COMPETION, INTERLISTING AND THIN TRADING IN CANADIAN OPTIONS MARKETS

PRELIMINARY VERSION

Nabil Khoury*
Stylianos Perrakis**
Marko Savor***

This version June 2008

*Professor of Finance and Desjardins Chair in the management of derivative products, University of Quebec in Montreal, ** Professor of Finance Concordia University and ***assistant professor, University of Quebec in Montreal respectively. The authors are particularly grateful to Richard Roll for his insightful comments on a previous version of this paper. Thanks are also due to S. Meknassi, K. Gikas, H. El-Ibrami, V. Valentir for their able assistance. Data for the study was graciously supplied by the Montreal Exchange. Financial support from the Desjardins Chair in the Management of Derivative Products is gratefully acknowledged.

Corresponding author:
N. Khoury, nabilkhoury@sympatico.ca, (514) 987-3000 #6717

COMPETION, INTERLISTING AND THIN TRADING IN CANADIAN OPTIONS MARKETS

PRELIMINARY VERSION

Abstract

This paper examines the Canada-US cross-listing of options by focusing on quoted and effective spreads while integrating the joint impact of time of day and volume of transactions into the analysis. It uses intra-day data on options and their underlying securities in order to analyse the behaviour of quoted and effective bid-ask spreads of interlisted options as order flows fluctuate during the day. We analyze option quotes as a duopoly model, with cross-listing reducing effective demand for the duopoly to the level where price equals marginal cost. We find that the cross-listing effects are fully consistent with our hypothesized market structure in the Canadian market with respect to quoted spreads. We find that cross-listing tightens quoted spreads but not effective spreads, a result that is consistent with the changing rules of the game in the duopoly when faced with limit orders. We also find that neither informed trading nor market thinness affect the differential impact of cross-listing. Last, we analyze the volatility smile, which differs significantly for cross-listed options, although this difference is hard to interpret. Our results also show that by relying on end-of-day quotes, empirical studies can overlook many relevant aspects.

COMPETITION, INTERLISTING AND THIN TRADING IN CANADIAN OPTIONS MARKETS

This paper examines the behaviour of both quoted and effective spreads for options listed in the Montreal Exchange (ME), the only options market operating in Canada. We focus in particular on an important feature that characterizes the Montreal options market, namely the extensive cross-listing of several of its traded options in US exchanges, which in many cases includes most of the volume of the traded options. We use intraday transactions data to investigate the impact of competition in that venue for both cross-listed and non cross-listed options. We also examine the impact of features such as informed trading and the thinness of the market, which have not been considered in earlier studies. We model the ME as a Cournot duopoly for quoted spreads, but we argue that the market mechanism changes when it comes to limit orders, implying that it then becomes competitive even with two firms. We find that competition from US cross-listing affects quoted spreads but not effective spreads, implying that the market is in fact fully competitive for all options whether cross-listed or not, consistent with our hypothesized model. Market thinness and informed trading, on the other hand, seem to have only a marginal impact on the quality of the market as measured by the size of the spreads. A novel feature of our study is also the fact that we use intraday data to document the evolution of the spreads and their determinants throughout the trading day under alternative assumptions about the traders' correct anticipation of end of day prices and volumes of transactions.

The impact of cross-listing of options on either their quoted or their effective spreads was first analyzed by Neal (1987, 1992), who showed that, as suggested by financial theory, quoted option spreads tend in general to decrease under the influence of either realized or potential competition. The size of this reduction is, however, affected by the volume of the transaction. This issue was addressed by Khoury & Fischer (2002) in the context of Canadian options cross-listed in US options markets. They noted in their study that their samples are typically clustered around the volume of transactions and that there are four distinct levels of concentration. This evidence points to a non-linear relationship between the volume of transactions and the bid-ask spread. Nonetheless after adjusting for this non-linearity Khoury and Fischer still find a tighter spread for Montreal options interlisted in US markets than for the noninterlisted. It is also worth noting that the three studies mentioned above have relied on end of day quotes since these were the only available data at the time.

Mayhew (2002) also analyzed the impact of market structure and competition on quoted and effective spreads. He addressed the problem of non-linearity by relying on option pairs matched as to price, volume of transactions and implied volatility for the period 1986-1997 and found that both quoted and effective spreads were smaller for cross-listed options. Using pooled time series and cross section regressions De Fontenouvelle, Fishe and Harris (2003) focused on the impact of the listing event on the spreads. They found smaller quoted and effective spreads for cross-listed options, with an insignificant reversion effect even after one year of listing. Furthermore, they confirm that this reduction in spreads cannot be explained by economies of scale or the cost of hedging but rather by increased competition. In the same vein, Battalio, Hatch and Jennings (2004) analyse option quotes across U.S. markets from June 2000 to January 2002 and report evidence of an evolution towards an integrated market system. They also use effective spreads to examine execution quality between markets and report that differences between option markets have markedly declined in that regard during the 2000-2002 period.

We note that with the exception of the Khoury and Fisher (2002) study all other option cross-listing studies have been in US markets. The Canada-US interlisting effect is qualitatively different from the purely US studies, insofar as the competition between exchanges must take the added factor of the Canada-US exchange rate into account, given that trading of the same security takes place in different currencies. This is an added risk factor for an investor considering a trade in either market and, thus, tends to reduce competitive pressures. On the other hand the foreign exchange market is considered quite efficient in these two currencies, implying that the currency differences may have only a minimal impact. Further, the relative size of the two markets is so disparate that the competitive pressures from the US listings are bound to be particularly strong for the Canadian options markets, especially if they are combined with the cross-listing of the underlying security.

Several studies have examined the impact of cross-listing for Canadian-US equities using event study methodology. Foerster and Karolyi (1993) document a large increase in trade volume following the cross-listing, as well as abnormal returns before and after the cross-listing date. The same authors in a 1999 study confirm these results in a sample of international firms cross-listed on US exchanges and find significant reductions in the risk premium post-US listing, a finding consistent with market integration. They attribute a large part of their results to increased investor recognition, in line with the Merton (1987) Capital Asset Pricing Model under incomplete information. In a 1998 study of the microstructure effects of cross-listing these same authors document an expected reduction in both quoted and effective spreads that is overwhelmingly concentrated in stocks that experience a significant shift in trading volume to the US post-cross-listing. Similar shifts in trading volume were also observed in the Khoury-Fisher (2002) option cross-listing study. A more recent microstructure study of Canada-US cross-listings was carried out by Eun and Sabherval (2003), who focused on price discovery and found that both markets contribute to such discovery, with their contributions depending positively on each market's share of trading volume and inversely on the bid-ask spread.

Market thinness, unlike cross-listing, has not been a factor in market microstructure studies, neither in equities nor in options. Yet any empirical study in the Canadian financial markets or, we suspect, in most financial markets outside North America, must deal with the impact of thin trading, which is a fact of life for most of the traded securities in those venues. To our knowledge, thinness has been recognized as an important factor only in risk and return estimation in equities markets, where it has been shown to lead to biases in various measures of risk, return and autocorrelation. Examples of such studies include: Claire, Morgan and Thomas (2002), who analyzed non-trading on the London Stock Exchange for the period 1975-1995 and reported important discontinuities that affect systematic risk measures for portfolios; Wang and Jones

(2005), who examined the daily prices and net asset values of 53 UK investment trust companies in the context of thin trading for the period 1990 to 1993 and showed that cointegration analysis corrects the bias in beta estimates that results from correlation in the lagged series; Diacogiannes and Makri (2008), who studied stocks listed on the Athens Stock Exchange from January 2001 to December 2004 and found no statistically significant differences between the mean beta estimated using OLS and the mean beta obtained from models that take market thinness into account; and Sercu, Vanderbroek and Vinaimont (2006) who present Monte-Carlo results on the comparative performance of a number of models for estimating betas in the context of thin trading. In the Canadian context, Brooks, Faff, Fry and Bissoondoyal-Bheenick (2005) present a two-step procedure with a selectivity component and a regression component to estimate stock betas from daily data impacted by the presence of zero returns for the period of November 1999 to November 2000 and show that the proposed method does correct the downward bias in the OLS beta estimated for thinly traded stocks.

Market thinness' effects on microstructure are likely to be complex, but the net effect is expected to be clearly negative on the quality of trading. By definition, thinness is associated with infrequency of transactions and, hence, with the illiquidity of the instrument. This implies that most trading will take place on the quoted bid and ask prices and there is going to be little difference between quoted and effective spreads for thinly traded financial instruments. Similarly, thinly traded instruments attract little interest from financial analysts. As a result, most trading in them is probably dominated by informed traders, implying that this component of the bid-ask spread will be higher for thinly traded stocks. On the other hand, these effects will be difficult to isolate from the volume effect, which is also low for illiquid stocks and tends to increase the spreads as well.

On the key issue of the differential effect of thinness on interlisted versus non-interlisted options, the increased competition is clearly expected to reduce quoted spreads. It also may impact the effective spread, since liquidity increases as a result of interlisting, given the availability of more potential market makers for any prospective investor.

Consequently, we expect thinness to be a significant determinant of both quoted and effective spreads only for non-interlisted options.

In this paper we examine the effects of interlisting throughout the day by distinguishing three different intraday time periods. We also take into account transactions volume by including separate variables for each volume cluster. We show that interlisting has a strong effect in reducing *quoted* spreads in most (but not all) time slots and volume clusters, but also that this effect is significantly attenuated or non-existent when considering effective spreads. We also show that market thinness has some significant effects in increasing spreads but is not a significant factor in many volume clusters and time slots. Furthermore, we examine the information effects of interlisting to see if market makers price the possibility of informed trading differently for interlisted than for non-interlisted options. We measure informed trading in two different ways and find that in both cases its effect is not significantly different in cross-listed securities. Last, we also analyze the intraday pattern of the volatility smile with respect to interlisting. We measure the volatility smile as the ratio of the largest to the smallest implied volatility in a given cross section of options with varying expiration dates and strike prices. Preliminary results show that interlisting has on the aggregate a significant effect on the smile for most volume categories, but this is a result that is difficult to interpret and needs more detailed study.

The paper is organized as follows. The next section describes the methodology and data used in the analysis. This is followed by the empirical results on quoted and effective spreads for both exogenous and endogenous interlisting indicators in the context of thin markets. Empirical results also detail the analysis of the information effects of interlisting and finally the interlisting impact on the volatility smile. The last section draws the conclusions of the study.

Methodology

It is now common knowledge in the financial literature that there are three components to the costs of trading financial securities: order processing costs, inventory costs, and asymmetric information costs (Huang & Stoll, 1997; Khoury et al., 1991; Stoll, 2000). The total trading costs are measured by several indicators, of which the quoted and the effective bid-ask spreads are the most popular. In this paper, we adopt the inventory based framework of bid-ask spreads and use a statistical procedure adapted to the panel nature of the data in order to examine the impact of US-Canada interlisting on options bid-ask spread in the context of thin markets.

Since 1999 trading in Canadian equities has been centralized in the Toronto Stock Exchange (TSE) and trading in derivatives has been centralized in the Montreal Exchange (ME). Both TSE and ME face competition from several US exchanges, which have eroded the market shares of both Canadian exchanges to a major degree, with the result that for several Canadian firms most of the volume in both equities and stock options trades currently in the US. Descriptive statistics provided by the Montreal Exchange show that, although overall volume continues to increase, total market share for option contracts on interlisted stocks has declined form an average of 34.75% for 2002, to 30.09% for 2003, to 18.60% for 2004.

ME also introduced a major change in its trading rules in 2001, switching from a trading system with a monopolistic market maker (specialist) for each underlying security to a system of competitive market making, in which the announced quote is the lowest quote from several competing market makers. Neither the order book nor the corresponding amounts of the quotes are made public. In practice the market that has developed is an oligopoly in which two or three major players compete for the major orders, with a competitive fringe of small firms taking the rest.

We model the quotes in the Montreal market as a Bertrand or Cournot duopoly, with either the price quotes or the contract sizes as strategic variables, and with the cost function a convex function of quantity. For the Bertrand duopoly, let $\pi_i(p_i, p_j) = p_i q_i(p_i, p_j, c) - C(q_i(p_i, p_j, c)),\ i, j = 1,2$ denote the profit functions of the duopolists, with p_i denoting the price, $q_i(p_i, p_j, c)$ the demand function and $C(q_i(p_i, p_j, c))$ the cost function of the i[th] firm. The term c is a variable that represents competition outside the duopoly, from the competitive fringe or from firms outside the market. It is clear that $\frac{\partial q_i(p_i, p_j, c)}{\partial p_i} < 0,\ \frac{\partial q_i(p_i, p_j, c)}{\partial p_j} > 0,\ \frac{\partial q_i(p_i, p_j, c)}{\partial c} < 0$; we also assume that $\frac{\partial^2 q_i(p_i, p_j, c)}{\partial p_i \partial c} < 0$. The first order conditions that establish the Bertrand duopoly equilibrium are $\frac{\partial \pi_i(p_i, p_j)}{\partial p_i} = 0,\ i = 1,2$, from which we get

$$p_i = \frac{\partial C(q_i(p_i, p_j, c))}{\partial q_i} - \frac{q_i(p_i, p_j, c)}{\frac{\partial q_i}{\partial p_i}},\ i = 1,2. \tag{1}$$

For a symmetric Bertrand duopoly with a homogenous product it can be shown that Bertrand competition ends up with price equal to marginal cost as an equilibrium solution.

A similar result holds also for the Cournot duopoly, with the duopoly demand curve $p(q_1 + q_2, c)$ being again a decreasing function of the competitive factor c.

$$p(q_1 + q_2, c) = \frac{\partial C_i(q_i)}{\partial q_i} - \frac{q_i \partial p(q_1 + q_2, c)}{\partial q_i},\ i = 1,2. \tag{1'}$$

In other words, in both duopolies the equilibrium price quote exceeds marginal cost, the first term in the right-hand-side (RHS) of (1) or (1'), by the second factor, which is positive. Further, it can be shown that these equilibrium prices are decreasing functions of the variable c, the strength of competition outside the duopoly. We expect, therefore, our quoted spreads to show a strong effect for cross-listing.

The *effective spread*, on the other hand, is measured by actual trading prices, which may be within the bid-ask spread. In the ME a limit order that falls within the quotes will go to the first market maker who will accept it. Assuming that there is no collusive behaviour, the order will be executed by one of the duopolists as long as the price exceeds marginal cost. Competition from cross-listing, therefore, is not expected to affect the effective spread for limit orders. Furthermore, in the long run and especially for informed traders the realization that limit orders would achieve better terms of trade for investors would induce a preponderance of limit orders for non-interlisted options. We expect, therefore, to observe a sharply reduced effect of cross-listing for effective as compared to quoted spreads.

Our empirical work is based on (1) or (1'). We model the cost in the RHS by variables that represent the order processing and inventory costs. For the order processing we use the volume of the transaction. Several studies, such as those of Demsetz (1968) and Hasbrouck (1988) have shown that the order processing cost component of stock spreads is negatively related to volume of transactions. This could be due to the fact that higher volume of transactions, as an indicator of higher liquidity, can possibly lead either to economies of scale in processing costs and/or to a lower quoted markup per trade as it is compensated by the greater volume. The same effect also holds for options as in Neal (1987, 1992), and Khoury and Fischer (2002). Since the volume effect is known from earlier studies to be non-linear, we also refine model (1) by segregating the various effects of the determinants on the basis of clusters of daily volume for specific option contracts. In turn, the clusters are defined on the basis of quintiles of total volume per contract for each trading day.[1]

Inventory costs in equity microstructure studies are measured by the stock price and its volatility the latter measured as the Black-Scholes-Merton implied volatility. We also used the option's delta, defined as the variation of the option price to small variations in the underlying security's price, and gamma, a measure of the variation of delta to small variations in the underlying security's price, as additional independent variables in the model. These were included in the model as measures for the cost of hedging the option

[1] The daily volume is used even for the intraday estimations. We also tried the volume at time of day; the results were of lower quality but not significantly different in most cases.

portfolio of the market maker, which is assumed to be kept close to delta-neutral by holding the appropriate inventory of the underlying stock.[2]

Asymmetric information costs are also influenced by price and volatility.[3] Their impact can be measured directly at each time point in the case of effective spreads, by observing whether the investor side in the trade is in the direction of the end-of-day price change of the underlying asset. For quoted spreads this is not possible intraday, and we use as an alternative measure the proportion of informed trades in the total daily trades. Even that measure is questionable, because the thinness of the market is such that for many contracts in our sample there are no trades for several days. For this reason we include in our independent variables alternative measures of market thinness. Three measures have been estimated in this study to gauge market thinness for each option contract in a given period, namely: (1) the number of days without any trading, (2) the average daily number of trades, and (3) the average daily number of traded contracts. The analysis shows that on a per contract basis the overall number of days without any transaction averages 61.80% of total trading days on the Montreal Exchange for the period under study. Similarly, the average daily number of transactions per contract amounts to 1.58 trades and the average daily trade volume per contract is only 29.63 contracts. Only the first measure of thinness however will be used in the subsequent empirical analysis as it captures this market feature best.

Last, we measure the competitive variable c in two different ways: by a dummy variable representing cross-listing, and by a set of firm-specific variables that are significant determinants of cross-listing. These are the market capitalization and the industry to which the firm belongs. We included as an independent variable the endogenous estimate of the probability of cross-listing for a firm's options. The results show no significant effects on the regression and are omitted from this presentation.

---

[2] The results are available from the authors on request. These two variables turned out to be non-significant in most cases.
[3] See Copeland and Galai (1983).

On the basis of these remarks we postulate the following empirical model (2) to represent (1) or (1'), as in the similar studies of Neal (1987, 1992), Khoury & Fischer (2002), and De Fontenouvelle, Fishe &Harris (2003). We use indicator variables (not shown in the regression equation (2)) to represent various levels of daily trading volumes and allow all the regression coefficients to differ between levels. The model also introduces interaction terms that allow the slope to be different in the regressions of interlisted and non-interlisted options. The model is then estimated at different times during the day in an effort to analyse the intraday evolution of observed effects. Whenever appropriate, White (1980) correction of the covariance matrix for heteroskedasticity is applied.

Spr_{jt}^{k} = intercept + β_1 (volume)$_j$ + β_2 (price)$_{jt}$ + β_3(volatility)$_{jt}$ + β_4(INT) + β_5(THIN)$_j$ + β_6(INT)*(THIN)$_j$ + β_7(INT)*(price)$_{jt}$ + β_8(INT)*(volume)$_j$ + β_9(INT)*(volatility)$_{jt}$+ ε (2)

where

Spr_{jt}^{k} = quoted and effective spreads for k=q,e, respectively, for option j at time t as proportions of the option price

1) Quoted spread is equal to (quoted option ask price – quoted option bid price)
2) Effective spread is equal two times the absolute value of the difference between the execution price and the average between the option's quoted bid & ask prices. More specifically:
   Effective spreads = 2 | [trade price – (bid + ask) / 2] |

(volume)$_j$ = natural logarithm of the total daily trading volume for option j

INT = 1 if the option is interlisted and 0 otherwise

(THIN)$_j$ = percentage of days in a month with no trading for option j

(price)$_{jt}$ = average of bid and ask prices on the underlying security

$(\text{volatility})_{jt}$ = standard deviation of the underlying stock return, implied for option j at time t

For all these variables we allowed the coefficients to be different by using the following indicator variables

VOL15 An indicator variable equal to 1 if the total daily volume for the option is between 0 and 15 contracts and 0 otherwise

VOL50 An indicator variable equal to 1 if the total daily volume for the option is between 16 and 50 contracts and 0 otherwise

VOL100 An indicator variable equal to 1 if the total daily volume for the option is between 51 and 100 contracts and 0 otherwise

VOL500 An indicator variable equal to 1 if the total daily volume for the option is between 101 and 500 contracts and 0 otherwise

VOL501 An indicator variable equal to 1 if the total daily volume for the option is above 500 contracts and 0 otherwise

Data

To compile the data for this study, options listed on the Montreal Exchange for the period January 1st 2002 to December 31st 2004 were first classified on the basis of the combined total volume of transactions of each option's series and classes on the same underlying security. The initial sample was then limited to options with a total volume of transactions in the top 20% of this classification which are thus among the most actively traded options on this exchange during the period under study. This filter yielded a total of 2620 options with 42 series. However, 25.76 % of these contracts were never traded before their expiration date and were consequently eliminated from the sample. The final sample is thus comprised of 7262 quoted spreads on 1945 distinct option contracts traded on the Montreal Exchange. These options have 42 different underlying securities and 58.7% of their quotes relate to options also listed on a US market. The filtering procedure provides however a lower bound of any thinness effects since it biases against options with extremely thin trading. Note also that the use of quoted spreads implicitly assumes that any such quotes remain valid as long as they are unchanged. In an effort to minimize any bias that this last assumption may introduce, we have eliminated all observations where the quote remains unchanged for more than 15 minutes. Furthermore, the sample has been filtered to exclude quotes exhibiting zero bid with positive ask prices, which represent approximately 2% of total observations. Such observations truncate the distribution and bias the spread towards zero.

Maximum likelihood tests show that the samples are clustered around the volumes of transactions. The Appendix provides an illustration of these clusters. Three cluster times have been defined in this paper namely 10:30, 12:30 and closing time. In what follows, intra-day volume clusters refer to the 10:30 and 12:30 clusters. The results also show that the average quoted spreads increase by 17.8% as the day progresses. They increase from 0.122332$ in the morning to 0.142975 at market closing time.

Empirical results

Table I presents descriptive statistics of quoted and effective spreads for the described trade volume clusters. The results show that the quoted spreads for interlisted option contracts are different form their non interlisted counterparts but that the sign and statistical significance of this difference remains somewhat ambiguous and varies according to time of day and trade volume cluster. In contrast, interlisted options' average effective spreads are almost never statistically significantly different from non-interlisted options. Nonetheless, effective spread averages and the sign of the interlisting difference vary both in magnitude and sign according to the time of day and trade volume category. These interesting results provide preliminary evidence that the interlisting effect may be different for quoted and effective spreads. Additional analysis is thus warranted to reflect the fact that spreads are affected by a variety of other factors that should also be accounted for in a multivariate setting, which will better isolate the marginal effect strictly related to the interlisting of option contracts.

(TABLE I ABOUT HERE)

Effect of Interlisting on quoted spreads

Table II presents the results of the estimation of the quoted spread model for non-zero transaction days with end of day anticipation of prices and volumes of transaction, using OLS and including interaction terms. As the table shows, the impact of interlisting on the quoted spread is generally negative for all volume clusters, although there are some differences across trading times. Thus, for all trading clusters the intraday advantage of cross-listing in the morning is strongly significant and of comparable size. The noon-time and end-of-day effects of cross-listing for these same trading clusters are, however, most often not significant. For the largest trading cluster of above 500 contracts, the end-of-day effect of cross-listing is not only significant but also very large, with a much higher coefficient than for the comparably-sized intraday effects for this trading cluster. The same is true although to a lesser extent for end-of-day smallest trading cluster of 15 contracts or less. It is interesting to note that the model that does not assume that market makers integrate their end-of-day price and volume anticipations into their quoted spreads yields very similar interlisting effects[4].

For noon trading, it seems that the interlisting impact on quoted spreads is less consistent compared to market morning and closing, since there are no significant interlisting effects. All the interlisting effects, however, remain negative and could be detected when dealing with averages across all intraday transaction times. The bid-ask spread of interlisted options is significantly narrower for very large trading volume clusters compared to small trading volume clusters, particularly at closing time. Indeed, this effect shows an improvement of almost 226% for very large volume clusters relative to very low volume clusters at market close. Since we have allowed all coefficients of the regression to differ to differ by volume clusters, this differential response to competition

[4] These results are available from the authors upon request.

between high and low volume clusters may also imply lower competitive pressures for low than for high-volume clusters.

We also observe that our results on quoted spreads are strongly consistent with the duopoly model presented earlier, especially the more relevant Cournot version (1'). Consider, for instance, the following stylized version, with a constant elasticity demand function and symmetric quadratic cost functions for both firms, that yields a closed-form solution but whose conclusions are robust against the relaxation of several of its assumptions. Let the demand be $p(q_1+q_2,c)=A(c)(q_1+q_2)^{-\varepsilon}$, with $\frac{\partial A(c)}{\partial c}<0$ as long as the price stays above marginal cost. For marginal cost we assume $\frac{\partial C_i(q_i)}{\partial q_i}=\lambda q_i,\ i=1,2$ for q_i above a certain minimum value and constant and equal to k thereafter. It is easy to see that the equilibrium price in this Cournot duopoly is $p(q_1+q_2,c)=[\frac{3}{\lambda}]^{-\frac{\varepsilon}{1+\varepsilon}}[A(c)]^{\frac{1}{1+\varepsilon}}$ as long as $p(q_1+q_2,c)\geq k$, or if the competition variable c does not drive the price to marginal cost, and becomes equal to k thereafter. The market maker's cost variables are represented by the parameters λ and k. The regression variable INT measures the demand-shifting term c, which is all-or-nothing, either competitive or not. It is easy to see that the model predicts negative coefficients for INT, positive coefficients for the variables $(\text{volatility})_{jt}$ and $(\text{price})_{jt}$ that shift the parameters λ and k up and negative coefficients for the variable $(\text{volume})_j$, that shifts these same parameters down. These predictions are all verified, strongly for INT as noted above, but also for $(\text{price})_{jt}$, which exhibits a positive and most often a statistically significant relationship with quoted spreads irrespective of the time of day and volume clusters. The results are weaker for $(\text{volatility})_{jt}$, which is rarely statistically significant, although it is positive as expected when it is significant. A possible explanation for this result is provided by Mayhew (2002) who argued that the interlisting decision in option markets is a positive function of volatility which may thus be captured in our model's interlisting indicator.[5]

[5] The number of transactions is also often used as a cost factor. In our case, for their coefficients and their interaction terms, the analysis shows that they are not, in general, statistically significant across trading

More to the point, the model predicts positive coefficients for the interaction terms of INT with $(volatility)_{jt}$ and $(price)_{jt}$ and negative ones for the interaction of INT with $(volume)_{j}$. Indeed, in the presence of competition the price is equal to marginal cost and the cost variables shift the parameter k . These results are fully verified, especially for the predicted positive interaction coefficients that are all of the correct sign and many are strongly significant, while for $(volume)_{j}$ the majority of the coefficients and all significant ones are negative, as predicted.

(TABLE II ABOUT HERE)

Informed trading is also a cost variable, since its presence in a market induces losses for the market makers whenever it occurs. We have already noted the problems with the variables that we use to measure it, given the thinness of trading for most contracts in our sample. It is not, therefore, surprising that most of the coefficients are not significant, although most of them have the correct sign. The same conclusion applies to the interaction terms with the interlisting variable INT. On the other hand market thinness, as measured by the percentage of the days in a month where no trading occurred on a given contract, has a positive and significant impact on quoted spreads primarily at noon and end-of-day, implying that it is a valid proxy for informed trading. In fact, quoted spreads generally increase in the presence of market thinness as the volume clusters decrease throughout the trading day, with the exception of morning trading, which, as can be observed in the appendix, is usually the most active trading period of the day[6]. However the marginal impact of thinness on quoted spreads almost never exhibits significant results when interlisting is considered. In general, therefore, the combined marginal impact of market thinness and informed trading on the interlisted bid-ask spreads do not provide a statistically significant explanation of observed interlisting spread reduction.

---

volumes and trading times. This is not surprising since we are able to capture the effect of the number of transactions through our volume clusters.

[6] This observation was also privately confirmed to us by the authorities of the Montreal Exchange where morning trading is sometimes referred to as “speed and greed” trading.

Effect of Interlisting on Effective Spreads

Table III presents the results for the corresponding regressions on effective spreads. As the table shows, none of the interlisting effects, save one, exhibit a statistically significant narrowing of effective spreads irrespective of time of day and volume clusters. This important result is consistent with the predictions of our theoretical framework, namely that internal competition among market makers on the home venue for non-interlisted options reduces execution prices to the level of marginal costs, as with interlisted options which are subjected to internal and external competition. The rules of competition have now changed, and instead of a duopoly game we now have a decision to accept/reject a given limit order, which clearly depends on whether the order exceeds marginal cost. Hence, competition on the home venue can yield the same pricing benefits to investors as competition arising from interlisting. This is true irrespective of trading time and volume clusters. Similar results also emerge when end-of-day prices and volume of transactions are not assumed to be integrated into market makers anticipations[7]**.** The results in table III further show that the interaction terms between interlisting and price, volume and volatility do not have consistent signs and are not generally statistically significant, which provides further support for the effectiveness of internal competition among home venue market makers for non-interlisted options relative to the interlisted options subjected to both internal and external competition.

(TABLE III ABOUT HERE)

The analysis also tests for information effects of interlisting on effective spreads. More specifically, it may be possible that market participants integrate information in a different manner for interlisted than for non-interlisted options. If such is the case, the

[7] These results are available from the authors upon request.

interlisting of options may be related to adverse selection when trading with informed and uninformed (liquidity) traders. We analyse whether market makers integrate this possibility by estimating the marginal effect of informed trading on effective spreads. The informed trading indicator (INFORMED) is empirically measured as a trade that goes in the same direction as the underlying stock price during the day[8]. The results of this test are often inconclusive. When statistically significant, the results indicate that informed trading is associated, as expected from the literature, with wider effective spreads irrespective of interlisting and volume clusters. Again, the absence of any difference between interlisted and non-interlisted options on this score provides further evidence on the effectiveness of home venue competition.

It is also important to mention that the effect of volatility was analysed in greater depth in an effort to determine the source of its combined effect with model (1) interlisting indicator. More specifically, the average implicit volatility was segregated according to trading volume, time to maturity and moneyness. The overall results, unreported but available from the authors upon request, show a smile like pattern for put and for call contracts irrespective of time to maturity, time of day or trade volume clusters. The observed pattern of volume of transactions in general indicates that volume is mainly concentrated around parity irrespective of the time of day.

However, the results also show that the volume distributions exhibit thicker tails for interlisted options irrespective of time of day. This indicates that interlisted options are traded across a wider range of moneyness than non-interlisted options. Another interesting observation is that non-interlisted options exhibit a smirk-like pattern irrespective of time for moneyness ratios ranging from 0.6 to 1.5. In comparison interlisted options exhibit a smile-like pattern over the same moneyness range.

Further analysis was conducted to test for differences in the intensity of the volatility skew between interlisted and non interlisted option contracts. More specifically a ratio of the maximum implicit volatility divided by the minimum implicit volatility for each

[8] For example, a purchase of a call option when the underlying stock price increases during the day.

option class was estimated on a monthly basis where the implicit volatility was conditioned according to the contracts' moneyness and time to maturity. Table IV shows that the volatility skew ratio is generally greater for interlisted option contracts and that this diffence is most often statistically significant. These results, although preliminary, are quite promising and warrant further analysis.

(TABLE IV ABOUT HERE)

Conclusion

We have presented results on the effect of options cross-listing between Canada and the US on the microstructure of the Canadian market. As in previous studies, we examined the quality of trading as measured by both quoted and effective spreads. In particular, we focused on the the competitive structure of the Montreal market and the effects of thin trading on market quality, features that have been ignored in previous studies. We allowed for differential microstructure effects depending on the volume of the transaction and we distinguished three different time-of-day periods.

We find that quoted spreads conform very closely to the predictions of a Cournot duopoly model, which is the structure that prevails in the ME. The quotes are fully consistent with the predictions of the model with respect to the effects of cross-listing, which makes the market competitive, and are also responsive as predicted to the variables that affect the cost, such as price, volatility and volume. We also find that market thinness is a significant determinant of the quoted spreads, insofar as it seems to affect the cost component related to asymmetric information. The interactions of thinness with other measures of information, however, may obscure the impact of cross-listing on the size of the spreads.

Our overall results for effective spreads are less statistically significant than for quoted spreads, partly because market thinness reduces significantly the size of our sample to the observations for which a trade has occurred. The main result that we find is that cross-listing is no longer a significant determinant of the spread, as it was for the quoted spread. This is consistent with the trading mechanism on the ME, which for limit orders within the bid-ask spread is similar to an auction and will eventually converge to a competitive price structure, as with the cross-listed options. We also find that the information component is often a significant determinant of the spread, although here as well interlisting does not seem to play any role.

We have also presented some preliminary results on the volatility smile, its intra-day evolution and the effects of interlisting. The results are so far preliminary, but there are definite smile effects and also significant differences in the size of the volatility skew, whose interpretation is a topic of our ongoing research.

BIBLIOGRAPHY

Amihud, Y., & Mendelson, H., (1980). Dealership market: Market-making with inventory. *Journal of Financial Economics,* 8, 31-53.

Battalio, R., B. Hatch and R. Jennings, (2004), Toward a National market System for U.S. Exchange-listed Equity Options, *The Journal of Finance*, LIX(2), 933-962

Benston, G. J., & Hagerman R. L., (1974). Determinants of the bid-ask spreads in the over-the-counter market. *Journal of Financial Economics,* 1, 353-364.

Bessembinder, H., & Kaufman, H. M., (1997). A cross-exchange comparison of executioncosts and information flow for NYSE-listed stocks. *Journal of Financial Economics*, 46(3), 287-310.

Bessembinder, H., & Kaufman, H. M., (1997). A Comparison of Trade Execution Costs for NYSE and NASDAQ-Listed Stocks. *Journal of Financial and Quantitative Analysis*, 32(3), 293-319.

Chung, K.H., Van Ness, B.F. and Van Ness, R.A., (2004). Trading Costs and Quote Clustering on the NYSE and NASDAQ after Decimalization. *The Journal of Financial Research Columbia*, 27, 3, 309-328.

Chowdhry, B., & Nanda, V., (1991). Multimarket Trading and Market Liquidity. *Review of Financial Studies,* 4 (3), 483-511.

Chung, K. H., Van Ness, B. F., & Van Ness, R. A., (2004). Trading costs and quote clustering on the NYSE and Nasdaq after decimalization. *The Journal of Finance*, 27(3), 309-328.

Copeland, T. E., & Galai, D., (1983). Information effects on the bid-ask spread". *Journal of Finance,* 38, 1457-1469.

De Fontenouvelle, P., R. P.H. Fische and J.H. Harris, (2003), The Behaviour of Bid-Ask Spreads and Volume in Options Markets during the Competition for Listings in 1999, *The Journal of Finance*, LVIII(6), 2437-2463

Demsetz, H., (1968), The cost of transacting, *Quarterly Journal of Economics* 82, 33-53.

Foerster, S. R., & Karolyi, G. A. (1998). Multimarket trading and liquidity: A transaction data analysis of Canada – US interlistings. *Journal of International Financial Markets, Institutions and Money,* 8, 393-412.

Glosten, L. R., & Harris, L. E., (1988). Estimating the components of the bid-ask spread. *Journal of Financial Economics*, 21, 123-142.

Glosten, L. R. & Milgrom, P. R., (1985). Bid-ask and transaction prices in a specialist market with heterogeneously informed traders. *Journal of Financial Economics,* 14, 71-100.

Hasbrouck, J., (1988). Trades, Quoted, Inventories, and Information. *Journal of Financial Economics*, 22, 2, 229-253.

Ho, T., & Stoll, H., (1980). On Dealer Markets Under competition. *Journal of Finance,* 35, 259-267.

Huang, R. D., & Stoll, H. R., (1994). Market Microstructure and Stock Return Predictions. *The Review of Financial Studies (1986-1998)*, 7, 1, 179-214.

Huang, R. D., & Stoll, H. R. (1997). The components of the Bid-Ask Spread: A General Approach. *The Review of Financial Studies,* 10(4), 995-1034.

Huang, R. D., & Stoll, H. R., (2001). Tick size, bid-ask spreads, and market structure. *Journal of Financial and Quantitative Analysis*, 36(4), 503-522.

Khoury N., Yourougou, P., & Vigneau, G. (1991). Les déterminants du coût de la liquidité immédiate sur le marché canadien des options. *L'actualité économique,* 67(4), 499-516.

Khoury, N., & Fischer, K., (2002). The effect of multiple listings on the bid-ask spread in option markets: The case of Montreal exchange. *The Journal of Futures Markets,* 22(10), 939-957.

Khoury, N., Perrakis, S. & Savor, M., (2007). Price Improvement, Price Discovery and Order Execution Quality on the Boston Options Exchange. *Working paper*, 40 pages.

Kim, S., & Ogden, J. P., (1996). Determinants of the components of bid-ask spreads on stocks. *European Financial Management,* 1, 127-145.

Kryzanowski, L., & Zhang, H. (2002). Intraday market price integration for shares cross-listed internationally. *Journal of Financial and Quantitative Analysis,* 37(2), 243-269

Kyle, A.S., (1985). Continuous auctions and insider trading. *Econometrica* 53, 1315-1335.

Mayhew, S., (2002), Competition, Market Structure, and Bid-Ask Spreads in Stock Option Markets, *The Journal of Finance*, LVII(2), 931-958

Neal, R., (1987). Potential competition and actual competition in equity option. *Journal of Finance*, 42(3), 51 1-531.

Neal, R., (1992). A comparison of transaction cost between competitive markets and dpecialist market dtructures. *Journal of Business*, 65(3), 317-334.

Oppenheimer, H. R., & Sabherwal, S. (2003). The competitive effects of US decimalization: Evidence from the US-listed Canadian stocks. *Journal of Banking & Finance,* 27, 1883-1910.

Roll, R., (1984). A simple implicit measure of the effective bid-ask spread in an efficient market. *Journal of Finance*, 39, 1127-1139.

Stoll, H. R., (1989). Inferring the components of the bid-ask spread: Theory and empirical tests. *Journal of Finance,* 44, 115-134.

Stoll, H. R., (2000). Friction. *The Journal of Finance*, 55(4), 1479-1514.

Van Ness, B.F., Van Ness, R.A., & Hsieh, W-L. (1999). Nasdaq and the Chicago stock exchange: An analysis of multiple market trading. *Financial Review,* 34(4), 145-158.

White, H., (1980). A Heteroskedasticity-consistent Covariance Matrix Estimator and A Direct Test for Heteroskedasticity. *Econometrica*, 48, 4, 817-839.

Table I - Intra day and end-of-day quoted and effective spreads' descriptive statistics

This table provides descriptive statistics for quoted and effective spreads for both interlisted and non-interlisted options. The statistics are conditioned on clusters of the total daily volume per contract where VOL15, VOL50, VOL100, VOL500, VOL501 are indicator variables equal to1 if the total daily volume per contract falls within the interval of 0 to 15, 16 to 50, 51 to 100, 101 to 500 and more than 500 respectively and zero otherwise.

Quoted Spreads

Sample size = 7262	Non-Interlisted options			Interlisted Options			Difference of means t-statistic		
	10h30	12h30	16h00	10h30	12h30	16h00	10h30	12h30	16h00
Trade volume cluster									
VOL15	0,1918	0,1817	0,1753	0,2242	0,2129	0,2054	7,7292	8,3720	8,7068
VOL50	0,1774	0,1663	0,1631	0,1948	0,1825	0,1740	3,9872	4,1649	2,7342
VOL100	0,1573	0,1531	0,1470	0,1651	0,1577	0,1531	1,4025	0,8602	1,1931
VOL500	0,1630	0,1494	0,1449	0,1411	0,1363	0,1337	-3,2435	-3,2063	-2,7915
VOL501	0,1782	0,1599	0,1537	0,1872	0,1686	0,1699	0,6131	0,9238	1,7244
Overall	0,1774	0,1669	0,1618	0,1910	0,1806	0,1746	5,3696	6,3986	6,1508

Effective Spreads

Sample size = 1408[9]	Non-Interlisted options			Interlisted Options			Difference of means t-statistic		
	10h30	12h30	16h00	10h30	12h30	16h00	10h30	12h30	16h00
Trade volume cluster									
VOL15	0,3055	0,2583	0,2678	0,3319	0,2846	0,2556	0,7654	0,6783	-0,4639
VOL50	0,3291	0,3453	0,2516	0,3472	0,3144	0,2753	0,5312	-0,5320	0,9328
VOL100	0,4163	0,3414	0,3243	0,3831	0,3197	0,2499	-0,7028	-0,3861	-1,8476
VOL500	0,4142	0,2844	0,2578	0,4489	0,3652	0,2713	0,7108	2,0477	0,4470
VOL501	0,2562	0,3094	0,1598	0,3568	0,2984	0,2074	2,1642	-0,1096	1,5697
Overall	0,3524	0,3062	0,2619	0,3746	0,3201	0,2581	1,1554	0,5724	-0,2775

[9] All difference of means for quoted spreads where also tested on the subsample for which effective spreads are available. The results provide similar conclusions.

Table II – Effect of Interlisting on intra day and end-of-day quoted spreads

This table provides results for model (1) that estimates the impact on quoted spreads. The model regressors include Volume, the total daily trading volume per contract, INT, an indicator variable equal to 1 if the contract spread relates to an interlisted option and 0 otherwise, INT_FITTED, an endogenous estimate of the interlisting indicator variable based on the underlying securities market capitalization and industry, PRICE, the average of the option's bid and ask prices, INFORMED, the percentage of trades by informed traders relative to the overall number of trades, VOLATILITY, the implied standard deviation of the underlying stock return according to Black & Scholes model, THIN, the number of days within the month where no trade occurred for a given option series. The parameters are conditioned on clusters of the total daily volume per contract where VOL15, VOL50, VOL100, VOL500, VOL501 are indicator variables equal to1 if the total daily volume per contract falls within the interval of 0 to 15, 16 to 50, 51 to 100, 101 to 500 and more than 500 respectively and zero otherwise[10].

	10h30 quotes		12h30 quotes		16h00 quotes	
Variable	Coefficient	Signif.	Coefficient	Signif.	Coefficient	Signif.
Constant	0.155859	*	0.061568	*	0.034225	
INT*VOL15	-0.153640	*	-0.046011		-0.046729	***
INT*VOL50	-0.111154	*	-0.004144		-0.008577	
INT*VOL100	-0.170806	*	-0.003222		-0.083796	
INT*VOL500	-0.109958	**	0.003389		-0.001519	
INT*VOL501	-0.180275	**	-0.013093		-0.150243	**
PRICE*VOL15	0.001529	*	0.000537	**	0.000783	*
PRICE*VOL50	0.000883	*	0.001011	*	0.001257	*
PRICE*VOL100	0.000359		0.000426		0.000654	**
PRICE*VOL500	0.000593		0.000557	**	0.000836	*
PRICE*VOL501	0.000594		0.000681		0.000290	
PRICE*VOL15*INT	0.001245	*	0.002305	*	0.001584	*
PRICE*VOL50*INT	0.001530	*	0.000986	*	0.000493	**
PRICE*VOL100*INT	0.002361	*	0.001431	*	0.001825	*
PRICE*VOL500*INT	0.001079	**	0.000983	*	0.000826	*
PRICE*VOL501*INT	0.003105	*	0.001125	***	0.003508	*
VOLUME*VOL15	-0.008057		-0.004065		0.000742	
VOLUME*VOL50	-0.017299	**	-0.003354		-0.003757	
VOLUME*VOL100	0.002749		0.006220		0.007458	
VOLUME*VOL500	-0.003087		-0.004528		0.005906	
VOLUME*VOL501	0.006034		-0.000919		0.007158	
VOLUME*VOL15*INT	-0.000768		-0.013481	**	-0.013810	*
VOLUME*VOL50*INT	0.012537		-0.000945		-0.003018	
VOLUME*VOL100*INT	-0.007186		-0.005646		-0.005592	
VOLUME*VOL500*INT	0.001086		0.001498		-0.010122	
VOLUME*VOL501*INT	-0.008390		-0.003871		-0.001341	
INFORMED*VOL15	-0.083921	***	0.049243		0.070142	**
INFORMED*VOL50	-0.017146		0.069302	**	0.073286	**
INFORMED*VOL100	-0.003013		0.006996		0.006739	
INFORMED*VOL500	-0.056961		0.048970		0.012451	
INFORMED*VOL501	-0.081064		0.051533		0.011976	
INFORMED*VOL15*INT	0.227009		0.050035		0.071211	**
INFORMED*VOL50*INT	0.047570		-0.091664	**	0.013762	
INFORMED*VOL100*INT	0.072179		-0.018857		0.089609	
INFORMED*VOL500*INT	0.068923		-0.090071		0.014267	
INFORMED*VOL501*INT	0.113767		-0.106043		0.005712	
VOLATILITY10*VOL15	0.060540	*	0.008179		0.017530	*

[10] *** Statistically significant at the 10% level; ** statistically significant at the 5% level; * statistically significant at the 1% level.

VOLATILITY10*VOL50	0.060578	*	0.033989	*	0.048595	*
VOLATILITY10*VOL100	-0.008988		-0.001641		-0.000971	
VOLATILITY10*VOL500	0.000416		-0.000797		-0.001587	
VOLATILITY10*VOL501	-0.007496		-0.004736		-0.008238	
VOLATILITY10*VOL15*INT	0.019261		0.082068	*	0.057567	*
VOLATILITY10*VOL50*INT	0.007824		0.024526	**	0.005513	
VOLATILITY10*VOL100*INT	0.059234	*	0.029430	*	0.059874	*
VOLATILITY10*VOL500*INT	0.010888		0.024100	*	0.021099	*
VOLATILITY10*VOL501*INT	0.041283	*	0.023933	**	0.062289	*
THIN*VOL15	0.024282		0.102705	*	0.089863	*
THIN*VOL50	0.022465		0.027330		0.043774	**
THIN*VOL100	-0.033879		0.073296	**	0.079177	*
THIN*VOL500	0.014519		0.086926	*	0.066600	**
THIN*VOL501	0.018811		0.065748		0.094580	***
THIN*VOL15*INT	-0.025012		-0.094842	*	-0.050091	**
THIN*VOL50*INT	0.009603		0.041847		0.004222	
THIN*VOL100*INT	0.087182		-0.035279		-0.037323	
THIN*VOL500*INT	0.040122		-0.004923		0.014992	
THIN*VOL501*INT	0.001694		0.056021		-0.023217	
R-squared	0.341950		0.316072		0.322327	
Adjusted R-squared	0.330390		0.306628		0.317155	
Number Of Observations	3 187		4 039		7 262	

Table III – Effect of Interlisting on intra day and end-of-day effective spreads

This table provides results for model (1) that estimates the impact on effective spreads. The model regressors include Volume, the total daily trading volume per contract, INT, an indicator variable equal to 1 if the contract spread relates to an interlisted option and 0 otherwise, INT_FITTED, an endogenous estimate of the interlisting indicator variable based on the underlying securities market capitalization and industry, PRICE, the average of the option's bid and ask prices, INFORMED, an indicator variable if the trade is from an informed investor and zero otherwise, VOLATILITY, the implied standard deviation of the underlying stock return according to Black & Scholes model. The parameters are conditioned on clusters of the total daily volume per contract where VOL15, VOL50, VOL100, VOL500, VOL501 are indicator variables equal to1 if the total daily volume per contract falls within the interval of 0 to 15, 16 to 50, 51 to 100, 101 to 500 and more than 500 respectively and zero otherwise[11].

	10h30 trades		12h30 trades		16h00 trades	
Variable	Coefficient	Signif.	Coefficient	Signif.	Coefficient	Signif.
Constant	0.061185		-0.095881		-0.063273	
INT*VOL15	-0.040618		0.135216		0.007696	
INT*VOL50	0.017766		-0.307032		0.044487	
INT*VOL100	0.017358		0.037803		-0.270108	
INT*VOL500	0.008651		0.046383		0.317811	
INT*VOL501	-0.068009		0.364467	*	-0.312219	
PRICE*VOL15	0.004842	*	0.003711	*	0.004151	**
PRICE*VOL50	0.000604		0.005870	*	0.009011	*
PRICE*VOL100	0.000472		0.001950		0.000878	
PRICE*VOL500	0.001353		0.002531	**	0.002557	***
PRICE*VOL501	0.000992		0.007318	*	0.012026	*
PRICE*VOL15*INT	-0.002557	*	-0.001330		-0.000593	
PRICE*VOL50*INT	0.000581		0.004842	*	-0.006296	*
PRICE*VOL100*INT	0.001948		8.59E-05		0.002185	
PRICE*VOL500*INT	-0.000397		0.002016		0.003258	***
PRICE*VOL501*INT	0.002298		-0.006025	*	-0.006553	**
VOLUME*VOL15	-0.080295	*	0.000833		0.010169	
VOLUME*VOL50	0.013158		-0.029786		-0.081423	**
VOLUME*VOL100	0.003055		0.025528		0.037405	
VOLUME*VOL500	-0.001278		0.012979		0.004642	
VOLUME*VOL501	0.040360		-0.049503	**	-0.065544	**
VOLUME*VOL15*INT	0.079145	*	-0.024862		0.007088	
VOLUME*VOL50*INT	-0.005447		0.030742		0.092976	
VOLUME*VOL100*INT	-0.006933		-0.008430		0.019885	
VOLUME*VOL500*INT	0.001708		-0.012940		-0.066304	
VOLUME*VOL501*INT	-0.037081		0.002810		0.120850	*
INFORMED*VOL15	-0.002309		0.085044	**	0.044359	
INFORMED*VOL50	0.006037		0.079692	**	0.029068	
INFORMED*VOL100	-0.003180		-0.010456		-0.005773	
INFORMED*VOL500	-0.023064		0.081510	***	0.088487	***
INFORMED*VOL501	-0.039828		0.170734	**	0.076265	
INFORMED*VOL15*INT	0.025470		-0.010797		-0.014584	
INFORMED*VOL50*INT	-0.011176		0.037977		-0.032138	
INFORMED*VOL100*INT	-0.023350		0.064491		0.134733	**
INFORMED*VOL500*INT	0.031864		-0.053143		-0.081979	
INFORMED*VOL501*INT	0.003528		-0.115606		-0.110825	
VOLATILITY10*VOL15	0.156630	*	0.023896		0.028439	

11 *** Statistically significant at the 10% level; ** statistically significant at the 5% level; * statistically significant at the 1% level.

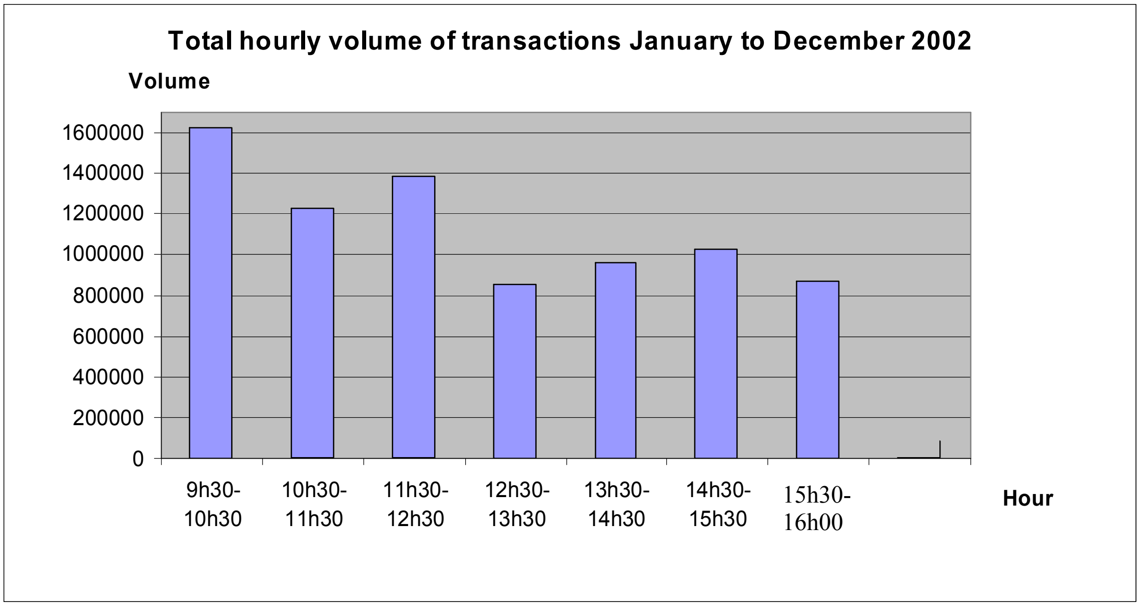
VOLATILITY10*VOL50	-0.013382		0.140503	*	0.238286	*
VOLATILITY10*VOL100	0.015787		0.038336		-0.042860	
VOLATILITY10*VOL500	0.024613		0.024708		0.010369	
VOLATILITY10*VOL501	-0.163350		0.053544		0.156385	*
VOLATILITY10*VOL15*INT	-0.098206	**	0.038285		0.042211	
VOLATILITY10*VOL50*INT	0.045365		0.074797		-0.167105	**
VOLATILITY10*VOL100*INT	-0.017676		0.033149		0.200489	
VOLATILITY10*VOL500*INT	-0.039502		0.042354		0.092945	**
VOLATILITY10*VOL501*INT	0.178089		-0.023843		-0.119752	**
R-squared	0.110403		0.324433		0.196898	
Adjusted R-squared	0.081011		0.293027		0.154381	
Number Of Observations	1 408		1 014		896	

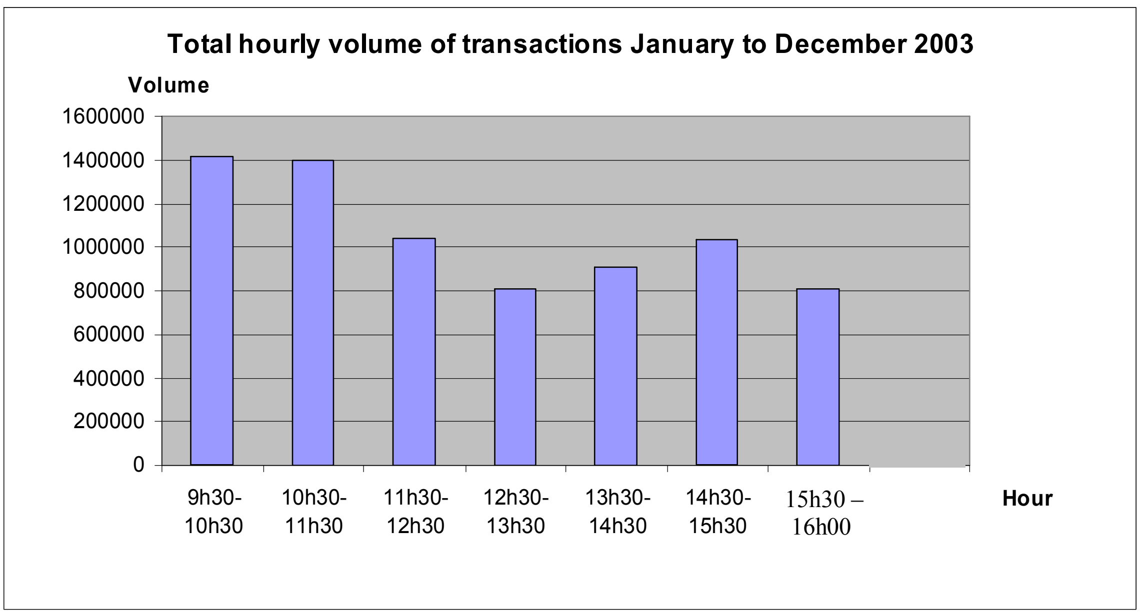
Table IV – Interlisting Effect on Implicit Volatility Ratio

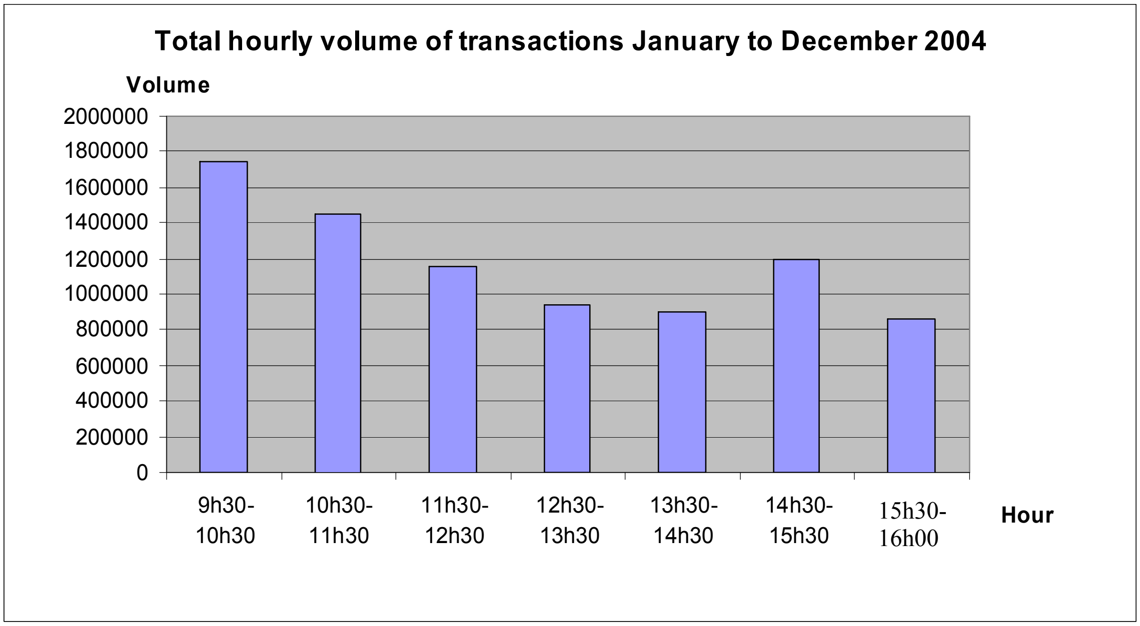
This table provides descriptive statistics for implicit volatility ratio defined as the the maximum implicit volatility divided by the minimum implicit volatility for each option class was estimated on a monthly basis where the implicit volatility was conditioned according to the contracts' moneyness and time to maturity. The implied volatility is defined as the standard deviation of the underlying stock return according to Black & Scholes model. The statistics are conditioned on clusters of the total daily volume per contract where VOL15, VOL50, VOL100, VOL500, VOL501 are indicator variables equal to1 if the total daily volume per contract falls within the interval of 0 to 15, 16 to 50, 51 to 100, 101 to 500 and more than 500 respectively and zero otherwise.

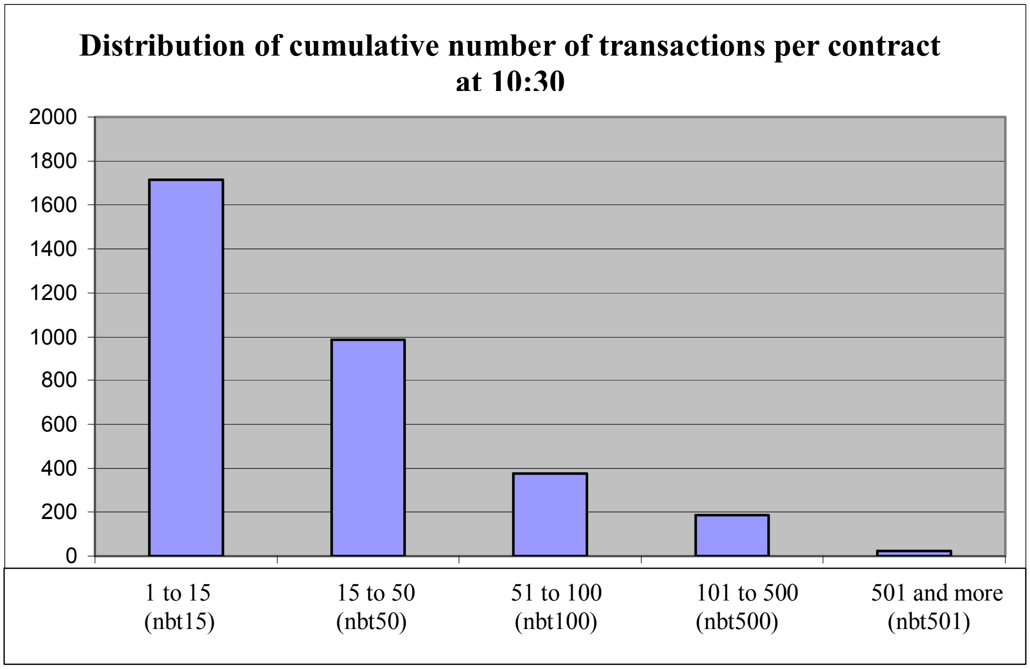
	Non-Interlisted options			**Interlisted Options**			**Difference of means t-statistic**		
	10h30	12h30	16h00	10h30	12h30	16h00	10h30	12h30	16h00
Trade volume cluster									
VOL15	2,0979	2,0809	2,10950251	2,4746	2,4468	2,3587	2,7232	2,4736	1,4958
VOL50	2,1464	2,0736	2,05912495	2,4542	2,4019	2,3280	1,8795	2,0995	1,8981
VOL100	1,4626	1,4556	1,42290311	1,6491	1,6858	1,6718	1,5011	1,7127	2,0366
VOL500	2,0543	1,8715	1,85620865	2,3388	2,2502	2,1239	1,1904	1,8647	1,4135
VOL501	1,7498	1,6965	1,72121322	2,4916	2,3833	2,4714	2,6841	2,4792	2,1796

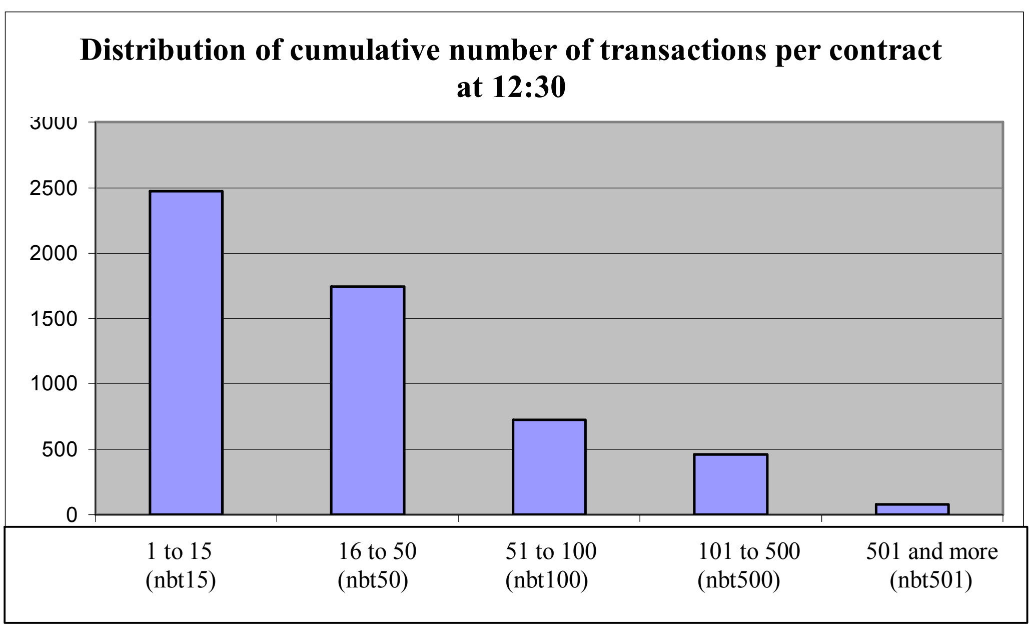
APPENDIX

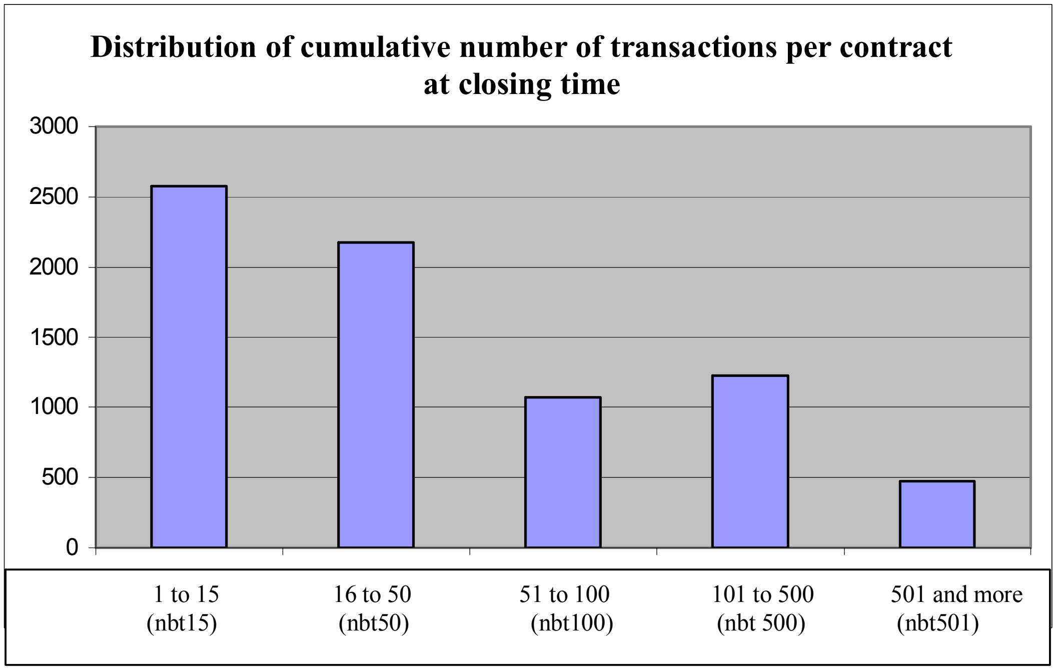

Total hourly volume of transactions January to December 2002
Volume
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
9h30-10h30
10h30-11h30
11h30-12h30
12h30-13h30
13h30-14h30
14h30-15h30
15h30-16h00
Hour


Total hourly volume of transactions January to December 2003
Volume
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
9h30-10h30
10h30-11h30
11h30-12h30
12h30-13h30
13h30-14h30
14h30-15h30
15h30 – 16h00
Hour


Total hourly volume of transactions January to December 2004
Volume
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
9h30-10h30
10h30-11h30
11h30-12h30
12h30-13h30
13h30-14h30
14h30-15h30
15h30-16h00
Hour


Distribution of cumulative number of transactions per contract at 10:30
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1 to 15 (nbt15)
15 to 50 (nbt50)
51 to 100 (nbt100)
101 to 500 (nbt500)
501 and more (nbt501)


Distribution of cumulative number of transactions per contract at 12:30
3000
2500
2000
1500
1000
500
0
1 to 15 (nbt15)
16 to 50 (nbt50)
51 to 100 (nbt100)
101 to 500 (nbt500)
501 and more (nbt501)


Distribution of cumulative number of transactions per contract at closing time
3000
2500
2000
1500
1000
500
0
1 to 15 (nbt15)
16 to 50 (nbt50)
51 to 100 (nbt100)
101 to 500 (nbt 500)
501 and more (nbt501)