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Price Clustering in the CAC 40 Index Options Market

Gunther Capelle-Blancard[§]

and

Mo Chaudhury[¶]

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Corresponding Address: Mo Chaudhury, Faculty of Management, McGill University, 1001Sherbooke St W, Montreal, QC, Canada H3A 1G5, Tel: (514) 398-5927, Fax: (514) 398-3876, Email: mo.chaudhury@mcgill.ca.

[§] EconomiX-Université Paris X *Nanterre*, TEAM-Université Paris 1 *Panthéon-Sorbonne* & CNRS. 106-112 Bd de l'Hôpital 75647 Cedex 13 Paris, France, Tel: 33-1-44078271, Fax: 33-1-44078270, Email: gunther.capelle-blancard@univ-paris1.fr.

[¶] Faculty of Management, McGill University, 1001 Sherbrooke Street West, Montreal, QC, Canada H3A 1G5, Tel: (514) 398-5927, Fax: (514) 398-3876, Email: mo.chaudhury@mcgill.ca.

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Abstract

We examine in details the pattern and systematic tendencies of clustering in CAC 40 index option transaction prices during the 1997-1999 period. Similar to extant studies in many financial markets, there is evidence of strong clustering at full index points and option prices are 90% more likely to end with the digit 0 (multiples of 10) than with the digit 5. While the 1999 contract downsizing led to some reduction in clustering at full index point, the basic pattern of clustering remains intact. The pattern of clustering rejects the attraction theory, but is consistent with the notion of cost recovery by market makers. We find important drivers for CAC 40 index option price clustering, namely, the level of option premium, option volume and underlying asset volatility. Higher premium level, higher asset volatility and lower volume are seen to increase option price clustering. We also observe a U-shaped pattern of clustering on an intraday and intra-year basis. The option premium and volatility effects are consistent with a price level effect. The volatility effect also lends support to the notion of cost recovery by market makers. The volume effect likely represents a liquidity effect and is consistent with the Price Precision Hypothesis.

Keywords: Clustering, Tick, Euronext.

1. Introduction

Price clustering refers to the overwhelming occurrence of quoted and/or traded (transaction) prices at certain fractions or digits. By causing discreteness in observed prices or amplifying any discreteness arising from the formal or informal institution of minimum price moves known as ticks, clustering can significantly affect the transaction costs and liquidity in a market. Further, clustering may constitute a significant source of measurement error around the true or equilibrium moments of returns.

Studies of price clustering in financial markets began with Osborne (1962, US stocks), Niederhoffer (1965, 1966, NYSE) and Niederhoffer and Osborne (1966, NYSE). More recently, Harris (1991, US stocks markets), show a significant tendency for prices to cluster on integers, halves, odd quarters and odd eighths in descending preference that is persistent over time and across stocks for the various US markets. The price clustering phenomenon has drawn much attention since Christie and Schultz (1994) attributed extreme clustering of quotes at even-eighths for actively traded NASDAQ stocks to possible collusion among the market makers. In a later study, Huang and Stoll (2001) examine the relationship between clustering and ticks size, bid-ask spread and market structure using New York Stock Exchange and London Stock Exchange data. Clustering in other markets is reported by Ball, Torous and Tschoegl (1985, Gold), Goodhart and Curcio (1991, Foreign Exchange), Sopranzetti and Datar (2002, Foreign Exchange), Kahn, Pennachi and Sopranzetti (1999, Bank Deposit Rate), Hameed and Terry (1998, Singapore Stock Exchange), Aitken, Brown, Buckland, Izan and Walter (1996, Australian Stock Exchange), Ap Gwilym, Clare and Thomas (1998b, Bond Futures), Bollen, Smith and Whaley (2003, S&P 500 Futures), and Schwartz, Van Ness and Van Ness (2004, S&P 500 Futures).

There are a number of explanations available in the literature as to why clustering occurs. Goodhart and Curcio (1991) advance the attraction theory or round number syndrome that as a matter of behavior people are more attracted to certain digits than others. According to Ball, Torous and Tschoegl (1985), a courser price resolution leading to clustering may result from the imprecision in valuation due to lack of information, volatility of price when information is revealed, and a higher level of price. The related reasoning of Grossman et al (1997) is that precision in valuation is costly and factors that increase this cost and/or reduce the benefit of precision (e.g., uncertainty about value, high price level, lack of liquidity, high volatility, higher risk exposure due to rapidly changing prices, smaller trade size) will lead to greater clustering. Harris (1991) argues that a courser price grid simplifies the process of negotiation among traders and as such reduces the cost of negotiation among traders. Hence, we should expect greater clustering when negotiation costs are higher such as with higher volume and higher volatility, or when negotiation benefits are lower such as with lower trade size and higher price level. Christie and Schultz (1994) attribute clustering to collusion among market makers. In a more recent work, the theory of market making provided by Anshuman and Kalay (1998) implies that price clustering may be necessary if the minimum tick (or small multiples of the minimum tick) proves to be inadequate for the market makers to provide liquidity in a profitable manner.

Whether behavioral or economic factors lead to clustering of asset prices, it seems that the option prices may also be prone to clustering due to similar reasons although the degree and pattern of clustering need not be the same. Clustering is particularly important for options on several counts. *First*, option prices are in general much lower than the underlying asset price. As such, high degree of option price clustering at some limited multiples of the tick may significantly increase the bid-ask spread component of option trading cost for non-market makers. *Second*, to the extent options are priced using hedging strategy and are used for risk management purposes, substantial pricing and hedging inaccuracy may result from high degree of price clustering. *Third*, option prices are increasingly used for implying market expectations about future volatility of the underlying asset. Such implied volatility measures and their manifold applications will be rendered imprecise by a high degree of clustering in option prices.

Over and above the importance of clustering in option markets, options of various types, strikes and maturities on an underlying asset also provide a valuable research opportunity for a more controlled study of cross-sectional variation in price clustering. Unlike a cross section of assets or stocks, options on an asset share the same market microstructure including the same market maker(s) on an exchange while allowing for different price levels, volumes, volatilities, liquidities, etc. Suppose that these and possibly other factors lead to varying degree of market making costs for options differing in type, strike, maturity and otherwise. Then, clustering (indirect estimate of bid-ask spread) and systematic tendencies in clustering are all the more natural for options than for futures or stocks. Despite these factors favoring examination of option price clustering, published research in this area is rather limited.

Ap Gwilym, Clare and Thomas (1998a) provide the first evidence of price clustering in the (index) options market. They examine 97,574 trades and 223,681 matched bids for options (American-style) on the FTSE100 stock index from January 4, 1993 to March 31, 1994. Although the minimum tick for these contracts is one-half index point, valued at 5 UK Pounds, Ap Gwilym, Clare and Thomas (1998a) find that over 95% of quotes and transaction prices occurred at full index point (even tick). Further, 30% (9.6%) of transaction prices had 0 (5) as the final digit.

In this paper, we examine the pattern of CAC 40 price clustering. Specifically, we investigate if the incidence of clustering is systematically related to factors such as option type (call or put), moneyness or the level of option premium, time to maturity, contract volume, the structural change in 1999 as well as calendar periods (month of the year and trading hour of the day). Empirical evidence produced in this paper should therefore be useful to researchers and practitioners in understanding what factors may associate with or contribute to clustering of option prices.

Further, this paper provides important empirical evidence about the implications of downsizing on the pattern of option price clustering. While there is a long tradition in the study of stock splits, the effect of downsizing stock index option contracts on option price clustering is not known. Starting in January 1999, the currency denomination of the CAC 40 index options was changed to Euro and the contracts were downsized significantly. In the US market, the CBOE has introduced mini (downsized) versions of the popular index contracts like the S&P 500. However, these mini contracts do not attract much volume and the fact that they co-exist with the larger contracts restricts the study of downsizing index option contracts. In contrast, since the switch to the Euro and the associated contract modifications in 1999, CAC 40 index options have surpassed S&P 500 and DAX in terms of volume (number of contracts). From a research point of view, the opportunity to study the changes, if any, in the clustering pattern of the CAC 40 index option prices is valuable. Not only we are dealing with a leading and liquid market, the investigation is clean in the sense that all securities (options) in question experienced the change(s) at the same point in time.

Our major findings are as follows. *First*, clustering at full index point seems more likely at higher levels of the premium and increasing moneyness of the option, for call options compared to put options and prior to the contract downsizing in 1999 than after. Since option premium increases with moneyness, call options are typically more expensive than put options and pre-downsizing premiums are higher than post-downsizing premiums, our findings are consistent with a price level effect reported by Ap Gwilym, Clare and Thomas (1998a) for FTSE 100 futures and options and predicted by the Price Resolution Hypothesis of Ball, Torous and Tschoegl (1985).

Second, lower volume and higher underlying asset (CAC 40) volatility are seen to contribute to option price clustering. This finding supports Grossman et al's (1997) Precision Hypothesis to the extent lower volume reflects poorer liquidity, but the lower volume effect is in conflict with the Negotiation Hypothesis of Harris (1991). From the unique effects of asset volatility on option prices, the volatility effect is consistent with a price level effect as well as the cost recovery implication of Anshuman and Kalay (1998). This is because higher asset volatility enhances option values and persistence of stochastic asset volatility at higher level means continued higher volatility of option values and thus adds to the risk of market making.

Third, similar to the US stock evidence of Harris (1991) and the FTSE 100 Option results of Ap Gwilym, Clare and Thomas (1998a), our results provide only limited support for the "attraction theory" of Goodhart and Curcio (1991). Accordingly, economic rather than behavioral explanations are presumably more important for the CAC 40 index option price clustering phenomenon.

Lastly, the downsizing of CAC 40 index option contract in 1999 moderated the association of clustering with in-the-money options and call options in a sizeable fashion and the effects of premium level and volume only in a mild manner. On the other hand, the volatility effect became much stronger.

The remainder of this paper proceeds as follows. Section 2 describes the CAC 40 index options market and the data. Section 3 presents evidence of clustering of the CAC 40 index options transaction (trade) prices. Section 4 contains multivariate probit analysis of clustering and potential determinants (moneyness, maturity, premium level, volume, asset volatility, option type, month of the year, contract change). A summary and concluding comments follow in Section 5.

2. The CAC 40 Index Options

Our study focuses on the European CAC 40 index options (PXL contracts) for the January 1997 to December 1999 period. We use the same sample as Capelle-Blancard and Chaudhury (2002). The database includes a time-stamped record of every trade that occurred on the MONEP and the transaction volume for all call and put options.

Some features of these option contracts have changed with the shift to the Euro. Before January 1999, options were available for two half-yearly expiration dates and consecutive strike prices were separated by 150 index points. The contract size was FRF 50 × the CAC 40 index and the minimum price fluctuation was 0.01 index point. At expiration, the cash settlement was equal to the difference between the exercise price and the expiration settlement index × FRF 50. Starting in January 1999, options are available for eight expiration dates (3 monthly, 3 quarterly and 2 half-yearly). The consecutive strike prices are separated by 50 index points for monthly expirations, 100 index points for quarterly expirations and 200 index points for half-yearly expirations. The contract size has changed to EUR 1 × the CAC 40 index and the tick size is now 0.10 index point.[1] The cash settlement at expiration is the difference between the exercise price and the expiration settlement index × EUR 1 (= FRF 6.55957).

3. Evidence of Clustering

The CAC 40 index option prices are recorded in the database in terms of index points with the last two digits representing the fractional part of an index point. We classify the CAC 40 transaction prices in increments of 5 according to the last two digits. Specifically these last two digits are 00, 05, 10, 15, ... , 50, .., 90, 95. If the last two digits of a transaction price is 50 (00), it means that the fractional part of the transaction price expressed in index points is one-half (full) index point. The minimum tick size of 0.01 index point prior to contract change in 1999 means that the last two digits could then vary between 00 and 99 in increments of 1. Following the contract change in 1999, the minimum tick size of 0.10 index point dictates that the last two digits should now vary between 00 and 90 in increments of 10.

[1] In fact, traders are still allowed to use 0.01 index point when they pass “link orders”, such as spreads.

As the increments of 05 and 10 account for the vast majority of transaction prices, we focus on the frequency of these digits presented in Table I.[2] We report the range (Range) between the highest and lowest percentage frequencies of the final digit as a measure of the level of price clustering. In order to compare clustering in the CAC 40 index options market with clustering in other markets, standardized range is reported as the Range of the variable Prop, namely the observed percentage for each digit by its expected percentage without clustering.

The CAC 40 index option transaction prices show some clustering patterns. *First*, similar to Ap Gwilym, Clare and Thomas (1998a), the distribution of the CAC 40 index options transaction prices is not uniform. There is a great deal of clustering around 00 and 50. Over the full sample period 1997-1999, 64.31% of the 215,767 transactions took place at full index point (last two digits: 00) while 12.28% of the transactions occurred at one-half index point (last two digits: 50). Since the smallest percentage is under 1%, the Range of 64.20% is practically the same as the percentage frequency of full index point (00) transactions and confirms the high level of clustering in CAC 40 index option transaction prices. The standardized range of 12.84 in addition portrays the overwhelming degree of clustering in CAC 40 index option prices compared to some other derivative markets where the standardized range information is available. Grossman et al. (1997) report standardized range of 2.4 for USD/JPY quotes, 2.0 for USD/DEM quotes, 1.4 for London gold market clearing prices, 1.36 for NASDAQ quotes, 0.8 for JPY/DEM quotes, 0.7 for ISE quotes and 0.24 for quotes at NYSE and AMEX. According to Ap Gwilym et al. (1998), the standardized ranges for trades and quotes respectively are 0.187 and 0.120 for Bund, 1.064 and 0.862 for BTP, 1.314 and 0.711 for JGB, and 0.132 and 0.123 for Long Gilt on the LIFFE.

Second, prices ending with the digit 0, i.e., multiples of 10, are more popular than those ending with the digit 5. This is evident in the rows Diff1 and Diff2 of Table I. The row Diff1 represents the difference between the sum for the digits ending with 0 and the sum for the digits ending with 5 while the row Diff2 represents similar figures excluding the cases of full (00) and 50 (one half) index points. Considering say the percentage frequency figures, Diff1 is more than 90% in the overall sample as

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[2] Classification by increments of 01 (1/100 of a full index point) are available on request. Although in the post-Euro 1999 period the tick size is 0.10 index point, we still see some transactions continuing to

well as the two sub-periods. This means that the CAC 40 index option prices are 90% more likely to end with the digit 0 (multiples of 10) than with the digit 5. That this pattern is not solely driven by the cases of full (00) and half (50) index points is shown by the Diff2 figures. Even when these two overwhelmingly popular pricing practices are excluded, the percentage frequency of prices ending with 0 in the total sample is 15.45% more than the percentage frequency of prices ending with 5.

Third, the significant clustering at full and half index points followed by the relative popularity of the multiples of 10 is common in the two sub-periods 1997-1998 and 1999. Thus, the move to denomination in Euro and the associated changes in contract specification including a change in the tick size did not fundamentally affect the pattern of price clustering.

Fourth, while the basic pattern of clustering remains the same following the Euro-related changes, the degree of clustering seems to have abated somewhat, as shown by the drop in the Range (from 75.49% to 57.30%) and the Standardized Range (from 15.10 to 11.46). This is because the clustering at full index point has dropped substantially from 75.59% in 1997-1998 to 57.41% in 1999. The transaction frequency at half index point remained virtually the same but the popularity of the multiples of 10 increased in the 1999 sub-period.

We believe these changes are due to the change in tick size and contract downsizing. As noted earlier, starting in January 1999, the contract size is Euro 1 × the index while previously it was FRF 50 × the index and the tick size has changed from 0.01 index point to 0.10 index point. The tick value accordingly has changed from FRF 0.50 (EUR 0.0762) to about FRF 0.6560 (EUR 0.10). Changing the tick to 0.076 index point to go along with downsizing would have maintained the same tick value as before. But increments of EUR 0.076 or 1/13.16 do not seem appealing even by some existing or prior norms in the USA like 1/32, 1/16, and 1/8. A tick of 0.0625 index point or EUR 1/16 would have lowered the minimum bid-ask spread income for the CAC 40 index options market makers in the post-Euro era, an unlikely proposition if the Exchange (MONEP) wanted the market makers to provide at least the same level of liquidity as before. A tick of 0.0833 index point or EUR 1/12 instead would have increased the minimum bid-ask spread income for the market makers.

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take place at odd multiples of 0.05 index point and for that matter at multiples of 0.01 index point similar to the pre-Euro 1997-1998 period.

However, the high degree of clustering in the pre-Euro era at full and half index points suggests that a tick value of EUR 0.076 was deemed quite inadequate by market makers as the minimum bid-ask spread income. As such, increasing the tick value by about 32%, from EUR 0.076 to EUR 0.10, perhaps provided sufficient incentive for the market makers for at least some types of trades.[3] This, in our view, constitutes a likely explanation for the increased frequency for the multiples of 10 other than 00 and 50 following the 1999 contract changes.

Bollen, Smith and Whaley (2003) report that strong clustering of S&P Futures prices at 0.00 and 0.50 continued even after doubling the tick size starting on November 03, 1997 when the contract was downsized by 50%. Further analysis of the market making costs led them to conclude that the previous tick size was too small for the S&P 500 Futures market makers to recover their costs.[4] Thus, our CAC 40 findings here extend support for the long held belief (Grossman et al (1997)) and the theory (Anshuman and Kalay (1998)) that clustering is a rational result of cost recovery and profit maximization by competitive market makers.[5]

Lastly, our results provide only limited support for the "attraction theory" of Goodhart and Curcio (1991). This theory assumes that the digit 00, which is likely to be the more salient, is a stronger attracter than 50, which is stronger than any others. According to the theory, 10 and 90 will be strongly attracted to 0 and not very common, unlike 20 and 80 which will be more common than the others (except 00 and 50). Our results, as indicated previously, do indicate 00 to be the most popular digits followed by 50. However, inconsistency with the attraction theory arises in that the digits 10 and 90 have frequency of 2.65% and 2.52% respectively in the full sample period 1997-1999 while the frequency of 20 and 80 are lower at 2.13% and 2.20% respectively. This is also the case in the 1999. Further, the frequencies of 10 and 90 are greater than the frequencies of 30, 40, 60 and 70 in the full sample period as well as the two sub-periods. These results confirm Harris (1991) results on US stock market and Ap Gwilym, Clare and Thomas (1998) results for the FTSE 100

[3] It can also be argued (Mitchell (2001), p. 405) that the decimal system of number counting and presentation suggest a natural tendency to think in terms of 10s (or powers of 10).

[4] Ap Gwilym, Mcmanus and Thomas (2005) report that move from fractional to decimal pricing in the UK Long Gilt futures leads to an increase in price clustering.

[5] Indirect support for the cost recovery line of reasoning is also provided by ap Gwilym and Alibo (2003). They find that price clustering for the FTSE 100 Futures is reduced after migrating from the open outcry system to electronic system, with the latter system being more cost efficient.

options, but contrast with Aitken et al. (1996) support of the "attraction assumption" for Australian stocks.

4. Multivariate Probit Analysis

In an effort to understand what drives clustering, we estimate a multivariate Probit regression equation. The dependent variable (NCD) is:

NCD = 0 if the transaction price ends with 00 (full index point), 1 otherwise

Accordingly, our regression equation predicts the probability of fractional instead of full index point transaction price in terms of the explanatory variables.

Model A:

$P(NCD=1) = E(NCD) = \Phi(\beta_0 + \beta_1 \ln \text{Premium} + \beta_2 \ln \text{Maturity} + \beta_3 \ln \text{Volume} + \beta_4 |\text{CAC40 Daily Return}| + \beta_5 \text{Dum\_OTM} + \beta_6 \text{Dum\_ITM} + \beta_7 \text{Dum\_99} + \beta_8 \text{Dum\_Put} + \beta_9 \text{Dum\_Jan\&Feb})$

where is $\Phi(.)$ is the Normal distribution function. Since P(NCD=0) = 1 − P(NCD=1), a positive (negative) coefficient implies that the variable reduces (enhances) the chances of clustering at full index point (00). Our choice of the Probit model and the no clustering dummy is in tradition of some of the studies in the literature (e.g.,) while our evidence so far suggests that full index point is the single most dominant point of clustering in the CAC 40 index option prices.

|CAC 40| is the absolute value CAC 40 return on the trading day and is included in the regression to assess the impact of underlying asset volatility on option price clustering. It is well known from option pricing theory that option price volatility is a positive monotonic function of underlying asset volatility. Accordingly, the variable |CAC 40| may also be viewed as a proxy for the volatility of option prices.

The dummy variable definitions are as follows: Dum_OTM = 1 if the option is out of the money (S/K < 0.97 for calls and S/K > 1.03 for puts), Dum_OTM=0 otherwise; Dum_ITM = 1 if the option is in the money (S/K > 1.03 for calls and S/K < 0.97 for puts), Dum_ITM=0 otherwise; Dum_99 = 1 for transactions in 1999, Dum_99=0 for transactions in 1997 and 1998; Dum_Put =1 if it is a put option, Dum_Put =0 if it is a call option; and Dum_Jan&Feb =1 for transactions in the months of January and February, Dum_Jan&Feb =0 for transactions in the months of March through December. The coefficients of these dummy variables capture the differential clustering impacts of the categories that are assigned a value of 1.0 over the complementary categories. For example, if the coefficient of Dum_OTM = 1 is positive, it means that if the option is out of the money instead of at or in the money, P(NCD) is relatively higher, i.e., we should expect reduced price clustering at full index point, controlling for other variables included in the regression.

To obtain insights into the effects of 1999 contract changes on the relationship between clustering and the right hand side variables in Model A, we estimate an expanded equation allowing for additional regressors obtained through the product of a variable and Dum_99:

Model B:

P(NCD=1) = E(NCD) = Φ (γ_0 + γ_1 ln Premium + γ_2 ln Maturity + γ_3 ln Volume + γ_4 |CAC40 Daily Return| + γ_5 Dum_OTM + γ_6 Dum_ITM + γ_7 Dum_99 + γ_8 Dum_Put + γ_9 Dum_Jan&Feb + δ_1 ln Premium * Dum_99 + δ_2 ln Maturity * Dum_99 + δ_3 ln Volume * Dum_99 + δ_4 |CAC40 Daily Return| * Dum_99 + δ_5 Dum_OTM * Dum_99 + δ_6 Dum_ITM * Dum_99 + δ_8 Dum_Put * Dum_99+ δ_9 Dum_Jan&Feb * Dum_99)

In Model B, the γ coefficients (except γ_7 for Dum_99) measure the relationship of Model A variables to clustering in the 1997-1998 sub-period while the δ coefficients measure how the relationship of Model A variables (except Dum_99) to clustering has changed in the 1999 sub-period. The 1999 relationships can be estimated by adding the corresponding γ and δ coefficients. In other words, in Model A we implicitly assume that the relationship of an included right hand side variable to clustering is stable over the two sub-periods, but in Model B these relationships are allowed to vary in order to gauge the impact of 1999 contract changes. If $\gamma_i>0$, it means that an increase in the variable tended to reduce clustering during the 1997-1998 period. Given $\gamma_i>0$, if $\delta_i>0$, then it means that the clustering-reduction effect of the variable has become stronger after the 1999 contract changes; on the other hand if $\delta_i<0$, it indicates a lessening of the clustering-reduction effect of the variable and a possible negation ($\gamma_i = \delta_i$) or even reversal ($|\gamma_i|<|\delta_i|$ of this effect in the wake of the 1999 contract changes. Now suppose that $\gamma_i<0$ meaning that an increase in the variable enhanced the chances of clustering in the 1997-1998 sub-period. Given a negative γ_i, a positive δ_i means that the 1999 contract changes helped to reduce perhaps to the point of negation or even reversal of the clustering-enhancement effect of the variable. Of course, a negative δ_i in this case intensifies the clustering-enhancement effect of the variable following the 1999 contract changes.

It is worthwhile to note here the relationships predicted by various explanations of clustering available in the literature. A price level effect, consistent with the Price Resolution Hypothesis of Ball, Torous and Tschoegl (1985), the Price Precision Hypothesis of Grossman et al (1997), and the Negotiation Hypothesis of Harris (1991)), suggest the following signs: premium (–), maturity (–), in-the-money dummy (–), out-of-the-money dummy (+), put dummy (+), and the post-Euro 1999 period dummy (+). Typically, out-of-the-money and in-the-money options attract less trading than near-the-money options. Longer maturity options also usually attract less trading. If this liquidity pattern dominates, then according to the Price Precision Hypothesis of Grossman et al (1997), we should expect the same negative (–) coefficients for the maturity and the in-the-money dummy variables, but now a negative (–) coefficient for the out-of-the-money dummy as well.

If volume proxies more for uncertainty than for liquidity, then both the Negotiation Hypothesis of Harris (1991) and the Price Precision Hypothesis of Grossman et al (1997) suggests a negative (–) coefficient of volume. On the other hand, a positive (+) coefficient of volume is predicted by the Price Precision Hypothesis of Grossman et al (1997) if volume primarily proxies for liquidity. It is not clear why option volume should be closely related to uncertainty about the fair value of option price. This is particularly so given that it is very common to estimate the fair value of options using arbitrage or hedging arguments. It seems more intuitively appealing that option volume is a good indicator of its liquidity. For an arbitrageur simultaneously trading in multiple markets or for a hedger to establish an accurate hedge, higher volume is important in that option orders can then be filled quickly. Higher volume is also important for a market maker as the risk of an unbalanced options book diminishes with higher volume. Accordingly, higher option volume should help reduce the economic cost of transacting or market making in options and hence result in less options price clustering.

For own price volatility, a negative (–) coefficient is indicated by both the Negotiation and Price Precision Hypotheses.[6] Since option price volatility is directly related to underlying asset volatility, the same arguments apply with respect to the effect of asset volatility on option price clustering. There are, however, two unique arguments in the case of options. First, when the underlying asset volatility is higher, option values are higher and as such there may be a price level effect (negative coefficient) through asset volatility. Second, there is substantial empirical evidence that asset volatilities evolve in a stochastic fashion that is characterized by persistence. In this case, high asset volatility at current time means continued high volatility in option prices adding to risks of market making and hence resulting in wider bid-ask spreads and clustering.

Table II reports the estimation results. In Model A, with the exception of the January-February seasonal dummy, the coefficients for all the variables are highly significant. Clustering at full index point seems more likely with higher levels of the premium and moneyness (ITM) of the option. Clustering is also more likely for call options than for put options and in an environment prior to the contract changes in 1999 than after. Maturity has a positive coefficient contradicting a price level effect, but the coefficient becomes negative and loses significance in the more general Model B. Although the 1999 dummy interaction is positive and significant for maturity, it is only modestly positive indicating a benign role of maturity in both sub-periods. As a result, our results are broadly supportive of a price level effect that is consistent with several hypotheses (Price Resolution Hypothesis of Ball, Torous and Tschoegl (1985), Price Precision Hypothesis of Grossman et al (1997), Negotiation Hypothesis of Harris (1991)). The coefficient of the OTM dummy is negative in both Models A and B and significant in Model A, suggesting that this variable may be proxying for liquidity instead of price level. However, the variable loses its significance in the more general Model B.

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[6] There appears to be a U-shaped pattern of clustering at full index point on an intra-day basis (available on request). The pattern is similar to but weaker than that observed by Ap Gwilym, Clare and Thomas (1998a) for FTSE 100 Futures and by Schwartz, Van Ness and Van Ness (2004) for S&P 500 Futures. Since usually there is greater uncertainty about valuation towards the open and the close, the intra-day U-shaped pattern of clustering provide indirect support for the Precision Hypothesis of Grossman et al (1997). Further analysis may reveal if there is a U-shaped intra-day and intra-year pattern in CAC 40 index options volume. In that case, the U-shaped pattern in clustering may also lend some support to the Negotiation Hypothesis of Harris (1991).

Significant positive coefficient for option volume and negative coefficient for asset volatility in both Models A and B means that lower option volume and higher asset volatility contribute to greater clustering. The volume effect suggests that this variable may be proxying more for liquidity instead of uncertainty. In this liquidity sense, the volume effect is supportive of the Price Precision Hypothesis of Grossman et al (1997). The volatility effect clearly supports the Price Precision Hypothesis of Grossman et al (1997) and the Negotiation Hypothesis of Harris (1991). From option valuation perspective, this is consistent with a price level effect. From option market making perspective, the volatility effect is consistent with the cost recovery dimension of clustering (Jameson and Wilhelm (1992), Anshuman and Kalay (1998)).

The clustering enhancement roles of higher premium level and lower volume remain highly significant accounting for contract change impacts. Although the 1999 dummy interactions act to attenuate these effects, the magnitude of reversal appears modest. On the other hand, the 1999 changes in the coefficients of the ITM measure of moneyness and the option type are quite sizeable. These changes tend to minimize the price level effect via increasing moneyness and option type in the 1999 sub-period. However, in the wake of contract changes in 1999, the clustering enhancement role of volatility has become much stronger.

It seems that the 1999 contract downsizing did not fundamentally change the economics of CAC 40 index option price clustering. There is consistent evidence that price level (via premium), uncertainty (via asset volatility) and liquidity (via volume) are important economic factors behind clustering of CAC 40 option transaction prices.

5. Conclusion

In this paper, we have examined in details the pattern and systematic tendencies of clustering in CAC 40 index option prices during the 1997-1999 period. As in the study of FTSE 100 index option price clustering by Ap Gwilym, Clare and Thomas (1998a), there is evidence of strong clustering in CAC 40 index option transaction prices at full index points, and CAC 40 index option prices are 90% more likely to end with the digit 0 (multiples of 10) than with the digit 5. The 1999 contract downsizing led to some reduction in clustering at full index point. However, the basic pattern of clustering remains intact. This CAC 40 evidence is similar to the S&P Futures evidence of Bollen, Smith and Whaley (2003) and is consistent with the premise that cost recovery by market makers contributes to clustering (Grossman et al (1997), Anshuman and Kalay (1998)).

We find important drivers for CAC 40 index option price clustering. These are the level of option premium, option volume and underlying asset (CAC 40) volatility. Consistent with a price level effect (Price Resolution Hypothesis of Ball, Torous and Tschoegl (1985), Price Precision Hypothesis of Grossman et al (1997), Negotiation Hypothesis of Harris (1991)), higher option premiums and higher asset volatility lead to greater clustering. The volatility effect is also in line with the notion of persistence in asset volatility at a high level leading to continued high volatility of option values and hence greater clustering as risk and costs for option market makers rise. This lends indirect support for the cost recovery concept (Grossman et al (1997), Anshuman and Kalay (1998)). With regards to volume, we find lower option volume to increase clustering, in conflict with the Negotiation Hypothesis of Harris (1991) but in support of Price Precision Hypothesis of Grossman et al (1997) if volume is treated as a proxy for liquidity and not uncertainty. It seems more intuitive that option volume proxies for option liquidity as timely trade execution by arbitrageurs and hedgers and balancing of options book by market makers are facilitated by higher option volume.

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Table I:

Distribution of the Last Two Digits of CAC 40 Index Option Transaction Prices

This table reports the numeric frequency (Number) and the percentage frequency (%) of the last two digits (in increments of 5) of the transaction price for the CAC 40 index options (PXL contracts). Prop is the observed percentage divided by the expected percentage without clustering (1/20 or 5%). Range is the range between the highest and lowest percentages for the last two digits, and StD is the standard deviation of the observed percentages. The row Diff1 represents the difference between the sum for the digits ending with 0 and the sum for the digits ending with 5; and the row Diff2 represents similar figures excluding the cases of 00 (full index point) and 50 (one half index point). The sample period extends from January 2, 1997 through December 30, 1999.

	1997-1999			1997-1998			1999		
Digit	**Number**	**%**	**Prop**	**Number**	**%**	**Prop**	**Number**	**%**	**Prop**
00	145,916	64.31%	12.86	65,058	75.59%	15.12	80,858	57.41%	11.48
05	306	0.13%	0.03	124	0.14%	0.03	182	0.13%	0.03
10	6,013	2.65%	0.53	954	1.11%	0.22	5,059	3.59%	0.72
15	274	0.12%	0.02	113	0.13%	0.03	161	0.11%	0.02
20	4,828	2.13%	0.43	925	1.07%	0.21	3,903	2.77%	0.55
25	656	0.29%	0.06	361	0.42%	0.08	295	0.21%	0.04
30	3,789	1.67%	0.33	476	0.55%	0.11	3,313	2.35%	0.47
35	255	0.11%	0.02	87	0.10%	0.02	168	0.12%	0.02
40	4,545	2.00%	0.40	790	0.92%	0.18	3,755	2.67%	0.53
45	260	0.11%	0.02	97	0.11%	0.02	163	0.12%	0.02
50	27,864	12.28%	2.46	10,295	11.96%	2.39	17,569	12.47%	2.49
55	297	0.13%	0.03	90	0.10%	0.02	207	0.15%	0.03
60	4,940	2.18%	0.44	800	0.93%	0.19	4,140	2.94%	0.59
65	247	0.11%	0.02	83	0.10%	0.02	164	0.12%	0.02
70	3,673	1.62%	0.32	416	0.48%	0.10	3,257	2.31%	0.46
75	585	0.26%	0.05	365	0.42%	0.08	220	0.16%	0.03
80	5,003	2.20%	0.44	973	1.13%	0.23	4,030	2.86%	0.57
85	279	0.12%	0.02	100	0.12%	0.02	179	0.13%	0.03
90	5,721	2.52%	0.50	795	0.92%	0.18	4,926	3.50%	0.70
95	316	0.14%	0.03	117	0.14%	0.03	199	0.14%	0.03
Total	215,767	95.09%		83,019	96.46%		132,748	94.25%	
Range		64.20%	12.84		75.49%	15.10		57.30%	11.46
StD		14.28%	2.86		16.86%	3.37		12.72%	2.54
Diff1	208,817	92.04%	18.41	79,945	92.88%	18.58	128,872	91.48%	18.29
Diff2	35,0371	15.45%	3.09	4,592	5.33%	1.07	30,445	21.60%	4.32

Table II: The Determinants of Price Clustering in CAC 40 Index Options

This table reports the Probit regression results for Models A and B. The dependant variable NCD assumes a value of 0.0 if the last two digits of a transaction price are equal to 00 and a value of 1.0 otherwise; therefore, a higher (lower) predicted value of the dependant variable indicates a prediction of less (more) clustering at full index point. In Model A, the explanatory variables are ln(option premium), ln(maturity), ln(volume), absolute value of CAC40 daily return, two moneyness dummies, 1999 sub-period dummy, option type dummy, and the seasonal dummy for January-February. In Model B, variables interacting with the 1999 sub-period dummy are added. The sample is all trades of European CAC 40 index options between January 2, 1997 through December 30, 1999.

	Expected	Model A			Model B		
	Sign	Coeff.	t-stat		Coeff.	t-stat	
Constant	?	-0.8445	-52.94	***	-0.3487	-10.83	***
Premium (Index Pts)	–[a]	-0.0972	-32.45	***	-0.1931	-39.08	***
Maturity (# Days)	–[a,e]	0.0334	10.35	***	-0.0042	-0.77	
Volume (# Contracts)	+[b],–[c]	0.1946	126.80	***	0.2163	81.84	***
|CAC 40 Daily Return|	– [d]	-2.0176	-6.85	***	-1.4322	-3.41	***
Dummy OTM = 1	+[a],–[e]	-0.0328	-3.51	***	-0.0037	-0.22	
Dummy ITM = 1	–[a,e]	-0.1212	-14.73	***	-0.1363	-8.46	***
Dummy 1999 = 1	+[a]	0.0498	6.17	***	-0.5508	-15.05	***
Dummy Put = 1	+ [a]	0.0843	10.45	***	0.1543	10.17	***
Dummy Jan/Feb = 1	?	-0.0025	-0.27		-0.1079	-8.74	***
Premium × Dum 99					0.0062	0.000	***
Maturity × Dum 99					0.0068	0.000	***
Volume × Dum 99					-0.0311	-9.59	***
|CAC 40| × Dum 99					-2.4988	-4.16	***
OTM × Dum 99					-0.0221	-1.06	
ITM × Dum 99					0.0481	2.54	**
Put × Dum 99					-0.1211	-6.71	***
Jan/Feb × Dum 99					0.2126	10.37	***
Adjusted R^2		0.0928			0.0972		

*, **, *** indicate significance at the 10%, 5%, 1% level respectively.

a: Price Level Effect (Price Resolution Hypothesis of Ball, Torous and Tschoegl (1985), Price Precision Hypothesis of Grossman et al (1997), Negotiation Hypothesis of Harris (1991)).

b: Price Precision Hypothesis of Grossman et al (1997) with volume primarily proxying for liquidity.

c: Negotiation Hypothesis of Harris (1991), Price Precision Hypothesis of Grossman et al (1997) with volume primarily proxying for uncertainty.

d: Negotiation Hypothesis of Harris (1991), Price Precision Hypothesis of Grossman et al (1997).

e: Price Precision Hypothesis of Grossman et al (1997) with out-of-the-money and in-the-money dummy variables as well as maturity primarily proxying for liquidity instead of price level.