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隨機過程能否解釋隱含波動率的形態？以台灣衍生性金融市場為例

DOES THE STOCHASTIC PROCESS EXPLAIN THE BIZARRENESS OF IMPLIED VOLATILITY FUNCTION? EVIDENCES FROM TAIWAN DERIVATIVE MARKETS

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摘要

隱含波動率微笑現象始終為選擇權理論探討話題，部份學說相信此是因罕見事件其實比想像中還常見的報酬率胖尾分配所造成，另說則相信此是因選擇權所連結資產報酬率的變異數異質性所造成。本研究以台灣指數與個股選擇權市場為對象，實證結果認為經濟性因素，如選擇權合約供需數量與淨買壓，才是形成隱含波動率形態的主要原因。實證結果亦顯示，報酬率分配與隱含波動率形態無顯著關係；造市者因應市場需求以進行避險的限制套利假說獲得支持；模擬分析中產生的超常報酬，會隨選擇權合約價格深度不同而不同，與隱含波動率並非水平直線情況吻合。

關鍵字：隱含波動率、淨買壓、選擇權、微笑

ABSTRACT

The mysterious smile shown on implied volatility (IV) function of options has lastingly been discussed. A major stream of studies attributes the smile is reproduced by the transformed return distributions due to higher chance of rare events; some literature attribute the smile is caused by the dynamic variance of underlying asset. However, this study, based a Taiwan case of index and individual stock options market, advocated a more economic reason related with a strength of supply and demand, the net buying pressure (NBP), which is the main factor to affect the shape of IV function especial for index options. The analysis revealed that, the return distribution of underlying asset is not necessarily related with IV; the market maker hedges itself referring to demand of contracts thus the limits to arbitrage hypothesis is supported; the abnormal return generated from simulations supported that price premium shall be collected by different series of contracts and a non- horizontal IV as well.

Keywords: Implied Volatility, Net Buying Pressure, Options, Smile

1. Introduction

Back to 2007, the crunch of subprime mortgage and its sequential turmoil the so called Financial Crisis have caused a tremendous impact on global economics. As an emerging market, Taiwan was inevitably influenced by this crisis like other major markets. Figure 1 showed that the Taiwan stock exchange capitalization weighted stock index, TAIEX, felled to the trough of 3,955.43 points on Nov.-21, 2008. Comparing to its acme 9,309.95 points in the same year, TAIEX dropped 58%. In this figure, we can see a negative relationship between index and volatility. Whaley (2000) asserted that the volatility is a gauge of fear thus it shall go up if the prospect of underlying asset is gloomy. Generally, the mentioned Financial Crisis have surged the Taiwan markets since 2007 to end of 2010.

In periods like financial crunch, investors shall particularly be aware on hedging possessed portfolio and as a consequence, the demand on either futures or options will increase, which will drive the contracts price up as well. In another words, such price increasing can be seen as that investors are willing to pay additional cost for insurance. However, such a price increment will conflict to the Black-Scholes settings- the variance of underlying asset is constant thus should be no premium being found; the supply curve is horizontally flat as the offering quantity is unlimited for any series of contracts. If the Black-Scholes settings are true, the market maker should be vulnerable in facing with prudent arbitragers especial in long lasting bullish or bearish market.

An intriguing phenomenon of volatility 'smile' or 'smirk' may provide clues to above poser. In real markets, the price of option contracts usually deviates from the Black-Scholes price and mostly it will be higher especial contracts not the at-the-money series. If we convert the contract price to level of volatility (an implied one) and diagram it with axis of execution price, the 'smile or smirk can be reproduced; this reproduced curve is generally called implied volatility (IV) function. IV is a start point to contemplate posers left behind Black-Scholes model; furthermore, we shall discuss the background factors in forming IV.

In this study, we tested whether the hypothesis of net buying pressure (NBP) affecting IV of Taiwan market; we measured the NBP belonging to respective contract series and discussed the affecting strength behind. As a general concept, high NBP is tantamount to high volatility and high contract price; we tried to identify who is the initiator, the market maker or the market itself, to influence NBP and option price as well. We conducted simulations to see possible gain / loss of market maker when issuing different series of contracts. As explained, the event of Financial Crisis is utilized for polarized outcome to help us getting more insightful yield.

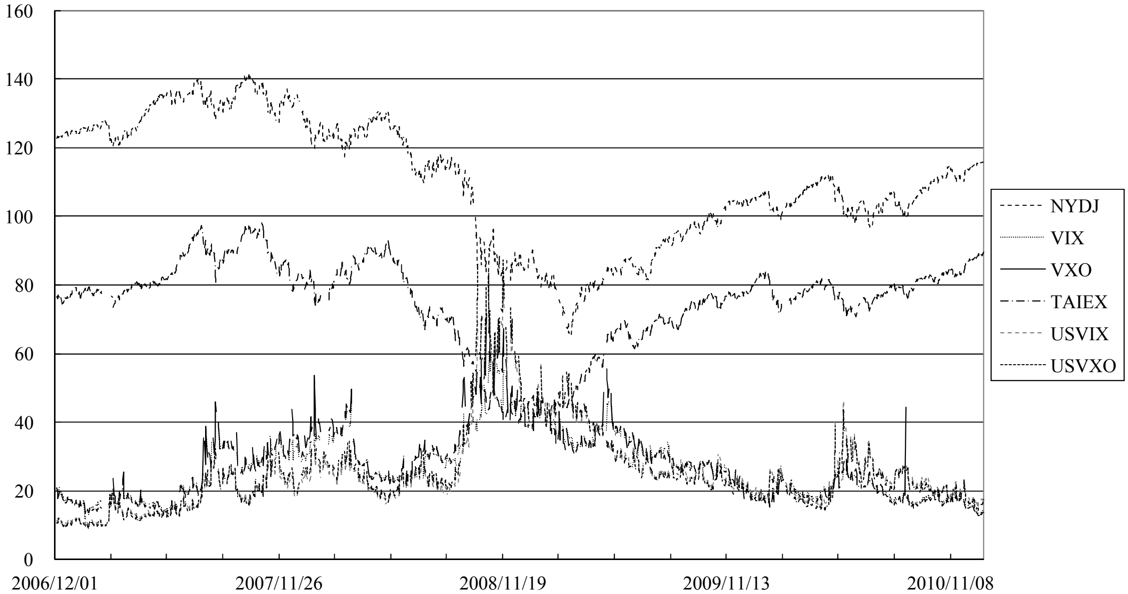


Figure 1　Trend chart of stock index and volatility of Taiwan and U.S.

NYDJ is the New York Dow-Jones stock index; USVIX and USVXO are the volatility indices bulletined by Chicago Board Options Exchange (CBOE); TAIEX is the Taiwan stock index; and the VIX and VXO are the volatility indices bulletined by Taiwan Futures Exchange (TFE). The period is from Dec., 1st, 2006 to Dec., 31st, 2010.[1a]

A bottleneck of stochastic modeling in explaining the IV has emerged since it did not meet with reality well. In this research, we are trying to adopt economic orientation in approaching the entity of IV. If this temptation succeeded, more strategic implication could be learned by the investors than purely mathematical expressions.

2. Literature Backgrounds

The shape of smile or smirk IV revealed that the buyers are willing to pay higher price for series of either in-the-money or out-of-money options; however, it could also indicate an error between practical and theoretical prices. To identify which one is true, researchers adopted mostly dichotomous approaches, the deterministic and stochastic ways for analysis. In a deterministic way, Cox and Ross (1976) exploited a new parameter in the stochastic differential equation to represent the leverage effect; their new settings enabled the variance of underlying asset changing with elasticity instead of being constant. In the same stream, Dupire (1994) used local Lévy process to generalize the local volatility function. In the sample, Dupire's model can nicely reproduce the option price with strikes.

A major merit of stochastic models is to avoid arbitrary settings. Duan (1996) incorporated GARCH process in pricing model and acquired good fitness with implied volatility when out of sample by means of Monte Carlo simulation. Heston and Nandi (2000) focused on the stochastic process of underlying asset and reformed the partial differential equation (PDE). Singh and Pachori (2013) compared dominant stochastic models for empirical test on Indian market; the jump model is preferred since it can capture spiky events like elections or other turmoil. Chernov, Gallant, Ghysels, and Tauchen (2003) advocated the 'affine model' incorporating with stochastic volatility and jump process since it fits the derivative price well. To sum up, either deterministic or stochastic models all elaborate to mimic the market behavior; they can be categorized as the market-based model (Koichi, 2007).

The market-based model, however, is still suffered with some shortcomings. Firstly, it performs well when in the sample but does no better than the constant volatility model while out the sample (Emanuel & MacBeth, 1982). Dumas, Fleming, and Whaley (1998) noticed the capriciousness of parameters through time of determinant models, an obvious drawback belonging to the determinant model. Bates (2000) affirmed that the incorporation of jump can imitate the market price better; but in achieving good fitness the parameters have to be set to unreasonable levels. Daouk and Guo (2004) commented that GARCH model has mispricing problem especial under situations like regime switch (ex. the Markovian shift on volatility) and volatility asymmetry (ex. the leverage effect). To sum up, whether determinant or stochastic models are more or less the Ornstein-Uhlenbeck based therefore it eventually implies a horizontal flat IV.

A well known fact is that the option contracts can be utilized as insurance for portfolios. To be more general, when the tendency of bullish or bearish of market get stronger, the demand on a particular series of option contract will be heaved as well as its price. In this study we followed the path of Bollen and Whaley (2004) and Chan, Cheng, and Lung (2006) who set the IV a function of net buying pressure (NBP); if demand on a certain series of contract raises high, the price will be high with a slopped curve. The path we followed is more affiliated with economic approach instead of the financial engineering means. Be noted that the NBP based theory is widely used in edging issues. Chan, Chen, and Lung (2010) analyzed the relation between business cycle and NBP in depicting the return of S&P 500 futures option; Larkin, Brooksby, Lin, and Zurbruegg (2012) took Australian index options as example to see how the NBP migrated from mispricing problem affecting the option price and implied volatility as well. Chen and Wang (2016) focused on how NBP driving the trading behavior of options. We focused on how the economic strength like the market demand to influence the shape of IV, which is different than the conventional approach of stochastic modeling on IV.

3. The shape of IV

Numbers of literatures mentioned that the shape of IV is related with the stochastic process of underlying asset with the expression of cumulative distribution function (cdf). Bollen and Whaley (2004) summarized the findings and concluded that a cdf with leptokurtosis (fat tail) will generate the IV smile; meantime, a bizarre shape like smirk could be the yield of skewness; a negative skewed cdf of underlying asset shall be expected to display a slanting to right IV curve. We are curious whether the mentioned rules are true in Taiwan market during the Financial Crisis.

In order to plot IV, we use method of Bollen and Whaley; Chan, Cheng, and Lung (2006) as dividing the contracts into different moneyness by delta value. The merit to use delta include, first, it is a standardized gauge while comparing index and individual stock option no matter to respective prices; second, the delta is sensitive to the expiration and volatility therefore it gives an universal measurement for contracts with various expiration and volatility. The moneyness is categorized in Table 1.

For index options, we utilized the intra-day data of Taiwan index option market (ticker: TXO) provided by Taiwan Economic Journal (TEJ) since Jan.-1, 2007, to Dec.-31, 2010. For stock options, we select five underlying stocks listed in Table 2 with same period like TXO; these five stocks are the initial constituents of Taiwan stock option market and still most heavily transacted in spot market. In Taiwan, both index option and stock option belongs to European style contract.

Table 1 Moneyness based on delta value

Category	Labels		Range
1	Deep in the money call	DITMC	$0.875 < \Delta C \le 0.980$
	Deep out of the money put	DOTMP	$-0.125 < \Delta P \le -0.020$
2	In the money call	ITMC	$0.625 < \Delta C \le 0.875$
	Out of the money put	OTMP	$-0.375 < \Delta P \le -0.125$
3	At the money call	ATMC	$0.375 < \Delta C \le 0.625$
	At the money put	ATMP	$-0.625 < \Delta P \le -0.375$
4	Out of the money call	OTMC	$0.125 < \Delta C \le 0.375$
	In the money put	ITMP	$-0.875 < \Delta P \le -0.625$
5	Deep out of the money call	DOTMC	$0.020 < \Delta C \le 0.125$
	Deep in the money put	DITMP	$-0.980 < \Delta P \le -0.875$

The range of categories follows with the theory of put-call parity- $\frac{\partial C}{\partial S} - \frac{\partial P}{\partial S} = 1$. If $\frac{\partial C}{\partial S} = 0.875$, then the case $\frac{\partial P}{\partial S} = -0.125$ will assigned in a same category.

Table 2 Major constituents of the Taiwan stock option market

Option Ticker			Stock Code	Company Name
I	II	III		
AA	AF	CA	1303	Nan Ya Plastics Corporation, NPC
AB	AG	CB	2002	China Steel Corporation, CSC
AC	AH	CC	2303	United Microelectronics Corporation, UMC
AD	AI	CD	2330	Taiwan Semiconductor Manufacturing Company Limited, TSMC
AE	AJ	CE	2881	Fubon Financial Holding Company, FHC

For example, the option ticker of Nan Ya (NPC) has three expressions (AA, AF and CA) in different period. The period of ‘I’ started from Jan.-20, 2003, the IPO date of stock option in Taiwan; ‘II’ started from Aug.-2, 2004; ‘III’ started from Jan.-1, 2009. The scale per contract in respective period is 1,000 shares, 5,000 shares and 2,000 shares.

Different than Bollen and Whaley made comparison on implied volatility between index and averaged 20 stocks, we demonstrate the respective diagrams including index and five individual stocks simultaneously to see the idiosyncrasy between. In Figure 2, the IV of TSMC and Fubon FHC is saliently different thus we shall compare them with TXO by the viewpoint of both cdf and probability density function (pdf).

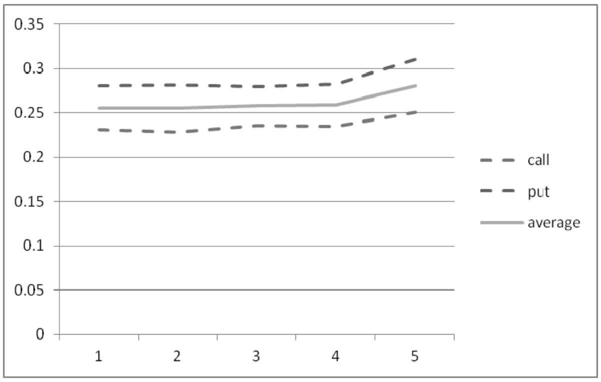
In Figure 3, we used the return rate of underlying asset in making empirical distribution. Congenitally, we shall expect fat tailed (leptokurtic) distribution for TXO and Fubon (smiling IV) and thin tailed (platykurtic) distribution of TSMC (depressed IV). In Figure 3, however, TXO, TSMC and Fubon are more or less fat tailed; TXO has most spiny cdf which is tantamount to fattest tail in three cases. This yield does not correspond to the symptom showing in IV, thus, we shall doubt that- can the ‘fat tail’ theory explain the shape of IV? To answer it, we took means of numerical illustration in line with Lan, Huang, and Chang (2009) and Lo and Lan (2010) to imitated the (pseudo) normal distribution belonging to TXO, TSMC and Fubon then replace parameters in the Black-Scholes formula including N(d1)(N(-d1)) and N(d2)(N(-d2)),

$$d_1 = \frac{\ln((S - \sum_{t=1}^{n} D_t e^{-r_t t})e^{rT} / K) + 0.5\sigma^2 T}{\sigma\sqrt{T}}, \quad d_2 = d_1 - \sigma\sqrt{T} \qquad (1)$$

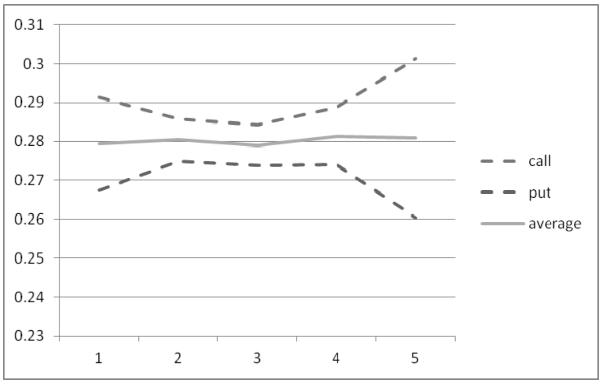
here S is the underlying asset price on mature date, D_t is the periodical dividend, T is time to maturity ($T = nt$), K is execution price and σ is the volatility.

For the convenience of comparison, we set the stock price being 100, maturity is one month, volatility is 20% and risk free rate is 5%. Here we choose only put contract due to that put function play as insurance the most; eminent smile of IV trace is expected to be seen especial in a crisis. The IV acquired by the Newton Raphson method is plotted in Figure 4.

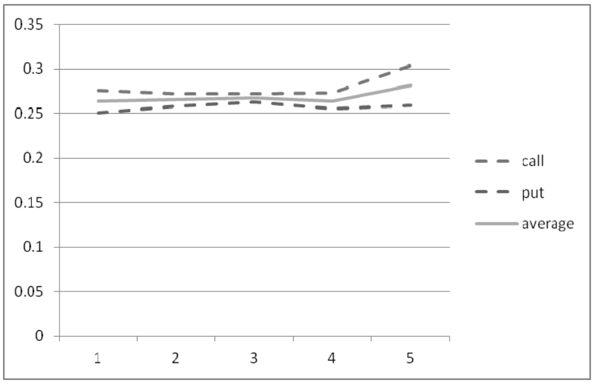
The images in Figure 4 are departed from the practical IV in Figure 3. All three cases uniformly showed that ATMP (at the money put) has high premium as well as the 3rd points of IV reached high. This could be attributed to the shape of return distribution of underlying asset as they are all leptokurtosis. Taking TXO as example, while the execution price (K) is around the 3rd point thus near to underlying asset price, the difference between N(-d2) and N(-d1) becoming larger, this will heave the put price remarkably. The results here are in line with Bollen and Whaley as they found that the



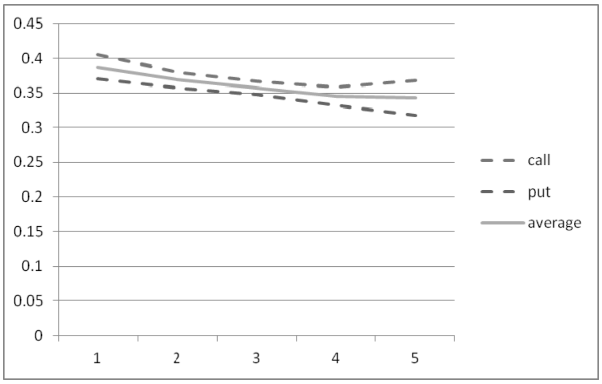
TXO



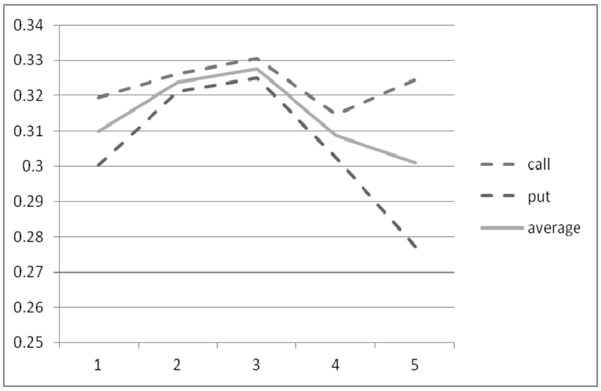
NPC



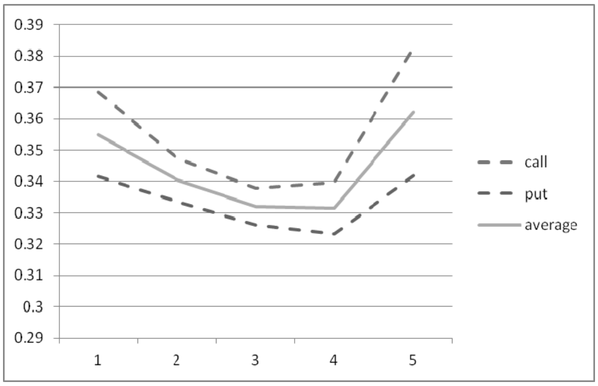
CSC



UMC

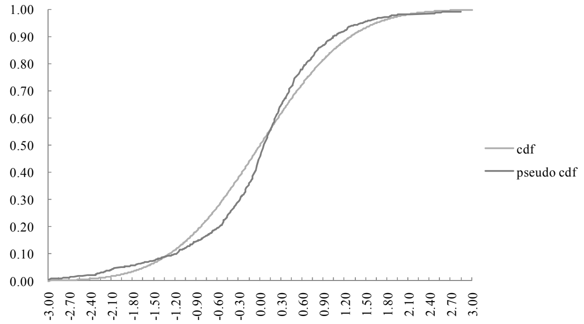


TSMC

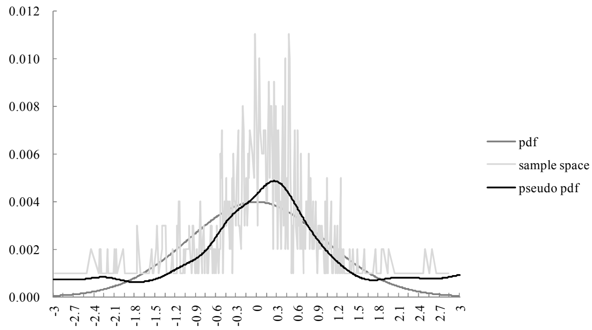


FHC

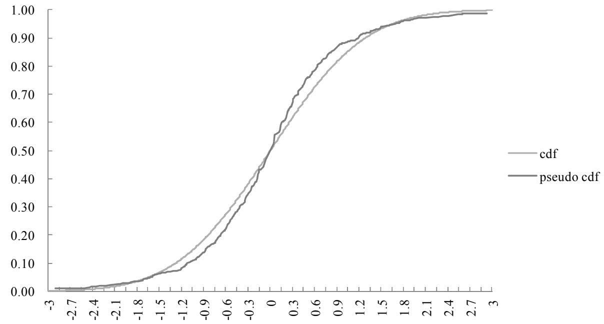
Figure 2　IV of TXO and five individual stock options by empirical base



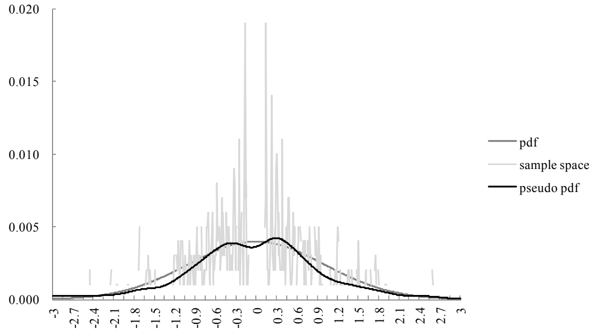
TXO cdf



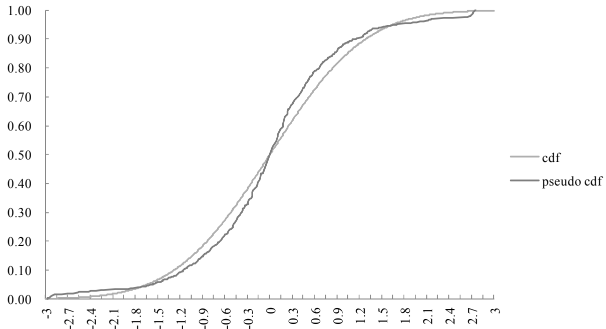
TXO pdf



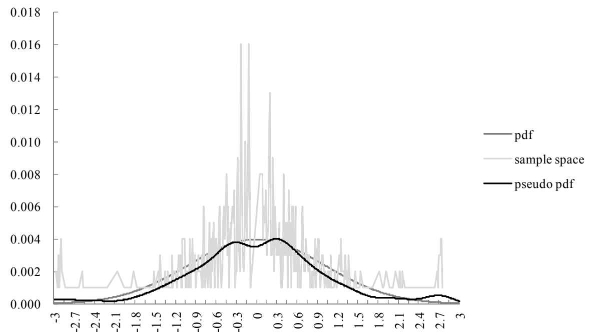
TSMC cdf



TSMC pdf

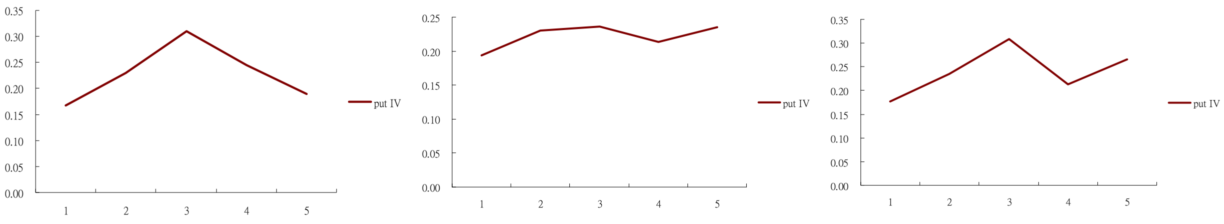


Fubon FHC cdf



Fubon FHC pdf

Figure 3　Statistic distribution inferential based



TXO put IV　　TSMC put IV　　Fubon FHC put IV

Figure 4　IV of TXO and representative stock options converted by pseudo cdf

recreated IV is not surely being monotonic with practical IV. The results also tell a fact that the stochastic way based on the shape of normal distribution could be weak in explaining IV.

4. Does NBP influence IV?

In a frictionless world, the supply curve is horizontal because contract position can be infinitely created thus, the instantaneous imbalance of public order will neither influence the option price nor IV. Contradict to above, a different viewpoint sustains that higher demand on particular contract will heave the option price. Under this stream, the price of OTM put will appreciate when market is bearish and, the price of OTM call will appreciate when market is bullish.

We hereby expand an analysis to quantify the demand on particular series of option contract; a variable called net buying pressure (NBP) is exploited here. NBP is calculated by the difference between the contracts those deal above the averaged price and beneath the averaged price on daily base; the higher NBP can bring up the option price and IV as well.

Even holding with the recognition of positive relation between NBP and IV, the reasons behind it could be somehow intrigue. The positive relation could be caused by market makers, who raised the contract price to protect itself form a booming demand on particular contract series of either put or call; or, it could be caused by the process of supply-demand equilibrium. To find out the causing reason, we shall test two alternatives including ‘limit to arbitrage hypothesis’ and ‘learning hypothesis’ for identification.

However, tests on the dynamics of IV will be firstly deployed to avoid spurious yield in latter analysis.

5. Dynamics of IV

We have two reasons to test whether IV is stationary. First, the trading volume of stock market is plausibly increasing; such a trend could lead to non stationary series of IV and biased regression result; second, a stationary series is required if the GARCH model is going to be used.

In Table 3, we see that all the IV belonging to different securities is timing stationary but have heteroskedasticity phenomenon.[2] To have a better understanding to the IV behavior, we use GARCH model to catch its heteroskedasticity:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2 \tag{2}$$

Considering that the securities could react differently to the positive and negative event, we used the TGARCH model to depict with,

$$\begin{aligned} &\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 D_{t-1} + \alpha_3 \sigma_{t-1}^2, \\ &D_{t-1} = 1 \ \text{if} \varepsilon_{t-1} < 0, \\ &D_{t-1} = 0 \ \text{if} \varepsilon_{t-1} \geq 0 \end{aligned} \tag{3}$$

If the leverage effect does exist, α_2 should be positive and significant.

We also exploited the EGARCH as an alternative,

$$\ln(\sigma_t^2) = \alpha_0 + \alpha_1 \left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| + \alpha_2 \left(\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right) + \alpha_3 \ln(\sigma_{t-1}^2) \tag{4}$$

while bad news[3] leads to greater variance, α_2 should be negative and significant.

All the models will be compared by criteria of Akaike information criterion (AIC) and Bayesian information criterion (BIC) to decide an optimal one in representing IV.

Taking TXO as an example, EGARCH is the most suitable one in formulating its behavior. It sounds reasonable to see that TXO is ‘vulnerable’ to negative news especial in a vicious spiral like the Financial Crisis. For the other individual stocks, they are more or less the GRACH family just like TXO. We further conducted the coefficients test based on

Table 3 Dynamic of the market and individual stocks' return

	TXO	NPC	CSC	UMC	TSMC	FHC
Unit root test	-29.71***	-27.66***	-29.73***	-29.39***	-32.10***	-30.27***
	(0.000)	(0.000)	(0.00)	(0.000)	(0.000)	(0.000)
ARCH LM test	10.73***	30.16***	77.86***	53.82***	22.65***	48.36***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ARCH	AIC=3.55	AIC=4.11	AIC=3.87	AIC=4.42	AIC=4.08	AIC=4.46
	BIC=3.59	BIC=4.14	BIC=3.90	BIC=4.46	BIC=4.11	BIC=4.49
GARCH	AIC=3.49	AIC=4.10	AIC=3.78	AIC=4.36	AIC=4.02	AIC=4.38
	BIC=3.51	BIC=4.12	BIC=3.80	BIC=4.38	BIC=4.04	BIC=4.40
TGARCH	AIC=3.48	AIC=4.09	AIC=3.78	AIC=4.35	AIC=4.01	AIC=4.38
(GJR-GARCH)	BIC=3.51	BIC=4.11	BIC=3.80	BIC=4.38	BIC=4.04	BIC=4.41
EGARCH	AIC=3.48	AIC=4.09	AIC=3.78	AIC=4.46	AIC=4.00	AIC=4.39
	BIC=3.50	BIC=4.12	BIC=3.81	BIC=4.38	BIC=4.03	BIC=4.41

1. *** means statistics' p value <0.01, **: p value <0.05, *: p value <0.1.

2. Unit root test: augmented Dickey-Fuller (ADF) test was used.

3. AIC: Akaike information criterion, BIC: Bayesian information criterion.

respective categorization with different period. Table 4 tells that the TXO coefficients changed remarkably between periods, the equality test (Wald test; null hypothesis: no level change between time series) also statistically sustained the significant difference which means, our segment to the Financial Crisis is adequate.

Table 5 and Table 6 expressed the contract numbers and NBP of TXO and individual stocks respectively within observed period. In Table 5, the series OTMC of TXO has both positive NBP and highest contract number which means, investors of TXO have preference on OTMC and are willing to pay it with higher premium. Situation in the aggregation of individual stocks is different, though OTMC had highest trading volume but its NBP is negative, the negative NBP means that this series of contract is oversold. Be noticed that NBP of call is mostly negative through series whatever the individual stocks or TXO; meanwhile, we see more positive NBP in put especial the individual stocks.

Table 4 Comparisons on coefficients by different period

		α_0	α_1	α_2	α_3	equality test
TXO	pre-	-0.09	0.12	-0.05	0.98	F=5.50***
EGARCH		(-7.55)***	(8.14)***	(-3.48)***	(168.74)***	χ^2=11.01***
	crisis	-0.13	0.18	-0.07	0.98	
		(-7.62)***	(7.90)***	(-4.64)***	(195.04)***	
	post-	-0.03	0.04	-0.10	0.99	
		(-2.78)***	(2.58)***	(-11.21)***	(393.84)***	
NPC	pre-	0.04	0.05	0.06	0.90	F=2.05*
TGARCH		(3.39)***	(4.08)***	(2.83)***	(77.52)***	χ^2=4.11*
	crisis	0.17	0.04	0.09	0.87	
		(4.28)***	(3.25)***	(3.49)***	(39.71)***	
	post-	0.23	0.05	0.10	0.82	
		(4.16)***	(2.69)***	(3.21)***	(22.08)***	
CSC	pre-	0.05	0.05	0.00	0.92	F=3.49**
TGARCH		(4.09)***	(4.37)***	(0.04)	(68.98)***	χ^2=6.99**
	crisis	0.02	0.09	-0.01	0.91	
		(1.95)**	(5.86)***	(-0.50)	(57.13)***	
	post-	0.05	0.03	0.14	0.85	
		(5.03)***	(1.78)*	(4.51)***	(42.44)***	
UMC	pre-	6.95	0.05	-0.03	-0.71	F=0.17
TGARCH		(17.33)***	(2.99)***	(-1.46)	(-15.79)***	χ^2=0.48
	crisis	0.07	0.04	0.06	0.92	
		(3.49)***	(2.96)***	(3.02)***	(74.97)***	
	post-	0.09	0.06	0.02	0.90	
		(3.64)***	(4.50)***	(1.25)	(53.33)***	
TSMC	pre-	-0.03	0.05	-0.03	0.99	F=0.89
EGARCH		(-2.28)**	(2.76)**	(-3.01)***	(203.59)***	χ^2=0.79
	crisis	-0.09	0.13	-0.08	0.99	
		(-5.43)***	(6.19)***	(-4.67)***	(247.38)***	
	post-	0.68	0.29	-0.06	-0.20	
		(4.39)***	(6.31)***	(-1.93)*	(-1.12)	
FHC	pre-	0.16	0.05	0.90		F=0.17
GARCH		(3.16)***	(4.14)***	(36.53)***		χ^2=0.35
	crisis	0.03	0.06	0.93		
		(2.03)**	(6.01)***	(88.19)***		
	post-	0.05	0.07	0.91		
		(3.18)***	(5.66)***	(64.39)***		

*** means statistics' p value <0.01, **: p value <0.05, *: p value <0.1.

Table 5 The contracts numbers of individual stocks and TXO within sample period

		NPC		CSC		UMC		TSMC		FHC		all		TXO	
call															
1	DITMC	0	0%	7	0%	2,967	10%	56	0%	10	0%	3,040	0%	2,098,985	1%
2	ITMC	58,061	27%	68,408	12%	89	0%	34,601	3%	22,645	25%	183,804	9%	10,654,615	5%
3	ATMC	16,982	8%	1,040	0%	4,067	14%	68,685	6%	11,702	13%	102,476	5%	37,973,739	17%
4	OTMC	42,522	20%	162,568	29%	4,934	17%	198,623	19%	13,150	14%	421,797	21%	49,791,224	22%
5	DOTMC	11,971	6%	49,753	9%	2,593	9%	39,454	4%	0	0%	103,771	5%	17,862,331	8%
	total	129,536	60%	281,776	50%	14,650	51%	341,419	32%	47,507	52%	814,888	41%	118,380,894	53%
put															
1	DOTMP	9,385	4%	43,533	8%	6,040	21%	6,843	1%	3,852	4%	69,653	4%	25,108,934	11%
2	OTMP	38,818	18%	153,491	27%	708	2%	515,259	48%	17,242	19%	725,518	37%	50,006,155	22%
3	ATMP	27,454	13%	86,091	15%	1,453	5%	198,197	19%	20,320	22%	333,515	17%	23,318,274	10%
4	ITMP	11,493	5%	3,877	1%	5,603	20%	992	0%	2,048	2%	24,013	1%	5,904,895	3%
5	DITMP	30	0%	21	0%	31	0%	57	0%	0	0%	139	0%	1,580,083	1%
	total	87,180	40%	287,013	50%	13,835	49%	721,348	68%	43,462	48%	1,152,838	59%	105,918,341	47%
	grand total	216,716		568,789		28,485		1,062,767		90,969		1,967,726		224,299,235	

Table 6 The NBP of individual stocks and TXO within sample period

		NPC	CSC	UMC	TSMC	FHC	all	TXO
call								
1	DITMC	0	-6	2,541	-15	0	2520	-542,603
2	ITMC	3,521	-11,212	16	-7,251	-6,068	-20,994	-3,905,794
3	ATMC	-1,553	-3,237	-894	-14,840	-3,686	-24,210	-3,528,755
4	OTMC	-1,543	-16,727	-1,001	-26,889	-964	-47,124	1,198,776
5	DOTMC	-382	-1,217	-23	-1,355	0	-2,977	-2,899
	total	43	-32,399	639	-50,350	-10,718	-92,785	-6,781,275
put								
1	DOTMP	53	538	61	483	133	1,268	76,146
2	OTMP	1,440	11,456	41	36,899	991	50,827	112,627
3	ATMP	-1,210	19,903	-268	35,500	6,367	60,292	-1,655,970
4	ITMP	3,019	851	614	-186	751	5,049	-185,375
5	DITMP	-18	-18	-19	-34	0	-89	-99,714
	total	3,284	32,730	429	72,662	8,242	117,347	-1,752,286

To have a closer look on put contracts, TXO have positive NBP on DOTMP and OTMP; individual stocks have all positive NBP except the DITMP. Referring to Bollen and Whaley (2004), we corroborated it again the investors' motivation between index and individual stocks are different. For TXO, the managers took put especial the out of money contracts including DOTMP and OTMP as the portfolio insurance with signs of over bought. For individual stocks, almost all the put series are over bought. Interestingly, investors of individual stock options seem cheerless to DITMP (NBP: -89) but cheerful to DITMC (NBP: 2520); the investors of individual stock options seem to have made their deployment to the reverse from trough of market.

In the following, we shall address attentions on the conceptual equation in verifying how the NBP influence IV,

$$\Delta\sigma_t = \alpha_0 + \alpha_1 R_t + \alpha_2 VOL_t + \alpha_3 NBP_{1,t} + \alpha_4 NBP_{2,t} + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t \qquad (5)$$ [1b]

Idea of (5) can be perceived as that the price (taking $\Delta\sigma_t$ as the proxy) is a function of market demand (taking NBP as the proxy).

The daily change of IV ($\Delta\sigma_t$) is assumed to be the function of underlying asset return n (R_t), underlying asset transaction volume (VOL_t), set of net buying pressure ($NBP_{1,t}$; $NBP_{2,t}$), and self regression factor ($\Delta\sigma_{t-1}$) according to the framework by Bollen & Whaley. R_t and VOL_t are placed as control variables. R_t is literarily negative since the underlying asset return should negatively relate with level of volatility recalling from Figure 1. VOL_t is synonymous to information flow therefore should move with $\Delta\sigma_t$ consistently. $\Delta\sigma_{t-1}$ is a checking variable to espionage whether null or alternative hypothesis stands. If the coefficient α_5 is not significant, it has two possibilities: one is genuinely no self regression found; another possibility is that the 'learning hypothesis' is advocated which means, the market maker learned the dynamics from markets thus updated their offering price at any pointy time. If the coefficient α_5 is significant, the hypothesis of 'limits to arbitrage' is thus supported; a passive rebalance was imposed daily by the market maker to offset the exposure risk from NBP belonging to a specific contract. Be noted that the regression (5) was transplanted from idea of Bollen and Whaley who utilized it in testing U.S. market. However, will it be suitable to apply the (5) with a either smaller scale or sub-efficient market? We shall use either ways in answering it. In a precedent vision, Chan, Cheng, and Lung (2006)；Chen and Wang (2016) and Larkin, Brooksby, Lin, and Zurbruegg (2012) demonstrated us its application whether in Hong Kong, Australia and Taiwan markets; if by a empirical vision, all the variables in (5) is mundane in most markets thus, it could be quite interesting for us to observe different scenario- by using a same kaleidoscope.

In Table 7, the signs of coefficient α_1 and α_2 belonging to TXO correspond to the expectation and literatures as well. The IV of ATMC is mainly affected by the NBP generated from itself (ATMC). α_5 is significantly negative representing that the market maker intentionally adjust offering price of high demand contract to offset the exposure risk. For managers who exploited TXO as the portfolio insurance, they seemed to rely on instantaneous information especial the NBP of ATMC. The results between individual stocks are idiosyncratic and generally distract from TXO.

In Table 8, the coefficient α_0 , α_1 and α_2 is within the range of expectation. For TXO, the NBP of ATMC is still dominant to the ATMP's changing volatility. This could be attributed to that the managers' preference on call rather than put referring to trading

Table 7 The time series regression of the implied volatility change based on ATMC

$$\Delta\sigma_{ATMC,t} = \alpha_0 + \alpha_1 R_t + \alpha_2 VOL_t + \alpha_3 NBP_{ATMC,t} + \alpha_4 NBP_{ATMP,t} + \alpha_5 \Delta\sigma_{ATMC,t-1} + \varepsilon_t \quad 5\text{-}1$$

	α_0	α_1	α_2	α_3	α_4	α_5	Adj.R^2	F
TXO	0.00	-0.00	2.26	2.23	-6.31	-0.30	0.09	125.50***
	(0.15)	(-1.74)*	(0.09)	(2.83)***	(-0.97)	(-24.83)***		
NPC	-2.32	0.00	-1.66	0.00	-0.00	-0.34	0.25	5.49***
	(-0.44)	(0.80)	(-2.22)**	(1.11)	(-0.53)	(-4.02)***		
CSC	-4.82	-0.00	-2.76	0.00	-0.00	-0.60	0.40	18.47***
	(-4.91)***	(-1.25)	(-0.31)	(0.92)	(-0.72)	(-8.01)***		
UMC	-0.01	-0.00	6.75	0.00	-0.00	-0.80	0.26	8.78***
	(-0.87)	(-0.59)	(0.42)	(1.00)	(-2.24)**	(-6.14)***		
TSMC	-0.00	0.00	2.28	-0.00	0.00	0.29	-0.01	0.63
	(-0.97)	(0.83)	(0.64)	(-0.52)	(0.49)	(1.40)		
FHC	-0.02	-0.00	2.26	0.01	0.00	-0.52	0.17	6.72***
	(-2.11)**	(-2.35)**	(1.15)	(1.77)*	(0.59)	(-5.09)		

*** means statistics' p value <0.01, **: p value <0.05, *: p value <0.1.

Table 8 The time series regression of the implied volatility change based on ATMP

$$\Delta\sigma_{ATMP,t} = \alpha_0 + \alpha_1 R_t + \alpha_2 VOL_t + \alpha_3 NBP_{ATMC,t} + \alpha_4 NBP_{ATMP,t} + \alpha_5 \Delta\sigma_{ATMP,t-1} + \varepsilon_t \quad 5\text{-}2$$

	α_0	α_1	α_2	α_3	α_4	α_5	Adj.R^2	F
TXO	-0.00	-0.00	4.34	6.74	7.86	-0.21	0.05	64.29***
	(-0.65)	(-5.73)***	(1.14)	(5.46)***	(0.08)	(-16.58)***		
NPC	0.01	0.00	-3.90	9.48	-6.63	-0.04	-0.06	0.27
	(1.27)	(0.28)	(-0.87)	(0.26)	(-0.09)	(-0.56)		
CSC	-0.00	0.00	1.92	-1.23	-0.00	-0.50	0.44	21.86***
	(-0.86)	(0.30)	(0.30)	(-3.87)***	(-4.62)***	(-8.02)***		
UMC	-0.01	-0.00	1.17	-0.00	0.00	-0.58	0.22	7.05***
	(-0.91)	(-0.74)	(0.77)	(-1.80)*	(1.16)	(-5.51)***		
TSMC	-0.00	0.00	1.89	-0.00	-7.59	0.00	-0.03	0.13
	(-1.00)	(0.07)	(0.62)	(-0.45)	(-0.05)	(0.01)		
FHC	-0.01	0.00	1.44E-07	0.01	0.00	-0.51	0.16	6.98***
	(-1.48)	(0.50)	(0.78)	(1.38)	(0.41)	(-5.50)***		

*** means statistics' p value <0.01, **: p value <0.05, *: p value <0.1.

volume. Market maker tried to hedge the risks from particular buying pressure referring to the negative α_5.

For individual stocks, dissimilarity can be seen between them. Some of the stocks are failed on regression referring to its low F value. The results could be attributed by that, investors in Taiwan of individual stocks prefer the spot market rather than future market. Taking FHC as an example, it has 5,180,075 stroke counts on stock but merely 90,969 option contracts were transacted within sample period.

For TXO, the call tendency drove portfolio managers to use instantaneous information of call even in a put transaction; this is somewhat different than the observation of Bollen and Whaley based on U.S. market. For individual stocks, put inclination is plausible. The put contracts took majority on whatever the quantity and NBP. The regressions belonging to companies UMC and CSC showed that NBP of ATMP is informative.

The coefficient of lagged implied volatility is significant in TXO with negative sign which means, the hypothesis of limits of arbitrage is supported. However, the significant auto-regression could be a symptom of non-simultaneity due to data error for example the record lags in bid or ask prices. This apprehension will scarcely be the case because the data what we used is based on precision of hundredth second. α_5 is mostly significant in individual stocks; it means that the contract price was adjusted by the issuer therefore the arbitrageurs' profit will be confined. The significant α_5 of both TXO and individual stocks correspond to the GARCH dynamics showed in Table 3. Be noticed, α_5 represents also the amplitude of price reversal; for TXO, the price reversal is about 30% on ATMC and 20% on ATMP.

Table 9 and Table 10 showed the implied volatility of TXO's OTMC is mainly affected by NBP of ATM instead of NBP of OTMC itself. This outcome corroborates that the ATM contract is most informative thus is determinant to market behavior. The call inclination is obvious since α_4 of NBP_{ATMC} is four times than NBP_{ATMP}. Again, the significant negative α_5 tells the limits to arbitrage hypothesis is supported. It will not surprise us for higher amplitude of 37% price reversal comparing with Table 7 and Table 8; TXO has both highest volume and NBP on the OTM series thus it should have more violent adjustment here. However, the analysis is not indicative in individual stocks.

Table 9 The time series regression of the implied volatility change based on OTMC with regressor the NBP of ATMC contracts

$$\Delta\sigma_{OTMC,t} = \alpha_0 + \alpha_1 R_t + \alpha_2 VOL_t + \alpha_3 NBP_{OTMC,t} + \alpha_4 NBP_{ATMC,t} + \alpha_5 \Delta\sigma_{OTMC,t-1} + \varepsilon_t \quad 5\text{-}3$$

	α_0	α_1	α_2	α_3	α_4	α_5	Adj.R^2	F
TXO	-0.00	-0.00	0.00	7.53	-8.32	-0.37	0.14	153.54***
	(-1.29)	(-2.58)***	(1.55)	(1.19)	(-2.00)**	(-27.55)***		
NPC	-0.01	0.00	0.00	-3.19	1.09	-0.22	0.02	1.25
	(-1.32)	(-0.32)	(1.30)	(-2.01)**	(0.65)	(-1.74)*		
CSC	0.00	-0.00	0.00	-7.60	2.19	0.01	-0.01	0.36
	(0.24)	(-1.21)	(0.20)	(-0.77)	(0.47)	(0.11)		
UMC	-0.06	-0.01	0.00	-0.01	-0.00	-0.32	0.07	1.40
	(-1.82)*	(-2.29)**	(1.67)	(-2.04)*	(-2.10)**	(-1.50)		
TSMC	-0.01	0.00	1.60E-07	-3.39	-1.33	-0.20	0.03	1.23
	(-2.46)**	(-0.45)	(2.21)**	(-0.42)	(-1.11)	(-1.29)		
FHC	-	-	-	-	-	-	-	-

*** means statistics' p value <0.01, **: p value <0.05, *: p value <0.1. '-' means 'omitting' while the F value of regression access to zero.

Table 10 The time series regression of the implied volatility change based on OTMC with regressor the NBP of ATMP contracts

$$\Delta\sigma_{OTMC,t} = \alpha_0 + \alpha_1 R_t + \alpha_2 VOL_t + \alpha_3 NBP_{OTMC,t} + \alpha_4 NBP_{ATMP,t} + \alpha_5 \Delta\sigma_{OTMC,t-1} + \varepsilon_t \quad 5\text{-}4$$

	α_0	α_1	α_2	α_3	α_4	α_5	Adj.R^2	F
TXO	-0.00	-0.00	4.18E-10	5.54	-2.11	-0.37	0.14	154.20***
	(-0.97)	(-2.46)**	(1.51)	(0.87)	(-2.46)**	(-27.59)***		
NPC	-	-	-	-	-	-	-	-
CSC	0.00	-0.00	2.80E-08	2.78	7.69	0.00	-0.02	0.49
	(0.07)	(-1.18)	(0.41)	(0.17)	(0.00)	(0.06)		
UMC	-	-	-	-	-	-	-	-
TSMC	0.00	0.01	-1.41E-07	0.00	0.00	-0.38	-0.01	0.95
	(0.59)	(1.69)	(-1.43)	(0.69)	(1.04)	(-1.53)		
FHC	-	-	-	-	-	-	-	-

*** means statistics' p value <0.01, **: p value <0.05, *: p value <0.1. '-' means 'omitting' while the F value of regression access to zero.

Table 11 and Table 12 showed that how the implied volatility of TXO's OTMP is driven by NBP of OTMP and ATM contracts. The influence from ATM contract is not as strong as in the implied volatility of call but, the corresponding OTMP is decisive instead. Implied volatility is still a gauge of fear (negative coefficient α_1) and it will be amplified by the information flow (positive coefficient α_2). Again, the hypothesis of limits to arbitrage is unexceptional advocated referring to significant negative α_5.

Investors shall spontaneously choose put to hedge the depreciation of asset in a bearish market; such a decision is not about information but mostly an 'ought to' choice. This could explain that the coefficient of NBP of ATM is not significant. The price is also reversed referring to the significant α_5 but magnitude is lower, only about 20% weaker. The analysis yield of individual stocks, however, is dimmed.

To sum above, OTMC and OTMP took major share of trading volume and greatest NBP in TXO. The call inclination in TXO made ATMC being the major information source for call trading on ATMC and OTMC. However, the motivation for put is mainly arbitrage; the contract price is mainly navigated by the information belonging to itself. The limits to arbitrage hypothesis is permanently supported referring to significant negative α_5. The magnitude of price reversal is varied depends on contracts. For ATMC and OTMC, α_5 reached up to more than 30%, For ATMP and OTMP, the α_5 is only about 20%. For ATM (both 'C' and 'P') and OTMC, the information carried by NPB of ATMC is important. For OTMP, arbitrageurs relied on the information from OTMP contracts only. The sign of control variables fit with general theories.

Situations are blurred in the individual stocks. However, price reversal is still commonly to be seen in this category. The information generated from NBP seems not decisive for the contract price. This could be attributed to sparse trading in future market referring to its more vigorous spot market.

Table 11 The time series regression of the implied volatility change based on OTMP with regressor the NBP of ATMP contracts

$$\Delta\sigma_{OTMP,t} = \alpha_0 + \alpha_1 R_t + \alpha_2 VOL_t + \alpha_3 NBP_{OTMP,t} + \alpha_4 NBP_{ATMP,t} + \alpha_5 \Delta\sigma_{OTMP,t-1} + \varepsilon_t \quad 5\text{-}5$$

	α_0	α_1	α_2	α_3	α_4	α_5	Adj.R^2	F
TXO	-0.00	-0.00	6.82E-10	-5.87	-9.92	-0.20	0.054	57.70***
	(-2.86)***	(-8.04)***	(2.09)**	(-5.61)***	(-1.67)*	(-14.46)***		
NPC	0.00	-0.00	-1.97E-07	2.74	-0.00	0.01	-0.05	0.07
	(0.50)	(-0.07)	(-0.25)	(0.28)	(-0.46)	(0.14)		
CSC	0.00	0.00	-4.01E-08	-1.51	-1.11	-0.00	-0.02	0.43
	(0.92)	(0.90)	(-1.38)	(-0.26)	(-0.03)	(-0.10)		
UMC	-	-	-	-	-	-	-	-
TSMC	0.00	0.01	-1.41E-07	0.00	0.00	-0.38	-0.01	0.95
	(0.59)	(1.69)	(-1.43)	(0.69)	(1.04)	(-1.53)		
FHC	0.03	0.00	-4.19E-07	0.00	0.00	-0.13	-0.02	0.88
	(1.48)	(1.30)	(-1.60)	(1.57)	(1.40)	(-0.84)		

*** means statistics' p value <0.01, **: p value <0.05, *: p value <0.1. '-' means 'omitting' while the F value of regression access to zero.

6. The possible payoff of different contracts

Will the investors in Taiwan be benefited by the option trade during Financial Crisis? What will the payoff be by different series of option contracts? Herewith we constructed 6 strategies with 5 categories of option contract by moneyness with streams of call and put. We considered possibilities including: strategy 1, which represents the delta hedge with no trading cost; strategy 2 represents the delta hedge with options sold at ask price with no trading cost; strategy 3 represents delta hedge with options sold at ask price with trading cost the 1/2 bid-ask price spread belonging to Taiwan Futures (ticker: TX) by TXO rebalancing; strategy 4 represents delta hedge with options sold at ask price with trading cost the 1/2 bid-ask price spread belonging to TX by TX rebalancing. The payoff of call (put) based on delta hedge are expressed herewith:

Table 12 The time series regression of the implied volatility change based on OTMP with regressor the NBP of ATMC contracts

$\Delta\sigma_{OTMP,t} = \alpha_0 + \alpha_1 R_t + \alpha_2 VOL_t + \alpha_3 NBP_{OTMP,t} + \alpha_4 NBP_{ATMC,t} + \alpha_5 \Delta\sigma_{OTMP,t-1} + \varepsilon_t$ 5-6								
	α_0	α_1	α_2	α_3	α_4	α_5	Adj.R^2	F
TXO	-0.00	-0.00	6.23E-10	-5.29	2.00	-0.18	0.04	46.82***
	(-2.58)***	(-7.99)***	(1.78)*	(-4.88)***	(0.23)	(-12.67)***		
NPC	0.00	0.00	-4.50E-07	1.03	-3.42	-0.13	-0.04	0.34
	(0.61)	(0.61)	(-0.51)	(0.12)	(-0.33)	(-1.17)		
CSC	0.01	0.00	-5.39E-08	-9.91	0.00	-0.36	0.10	4.12***
	(0.68)	(1.05)	(-0.62)	(-0.65)	(0.36)	(-4.44)***		
UMC	0.01	0.00	-8.86E-08	0.00	-7.15	-0.45	0.07	1.47
	(0.32)	(0.28)	(-0.20)	(0.71)	(-0.04)	(-2.62)**		
TSMC	-0.02	-0.00	2.68E-07	3.49	-5.79	-0.51	0.17	2.82**
	(-3.53)	(-1.95)*	(3.19)***	(1.86)*	(-0.37)	(-2.85)***		
FHC	-	-	-	-	-	-	-	-

*** means statistics' p value <0.01, **: p value <0.05, *: p value <0.1. '-' means 'omitting' while the F value of regression access to zero.

$$AR_C = \frac{\Delta_0 (S_T + \sum_{t=0}^{T} D_t e^{r(T-t)} - S_0 e^{rt}) - (C_T - C_0 e^{rT}) + \sum_{t=0}^{T-1} \Delta t (S_{t+1} + D_t - S_t) e^{r(T-t)}}{\Delta_0 S_0 - C_0} \quad (6)$$

$$AR_P = \frac{-\Delta_0 (S_T + \sum_{t=0}^{T} D_t e^{r(T-t)} - S_0 e^{rt}) - (P_T - P_0 e^{rT}) - \sum_{t=0}^{T-1} \Delta t (S_{t+1} + D_t - S_t) e^{r(T-t)}}{-\Delta_0 S_0 - P_0} \quad (7)$$

Here we shall extend our concern as to comprehend the vega hedge. Strategy 5 represents delta-vega hedge with options sold at ask price. For the vega, ATMC is bought at 1/2 bid-ask price spread and rebalanced daily; for the delta, TXO is rebalanced with trading cost the 1/2 bid-ask price spread belonging to TX. Strategy 6 represents delta-vega hedge with options sold at ask price. For the vega, ATMC is bought at ask price and rebalanced daily; for the delta, TXO is rebalanced daily with trading cost the 1/2 bid-ask price spread belonging to TX.

In Table 13, the call strategies are mostly bearing loss during the investigated period of Financial Crisis. The results are reasonable if investors chose buying asset in a long lasting recession, the investors shall expose themselves in the trend of depreciation. It is noticeable to that the realized outcome has coincidence to the simulated one with reference to Figure 5. In Figure 5 we demonstrated payoff of ITMC, OTMC, DOTMC and DITMP since they are ‘characteristic’ in Table 13. The data of ITMC showed that, it has biggest trading volume on Jun.-15, 2007 which is earlier than the deepest point Nov.-20, 2008; seemingly it is not a good entrance referring to the bearish ahead. It also has negative peak of NBP on Dec.-11, 2008, oversold in facing with bullish ahead which distressed ITMC further. The OTMC investors has much better strategies; they have positive NBP peak on Dec.-11, 2008; they maintained high trading volume around (and after) the deepest point which is helpful for forward gain. About DOTMC, with reference to its diversified transaction, the loss of DOTMC was diversified as well as its profit. The trading volume of DITMP was concentrated at early stages; this makes DITMP being benefitted by the latter depreciation of underlying asset. However, the trading volume of DITMP is sparse referring to both Table 5 and Figure 5.

7. Conclusion

We tested the applicability of Net Buying Pressure (NBP) hypothesis of Taiwan market within period of Financial Crisis from 2007 to 2010. Samples in a polarized period may help us to discern the behavioral difference between call and put rather than in ordinary days and be beneficiary to affirm the generality of NBP as well.

The graphic analysis revealed a negative relation between Implied Volatility (IV) and market index. Whatever the return of index or individual stocks did not follow with standard but more a ‘pseudo’ normal distribution; the ‘fat tail’ was found which means the probability of extreme loss or gain is higher than expected. TXO has fatter tail than individual stocks which corresponds Bollen and Whaley (2004). However, the shape of empirical IV seems not much relating with the pseudo normal distribution of underlying asset return. The derived IV based on pseudo normal distribution is highly deviated from empirical one. To sum up, analysis based on stochastic process of asset return in explaining IV could be inefficient; this outcome corresponds to Bollen and Whaley.

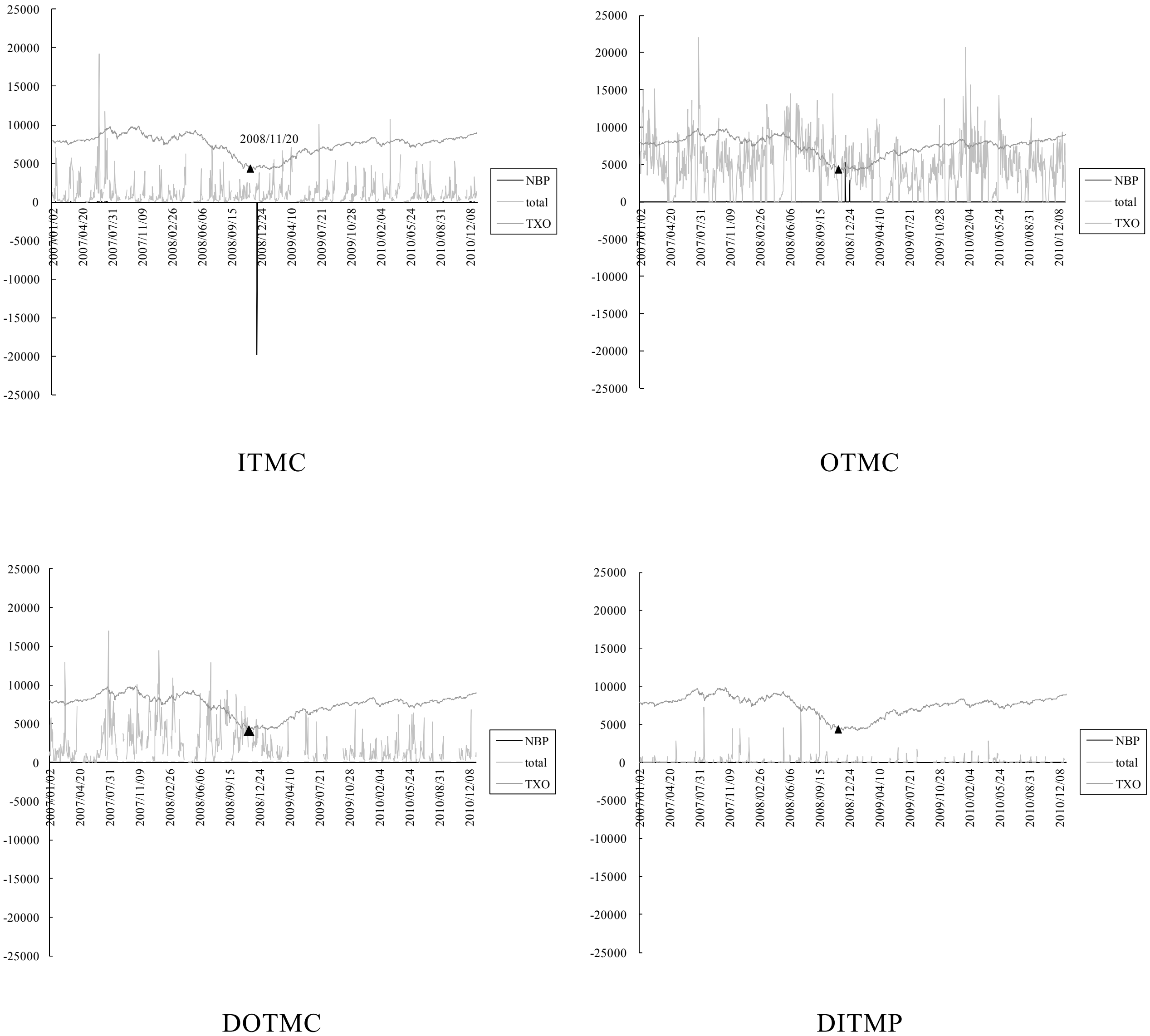


Figure 5 NBP and trading volume belonging to options comparing with TXO

Table 13 Simulated monthly abnormal return of TXO

	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6
Call						
DITMC	-32.24%	-32.22%	-34.00%	-33.81%	-33.25%	-33.18%
$0.875 < \Delta C \le 0.980$	(-10.39)***	(-10.34)***	(-9.71)***	(-9.60)***	(-8.32)***	(-8.17)***
ITMC	-32.45%	-32.46%	-34.32%	-33.51%	-36.04%	-32.632%
$0.625 < \Delta C \le 0.875$	(-14.06)***	(-14.08)***	(-13.33)***	(-12.94)***	(-2.40)**	(-2.66)***
ATMC	-30.10%	-30.00%	-32.36%	-31.89%	-17.55%	-21.42%
$0.375 < \Delta C \le 0.625$	(-8.44)***	(-8.73)***	(-8.38)***	(-8.23)***	(-1.96)*	(-2.32)**
OTMC	33.46%	33.45%	36.20%	35.87%	35.07%	35.15%
$0.125 < \Delta C \le 0.375$	(13.27)***	(13.30)***	(12.85)***	(12.74)***	(13.21)***	(13.48)***
DOTMC	-19.42%	-34.62%	-20.34%	-19.13%	21.69%	20.60%
$0.020 < \Delta C \le 0.125$	(-0.36)	(-0.72)	(-0.37)	(-0.35)	(3.58)***	(3.42)***
Put						
DOTMP	39.49%	48.02%	39.15%	48.59%	48.45%	48.07%
$-0.125 < \Delta P \le -0.020$	(6.09)***	(6.06)***	(6.00)***	(5.97)***	(9.59)***	(9.68)***
OTMP	45.19%	45.30%	45.30%	44.73%	42.43%	42.12%
$-0.375 < \Delta P \le -0.125$	(12.37)***	(12.35)***	(12.09)***	(11.91)***	(14.78)***	(14.92)***
ATMP	42.86%	42.88%	42.89%	42.46%	39.51%	39.42%
$-0.625 < \Delta P \le -0.375$	(12.07)***	(12.82)***	(11.77)***	(11.63)***	(12.01)***	(12.16)***
ITMP	36.49%	36.49%	36.50%	36.16%	35.07%	35.15%
$-0.875 < \Delta P \le -0.625$	(13.27)***	(13.30)***	(12.85)***	(12.74)***	(13.21)***	(13.48)***
DITMP	51.17%	51.08%	51.09%	50.45%	49.90%	49.79%
$-0.980 < \Delta P \le -0.875$	(15.70)***	(15.71)***	(16.87)***	(16.75)***	(16.68)***	(16.72)***

*** means statistics' p value <0.01, **: p value <0.05, *: p value <0.1.

The descriptive statistics sustained that all the data series are timing stable but having heteroskedasticity; the volatility of TXO and individual stocks are mostly asymmetric as to be more sensible to bad news. The period setting is appropriate since the coefficient of dynamic model changed significantly comparing to pre and post segment. The summarized contract numbers and NBP showed quite different aspect between TXO and stocks; corresponding to literatures, the behavior and strategies of investors between index and individual stocks are quite different.

As the setback of stochastic process in explaining IV, we choose NBP as the explanatory factor and acquired insightful findings. The NBP can efficiently explain the IV of TXO and beyond this, the hypothesis of limits to arbitrage is advocated which means, the market maker intentionally adjusts selling price with reference to supply (demand) versus to its exposure risk; this viewpoint conflict to the permanent volatility in common assertions but create a path in explaining the shape of IV. However, the NBP theory did not work well for individual stocks which could be attributed to that, transaction volume of individual stock options is small comparing with its spot market. The difference of transactional behavior between TXO and individual stock options is further affirmed referring to that, the NBP of call provide more information than put to TXO's IV since the traders of TXO are call inclined. The simulated return of respective moneyness contracts corresponds to either expectation or eventual payoff during the Financial Crisis.

Implications to individual investors are summarized- implied volatility is a useful gauge to measuring fear; when the fear increased, the price of call is heaved; the mechanism behind is that market maker percepts fear then adjust the price; so, if you are dull to the market emotion, you could buy a already too expensive call being profitless; in a late stage of downward market, the investors may buy cheap DITM puts to obtain future advantage from the revived market. In above aspects, information of IV and trading volume of contracts, including puts and calls, categorized by moneyness is required.

NOTES

1a & 1b. The regression (5) is under regime of ordinary least squares (OLS) thus concern of modeling stability shall be addressed. We can separate things in two ways; first, there indeed exist the structural changes while referring to whatever TAIEX, NYDJ, VIX and VXO in Figure 1. For example, the date of May.15, 2008 exhibited one of structural change on TAIEX with F value 73.86 (p value=0.00) by Chow's test which prelude the latter fiasco. However, the structural concern can be relieved from (5) since its dependent variable was in style of first order difference. The recursive residuals tested by the CUSUM technique (Brown, Durbin, & Evans, 1975) showed that the residuals are within standard error band telling that (5) is stable. Same manner was carried through analysis 5-1 to 5-6. We heartily thank the anonymous referee who rendered us insightful opinions here.

2. The model selection in Table 3 is somehow objective; we followed the framework suggested by Sayed Hossain (http://www.sayedhossain.com/EVIEWS.html). In his way, the principle of parsimony is followed as to start the selection from lower period lag. Once the model was chosen, we may further diminish its corresponding AIC and SIC value by different lag setting. For example, if we choose the lag of error equal 2, lag of variance equal 2 and amplitude of asymmetry equal 2, the AIC and SIC of this EGARCH (2, 2, 2) can be further reduced as being 3.45 and 3.49. However, we intend to focus on modeling categorization and temporarily disregard the lag setting issues.

3. The bad news for example an announcement relating with tight monetary policy usually bring up the downward movement in market and even higher volatility than a good news coming as well. Engle and Ng (1993) describe a news impact curve with asymmetric response to good news and bad news.

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