On the liquidity of CAC 40 index options Market

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Abstract

Daily data available between May 2005 and August 2012 show the presence of a considerable number of outstanding PXA contracts that have not expired and been offset by taking or making delivery. The current paper concludes that CAC 40 index options displays some illiquidity problems, particularly long term maturity options that are deep out or in the money.

To enhance liquidity, we test the generalized reset GR option of François-Heude and Yousfi (2013) in the PXA options' market.

Our preliminary results show a significant and positive effect on the liquidity of PXA options in several ways.

Keywords: strike reset, option, PXA, liquidity, reset option.

JEL Classification codes: G12, G13.

1 Introduction

CAC 40 options are "*the most heavily traded index options in the world*" (Capelle-Blancard and Chaudhury, 2001), does it mean that CAC 40 options market is very liquid?

The current paper shows that resetting the strike price at the underlying asset price at a preagreed point in time improves the PXA options' market. In line with François-Heude and

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Yousfi (2013), we replace Out-the-money and In-the-money of the CAC40 index options, namely PXA, by At-the-Money ones by resetting the strike price to the then CAC40 index value. Our results show that this increases the number of near the money options which increases the liquidity of CAC40 options market.

It is commonly known that liquidity issue is a major concern for practionners, financiers and policymakers. Handa and Schwartz (1996) argue that "*Investors want three things from the markets: liquidity, liquidity and liquidity*". It represents 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).

The literature on liquidity in options' market attracts an increasing interest of academics in microstructure and pricing options. There are many studies on liquidity determinants for stocks and bonds (see among others Easley and O'Hara, 2003 and Amihud et al. 2005) using one-dimensional and multidimensional liquidity measures, like for example bid-ask spread (Eleswarapu, 1997; Kamara, 1994; and Amihud and Mendelson, 1986, 1991), the price impact of trades (Brennan and Subrahmanyam, 1996) and volume and turnover ratio (Datar et al. 1998; and Haugen and Baker, 1996) and Liu measure (Liu, 2006). However, few studies have been conducted on liquidity in options' market and on the effect of options liquidity on options pricing. Most of them are conducted on North American markets; studies on European markets are still limited.

Some papers (Deville and Riva, 2007, Roll et al., 2007, Deville, 2004, Mittnik and Rieken, 2000 and Kamara and Miller, 1995) focus on the CAC 40 index market and provide evidence that it displays a high level of liquidity. However they are drawn on a short-term analysis. In contrast, the current study provides evidence that PXA contracts display some illiquidity problems, particularly long-term maturity PXA options that are deep ITM or OTM. Our sample covers a long period of time ; daily data on PXA liquidity between May 2005 and August 2012.

Our paper is related to three strands of the financial literature.

First, it is linked to the studies on the liquidity of the underlying asset and options pricing. For instance, in a comparative study, 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. Some studies, see among others Bollen and Whaley (2004) and Garleanu et al. (2009), find a link between buying and selling flows and the nature of the options (call, index put options or individual or single stock options). As options are contingent assets, other studies argue that the liquidity of the underlying asset may have an effect on the pricing of options. They pay particular attention to the spot liquidity risk in the pricing formulae of options. For instance, Frey (1998) shows that large agents whose trades may lead to a down/upward movements 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.

Second, our paper is related to the extensive literature on valuation problems for options, particularly options with either reset condition or a forward-start feature (see among others Rubinstein, 1991, Gray and Walhey, 1999 and Haug and Haug 2001). We test the generalized reset option of François-Heude and Yousfi (2013).

Finally, our paper is also related to the studies on CAC 40 options market. For instance, Gregoriou (2011) considers a slight different problem , i.e. the effects of addition or deletion of stocks on the CAC 40 index between 1997 and 2001. Liquidity variations are explained by the direct cost of trading and the asymmetric information cost of transacting. 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, 2009 and 2008). Similarly, Cont and Da Fonseca (2002) analyze and study the dynamics of the factors influencing the deformation of implied volatility surface.

In the current paper, we examine the option market liquidity drawn on all the data available between May, 2005 and August, 2012. Some of the data were hand-collected and the rest was provided by *Euronext data*. Our results provide evidence that PXA market displays some illiquidity problems when we consider PXA expiration dates, strike price series and moneyness. This analysis has never been done before.

To enhance PXA liquidity, we test the generalization of reset option discussed in François-Heude and Yousfi (2013) in PXA market. They propose an extension of reset option (Gray and Whaley, 1999). The intuition is to automatically reset the strike price to the underlying asset price before maturity whether the strike price is inferior or superior to the then underlying index value. The strike price such that OTM and ITM options is reset such that they become ATM in exchange for deposits in the Clearing House. These deposits can be considered as the cost paid by the holders of OTM options for obtaining more liquid options than theirs or the profit obtained by the holders of ITM options who want to lock in at a certain time point.

The contribution of this paper is double. First, it provides evidence that the PXA market displays some liquidity problems. Unlike previous studies, our data are collected over a long period of time: our analysis is drawn on data (80 completed options contracts and 13 current options contracts) between May, 2005 and August, 2012. Second, it provides some practical recommandations to overcome these liquidity problems in several ways.

The rest of this paper is organized as follows. Section 2 presents PXA data and highlights several illiquidity problems. Section 3 provides some practical recommendations. We conclude in Section 4.

2 Stylized facts on CAC 40 index option

2.1 Data

Data are hand-collected and are provided by:

- MATIF (Marché à Terme International de France) and MONEP between January, 1999 and April, 2009.
- BDM (Base de Données de Marché) of the SBF (Société Bourse de France) between December, 1999 and March, 2001.
- NYSE-EURONEXT databases between March, 2003 and August, 2012 [1].

We compare data and filter out outliers. These sources provide information on PXA option characteristics: trade date, type (call/put), option maturity, strike price, transaction volume, trades, open interest OI, the underlying closing and opening prices, and the highest and lowest prices. More informations on PXA options are available in appendix A.

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

Consequently, there are 1878 trade-dates between May, 2005 and August, 2012. To take into account the adoption's effects of new contracts form PXA, we screen the PXL data and eliminate transactions' volume between May 9, 2005 and August 19, 2005 but keep OI of August 22, 2005 to analyze options liquidity. In addition, there are no data available on trades between May and December 2009[2]. The remaining data is organized according to the market months[3] and the data that do not belong to the market month were not included in our data analysis: we obtain then 84 market months (1793 trade dates).

We structure our data into different series according to the level of analysis.

- If we consider expiration dates, there are 27 314 series
- If we focus on strike series for all the available maturities, we get 821 989 series.
- If we distinguish between call and put options, the number of series increases significantly to acheive 1 643 978.

We join Capelle-Blancard and Chaudhury (2007) and find that the volume of PXA options traded is significantly high (48 164 269): call options represent 44,46% of traded contracts (21 414 872). Put options capture around 55,54% of the total volume (26 749 397) which could be explained by the downward trend in the market.

There are missing data between May, 2009 and December, 2009. In addition, we do not include data that do not belong to the market month.

2.2 Descriptive statistics

The volume and OI display similar trends between May, 2005 and August, 2012. First, they were increasing between September, 2005 and September 2007. Then, the number of OI

[2] Because of the setup of 13 open maturities instead of 22 open maturities, some maturities of the previous regime were kept to facilitate the transfer. However, we delete them of 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.

[3] 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).

and PXA volume fluctuated until June 2009. Finally, they suddenly decreased (see figures 1 and 2).

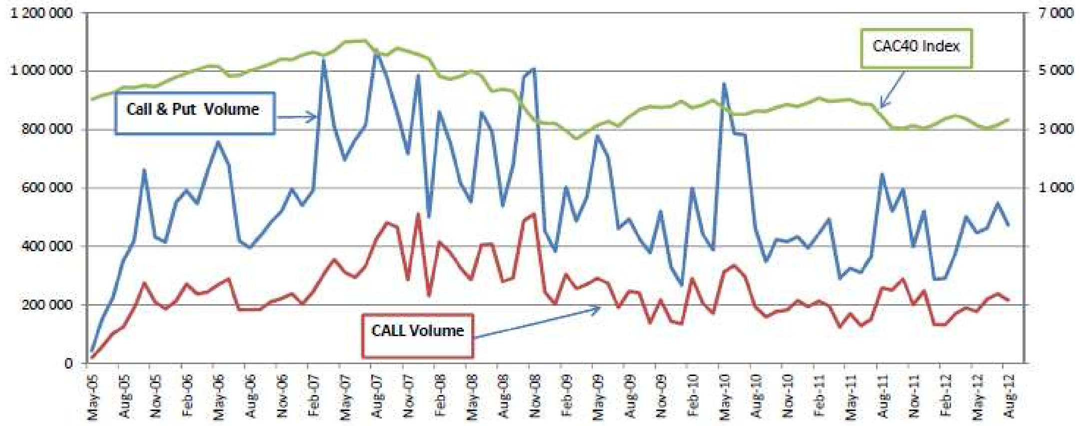

Figure 1: Monthly volume statistics of PXA (left-axis) and CAC 40 index (right-axis) between May, 2005 and August 2012.

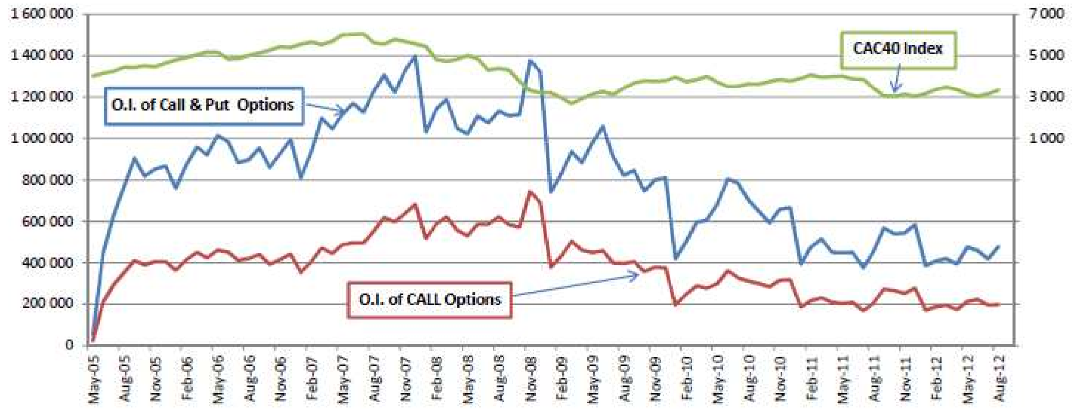

Figure 2: Monthly Statistics of PXA Open interest (left-axis) and CAC40 index (right-axis) between May, 2005 and August, 2012.

The descriptive statistics are summarized in tables 1 and 2. Table 1 provides monthly data while table 2 presents daily ones. It is straightforward to see that the CAC 40 index option market displays a high level of liquidity: the volume and number of trades. Notice that despite this high level of liquidity, the number and volume of OI are considerably high.

They show that on average there are 48 164 269 options traded on average per day: more than 55, 53 % of these transactions are put options. Notice that the number of trades varies between 170 (minimum) and 4 367 trades (maximum) which may explain the large standard deviation. This may be explained by the presence of high volatility. The number of OI varies significantly between 312 501 and 1 511 329. Thus we may suspect some illiquidity problems in PXL market during this period of time.

Monthly statistics show that CAC 40 index varies between 4 030, 60 in May 2005 and 3 338, 30 in August 2012. The decrease of the CAC 40 index is mainly explained by the subprime financial crisis. The highest index value was 6 048, 43 in July 2007 while the lowest value is reached in March 2009 (2 682, 02 points).

The average monthly OI of calls and puts is increasing between September 2005 and March 2009. After that it decreases 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 highlighted..

Monthly data	Volume			Trades			O.I.		
	Call	Put	Call+Put	Call	Put	Call+Put	Call	Put	Call+Put
Mean	254 939	318 445	573 384	9 425	10 127	19 552	254 939	318 445	573 384
Median	239 278	294 068	521 557	8 416	9 192	17 449	239 278	294 068	521 557
Standard deviation	90 797	121 738	198 818	3 515	3 778	7 129	90 797	121 738	198 818
Max	511 248	734 758	1 073 430	24 598	30 085	54 683	511 248	734 758	1 073 430
Min	123 437	131 256	266 019	5 293	5 437	10 856	123 437	131 256	266 019

Table 1: Descriptive statistics on PXA options over 84 market months between May 22, 2005 and August 20, 2012. Monthly data on Volume (84 obs), trades (78 obs) and OI (84 obs) where obs is the number of observations

Daily data	Volume			Trades			O.I.		
	Call	Put	Call+Put	Call	Put	Call+Put	Call	Put	Call+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	7 282	10 174	15 255	234	264	472	147 298	144 746	285 304
Max	82 155	106 871	152 896	1 798	2 704	4 367	817 854	778 441	1 511 329
Min	473	836	1 611	52	93	170	145 223	167 278	312 501

Table 2: Descriptive statistics on PXA options over 1793 market days between May 22, 2005 and August 20, 2012. Daily data on Volume (1793 obs), trades (1620 obs) and OI (1793 obs) where obs is the number of observations

In addition, tables 3 and 4 show strong and positive correlation between put and call OI in the daily and the monthly basis. Therefore, the increase of volume of PXA trades increases the number of OI and vice versa. However, when we consider daily statistics, almost all correlation coefficients are diminished. For instance, the linear correlation coefficient of total volume and OI decreases from 0, 70 to 0, 45. At an aggregate level, these analyses show that CAC 40 index options are highly traded and that PXL market is very liquid.

Linear Correlation		Call	
		monthly Vol	monthly PO
Put	monthly Vol	0,74	0,51
	monthly OI	0,67	0,91

Correlation between monthly Vol and OI of call and put options

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

Linear correlation		Call	
		daily Vol	daily PO
Put	daily Vol	0,51	0,30
	daily OI	0,40	0,93

Correlation between daily Vol and OI of call and put options

Table 4: Correlation between daily options Volume and OI over 1793 trading days.

2.3 Do statistics tell all the truth?

To develop our analysis of PXA option liquidity, we look for more specific measures of liquidity. The survey of the literature on liquidity show the presence of many measures of option liquidity, like for example width, depth and immediacy[4]. However, they cannot be used in daily data analysis.

[4]The main measures of option liquidity are:

- Width which is captured by the bid-ask spread and other transaction costs generated by the trade of

First, we use the two following ratios:

- Trading Volume/Transaction Trades ratio used to capture the average size of a transaction.
- Open Interest/Trading Volume ratio to assess the market trend.

However the second ratio has some weaknesses. For instance, OI is calculated end of the day while trading volume is the result of selling and buying orders during the trading day. This is why, it would be interesting to analyze OI variations (see table 5).

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

Table 5: Descriptive statistics on liquidity measures for call and put options over 84 market months. (No available data between May, 2009 and December, 2009)

The monthly average size of trade decreased by $62,36$ % from May, 2005 to August, 2012 (see figure 3). We recall that there are no available data on trades between May, 2009 and December, 2009. Although they fallen suddenly between May, 2005 and December, 2005, the variations of $\Delta OI/Volume$ ratio are more steady than those of $OI/Volume$ ratio. The ratio decreases form 9,1938 in May 2005 to 0,13 in August 2012 but the standard deviation is not very large. The decrease could be explained by the increase of the volume which is faster than the average number of open contracts per day. This tempts to point out some illiquidity problems.

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.

They are used in intraday data given by limit order book.

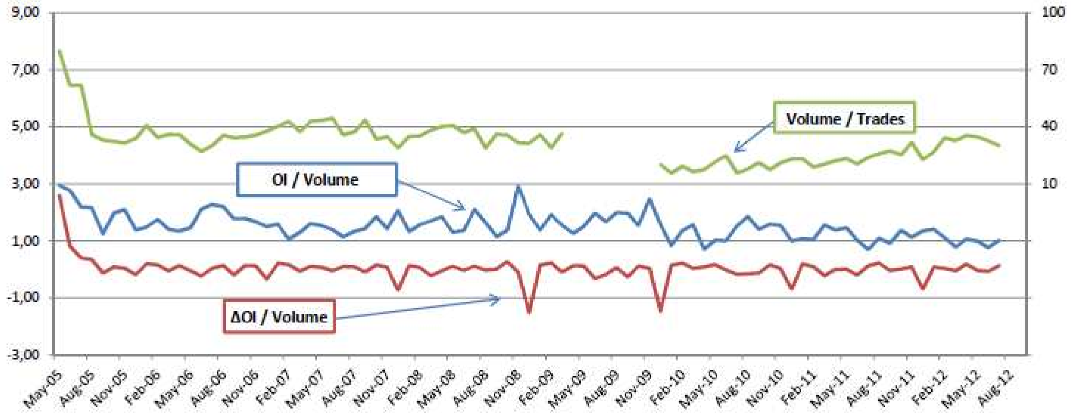

Figure 3: Variations of Volume/Trades Vol/TRA(right-axis), OI/Volume OI/Vol and Δ OI/Vol ΔOI/Vol monthly ratios (left-axis) between May, 2005 and August 2012.

To go further, this section examines the strike price series, PXA expiration dates and moneyness. We show that only short term near ATM PXA options are liquid. In fact, investors who hold deep OTM or ITM options cannot trade. As they are European options, options' holders have to wait until expiration. This could explain the high number of long term maturity PXA options available in the market and their low number of trades.

The number of PXA series is the sum of the call and put series. We recall that the number the PXA call series is equal to the PXA put series. They are symmetric with respect to ATM series. The following tables present the PXA series for call or put options.

Maturity n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Open maturity	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 FCE contracts were created for each maturity																					
Strike price interval	± 250			± 500																		

Table 6: Strike price series under the 22 open maturities scheme. The total number of strike series is $484 = 2\times 22 \times 11$ Between May 9^{th}, 2005 and May 21^{st}, 2007 (m: monthly, T: quarterly and Y: yearly).

Maturity n°	1	2	3	4	5	6	7	8	9	10	11	12	13
open maturity	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		± 800		$\pm 1\,200$							

Table 7: Strike price series under the 13 open maturities scheme. The total number of strike series is 194 between May 15^{th}, 2007 and March 8^{th}, 2010 (m: monthly, T: quarterly and Y: yearly).

Maturity n°	1	2	3	4	5	6	7	8	9	10	11	12	13
open maturity	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	$\pm 1\,200$		$\pm 1\,600$			$\pm 2\,800$				$\pm 2\,800$		

Table 8: Strike price series under the 13 open maturities scheme. The total number of strike series is 386 between March 8^{th}, 2010 and August 17^{th}, 2012 (m: monthly, T: quarterly and Y: yearly).

Between May 9, 2005 and May 17, 2007, the number of quarterly expiration dates was 19 (see table 6). After May 21, 2007, the quarterly expiration dates that last more than 2 years $T_i, i = 8, ..., 20$ were replaced by 3-year expiration dates $Y_i,\ i = 3, 4, 5$. Then, the number of strike price series decreased dramatically from 242 to 97 strike series but it rose 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, 7 and 8 show that strike price interval increased significantly. For instance, for the spot monthly maturity m_1, the interval scale becomes three time what is was under the 22 open maturities scheme. The intuition is to enable traders to take into account the high volatility of CAC40 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.

2.4 Expiration dates/Strike price series/Moneyness

As call and put options are symmetric, we focus on the distribution of one type PXA options. The following figure provides a summary of the distribution of series and maturities between September 2005 and August 2012. The number of quoted series is significantly superior to the theoretical number of series (242, 97 and 193 given respectively by tables 6, 7 and 8). 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 which 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.

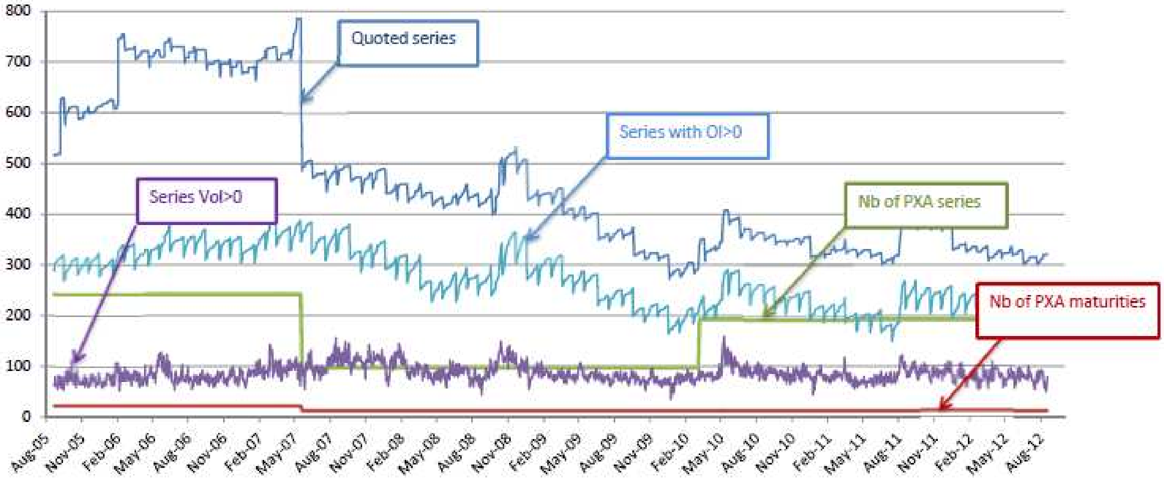

Figure 4: Distribution of PXA series between May, 2005 and August, 2012.

To examine these issues, we divide PXA maturities into 5 categories according to the following criteria:

Term	Category	delivery date	22 scheme	13 scheme
Very	1	$0 < T \leq 1\ m$	m_1	
Short	2	$1\ m < T \leq 3\ m$	m_2 and m_3	
Medium	3	$3\ m < T \leq 1\ y$	T_2, T_3 and T_4	
Long	4	$1\ y < T \leq 3\ y$	T_5-T_{12}	T_5-T_8 and Y_3
Very long	5	$3\ y < T \leq 5\ y$	T_{13}-T_{22}	Y_4 et Y_5

Table 9 : Categories of PXA expiration dates (m: month , y: year)

Adding these criteria changes the distribution of PXA call and put series and provides interesting results. Short term maturity categories (1 and 2) capture the highest number of PXA contracts: 83,37 % of PXA options mature before 3 months (see table 10). Long maturity index options display some liquidity problems: less than 3,5 % of PXA contracts in our data belong to the categories 4 and 5 (see appendix B for further statistics on call/put distribution).

Maturity category	1	2	3	4	5
Mean	43, 71 %	39, 66 %	13, 50 %	2, 70 %	0, 44 %
Median	44, 12 %	38, 46 %	13, 46 %	1, 70 %	0, 05 %
Standard deviation	7, 67 %	8, 80 %	5, 17 %	2, 83 %	0, 79 %
Max	60, 95 %	60, 00 %	29, 56 %	13, 65 %	4, 15 %
Min	27, 97 %	22, 12 %	4, 35 %	0, 02 %	0, 00 %
Average cumulative frequency	43, 71 %	83, 37 %	96, 87 %	99, 56 %	100 %

Table 10 : Descriptive statistics on the distribution of PXA options

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 is the underlying index price, X is the strike price and Δ is the interval scale. We calculate the percentage of volume of near the money options in the following:

$$|S - X| \leq \pm\alpha\frac{\Delta}{2} \text{ where } \alpha \in \mathbb{N}$$

Call and Put	$\pm 1\frac{\Delta}{2}$	$\pm 2\frac{\Delta}{2}$	$\pm 3\frac{\Delta}{2}$	$\pm 4\frac{\Delta}{2}$	$\pm 5\frac{\Delta}{2}$	$\pm 6\frac{\Delta}{2}$	$\pm 7\frac{\Delta}{2}$	$\pm 8\frac{\Delta}{2}$
ATM options	4,11%	8,18%	12,191%	16,10%	19,88%	23,56%	27,15%	30,57%

$\pm 9\frac{\Delta}{2}$	$\pm 10\frac{\Delta}{2}$	$\pm 11\frac{\Delta}{2}$	$\pm 12\frac{\Delta}{2}$	$\pm 13\frac{\Delta}{2}$	$\pm 14\frac{\Delta}{2}$	$\pm 15\frac{\Delta}{2}$
33,83%	37,07%	40,18%	43,04%	45,75%	48,45%	51,02%

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

$\alpha\Delta$	0,4	0,5	0,6	0,7	0,8	0,9	1,0
ATM $\pm\ \alpha\frac{\Delta}{2}$	$<$ 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 $\pm\,\alpha\frac{\Delta}{2}$	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 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 $\pm\,\alpha\frac{\Delta}{2}$	<0,45	0,45-0,55	0,55-0,65	0,65-,075	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 $\pm\,\alpha\frac{\Delta}{2}$	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%

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

However, table 11 provides aggregate results for both PXA call and put options. To examine closely the distribution of ATM options, we focus on the distribution of the PXA volume and OI with respect to the 5 categories of maturity.

First, we calculate the underlying CAC 40 index value and strike price ratio $\left(\frac{S}{X}\right)$ and consider that the interval scale unit is $\Delta = \pm\, 0,1$.A PXA option is ATM if $\frac{S}{X}$= 1± 5 %.

The main result of table 12 is that only 12,27 % (respectively 37,63%) of call (respectively put) options are ATM while almost 72% (respectively 33%) are OTM. In conclusion, 65,95% of PXA options are near the money. It would be better to reset all the OTM options into ATM ones to improve the PXA liquidity.

Table 13 shows that 65, 31% (respectively 54,76%) of PXA call (respectively put) series are OTM. Unlike PXA volume, OI are widely dispersed across the moneyness scale $\alpha\Delta$. For instance, 12,32 % of OI are ATM, 21,93% are near the money options and 20,71 % 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 across maturity categories.

3 Recommendations 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 introduce the Parity-reverting condition. In other words, we reset, each third Friday, the strike price to the current value of the underlying index.

Second, we keep 5 scales A, B, C, D and E such that the interval scale is 25 i.p.

Third, we propose to set up 10 PXA expiration dates instead of the 13. Then, PXA trading will cover:

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

Finally, we reduce the number of strike price series. For each maturity, we keep only three strike series (ATM, ITM and OTM).

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

Table 14: The distribution of PXA strike price series.

To analyze the consequences of these recommendations, we identify open positions of PXA series that are not ATM. August series that mature in 2012, expired in August 17^{th}, 2012. There are still open positions for the remaining 12 PXA maturities. For each contract, we define the ATM strike price.

	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
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%**	**Total**	**91,1%**	**84,1%**	**82,8%**	**79,9%**	**Total**	**86,6%**	**81,3%**	**70,2%**	**66,3%**	

(a)

	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
2 & 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 & 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%**

(b)

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.

It is straightforward to see that the distribution of OI is less dispersed when maturities are grouped in 5 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.

4 Conclusion

Our study provided evidence that the CAC 40 index options displays some illiquidity issues when some specific criteria are considered like for example strike price series, FCE maturities and moneyness.

Then, we proposed (1) to diminish the PXA maturity contracts from 13 to 10, (2) to keep only 3 strike price series (ATM, OTM and ITM) per interval scale and (3) *parity reverting* option which consists in resetting the PXA strike price at the value of the underlying FCE in exchange for deposit in the Clearing House. Under specific conditions, we show that this condition is applicable to several general settings.

Third, we derived general analytic pricing formulae to value this option inspired by among others, Gray and Whaley (1999), Haug and Haug (2001) and Cox et al. (1973), and used it to compare our model with BSM, Reset-in and reset-out. Results are quite satisfying.

In future research, several issues related to the liquidity of the CAC 40 index should be developped to improve our results. For instance, it would be interesting to study several extensions of the current paper. First, for simplicity we assumed that the risk free-interest rate, dividend yield rate and volatility are fixed until maturity but considering variable parameters will allow for a more flexibility of our model. For instance, we could suppose that before reset date t, we have r_t , d_t and σ_t, and $r_{(T-t)}$, $d_{(T-t)}$ and $\sigma_{(T-t)}$ after reset.

Finally, we focused only on European style option but we did not derive valuation for American style options. This would be quite useful to study the liquidity of the French equity options. 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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Appendix

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)[5]. 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[6]. 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 May 9, 2005 and May 18, 2007, trades covered 22 PXA open maturities: 3 monthly (each month) and the following 19 quarterly (March, June, September and December cycle) maturities. Since May 21st, 2007, PXA trading has covered 13 expiration dates:

Cycle	Expiry 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

Table 1: Expiration dates of PXA option (prospectusMonep,www.euronext.com)

Expiration date is the third Friday of the expiration month at 4 p.m. Central European Time. Once maturity expires, a new expiration month is opened the following Monday (see appendix A for more details).

Strike prices are standardized according to symmetric intervals around ATM calls and puts that depend closely on the lifetime of the contract (see appendix C). Strike prices and intervals are function of index point (i.p.). There are 6 CAC 40 index intervals according

[5] The latter value is the average of the CAC40 index values between 3:30 p.m. and 4:00 p.m.

[6] 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.

to the variation of the strike price[7]:

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

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 option strike 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 minimum number of strike price series per interval scale depend on the remaining lifetime of an option. Let consider an option matures at T:

- If the remaining lifetime $(T - t) \leq 1$ month, there are 5 strike prices around the money in interval scale A and 6 others in interval scale B.
- If $1 < (T - t) \leq 3$ months, there are 3 strike prices in interval scale B and 6 others in scale C.
- If $3 < (T - t) \leq 9$ months, there are 3 strike prices in interval scale C and 6 others in scale D.
- If $9 < (T - t) \leq 24$ months, there are 3 strike prices in interval scale D and 4 others in scale E.
- If $(T - t) > 24$ months, there are 3 strike prices in interval scale E and 2 others in scale F.

[7] For more details, see appendix A and http://www.euronext.com.

The number of PXA call series is equal to those of PXA put options. Let consider the change of PXA call series over May, 2005 and August, 2012.

		3 M		7 T		3 A
Scale	Interval	1	2, 3	6,9,12	15, 18, 21, 24	36,48,60
		01-12	01-12	03-06-09	03-06-09	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 & Put options		21	21	21	13	5

Table 1: Strike price series between March 8^{th}, 2010 and August 17^{th}, 2012.

		3 M		7 T		3 A
Scale	Interval	1	2, 3	6,9	12, 15, 18, 21, 24	36,48,60
		01-12	01-12	03-06-09	03-06-09	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 & Put options		11	9	9	7	5

Table 2: Strike price series between May 15^{th}, 2007 and March 8^{th}, 2010.

		3 M	19 T
Scale	Interval	1, 2, 3	6, 9, ..., 60
		01-12	03-06-09
A	25		
B	50	ATM ± 5	
C	100		ATM ± 5
D	200		
E	400		
F			
Call & Put options		11	11

Table 3: Strike price series between May 9^{th} , 2005 and May 21^{st}, 2007.

Appendix C: The liquidity effect of maturity categories

Maturity category	1	2	3	4	5
Mean	43, 60 %	38, 88 %	14, 18 %	2, 86 %	0, 47 %
Mediane	44, 44 %	38, 82 %	13, 20 %	1, 82 %	0, 00 %
Standard deviation	8, 03 %	9, 30 %	6, 13 %	3, 22 %	0, 89 %
Max	61, 09 %	62, 65 %	37, 77 %	17, 58 %	4, 91 %
Min	23, 65 %	18, 13 %	4, 26 %	0, 00 %	0, 00 %
Average cumultaive frequency	43, 60 %	82, 49 %	96, 67 %	99, 53 %	100 %

Table 1: Descriptive statistics on the distribution of PXA call options

Maturity category	1	2	3	4	5
Mean	43, 79 %	40, 29 %	12, 95 %	2, 57 %	0, 41 %
Mediane	43, 27 %	39, 01 %	12, 09 %	1, 51 %	0, 07 %
Standard deviation	8, 57 %	9, 56 %	5, 02 %	2, 77 %	0, 73 %
Max	61, 46 %	64, 44 %	27, 07 %	15, 72 %	3, 59 %
Min	23, 52 %	21, 33 %	3, 93 %	0, 01 %	0, 00 %
Average cumultaive frequency	43, 79 %	84, 08 %	97, 02 %	99, 59 %	100 %

Table 2: Descriptive statistics on the distribution of PXA put options

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.

The distribution Of PXA volume according to the 5 maturity categories:

	PXA call options						PXA put options						PXA call and put options					
αΔ	1	2	3	4	5	*Total*	1	2	3	4	5	*Total*	1	2	3	4	5	*Total*
0,4	3,6%	25,4%	63,0%	7,9%	0,0%	***0,92%***	10,5%	23,2%	59,0%	7,3%	0,0%	***0,29%***	5,6%	24,8%	61,9%	7,8%	0,0%	***0,57%***
0,5	6,5%	58,6%	30,9%	4,0%	0,0%	***1,42%***	10,4%	23,0%	58,0%	8,6%	0,0%	***0,03%***	6,6%	57,6%	31,6%	4,2%	0,0%	***0,65%***
0,6	11,2%	50,8%	34,7%	3,3%	0,0%	***3,23%***	23,4%	19,8%	26,3%	2,6%	27,9%	***0,04%***	11,4%	50,3%	34,6%	3,3%	0,4%	***1,46%***
0,7	18,4%	53,0%	26,7%	1,7%	0,2%	***8,91%***	39,4%	29,5%	18,2%	5,5%	7,4%	***0,21%***	19,0%	52,3%	26,4%	1,8%	0,4%	***4,08%***
0,8	32,2%	53,1%	13,3%	1,3%	0,1%	***25,13%***	32,9%	30,1%	23,2%	12,5%	1,3%	***1,03%***	32,2%	52,0%	13,7%	1,9%	0,2%	***11,75%***
0,9	57,9%	31,6%	9,0%	1,4%	0,2%	***47,10%***	47,5%	29,3%	18,5%	4,1%	0,6%	***11,30%***	55,5%	31,0%	11,2%	2,0%	0,3%	***27,21%***
1,0	47,9%	24,1%	14,5%	11,3%	2,2%	***12,27%***	56,7%	31,5%	8,1%	3,1%	0,6%	***37,63%***	54,9%	30,0%	9,4%	4,8%	0,9%	***26,35%***
1,1	33,3%	30,4%	21,3%	8,7%	6,3%	***0,61%***	46,6%	42,1%	10,2%	0,9%	0,2%	***21,81%***	46,3%	41,9%	10,5%	1,1%	0,3%	***12,39%***
1,2	21,0%	24,9%	40,7%	10,5%	2,9%	***0,12%***	32,7%	53,3%	12,7%	1,1%	0,1%	***10,84%***	32,6%	53,1%	12,9%	1,2%	0,1%	***6,08%***
1,3	13,7%	21,6%	41,8%	13,4%	9,5%	***0,06%***	23,4%	58,3%	16,4%	1,8%	0,0%	***6,23%***	23,4%	58,0%	16,6%	1,9%	0,1%	***3,49%***
1,4	2,4%	18,5%	21,2%	20,2%	37,7%	***0,05%***	17,9%	60,7%	19,3%	2,0%	0,0%	***4,12%***	17,8%	60,3%	19,3%	2,2%	0,4%	***2,31%***
1,5	2,4%	8,8%	62,9%	26,0%	0,0%	***0,03%***	15,2%	61,2%	20,3%	3,2%	0,2%	***2,29%***	15,1%	60,7%	20,7%	3,4%	0,2%	***1,29%***
1,6	11,4%	31,2%	51,7%	5,6%	0,0%	***0,15%***	8,9%	52,0%	34,4%	4,3%	0,3%	***4,17%***	9,0%	51,4%	34,9%	4,4%	0,3%	***2,39%***

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

The distribution Of PXA OI according to maturity categories:

	PXA call options						PXA put options						PXA call and put options					
αΔ	1	2	3	4	5	*Total*		2	3	4	5	*Total*	1	2	3	4	5	*Total*
0,4	13,1%	20,4%	39,7%	26,2%	0,6%	***13,26%***	8,6%	16,4%	38,7%	35,4%	1,0%	***8,95%***	11,2%	18,7%	39,3%	30,1%	0,8%	***11,00%***
0,5	19,5%	24,8%	39,6%	15,3%	0,8%	***5,05%***	12,2%	18,3%	43,1%	23,9%	2,5%	***2,52%***	16,9%	22,5%	40,8%	18,3%	1,4%	***3,73%***
0,6	18,7%	23,6%	41,9%	15,0%	0,7%	***6,96%***	10,5%	14,7%	44,5%	28,2%	2,1%	***3,00%***	16,1%	20,8%	42,7%	19,3%	1,1%	***4,89%***
0,7	22,3%	28,5%	35,9%	12,0%	1,2%	***10,14%***	13,8%	16,7%	43,3%	24,4%	1,8%	***3,62%***	19,9%	25,2%	38,0%	15,5%	1,3%	***6,73%***
0,8	26,7%	32,1%	28,8%	11,3%	1,1%	***13,95%***	16,8%	18,1%	39,8%	23,3%	2,0%	***4,99%***	23,9%	28,2%	31,9%	14,7%	1,4%	***9,25%***
0,9	30,0%	26,7%	26,9%	14,0%	2,4%	***15,95%***	21,1%	21,8%	33,6%	19,9%	3,6%	***8,85%***	26,6%	24,8%	29,4%	16,2%	2,9%	***12,23%***
1,0	20,2%	20,8%	30,1%	23,7%	5,2%	***11,02%***	28,7%	26,0%	24,8%	16,8%	3,7%	***13,32%***	25,0%	23,7%	27,1%	19,8%	4,3%	***12,23%***
1,1	12,3%	15,6%	32,9%	30,7%	8,4%	***6,73%***	29,9%	26,2%	24,7%	15,3%	3,9%	***12,39%***	24,1%	22,7%	27,4%	20,4%	5,4%	***9,70%***
1,2	8,7%	12,4%	35,8%	34,4%	8,8%	***4,65%***	25,8%	26,7%	26,8%	17,1%	3,6%	***9,77%***	20,6%	22,4%	29,5%	22,3%	5,2%	***7,33%***
1,3	7,6%	12,8%	35,9%	36,0%	7,5%	***3,42%***	21,7%	26,9%	30,7%	17,9%	2,8%	***7,51%***	17,6%	22,8%	32,2%	23,2%	4,2%	***5,56%***
1,4	7,6%	12,9%	39,7%	34,0%	5,9%	***2,58%***	20,6%	26,4%	33,4%	17,6%	2,0%	***5,94%***	16,9%	22,6%	35,1%	22,2%	3,1%	***4,34%***
1,5	6,8%	16,0%	36,2%	37,4%	3,5%	***1,93%***	19,4%	26,5%	32,9%	19,4%	1,8%	***4,58%***	15,9%	23,6%	33,8%	24,4%	2,3%	***3,32%***
1,6	8,3%	14,0%	34,8%	41,2%	1,7%	***4,36%***	16,3%	25,3%	37,5%	19,8%	1,1%	***14,57%***	14,6%	22,9%	36,9%	24,4%	1,3%	***9,71%***

Table 2: The distribution of the OI of PXA series according to the maturity categories $(\alpha\Delta = \pm 0,1)$.

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