212	-6	0.56	-0.2652
		p	Out-of-the-money	OTM	36.082	91	8.40	0.1930
		All Option Types			60.647	85	7.85	
>1.075	5	c	Deep-in-the-money	DITM	185.45	29	2.68	-0.1177
		p	Deep-out-of-the-money	DOTM	37.562	21	1.93	0.0412
		All Option Types			111.51	50	4.62	

This table reports the five categories of the option moneynesses. The classification is based on the ratio of S to K. S is for the FTSE 100 index price on day t in 2001 and K for the strike price of the options on FTSE 100 index at the expiry day. In addition, c is for the European call options on the FTSE 100 index and p for European put options. For the calls, the greater the S/K is, the more likely to be exercised on the expiry day. The reverse is true for the puts. The average implied volatility based on the FTSE 100 index options across the moneynesses, the daily net buying pressure, and the correlation between the net buying pressure and change in the implied volatility (ρ) are reported in the last four columns of the table. The daily average net purchase of the options in terms of the number of net buying contracts is defined as the number of buyer-motivated contracts less the number of seller-motivated contracts. The net buying ratio in terms of absolute percentage value is defined as net purchase contracts divided by daily total trading contracts.

The data in Table 2 shows the signs of the coefficients for the variable V_t are also mixed and all are insignificant. To check whether these results are sensitive to the tremendous trading volume, we use the natural logarithm of the trading volume to run the regression and the results are identical. This evidence supports the results of Bollen and Whaley's (2004) study using a different index option based on a different sample period. In their study, in spite of the corresponding estimates for most of the individual stocks being positively significant, five of six coefficients of the trading volume for the S&P 500 index in their six regressions were negatively insignificant. This evidence suggests that the information effect for the individual equity market does not always happen to the aggregate equity market. Our findings that the trading volume has no influence on the change in the implied volatility reconfirm that the aggregate market does not follow the learning process.

The results in Table 2 offer a number of interesting insights into the impact of the net buying pressure on the change in the implied volatility. The results of equation (3) show that the coefficient estimate of the net buying pressure of put options, β_3, is positive and significant at the less than 5% level of significance. On the contrary, β_4, the coefficient estimate of the net buying pressure of call options, is not significant. In

addition, the results show that β_3 is significantly greater than β_4. This evidence suggests that the net buying pressure of put options has greater influence on the implied volatility movement than does the net buying pressure of call options.

In equation (4), the results show the coefficient estimates of the net buying pressure for both OTM put and call options, β_3 and β_4, are positive but not significant. To make our testing more robust, we also used the net buying pressure of the ATM call and put options to run the regression with the same results. These findings suggest that the net buying pressure of options does not affect the change in implied volatility for the OTM call options. This evidence is inconsistent with the results of past studies (Bollen and Whaley, 2004; Chan et al., 2004). There are two possible explanations for our findings differing from the two previous empirical results. One is that, as discussed previously, the impact of the net buying pressure on the implied volatility is not even across all moneyness options. In particular, the net buying pressure does not affect the change in the implied volatility for the OTM call options. The other is that our research is based on the FTSE 100 index options with a downward trend (bearish market) over the period of 2001, whereas the two previous studies were based on the S&P 500 index and HSI options with upward trends (bullish markets) over several years respectively.

With respect to equation (5), the fourth column of Table 2 shows that the coefficient of the net buying pressure for the OTM put options, β_3, is 0.006002 with a t-statistic of 3.81, which is significant at the less than 1% level of significance. However, the estimate of β_4 for the ATM call options is negative but not significant. This evidence is consistent with the results of the previous studies (Bollen and Whaley, 2004; Chan et al, 2004). It proposes that the net buying pressure of the OTM puts influences the change in the implied volatility of the OTM put option itself relative to that of the ATM call option. In addition, the equality of these two coefficients ($\beta_3=\beta_4$) in equation (5) is strongly rejected at the 1% level of significance by executing the Wald coefficient restriction test. This means the net buying pressure is due to the limits to arbitrage instead of the learning process since β_3 is significantly greater than β_4. As discussed above, if the investors' trading activity follows the expectation of future volatility, there is no reason for them to prefer one moneyness option to another. Furthermore, the ATM option should carry more weight in determining the shape of the implied volatility since it is more sensitive to volatility. Since our ATM option ranges from 0.975 to 1.025 according to the S/K-ratio, the ATM options are regarded as moneynesses that are more informative. On the contrary, the limits to arbitrage result in the net buying pressure on the OTM puts being more important than others due to hedging the market crash.

Comparing equation (5) to equation (6), the only change is replacing the ATM call options in equation (5) for the ATM put options in equation (6) (see Table 2). Therefore, equation (6) is an attempt to further test whether the change in the implied volatility for the OTM put option stems from the net buying pressure of the put option when holding the net buying pressure of the OTM put options constant. The results of the coefficient estimates (β_3 and β_4) of the net buying pressures of both OTM and ATM put options are 0.004825 and 0.006472 respectively with significance of less than 1%. When these results are compared to the corresponding results of equation (5), the net buying pressure of the ATM put options influences the change in the implied volatility of the OTM put options more than does the net buying pressure of the ATM call options. The net buying pressure of the put options has more weight in determining the shape of the implied volatility for the FTSE 100 index options (see Table 2). All the coefficient estimates of one lagged change in the implied volatility corresponding to the option sources are negative and significant at the less than 1% level. They hover around a value of -0.428 regardless of option type and moneyness. This means the price will return to about 40% of the previous level on the next trading day. Hence, the net buying pressure is caused by the limits of arbitrageurs instead of the learning process and its impact on the change in the implied volatility is transitory.

However, the above results could be due to measurement error. Bollen and Whaley (2004) argue that the changes in the implied volatility for $\Delta\sigma_t$ and $\Delta\sigma_{t-1}$ are based on three consecutive days. Therefore, the

implied volatility for day t-1 has to be used twice with the opposite sign in the calculation of both $\Delta\sigma_t$ and $\Delta\sigma_{t-1}$. To some degree there will be a negative serial correlation in the observed change in implied volatility due to the measurement error including the bid-ask spreads and the non-syncronous record between the index and option price.

Table 2:   Impact of Net Buying Pressure on Implied Volatility

Equation	3	4	5	6
Dependent Variable	$\Delta\sigma_{all,t}$	$\Delta\sigma_{otmc,t}$	$\Delta\sigma_{otmp,t}$	$\Delta\sigma_{otmp,t}$
NBP$_1$ Source	All put	OTM put	OTM put	OTM put
NBP$_2$ Source	All call	OTM call	ATM call	ATM put
β_0	1.892331	-26.47512	1.320781	0.941685
	(0.621)	(-1.283)	(0.486)	(0.355)
β_1	1.522972***	-2.90083	0.265344	0.154311
	(-3.154)	(-0.885)	(0.602)	(0.357)
β_2	-3.98E-11	4.45E-10	-2.94E-11	-2.85E-11
	(-0.778)	-1.285	(-0.645)	(-0.641)
β_3	0.001296**	0.00765	0.006002***	0.004825***
	(2.193)	(0.642)	(3.814)	(3.058)
β_4	0.001163	-0.004436	-0.001934	0.006472***
	(1.193)	(-0.433)	(-0.696)	(3.328)
β_5	-0.384998***	-0.492087***	-0.427709***	-0.420164***
	(-6.372)	(-8.502)	(-7.013)	(-7.048)
R^2	0.198617	0.253182	0.211952	0.24731
Adj- R^2	0.180648	0.236586	0.19444	0.230583
Numbers of Observations	229	231	231	231
F-Statistic($\beta_3=\beta_4$)	0.012251	0.54441	6.150947***	0.355084

*This table reports the empirical results of the impact of the net buying pressure on the change in the implied volatility in different moneyness categories according to equations (3) through (6). The dependent variable is change in implied volatility. The independent variables are return on the underlying asset, r_t, trading volume of the FTSE 100 index, v_t, net buying pressure variables, NBP_1 and NBP_2, and one-period lag of implied volatility, $\Delta\sigma_{t-1}$. The coefficients of independent variables are as follows. β_0 is the intercept term. β_1 to β_5 are coefficient of r_t, V_t, NBP_1 and NBP_2, and $\Delta\sigma_{t-1}$, respectively. The *, **, and *** denote significant level of 10%, 5% and 1% respectively. T-statistics are reported in parentheses.*

Table 3 summarizes the results of equations (7) through (10) including the impact of 9/11 on the change in the implied volatility.   Table 3 offers a number of intriguing findings.   Note first that the estimates of the coefficients of the net buying pressure in equations (7), (9) and (10) are significantly positive, which is consistent with the results in equations (3), (5) and (6).   The magnitudes of the net buying pressure of the OTM put options increase by about 1%, 2.25% and 3.03% respectively.   This suggests that the tragedy of 9/11 exerted net buying pressure on the change in implied volatility through the net buying pressure of the OTM put options. The estimates of coefficients β_6 and β_7 represent the dummy variables (D$_{1t}$, 1 for the period of [9/9, 9/30] and zero otherwise; dummy D$_{2t}$ is one for after 9/10, 0 otherwise), and

further confirms that the 9/11 event exerted net buying pressure on changes in the implied volatility. The results in Table 2 show the signs of β_6 are mixed but negative for β_7 in equations (7) through (10). However, the estimate of β_6 in equation (9) is about 4.98 with a less than 5% level of significance. The estimate coefficient β_6 in equation (10) is about 4.25 and significant at the less than 10% level of significance. The findings indicate that the effect of the tragedy of 9/11 occurring in the US did spillover to the UK index option market during the period of [9/9, 9/30] and the ensuing jump fear made the market more volatile through the net buying pressure of the OTM put options. However, the shock was transitory. This is confirmed by estimates of the coefficients β_7 in equations (7) through (10) being non-significantly different from zero.

Table 3:   Impact of 9/11 Event on Implied Volatility via Net Buying Pressure

Equation	7	8	9	10
Dependent Variable	$\Delta\sigma_{all,t}$	$\Delta\sigma_{otmc,t}$	$\Delta\sigma_{otmp,t}$	$\Delta\sigma_{otmp,t}$
NBP_1 Source	All put	OTM put	OTM put	OTM put
NBP_2 Source	All call	OTM call	ATM call	ATM put
β_0	2.951928	-29.1396	2.750469	2.085402
	(0.864)	(-1.345)	(0.972)	(0.753)
β_1	-1.477515***	-2.92329	0.351762	0.237305
	(-3.035)	(-0.886)	(0.798)	(0.548)
β_2	-3.98E-11	5.11E-10	-5.42E-11	-4.67E-11
	(-0.723)	(1.353)	(-1.103)	(-0.97)
β_3	0.001309**	0.00731	0.006137***	0.004971***
	(2.184)	(0.609)	(3.909)	(3.146)
β_4	0.001217	-0.00442	-0.002038	0.006203***
	(1.243)	(-0.43)	(-0.736)	(3.179)
β_5	-0.387558***	-0.49142***	-0.439837***	-0.43119***
	(-6.39)	(-8.454)	(-7.213)	(-7.216)
β_6	1.736652	-5.64257	4.983275**	4.253643*
	(0.446)	(0.093)	(4.194)	(3.16)
β_7	-1.124654	-2.23426	-0.909519	-1.03182
	(0.624)	(0.055)	(0.536)	(0.719)
R^2	0.177752	0.253847	0.226633	0.258356
Adj- R^2	0.151708	0.230425	0.202357	0.235076
Numbers of Observations	229	231	231	231
F-Statistic($\beta_3=\beta_4$)	0.005717	0.506807	6.581213***	0.196475

*This table reports the empirical results of the impact of 9/11 event on the change in the implied volatility in different moneyness categories via net buying pressure according to equations (7) through (10). The dependent variable is change in implied volatility. The independent variables are return on the underlying asset, r_t, trading volume of the FTSE 100 index, v_t, net buying pressure variables, NBP_1 and NBP_2, one-period lag of implied volatility, $\Delta\sigma_{t-1}$, and dummy variables, $\Delta\sigma_{t-1}$, and D_{2t}. If the data period is between 9/9 and 9/30, D_{1t} takes the value of one on day t, and zero otherwise. D_{2t} is equal to one for the period of post-9/11, zero otherwise. The coefficients of independent variables are as follows. β_0 is the intercept term. β_1 to β_7 to are coefficient of r_t, v_t, NBP_1 and NBP_2, $\Delta\sigma_{t-1}$, D_{1t}, and D_{2t}, respectively. The * , ** , and *** denote significant level of 10%, 5% and 1% respectively. T-statistics are reported in parentheses.*

In summary, the above tests demonstrate strong statistical support for the contention that the net buying pressure of put options drives the implied volatility higher against a market crash when controlling for the effects of financial leverage, information flow and mean reversion. Furthermore, the nature of the change in the implied volatility is options specific for the FTSE 100 index options. Net buying pressure of the OTM put options plays a dominant role in determining the shape of the implied volatility.

<u>Hedging Pressure as an Explanation of Bias of the Implied Volatility from the Realized Volatility</u>

The correlation between the net buying pressure of the put options and the implied volatility minus the realized volatility is approximately 0.15. The coefficient is approximately 0.11 for the correlation between the net buying pressure of the call options and the implied volatility less realized volatility. This suggests that that implied volatility biased away from realized volatility is most likely caused by the net buying pressure of the put options when considering the net buying pressure of the call options, which has no influence on the change in the implied volatility as shown in the previous section.

Table 4 reports the empirical results of equations (11), to (13). The F-statistics of 223 and 165.82 indicate that the impacts of both of our instrument variables are not weak. According to Stock and Watson (2003), if the first-stage F-statistic exceeds 10, the instrument should not be weak. Our findings from Table 4 show that γ_1, the estimate of the coefficient of IV_t in equation (11), is about 0.17 with a t-statistic of 1.8, which is significant at the less than 10% level of significance. However, γ_{11}, the estimate of the coefficient of IV_{t1}, is approximately 0.33 and significant at the less than 1% level of significance. Therefore, after using the instrument variable to isolate the effect of hedging pressure on the implied volatility of all options, γ_{11}, the coefficient of the implied volatility, increased by about 17% relative to γ_1. In addition, the R^2 in instrumental variable regression (12) also increased by nearly 20% relative to OLS regression (11). This evidence suggests that hedging pressure does contribute to implied volatility biasing away from the realized volatility.

In contrast, the instrumental estimates based on the instrumental variable $Z_t = IV_{t-1}$ in equation (13) is about 0.2, but not significant. The R^2 is about 0.02, which is almost the same as the OLS in equation (3). This evidence suggests that there is no obvious measurement error effect. The result also confirms that the mean reversion cannot be due to the measurement error discussed previously.

Our findings from these two instrumental variables tests indicate that the difference between implied volatility and realized volatility is caused by net buying pressure rather than measurement error. However, hedging pressure is not able to be completely responsible for their difference because the coefficient restriction tests strongly reject both $\gamma_1 = 1$ and $\gamma_{11} = 1$. Therefore, there are other unknown factors contributing to the difference between implied volatility and realized volatility.

Table 4:   Bias between Implied Volatility and Realized Volatility

Equation	11	12	13
Independent Variable	IV_t	IV_{t1}	IV_{t11}
Coefficient Value	0.169678*	0.327599***	0.202429
T-Statistic	(1.80)	(6.16)	(1.51)
R-Squared	0.021897	0.219752	0.019202
Adjusted R-Squared	0.015151	0.213559	0.011828
First Stage F-Statistic		223.3963	165.8223
Number of Observations	147	128	135
F-Statistic(γ=1)	77.73368	159.8399	35.31285

*This table reports the empirical results of the information contained in the implied volatility according to the equations (11) through (13) and estimated using the two-stage least squares regression via instrumental variables method. The * , ** , and *** denote significant level of 10%, 5% and 1% respectively. T-statistics are reported in parentheses.*

CONCLUSIONS

In this paper, we adopt the Bollen and Whaley (2004) framework to examine whether the net buying pressure of put options influences implied volatility based on the U.K. FTSE 100 index options.   Further, we investigate whether the hedging pressure and the effects of the 9/11 event on implied volatility can explain the difference between implied volatility and realized volatility.   Finally, we examine whether the biases in using implied volatility to forecast volatility is due to hedging pressure based on the instrumental variable regression.

Our findings are generally consistent with the results from Bollen and Whaley (2004) and Chan et al (2004) and hence support the hedging pressure theory in the UK market.   The empirical results show that the FTSE 100 index options-based implied volatility derived from the BSOPM exhibits the classical smile surface during the period of year 2001.   The implied volatility function displays a steep slope.   The tests statistics show that put options are under heavier net buying pressure relative to call options. The OTM put options have the highest net buying pressure.

Our regression results indicate that the evolution of implied volatility is options specific.   Put options, particularly the OTM put options, play a dominant role in determining the shape of implied volatility. Based on the results of a negative correlation between implied volatility and its lagged one, and that the change in implied volatility is sensitive to both options type and moneyness specific, the net buying pressure is caused by the limits to arbitrage instead of the learning process.

In addition, we find that the salient event of 9/11 influenced the change in implied volatility for the OTM put options.   The impact is transitory because the dummy variable estimate is significantly positive only during the period of 9/9 through 9/30.   This evidence is also consistent with the mean reversion. Finally, our results show that the difference between implied volatility and realized volatility stems from the net buying pressure instead of measurement error.   Therefore, hedging pressure can explain the steep slope of the implied volatility.

In this paper, we only consider the implied volatility of options where the underlying asset is the stock index.   It is therefore interesting to extend this research to consider the behavior of implied volatility for option on individual stocks and examine whether any significant differences exist in the underlying asset, which is not the stock index.   Finally, another possible venue of future research is to extend this study to international markets and to more recent.

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