Original Article

On the liquidity of CAC 40 index options market

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ABSTRACT **The current article shows that CAC 40 index options (namely PXA) display some illiquidity problems. We examine daily data on PXA trades between May 2005 and August 2012. The study evidences the presence of a considerable number of outstanding PXA contracts; most of these options are long-term maturity options and are deep in or deep out the money options. To overcome the highlighted liquidity issues, we propose first to test the generalization of Gray and Whaley reset option introduced by François-Heude and Yousfi. The main idea is to reset the strike price PXA option to a new strike price given by the CAC 40 value at a pre-agreed point of time. Then we provide some additional measures regarding the number of the PXA strike price series and the PXA expiration dates. Finally, we test them on PXA market. Results show a significant and positive effect on the PXA liquidity.**

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INTRODUCTION

It is commonly known that liquidity issue is a major concern for practitioners, financiers and policymakers. 'Investors want three things from the markets: liquidity, liquidity and liquidity' (Handa and Schwartz, 1996). Liquidity is a key determinant of the price immediacy: if the market is liquid then investors can buy and sell

assets quickly without bearing high transaction costs at a price close to the previously prevailing price (Cho and Engle, 1999).

In this sense, CAC 40 options, namely PXA,[1] are 'the most heavily traded index options in the world' (Capelle-Blancard and Chaudhury, 2001); does this mean that PXA market is very liquid market?

Surprisingly, there are several issues covered in the CAC index market, for instance, market efficiency, the liquidity effect of changes on the CAC 40 index, the determinants of implied volatility and so on.

However, there is few empirical evidence on the link between liquidity of CAC 40 index and options markets, particularly the liquidity of PXA market (see, among others, Kamara and Miller, 1995; Mittnik and Rieken, 2000; Capelle-Blancard and Chaudhury, 2001, 2007; Deville, 2004; Deville and Riva, 2007; Roll *et al*, 2007). For instance, Deville (2004) tests the arbitrage relationships in option markets between August 2000 and July 2001 and determines the effective arbitrage profits obtained after constant execution delays. He concludes that profits are decreasing with the length of the delay. To measure the time needed to reach prices of no arbitrage conditions, he defines the 'Time To Efficiency' (TEF) indicator and points out the positive effect of this indicator on efficiency.

In Deville and Riva (2007), a structural approach on the link between the duration of arbitrage opportunities and liquidity factors is considered. They examine the put-call parity deviations and the return to no arbitrage conditions. Under specific conditions, the speed of reversion of arbitrage profits depends on a set of variables that are related to liquidity, for example, the volume dimension in the index constituent stocks and in the options market, the imbalance between put and call volume and the time to maturity. Furthermore, the addition or deletion of stocks in the CAC 40 index between 1997 and 2001 leads to liquidity variations. They are mainly explained with the direct cost of trading and the asymmetric information cost of transacting (Gregoriou, 2011).

Implied volatility in CAC 40 options is also a puzzling issue. Few studies explore factors influencing implied volatility surface in the CAC 40 options' market (Kermiche, 2008, 2009) and the dynamics of the factors influencing the deformation of implied volatility surface (Cont and da Fonseca, 2002). Most of these studies are conducted in short time periods.

To the best of our knowledge, only Capelle-Blancard and Chaudhury (2001) analyze the efficiency of PXL options[2] and the Euro adoption effect in Paris traded Options Market[3] between 2 January 1997 and 30 December 1999. They conclude that PXL options are heavily traded. In addition, the Euro and PXL adoptions improved the transaction volume of CAC 40 options but did not necessarily enhance efficiency. In 2007, they examine the pattern and systematic tendencies of clustering in CAC 40 index option transaction prices between 1997 and 1999 and point out that the level of option premium, option volume and underlying asset volatility are important determinants of CAC 40 index option price clustering. Moreover, they observe a U-shaped pattern of clustering based on intra-day and intra-year data. Finally, the liquidity effect is explained by the volume effect.

The current article is the first one conducted on the CAC40 index options after 2005 that focuses on PXA liquidity based on a large sample size over a long period of time (PXA trades between May 2005 and August 2012). Our results are not consistent with Capelle-Blancard

and Chaudhury (2001) and point out the presence of liquidity problems in PXA market, particularly options with long-term expiration dates and deep in or deep out the money options.

The study is related to the body of work on options' liquidity, particularly on microstructure and options pricing. Most studies analyze how the liquidity of the underlying asset could affect options' liquidity. For instance, Brenner *et al* (2001) consider non-tradable versus tradable currency options issued by the Bank of Israel. They provide evidence that liquidity has effect on the pricing of these options. Garleanu *et al* (2009), and Bollen and Whaley (2004), find a link between buying and selling flows and the option's type (call, index put options or individual or single stock options). As option is a contingent asset, other studies argue that the liquidity of the underlying asset may have an effect on the pricing of the option. They pay particular attention to the spot liquidity risk in the pricing of options. For instance, Frey (1998) shows that large agents whose trades may lead to a down/upward movement in the asset price can replicate the payoff of a derivative security. Cho and Engle (1999) propose the 'derivative hedge theory' in which the liquidity and spread can be determined by the spot market if the investors in the derivative market can hedge their positions using the underlying asset. They show that option market spreads are positively related to bid–ask spreads of S&P 100 index options. Most of these studies are conducted on non-European markets and cover a short-period data analysis.

To overcome the liquidity problems, we test the generalization of Gray and Whaley's (1999) reset option introduced by François-Heude and Yousfi (2013). The main idea is to reset the PXA strike price to a new strike price that is given by the value of CAC40 index. The reset is set up at a pre-agreed time point t. The intuition is to enable the holders of ITM options to replace them with ATM ones to lock in their profits given by the difference between the strike price and the then current value of the underlying asset. The profit has to be deposited into the Clearing House. The holders of OTM options can replace the less liquid options with more liquid ones that are ATM in exchange for cost paid to the Clearing House.

This article is therefore related to the extensive literature on valuation problems for options, particularly options with either reset condition or a forward-start condition (see, among others, Rubinstein, 1991; Gray and Whaley, 1999; Haug and Haug, 2001 and so on …). It proposes a combination of both conditions and provides an empirical validation of the generalization of Gray and Whaley's reset option presented by François-Heude and Yousfi (2013). They propose a combined extension of reset and forward-start options of Gray and Whaley (1999) and Rubinstein (1991), in which the strike price is automatically reset to the underlying asset price before the option matures. The reset is done whether the strike price is lower or higher than the underlying index value. Consequently, at a pre-agreed point of time t, OTM and ITM options are replaced by ATM options in exchange for deposits into the Clearing House. These deposits can be considered as the cost paid by the holders of OTM options for obtaining more liquid options or the profit of the holders of ITM options who want to lock in their profits at a certain time point.

The contribution of this article is double. First, it provides evidence that the PXA market displays some liquidity problems. Unlike previous studies, our data cover a long period of time. Second, it tests the generalization of Gray

and Whaley's reset option introduced by François-Heude and Yousfi (2013) and provides some practical recommendations to overcome these liquidity problems in several ways.

The rest of this article is organized as follows: The next section presents PXA data and highlights several illiquidity problems. The following section provides some practical recommendations. We conclude in the final section.

STYLIZED FACTS ON CAC 40 INDEX OPTIONS

Data

Before January 1999, CAC 40 index options, namely PXL, had been available for two half-yearly expiration dates and consecutive strike prices had been scaled by 150 index points (hereafter ip). The contract size had been equal to FRF 50 × the CAC 40 index and the minimum price fluctuation had been equal to 0.01 ip. At expiration, the cash settlement had been given by the difference between the exercise price and the expiration settlement index × FRF 50.

Because of the EURO adoption, PXL expiration dates changed and became eight expiration dates (three monthly, three quarterly and two half-yearly). The consecutive strike prices were separated by 50 ip for monthly expirations, 100 ip for quarterly expirations and 200 ip for half-yearly expirations. The PXL contract size was EUR 1× the CAC 40 index and the PXL tick size was 0.10 ip while the cash settlement was equal to the difference between the exercise price and the expiration settlement index time EUR 1. PXL option series were organized in at least three strike prices available: one around the CAC 40 index value and two OTM strikes closest to the CAC 40 index value. ITM options are usually automatically exercised at expiration, unless the option's holder decides not to do.

In May 2005, PXL options were replaced with PXA options. The new option contract has 13 expiration dates (three monthly, seven quarterly and three yearly)[4] while the consecutive strike prices are organized in six intervals: A (25 ip), B (50 ip), C (100 ip), D (200 ip), E (400 ip) and F (800 ip). The PXA contract size is equal to EUR 10× the CAC 40 index and the PXA tick size is equal to 1 ip.[5]

The current study focuses on PXA options and is drawn on a time-stamped record of every trade in the French options market MONEP (Marché des Options Négociables de Paris), in SBF (Société Bourse de France) and in NYSE-EURONEXT, and the transaction volume for all call and put options.

Some features of these option contracts have changed with the shift to the Euro and to the PXA contract. The data provide information on the number of trades, option's type (call/put), option's maturity, strike price, transaction volume, open interest (hereafter OI), the underlying closing and opening prices, and the highest and lowest prices.

The data set is hand-collected from the following sources:

- MATIF (Marché à Terme International de France) and MONEP between January 1999 and April 2009.
- BDM (Base de Données de Marché) of the SBF between December 1999 and March 2001.
- NYSE-EURONEXT databases between March 2003 and August 2012.[6]

We filter out PXL options that mature before May 2005 and keep all PXA options: there are

1878 trade dates between May 2005 and August 2012. In addition, to take into account the PXL/PXA adoption effects, we screen the PXL data and eliminate transactions' volume between 9 May 2005 and 19 August 2005, but keep OI of 22 August 2005. There are some missing data on trades between May and December 2009.[7]

The remaining data are selected regarding whether it belongs to the market months[8] or not. All data that are not in the market month are not included in our sample; we obtain then 84 market months that counts 1793 trade dates.

If we reorganize our data according to:

- the expiration dates, we obtain 27 314 series;
- the strike series, we have 821 989 series;
- the option's type (call and put), the number of series increases significantly to achieve 1 643 978.

Our data show that PXA volume is significantly high (total PXA volume is equal to 48 164 269 contracts). The number of daily trades considerably varies between 170 (minimum) and 4367 trades (maximum) that results on a large standard deviation (see Table 2). Thus, according to this first approach, we are tempted to join Capelle-Blancard and Chaudhury (2001) and conclude that like PXL options, PXA ones are heavily traded between 2005 and 2012 in spite of the financial crisis.

In addition, the database highlights that put options represent 55.54 per cent of the total PXA volume. This could be explained by the downward trend in the market particularly because of the financial subprime crisis. The variations of PXA volume and CAC 40 index are positively associated (see Figure 1) that may evidence the link between the liquidity of the option and the underlying asset.

Descriptive statistics

To analyze the liquidity of PXA market, we focus on outstanding positions and scrutinize OI. Figure 2 represents CAC 40 index, PXA volume and OI between May 2005 and August 2012. It shows that the three series vary similarly: they increase and decrease almost simultaneously.

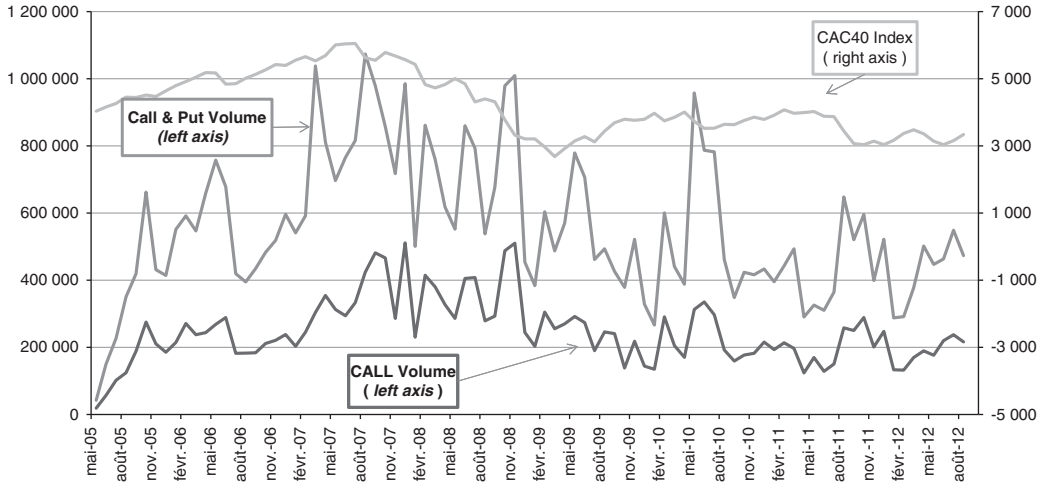

Figure 1: Monthly volume statistics of PXA (left-axis) and CAC 40 index (right-axis) between May 2005 and August 2012.

Furthermore, the variations of PXA total volume and OI are positively associated. For instance, they were increasing between September 2005 and September 2007. Then, they fluctuated until June 2009 and suddenly decreased (see Figures 1 and 2). The number of OI significantly varies (the minimum is equal to 312 501 and the maximum is equal to 1 511 329). It is straightforward to see that the level of outstanding positions is considerably large that may signal the presence of liquidity problems.

Descriptive statistics on monthly and daily data are summarized in Tables 1 and 2, respectively. CAC 40 index option market displays a high level of liquidity if we must consider the high trade volume and the large number of trades. However, the number and volume of OI are considerably high too. Indeed, the average monthly OI of calls and puts was increasing between September 2005 and March 2009, after that it decreased dramatically. In December 2007, the number of open contracts went up and reached 1 397 427. Also, OI is highly dispersed (283 395) which tempts to confirm the liquidity problem we suspected.

To go further and better assess the liquidity problems, we analyze correlation between open positions of calls and puts in both daily and

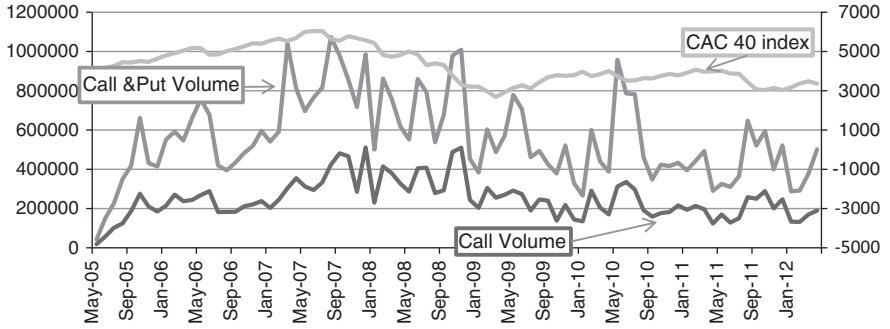

Figure 2: Monthly statistics of PXA open interest (left-axis) and CAC40 index (right-axis) between May 2005 and August 2012.

Table 1: Descriptive statistics on PXA options over 84 market months between 22 May 2005 and 20 August 2012

Monthly data	*Volume*			*Trades*			*OI*		
	Call	*Put*	*Call and put*	*Call*	*Put*	*Call and put*	*Call*	*Put*	*Call and put*
Mean	254 939	318 445	573 384	9425	10 127	19 552	254 939	318 445	573 384
Median	239 278	294 068	521 557	8416	9192	17 449	239 278	294 068	521 557
Standard deviation	90 797	121 738	198 818	3515	3778	7129	90 797	121 738	198 818
Maximum	511 248	734 758	1 073 430	24 598	30 085	54 683	511 248	734 758	1 073 430
Minimum	123 437	131 256	266 019	5293	5437	10 856	123 437	131 256	266 019

Note: Monthly data on volume (84 obs), trades (78 obs) and OI (84 obs), where obs is the number of observations (no trades between May and August 2009).

Table 2: Descriptive statistics on PXA options over 1793 market days between 22 May 2005 and 20 August 2012

Daily data	*Volume*			*Trades*			*OI*		
	Call	*Put*	*Call and put*	*Call*	*Put*	*Call and put*	*Call*	*Put*	*Call and put*
Mean	11 944	14 919	26 862	442	475	917	392 553	432 067	824 620
Median	10 359	12 860	23 794	390	409	808	394 934	445 585	846 149
Standard deviation	7282	10 174	15 255	234	264	472	147 298	144 746	285 304
Maximum	82 155	106 871	152 896	1798	2704	4367	817 854	778 441	1 511 329
Minimum	473	836	1611	52	93	170	145 223	167 278	312 501

Note: Daily data on volume (1793 obs), trades (1620 obs) and OI (1793 obs), where obs is the number of observations (no trades between May and August 2009).

monthly bases (see Tables 3 and 4). We find a strong and positive correlation between put and call OI, which implies that the increase of PXA volume has a positive effect on the number of OI and vice versa.

Liquidity issues

To analyze PXA option liquidity, we calculate some liquidity measures. The survey of the literature on liquidity shows the presence of many measures of option's liquidity, for example, width, depth and immediacy.

The main measures of option liquidity are:

- Width that is captured by the bid-ask spread and other transaction costs generated by the trade of a certain amount of the asset.
- Depth is the volume that can be traded at the observed bid–ask quotes.
- Immediacy measures how quickly an order with a given size and cost can be executed in the market.
- Resiliency captures how quickly asset prices and quotes react to large order flow imbalances or under asymmetric information to reach the equilibrium levels.

Table 3: Correlation between monthly volume and monthly OI over 84 market months

Linear correlation		*Call*	
		Monthly volume	*Monthly OI*
Put	Monthly Vol	0.74	0.51
	Monthly OI	0.67	0.91

Table 4: Correlation between daily volume and monthly OI over 1793 trading days

Linear correlation		*Call*	
		Daily volume	*Daily OI*
Put	Daily Vol	0.51	0.30
	Daily OI	0.40	0.93

They are used in intra-day data given by limit order book. However, they cannot be used in daily data set analysis. To the best of our knowledge, there are no previous studies on index option liquidity; in order to identify the

source of the liquidity problems we calculate the following ratios:

- PXA volume/number of trades ratio to measure the average size of a PXA trade.
- OI/volume ratio to analyze the relationship between the volume of open positions and the total PXA volume. This ratio assesses the market trend. However, open positions are calculated at the end of the day while PXA volume results from transacting through selling and buying orders during all the day. Accordingly, it is better to analyze the OI variations (see Table 5).

Table 5: Descriptive statistics on liquidity measures for call and put options over 84 market months

Monthly	*Volume/ trades*	*OI/ volume*	*ΔOI/ volume*
N	80	88	87
Mean	33.88	1.52	0.0051
Median	33.28	1.45	0.0354
Standard deviation	18.77	0.46	0.4201
Max	171.29	2.95	2.5985
Min	15.57	0.70	−1.5204

Note: No available data between May 2009 and December 2009.

Figure 3 shows that monthly average size of trade decreased by 62.36 per cent from May 2005 to August 2012, which must be considered carefully as no data were available on PXA trades between May 2009 and December 2009. Notice, however, that ΔOI/Volume ratio does not vary considerably. The ratio decreases from 9.1938 in May 2005 to 0.13 in August 2012 but the standard deviation is not very large. One explanation is that PXA volume increases more rapidly than open positions showing that PXA options are heavily traded.

To identify those options displaying liquidity issues, we examine the distribution of PXA trades and OI over strike price series, PXA expiration dates and moneyness.

The number of PXA series is the sum of the call and put series. We recall that the number of the PXA call series is equal to the PXA put series. They are symmetric with respect to ATM series.

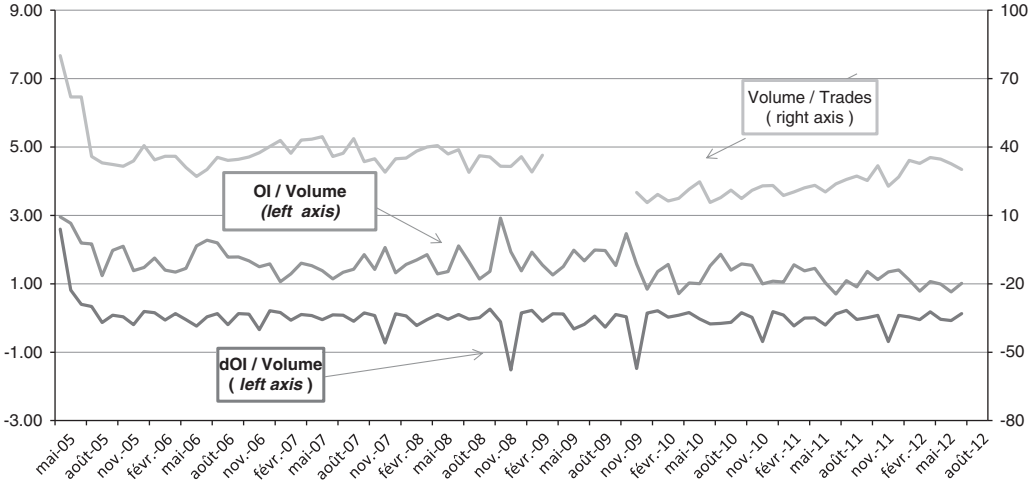

Figure 3: Variations of volume/trades Vol/TRA (right-axis), OI/volume OI/Vol and ΔOI/Vol ΔOI/Vol monthly ratios (left-axis) between May 2005 and August 2012.

The following tables present the PXA series for call or put options.

Between 9 May 2005 and 17 May 2007, the number of quarterly expiration dates was 19 (see Table 6). After 21 May 2007, the quarterly expiration dates of more than 2 years T_i, $i = 8, \ldots, 20$, were replaced by 3-year expiration dates Y_i, $i = 3, 4, 5$. Then, the number of strike price series dramatically decreases from 242 to 97 strike series, but it rises again and becomes 193. It is straightforward to see that strikes series decrease when open maturities become longer (more than 2 years) despite the fact that these maturities become more concentrated (see Table 8).

Also, Tables 6–8 show that strike price interval increased significantly. For instance, for the spot monthly maturity m_1, the interval scale becomes three times what it was under the 22 open maturities scheme. The intuition is to enable traders to take into account the high volatility of CAC 40 index; when it varies, this leads to the creation of new strike series around ATM to adjust traders' positions. Indeed, as long as open position exists, the strike series will not disappear.

Expiration dates/strike price series/moneyness

As call and put options are symmetric, we focus on the distribution of one type PXA options. Figure 4 provides a summary of the distribution of series and maturities between September 2005

Table 6: Strike price series under the 22 open maturities scheme

Maturity n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Expiration dates	*m*1	*m*2	*m*3	*T*2	*T*3	*T*4	*T*5	*T*6	*T*7	*T*8	*T*9	*T*10	*T*11	*T*12	*T*13	*T*14	*T*15	*T*16	*T*17	*T*18	*T*19	*T*20
Strike multiple	**50**			**100**																		
Nb of strike series	**11**																					
Strike price interval	**± 250**			**± 500**																		

Note: The total number of strike series is 484 = 2×22×11 between 9 May 2005 and 21 May 2007 (m: monthly, T: quarterly and Y: yearly).

Table 7: Strike price series under the 13 open maturities scheme

Maturity n°	1	2	3	4	5	6	7	8	9	10	11	12	13
Expiration dates	*m*1	*m*2	*m*3	*T*2	*T*3	*T*4	*T*5	*T*6	*T*7	*T*8	*Y*3	*Y*4	*Y*5
Strike multiple	**25**	**50**		**100**			**200**				**400**		
Nb of strike series	**11**	**9**					**7**				**5**		
Strike price interval	**± 200**	**± 350**		**± 600**			**± 800**				**± 1 200**		

Note: The total number of strike series is 194 between 15 May 2007 and 8 March 2010 (m: monthly, T: quarterly and Y: yearly).

Table 8: Strike price series under the 13 open maturities scheme

Maturity n°	1	2	3	4	5	6	7	8	9	10	11	12	13
Expiration dates	*m*1	*m*2	*m*3	*T*2	*T*3	*T*4	*T*5	*T*6	*T*7	*T*8	*Y*3	*Y*4	*Y*5
Strike multiple	**25**	**50**					**200**				**400**		
Nb of strike series	**21**						**13**				**5**		
Strike price interval	**± 700**	**± 1 200**		**± 1 600**			**± 2 800**						

Note: The total number of strike series is 386 between 8 March 2010 and 17 August 2012 (m: monthly, T: quarterly and Y: yearly).

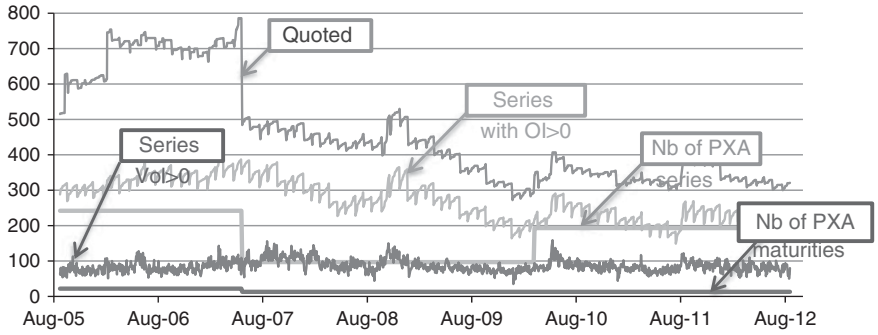

Figure 4: Distribution of PXA series between May 2005 and August 2012.

and August 2012. The number of quoted series is significantly superior to the theoretical number of series (242, 97 and 193 given by Tables 6–8, respectively). It suddenly decreased in May 2007. One explanation is the transferring of positions from PXL to PXA. In addition, series that did not expire before 2005 were kept that may increase the volatility. Another explanation is the setup of new PXA maturity scheme: since 2005, the number of expiration date contracts has been decreased from 22 to 13. Unlike the distribution of PXA contracts with positive OI, the variations of PXA contracts with positive volume were stable over the whole period. However, the number of illiquid series is significantly larger than the number of liquid series. All these findings highlight the presence of illiquidity problems.

To examine these issues, we divide PXA maturities into five categories according to the following criteria (see Table 9). We start from the shortest maturity to the longest one.

Taking into account these criteria changes, the distribution of PXA call and put series and provides interesting results (see Table 10). We find that short-term maturity categories (1 and 2) capture the highest number of PXA contracts: 83.37 per cent of PXA options mature before 3 months (see Table 10). Long maturity index options display some liquidity problems: less than

3.5 per cent of PXA contracts in our data belong to the Categories 4 and 5 (see Appendix B for further statistics on call/put distribution).

Table 9: Categories of PXA expiration dates

Term	*Category*	*Delivery date*	*22 scheme*	*13 scheme*
Very short	1	$0<T\leqslant 1$ m	m_1	
Short	2	1 m$<T\leqslant 3$ m	m_1 and m_2	
Medium	3	3 m$<T\leqslant 1$ y	T_2, T_3 and T_4	
Long	4	1 y$<T\leqslant 3$ y	T_5, T_{12}	T_5, T_8 and Y_3
Very long	5	3 y$<T\leqslant 5$ y	T_{13}, T_{22}	Y_4 and Y_5

Note: m: month, y: year.

Hereafter, we focus on the moneyness of PXA options and analyze the distribution of near money options. Strike series are similar for PXA call and put options and are symmetric with respect to ATM strike. Let us assume that S_t is the value of the underlying CAC 40 index at time point t, X is the strike price of the PXA option and Δ is the interval scale where $\Delta = 0.1$. The moneyness scale is given by:

$$\left|\frac{S_t - X}{X}\right| \leqslant \alpha \frac{\Delta}{2} \quad where\, \alpha \in N$$

Accordingly, we consider that ATM options satisfy the following:

$$\frac{S_t}{X} = 1 \pm 5\,\%$$

Then, we focus on the distribution of ITM, OTM and ATM options along the moneyness scale $\alpha(\Delta)/(2)$. Results are in Tables 11–13.

Table 10: Descriptive statistics on the distribution of PXA options

Call and put	*1 (%)*	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*
Mean	43.71	39.66	13.50	2.70	0.44
Maximum	60.95	60.00	29.56	13.65	4.15
Median	44.12	38.46	13.46	1.70	0.05
Minimum	27.97	22.12	4.35	0.02	0.00
Standard deviation	7.67	8.80	5.17	2.83	0.79
Average cumulative frequency	43.71	83.37	96.87	99.56	100

Table 11: The percentage of near the money PXA options according to the moneyness scale $\alpha\Delta$

Call and put	*±1(Δ/2) (%)*	*±2(Δ/2) (%)*	*±3(Δ/2) (%)*	*±4(Δ/2) (%)*	*±5(Δ/2) (%)*	*±6(Δ/2) (%)*	*±7(Δ/2) (%)*	*±8(Δ/2) (%)*	*±9(Δ/2) (%)*	*±10(Δ/2) (%)*
ATM options	4.11	8.18	12.191	16.10	19.88	23.56	27.15	30.57	33.83	37.07

Call and put	*±11(Δ/2) (%)*	*±12(Δ/2) (%)*	*±13(Δ/2) (%)*	*±14(Δ/2) (%)*	*±15(Δ/2) (%)*
ATM options	40.18	43.04	45.75	48.45	51.02

Table 12: The distribution of the PXA volume according to the moneyness scale $\alpha\Delta$

$\alpha\Delta$	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*	*0.9*	*1.0*
ATM$\pm\alpha\Delta/2$	<0.45	0.45–0.55	0.55–0.65	0.65–0.75	0.75–0.85	0.85–0.95	0.95–1.05
Call options (%)	0.92	1.42	3.23	8.91	25.13	47.10	12.27
Put options (%)	0.29	0.03	0.04	0.21	1.03	11.30	37.63
Total options (%)	0.57	0.65	1.46	4.08	11.75	27.21	26.35

$\alpha\Delta$	1.1	1.2	1.3	1.4	1.5	1.6
ATM$\pm\alpha\Delta/2$	1.05–1.15	1.15–1.25	1.25–1.35	1.35–1.45	1.45–1.55	>1.55
Call options (%)	0.61	0.12	0.06	0.05	0.03	0.15
Put options (%)	21.81	10.84	6.23	4.12	2.29	4.17
Total options (%)	12.39	6.08	3.49	2.31	1.29	2.39

Table 13: The distribution of the PXA OI according to the moneyness scale $\alpha\Delta$

$\alpha\Delta$	0.4	0.5	0.6	0.7	0.8	0.9	1.0
ATM$\pm\alpha\Delta/2$	<0.45	0.45–0.55	0.55–0.65	0.65–0.75	0.75–0.85	0.85–0.95	0.95–1.05
Call options (%)	13.26	5.05	6.96	10.14	13.95	15.95	11.02
Put options (%)	8.95	2.52	3.00	3.62	4.99	8.85	13.32
Total options (%)	11.00	3.73	4.89	6.73	9.25	12.23	12.23

$\alpha\Delta$	1.1	1.2	1.3	1.4	1.5	1.6
ATM$\pm\alpha\Delta/2$	1.05–1.15	1.15–1.25	1.25–1.35	1.35–1.45	1.45–1.55	>1.55
Call options (%)	6.73	4.65	3.42	2.58	1.93	4.36
Put options (%)	12.39	9.77	7.51	5.94	4.58	14.57
Total options (%)	9.70	7.33	5.56	4.34	3.32	9.71

However, Table 11 provides aggregate results for ATM options of both PXA calls and puts. To examine the distribution of ATM options, we focus on the distribution of the PXA volume and OI along the five maturity categories. The main result of Table 12 is that only 12.27 per cent (respectively 37.63 per cent) of call (respectively put) options are ATM while almost 72 per cent (respectively 33 per cent) are OTM. In conclusion, 65.95 per cent of PXA options are near the money.

Table 13 shows that 65.31 per cent (respectively 54.76 per cent) of PXA call (respectively put) series are OTM. Unlike PXA volume, OI are widely dispersed along the moneyness scale $\alpha\Delta$. For instance, 12.32 per cent of OI are ATM, 21.93 per cent are near the money options and 20.71 per cent are deep in and out of the money. The recommendation to replace all the OTM options with ATM ones seems again very intuitive (Appendix C provides more details on the

distributions of the volume and OI along maturity categories).

In conclusion, we evidence that only near ATM PXA options with short-term expiration dates are liquid. As PXA are European options, options' holders have to wait until the options mature to decide or not to exercise them that could explain to a large extent the large number of open positions in long term maturity PXA options available in the market and their low number of trades. In line with FraNçois-Heude and Yousfi (2013), it would be interesting for investors who hold deep OTM or ITM options to reset the strike price to a strike price equal to the value of CAC 40 index at a pre-agreed time point *t*. This will help ITM holders to lock in their profit and the OTM holders to replace their options with more liquid options.

HOW TO IMPROVE PXA LIQUIDITY?

Regarding the liquidity problems discussed in the previous section, we advance three practical recommendations to improve the liquidity of CAC 40 index options.

First, we propose to put into practice the generalization of Gray and Whaley (1999) reset option introduced by François-Heude and Yousfi (2013). The main idea is to replace all deep in ITM and OTM option with PXA options that are ATM. To do so, we propose to reset the strike price to a new strike price that is equal to the value of the CAC 40 index. For ITM holders, they will deposit their profit into the Clearing House. However, for OTM holders replacing their options with ATM ones is costly. In practice, this comes to reset each third Friday of the market month, the strike price to the then value of the underlying index.

Second, as strike price series that are deep ITM/OTM are the less liquid strike price series, we recommend to keep the five intervals A, B, C, D and E but to scale them differently such that all interval scales become 25 ip (see Table 14).

Third, despite that the number of expiration dates has been decreased, our results highlight that long-term expiration dates are less liquid than short-term ones. Accordingly we propose considering 10 PXA expiration dates rather than the 13 current expiration dates:

- Three spot contracts that mature before 3 months;
- Three quarterly contracts that mature between 3 months and 1 year (March, June and September cycles);
- Four yearly contracts that mature between 2 and 5 years (December cycles).

Table 14: The distribution of PXA strike price series

Scale	*Interval*	m_1	m_2, m_3	T_2, T_3, T_4	Y_2, Y_3	Y_4, Y_5
		01–12	01–12	03–06–09	Dec	Dec
A	25	ATM±1	—	—	—	—
B	50	—	ATM±1	—	—	—
C	100	—	—	ATM±1	—	—
D	200	—	—	—	ATM±1	—
E	400	—	—	—	—	ATM±1

Finally, for each strike price series, it is better to keep three strike series in each scale: ATM, ITM and OTM.

To analyze the impact of these recommendations on the PXA liquidity, we identify open positions of PXA series that are not ATM. August series that mature in 2012, expired in 17 August 2012. There are still some open positions for the remaining 12 PXA maturities. For each contract, we define the ATM strike price (see Table 15).

It is straightforward to see that the distribution of OI is less dispersed when maturities are grouped in five rather than with 13 PXA contracts. However, we cannot deepen more our analysis as the final impact depends on the variation of the CAC 40 index and the variations of the moneyness scale α.

Conclusion

Our study evidences that CAC 40 index options display liquidity problems when some specific criteria are considered, for example, strike price series, expiration dates and moneyness.

Then, we propose: (i) to decrease the number of PXA expiration dates from 13 to 10 as the

Table 15: The distribution of OI of PXA contracts under the 13 maturity scheme (a) and 10 maturity scheme (b) with respect to different values of α

	OI of PXA call options					*OI of PXA put options*					*OI of PXA call and put options*				
α	*0* (%)	*1* (%)	*2* (%)	*3* (%)	*Total* (%)	*0* (%)	*1* (%)	*2* (%)	*3* (%)	*Total* (%)	*0* (%)	*1* (%)	*2* (%)	*3* (%)	*Total* (%)
(a)															
2	79.8	64.5	48.4	34.5	34.2	97.1	94.8	93.4	88.8	45.9	91.2	84.4	78.0	70.1	41.1
3	94.8	90.8	55.0	54.6	6.6	84.2	84.1	82.6	82.4	7.4	88.2	86.7	72.0	71.7	7.0
4	87.6	86.7	68.7	67.4	40.6	94.5	94.2	81.5	80.5	30.7	91.1	90.6	75.3	74.2	34.8
5	82.3	78.3	57.5	54.3	6.6	95.2	94.5	83.1	82.6	5.3	89.2	86.9	71.1	69.4	5.8
6	44.7	24.2	13.1	12.1	2.2	90.7	57.2	48.7	42.3	1.9	70.3	42.6	32.9	28.9	2.0
7	100	65.6	32.8	32.8	0.0	80	60.8	52.9	52.9	0.0	87.7	62.6	45.4	45.4	0.0
8	62.7	26.5	0.2	0.2	6.7	64.5	55.1	48.2	45.0	6.4	63.8	43.0	27.9	26.0	6.5
9	0	0.0	0.0	0.0	0.0	100	0	0.0	0.0	0.0	50	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	13.8	10.8	10.8	10.8	2.5	15.7	13.2	13.2	12.8	1.8	14.7	12.0	12.0	11.8	2.1
12	0.1	0.0	0.0	0.0	0.6	16.8	11.2	11.2	7.0	0.5	12.8	9.1	6.0	6.0	0.6
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	80.0	60.4	52.4	46.8		91.1	84.1	82.8	79.9		86.6	81.3	70.2	66.3	
(b)															
2 and 3	82.2	68.7	49.4	37.7	40.7	95.3	93.3	91.9	87.9	53.3	90.7	84.7	77.1	70.4	48.1
4 à 6	85.0	82.8	64.8	63.2	49.4	94.4	92.4	80.1	78.8	37.9	89.9	87.8	72.8	71.4	42.7
7 à 11	49.4	22.3	3.2	3.2	9.2	53.9	45.9	40.5	37.9	8.3	51.9	35.5	24.0	22.6	8.7
12 and 13	0.1	0.0	0.0	0.0	0.6	16.8	11.2	11.2	7.0	0.5	12.8	9.1	6.0	6.0	0.6

number and the volume of open positions are considerably high for long-term expiration date, (ii) to keep only three strike price series in each strike price scale (one ATM, one OTM and another one ITM) and (iii) to reset the PXA strike price at the CAC 40 index value at a pre-agreed point of time t in line with François-Heude and Yousfi (2013) in exchange for deposit into the Clearing House. Under specific conditions, we analyze the distribution of OI regarding, for example, the strike price series and expiration dates, and we show that these recommendations provide quite satisfying results.

In future research, we would like to study the liquidity of the French equity options and the liquidity of other European and American index options to compare them with the results of the current article.

In addition, further research should be conducted on when to reset the strike option as the option could be exercised before it matures.

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NOTES

1 PXA is Paris index code for CAC 40 index options.

2 Before May 2005, there was PXL (Paris Index Long) options instead of PXA options.

3 It was previously called Marché des Options Négociables de Paris (MONEP).

4 Notice however, that many PXL options did not mature by May 2005. Consequently, many expiration dates were kept: between 9 May 2005 and 17 May 2007, the number of expiration dates was 22 (3 monthly and 19 quarterly). However the quarterly expiration dates of more than 2 years were replaced by 3-year expiration dates (Table 6 for more information).

5 More details are available in Appendix A.

6 Some of Euronext data are available at the following links: nysetechnologies.nyx.com/Data-Products/nyse-liffe-nexthistory-index-derivatives-eod; www.liffe.com/reports/eod?item=Histories&archive=994191131; globalderivatives.nyx.com/nyse-liffe/daily-statistics.

7 The PXL/PXA transfer leads to a decrease of the number of open maturities from 22 expirations dates to 13 expiration dates. Some maturities of the previous regime were kept to facilitate the transfer. However, we delete them from our data. We exclude the following maturities: June 2009, September 2009, March 2010, June 2010 and March 2011. Consequently, our data are missing:
- The OI of the June 2009 maturity (4250 contracts).
- The OI (1250 contracts) and the traded volume (253) of the June 2010 maturity.

8 The market month m starts the first Monday following the third Friday of the $(m-1)$th month and ends up the third Friday of the current month (m).

9 The latter value is the average of the CAC40 index values between 15:30 and 16:00.

10 PXL contract value is equal to the value of the CAC 40 index multiplied by one euro and the tick size is 0, 1 index point. PXA value is equal to 10 index points.

11 For more details, see Appendix A and www .euronext.com.

References

Bollen, N.P. and Whaley, R.E. (2004) Does net buying pressure affect the shape of implied volatility functions? *Journal of Finance* 59: 711–753.

Brenner, M., Eldor, R. and Hauser, S. (2001) The price of option's illiquidity. *Journal of Finance* 56(2): 789–805.

Capelle-Blancard, G. and Chaudhury, M. (2001) Efficiency Tests of the French Index (CAC 40) Option Market. McGill Finance Research Centre Working Paper SSRN, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=283695.

Capelle-Blancard, G. and Chaudhury, M. (2007) Price clustering in the CAC 40 index options market. *Applied Financial Economics* 7(15): 1201–1210.

Chen, J.Y. and Wang, J.Y. (2011) The Valuation of Forward-Start Rainbow Options. In the 2011 FMA European Conference; 8–10 June, Porto, Portugal.

Cho, Y. and Engle, R. (1999) Modeling the Impact of Market Activity on Bid-Ask Spread in the Options Market. NBER Working Paper No. 7331, http://www.nber.org/papers/w7331.pdf?new_window=1.

Cont, R. and da Fonseca, J. (2002) Dynamics of implied volatility surfaces. *Quantitative Finance* 2(1): 45–60.

Deville, L. (2004) Time to efficiency of the French CAC 40 index options market. EFMA 2004 Basel Meetings Paper, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=498942.

Deville, L. and Riva, F. (2007) Liquidity and arbitrage in options markets: A survival analysis approach. *Review of Finance* 11(3): 497–525.

François-Heude, A. and Yousfi, O. (2013) A Generalization of Gray and Whaley's Reset Option. Working paper, presented at the 30th AFFI conference, http://events.em-lyon.com/AFFI/Papers/47.pdf.

Frey, R. (1998) Perfect option hedging for a large trader. *Finance and Stochastics* 4(2): 115–141.

Garleanu, N., Pedersen, L.H. and Poteshman, A.M. (2009) Demand-based option pricing. *Review of Financial Studies* 22(10): 4259–4299.

Gray, S.F. and Whaley, R.E. (1999) Reset put options: Valuation. Risk charactheristics and an application. *Australian Journal of Management* 24(1): 1–20.

Gregoriou, A. (2011) The liquidity effects of revisions to the CAC40 stock index. *Applied Financial Economics* 21(4): 333–341.

Handa, P. and Schwartz, R.S. (1996) How best to supply liquidity to a securities market. *The Journal of Portfolio Management* 22(2): 44–51.

Haug, E. and Haug, J. (2001) The collector: Who's on first base? *Wilmott Magazine*, http://www.wilmott.com/pdfs/010721_collector_02.pdf.

Kamara, A. and Miller, T. (1995) Daily and intradaily tests of put-call parity. *Journal of Financial and Quantitative Analysis* 30(4): 519–539.

Kermiche, L. (2008) Modélisation de la surface de volatilité implicite par processus à sauts. *Finance* 29(2): 57–101.

Kermiche, L. (2009) Dynamics of implied distributions: Evidence from the CAC 40 options market. *Finance* 30(2): 64–103.

Mittnik, S. and Rieken, S. (2000) Put-call parity and the informational efficiency of the German DAXIndex options markets. *International Review of Financial Analysis* 9(3): 259–279.

Roll, R., Schwartz, E. and Subrahmanyam, A. (2007) Liquidity and the law of one price: The case of the futures/cash basis. *Journal of Finance* 62(5): 2201–2234.

Rubinstein, M. (1991) Pay now. Choose later. *Risk* 4(2): 13.

APPENDIX A

An overview of PXA option

PXA contracts are exclusively for European-style exercise options. PXA underlying asset is the CAC 40 index. At expiration date, if PXA's holders exercise their options, they are paid automatically the difference between the option strike price and the liquidation value of the CAC 40 index multiplied by the number of contracts exercised and the contract unit (€10).[9]

Under the demand of clients and to meet international standards, PXL options commonly exchanged since January 1999, had been replaced by PXA options since May 2005.[10]

They are traded until the third Friday of the expiry month. When the option contract expires, a new expiry cycle is open on the next Monday.

Between 9 May 2005 and 18 May 2007, trades covered 22 PXA open maturities: three monthly (each month) and the following 19 quarterly (March, June, September and December cycle) maturities. Since 21 May 2007, PXA trading has covered 13 expiration dates (see Table A1).

Expiration date is the third Friday of the expiration month at 16:00. Central European Time. Once maturity expires, a new expiration month is opened the following Monday.

Strike prices are standardized according to symmetric intervals around ATM calls and puts that depend closely on the lifetime of the contract. Strike prices and intervals are function of ip. There are six CAC 40 index intervals according to the variation of the strike price:[11]

- Short term maturity: Scale A (25 ip) and Scale B(50 ip).
- Medium and long term maturity: Scale C (100 ip), Scale D (200 ip), Scale E (400 ip) and Scale F (800 ip).

At time maturity T, ITM options are automatically exercised unless holders decide not to do so. Then, there is a cash transfer equal to the difference between the strike price option and the value of the expiry index, multiplied by the number of contracts exercised and the contract unit (€10).

APPENDIX B

PXA strike price series

The number of strike series in each interval depends on the remaining lifetime of an option. Let us consider an option matures at T:

- If the remaining lifetime $(T-t) \leqslant 1$ month, there are five strike prices around the money in interval scale A and six others in interval scale B.
- If $1 < (T-t) \leqslant 3$ months, there are three strike prices in interval scale B and six others in scale C.
- If $3 < (T-t) \leqslant 9$ months, there are three strike prices in interval scale C and six others in scale D.

Table A1: Expiration dates of PXA option

Cycle	*Expiration months*	*Lifetime (Months)*
3 Monthly	Every Month	1; 2; 3
7 Quarterly	March, June, September, December	6; 9; 12; 15; 18; 21; 24
3 Yearly	December	36; 48; 60

Source: prospectusMonep: www.euronext.com.

Table B1: Strike price series between 8 March 2010 and 17 August 2012

Scale	*Interval*	*3 M*		*7 T*		*3 Y*
		1 *01–12*	*2, 3* *01–12*	*6, 9, 12* *03–06–09*	*15, 18, 21, 24* *03–06–09*	*36, 48, 60* *12*
A	25	ATM±3	—	—	—	—
B	50	±3	ATM±3	ATM±3	—	—
C	100	±2	±4	±3	—	—
D	200	±2	±2	±2	ATM±2	—
E	400	—	±1	±2	±2	ATM±1
F	800	—	—	—	±2	±1
Call and put options		21	21	21	13	5

Table B2: Strike price series between 15 May 2007 and 8 March 2010

Scale	*Interval*	*3 M*		*7 T*		*3 Y*
		1 *01–12*	*2, 3* *01–12*	*6, 9* *03–06–09*	*12, 15, 18, 21, 24* *03–06–09*	*36, 48, 60* *12*
A	25	ATM±2	—	—	—	—
B	50	±3	ATM±1	—	—	—
C	100	—	±3	ATM±1	—	—
D	200	—	—	±3	ATM±1	—
E	400	—	—	—	±2	ATM±1
F	800	—	—	—	—	±1
Call and put options		11	9	9	7	5

Table B3: Strike price series between 9 May 2005 and 21 May 2007

Scale	*Interval*	*3 M* *1, 2, 3* *01–12*	*19 T* *6;9, … 60* *03–06–09*
A	25	—	—
B	50	ATM±5	—
C	100	—	ATM±5
D	200	—	—
E	400	—	—
Call and put options		11	11

- If $9<(T-t)\leqslant 24$ months, there are three strike prices in interval scale D and four others in scale E.
- If $(T-t)>24$ months, there are three strike prices in interval scale E and two others in scale F.

The number of PXA call series is equal to those of PXA put options. Let us consider the change of PXA call series over May 2005 and August 2012 (see Tables B1–B3).

APPENDIX C

The liquidity effect of maturity categories

The distributions of PXA call and put options are quite similar and show the same downward trend from Categories 1 to 5. Long maturity options display illiquidity problems (see Tables C1–C2).

The distribution Of PXA volume according to the five maturity categories (see Table C3).

The distribution of PXA OI according to maturity categories (see Table C4).

Table C1: Descriptive statistics on the distribution of PXA call options

Maturity category	*1 (%)*	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*
Mean	43.60	38.88	14.18	2.86	0.47
Median	44.44	38.82	13.20	1.82	0.00
Maximum	61.09	62.65	37.77	17.58	4.91
Minimum	23.65	18.13	4.26	0.00	0.00
Standard deviation	8.03	9.30	6.13	3.22	0.89
Average cumulative frequency	43.60	82.49	96.67	99.53	100

Table C2: Descriptive statistics on the distribution of PXA put options

Maturity category	*1 (%)*	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*
Mean	43.79	40.29	12.95	2.57	0.41
Median	43.27	39.01	12.09	1.51	0.07
Maximum	61.46	64.44	27.07	15.72	3.59
Minimum	23.52	21.33	3.93	0.01	0.00
Standard deviation	8.57	9.56	5.02	2.77	0.73
Average cumulative frequency	43.79	84.08	97.02	99.59	100

Table C3: The distribution of the volume of PXA series according to the maturity categories ($\alpha\Delta = \pm 0.1$)

$\alpha\Delta$	*PXA call options*					*Total (%)*
	1 (%)	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	
0.4	3.6	25.4	63.0	7.9	0.0	0.92
0.5	6.5	58.6	30.9	4.0	0.0	1.42
0.6	11.2	50.8	34.7	3.3	0.0	3.23
0.7	18.4	53.0	26.7	1.7	0.2	8.91
0.8	32.2	53.1	13.3	1.3	0.1	25.13
0.9	57.9	31.6	9.0	1.4	0.2	47.10
1.0	47.9	24.1	14.5	11.3	2.2	12.27
1.1	33.3	30.4	21.3	8.7	6.3	0.61
1.2	21.0	24.9	40.7	10.5	2.9	0.12
1.3	13.7	21.6	41.8	13.4	9.5	0.06
1.4	2.4	18.5	21.2	20.2	**37.7**	0.05
1.5	2.4	8.8	62.9	26.0	0.0	0.03
1.6	11.4	31.2	51.7	5.6	0.0	0.15
$\alpha\Delta$	*PXA put options*					*Total (%)*
	1 (%)	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	
0.4	10.5	23.2	59.0	7.3	0.0	0.29
0.5	10.4	23.0	58.0	8.6	0.0	0.03
0.6	23.4	19.8	26.3	2.6	**27.9**	0.04
0.7	39.4	29.5	18.2	5.5	7.4	0.21
0.8	32.9	30.1	23.2	12.5	1.3	1.03
0.9	47.5	29.3	18.5	4.1	0.6	11.30
1.0	56.7	31.5	8.1	3.1	0.6	37.63
1.1	46.6	42.1	10.2	0.9	0.2	21.81
1.2	32.7	53.3	12.7	1.1	0.1	10.84
1.3	23.4	58.3	16.4	1.8	0.0	6.23
1.4	17.9	60.7	19.3	2.0	0.0	4.12
1.5	15.2	61.2	20.3	3.2	0.2	2.29
1.6	8.9	52.0	34.4	4.3	0.3	4.17

Table C3: (*Continued*)

$\alpha\Delta$	*PXA call and put options*					*Total (%)*
	1 (%)	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	
0.4	5.6	24.8	61.9	7.8	0.0	0.57
0.5	6.6	57.6	31.6	4.2	0.0	0.65
0.6	11.4	50.3	34.6	3.3	0.4	1.46
0.7	19.0	52.3	26.4	1.8	0.4	4.08
0.8	32.2	52.0	13.7	1.9	0.2	11.75
0.9	55.5	31.0	11.2	2.0	0.3	27.21
1.0	54.9	30.0	9.4	4.8	0.9	26.35
1.1	46.3	41.9	10.5	1.1	0.3	12.39
1.2	32.6	53.1	12.9	1.2	0.1	6.08
1.3	23.4	58.0	16.6	1.9	0.1	3.49
1.4	17.8	60.3	19.3	2.2	0.4	2.31
1.5	15.1	60.7	20.7	3.4	0.2	1.29
1.6	9.0	51.4	34.9	4.4	0.3	2.39

Light shade is for PXA options that are in the money or out the money while dark shade is used for PXA options that are in the money or near the money.

Table C4: The distribution of the OI of PXA series according to the maturity categories ($\alpha\Delta = \pm 0, 1$)

$\alpha\Delta$	*PXA call options*					*Total (%)*
	1 (%)	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	
0.4	13.1	20.4	39.7	26.2	0.6	**13.26**
0.5	19.5	24.8	39.6	15.3	0.8	5.05
0.6	18.7	23.6	41.9	15.0	0.7	6.96
0.7	22.3	28.5	35.9	12.0	1.2	10.14
0.8	26.7	32.1	28.8	11.3	1.1	13.95
0.9	30.0	26.7	26.9	14.0	2.4	15.95
1.0	20.2	20.8	30.1	23.7	5.2	11.02
1.1	12.3	15.6	32.9	30.7	8.4	6.73
1.2	8.7	12.4	35.8	34.4	8.8	4.65
1.3	7.6	12.8	35.9	36.0	7.5	3.42
1.4	7.6	12.9	39.7	34.0	5.9	2.58
1.5	6.8	16.0	36.2	37.4	3.5	1.93
1.6	8.3	14.0	34.8	41.2	1.7	4.36

Table C4: (*Continued*)

$\alpha\Delta$	*PXA put options*					*Total (%)*
	(%)	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	
0.4	8.6	16.4	38.7	35.4	1.0	8.95
0.5	12.2	18.3	43.1	23.9	2.5	2.52
0.6	10.5	14.7	44.5	28.2	2.1	3.00
0.7	13.8	16.7	43.3	24.4	1.8	3.62
0.8	16.8	18.1	39.8	23.3	2.0	4.99
0.9	21.1	21.8	33.6	19.9	3.6	8.85
1.0	28.7	26.0	24.8	16.8	3.7	13.32
1.1	29.9	26.2	24.7	15.3	3.9	12.39
1.2	25.8	26.7	26.8	17.1	3.6	9.77
1.3	21.7	26.9	30.7	17.9	2.8	7.51
1.4	20.6	26.4	33.4	17.6	2.0	5.94
1.5	19.4	26.5	32.9	19.4	1.8	4.58
1.6	16.3	25.3	37.5	19.8	1.1	**14.57**

$\alpha\Delta$	*PXA call and put options*					*Total (%)*
	1 (%)	*2 (%)*	*3 (%)*	*4 (%)*	*5 (%)*	
0.4	11.2	18.7	39.3	30.1	0.8	**11.00**
0.5	16.9	22.5	40.8	18.3	1.4	3.73
0.6	16.1	20.8	42.7	19.3	1.1	4.89
0.7	19.9	25.2	38.0	15.5	1.3	6.73
0.8	23.9	28.2	31.9	14.7	1.4	9.25
0.9	26.6	24.8	29.4	16.2	2.9	12.23
1.0	25.0	23.7	27.1	19.8	4.3	12.23
1.1	24.1	22.7	27.4	20.4	5.4	9.70
1.2	20.6	22.4	29.5	22.3	5.2	7.33
1.3	17.6	22.8	32.2	23.2	4.2	5.56
1.4	16.9	22.6	35.1	22.2	3.1	4.34
1.5	15.9	23.6	33.8	24.4	2.3	3.32
1.6	14.6	22.9	36.9	24.4	1.3	**9.71**

Light shade is for PXA options that are in the money or out the money while dark shade is used for PXA options that are in the money or near the money.

