PRICE IMPROVEMENT AND ORDER EXECUTION QUALITY ON THE BOSTON OPTIONS EXCHANGE

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ABSTRACT

This study focuses on innovations in order execution processes within the context of the Boston Option Exchange (BOX). More specifically, it examines the impact of the Price Improvement Process (PIP) introduced by BOX on options spreads, the quality of order execution as measured by the cost of trading and the offering of price improvements to informed and uninformed traders on this venue. Using an original data set, the paper shows that the marginal price improvement averages 1.49% of the option price quoted immediately before the transaction, and that this improvement varies according to order size and market liquidity. We also find that informed traders are more affected than uniformed traders by PIP related price improvements. Moreover, the price effect appears to be temporary as quoted spreads immediately after PIP related transactions revert to their previous higher level. Thus it seems that when price improvement is generated through a competitive bidding process that is not limited by the tick size, the gain to investors comes at the expense of the market maker's inventory cost represented by the bid-ask spread.

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Numerous studies have examined the influence of different trading and cost structures on equity bid-ask spreads. They have compared, among other things, the spreads between auction and dealer markets, between markets of different quotation behaviour, between markets at different locations, and between floor and screen based trading markets. Other studies have also examined the influence on options' bid-ask spreads of market micro structure changing design resulting form new forms of competition between different venues. Of particular interest for this research are the studies that dealt with the impact of competition associated with interlisted options versus options listed exclusively on a single exchange, and those associated with options markets structured around competing market makers in comparison with those structured around specialists.

A recent innovation on the Boston Options Exchange (BOX) provides a unique opportunity to examine the influence of an innovative competitive trading structure on the bid-ask spread in options markets. Beginning in February 2004, BOX launched a new electronic auction process, called Price Improvement Process (PIP), that permits order flow providers to improve client orders by taking the other side as principals and improve the price by intervals of one cent. Order flow providers in the option class as well as other BOX designated trading participants may then compete for this order by bettering the price also by increments of one cent. All other orders can only be incremented by price intervals of five or ten cents. The Price Improvement Period lasts three seconds and must feature a higher bid price (lower offer price) than the contemporaneous bid posted on the BOX market for the same security and better than the National Best Bid Offer quote[1]. At the end of the price improvement period, the client side of the trade is matched with the best prices available on a price/time priority basis.

This study focuses on innovations in order execution processes within the context of BOX. More specifically, it looks at BOX's PIP as a recent example of such innovation and examines its impact on transaction execution quality and quoted bid-ask spreads on that venue. Since PIP allows order flow providers to compete regardless of the usual minimum tick size, it is expected to have a spread reducing effect on options quotes. Furthermore, contestable markets notions suggest that if PIP allows additional competition in order executions, irrespective of the minimum tick size, the quality of such executions should be improved on the market that introduces this innovation.

This study expands the current literature on the effectiveness of new competitive innovations in trading mechanisms introduced recently in financial markets by empirically testing the impact of PIP on BOX order execution quality. In this regard, historical information provided on the BOX web site boasts a PIP related price improvement averaging 2$ per contract as of the time of this study[2]. A first contribution of this paper is to validate this claim in a multivariate setting and to analyse the way potential price improvements vary according to market liquidity and order size. A

[1] Broker dealers who are unable to initiate a PIP but wish to offer to their clients access to it, can submit their orders through any BOX Order flow provider or other BOX Participant. In this way, PIP can be accessible to all investors.

[2] As of November 2006 their price improvement claim on the BOX web site increases to 3.23$ per contract.

second contribution of the paper to the current literature is to investigate whether BOX's order execution innovation is associated with diminishing quoted spreads and increasing execution quality on that market. A third contribution is to asses the extent to which PIP related price improvements are offered to informed rather than to uninformed traders on BOX.

In this paper we use an original dataset obtained from BOX to compare and contrast execution quality for PIPed transactions and non PIPed transactions on that venue, mainly through their impact on bid-ask spreads. The paper shows that the marginal PIP-related price improvement averages 1.49% of the option price quoted immediately before the transaction, and that this improvement varies according to order size and market liquidity. We also find that informed traders are more affected than uniformed traders by PIP related price improvements. Moreover, the price effect appears to be temporary as quoted spreads immediately after PIP related transactions revert to their previous higher level.

Accordingly, the next section presents the background of the study, followed by a survey of previous studies dealing principally with competitive options markets. Section II describes the data and presents the methodology of the research. Section III sets out the empirical results of the price improvement issue and analyses them. Concluding remarks are presented in the last section.

I- Background and review of the literature

The issue of price improvement in options markets brings into focus the quoted bid-ask spread as it is arguably the most cited indicator of trading costs. The quoted spread is usually defined as the difference between the Bid and Ask prices. It differs from the effective spread which is defined as the difference between the transaction price and the mid point of the quoted spread, and from the traded spread which is measured as the difference between average prices of trades on the Ask and on the Bid side (Stoll, 2000). As mentioned by Stoll, in most empirical studies, stocks quoted proportional spreads have consistently exhibited a negative relationship to stock price and to measures of trading activity, and a positive relationship to stock volatility. In addition, Stoll also shows that stocks effective and quoted spreads are highly correlated (to the tune of 99%) and concludes that the two measures are equivalent.

As regards the components of stocks' quoted bid-ask spreads, it is now a commonplace observation that they are: order processing costs, inventory costs, and asymmetric information costs (Huang & Stoll, 1997; Khoury et al., 1991; Stoll, 1989). As summarized by Stoll (2000), a first group of studies has focussed on inventory holding costs associated with the fluctuating level and lack of diversification of liquidity suppliers' inventories (Amihud & Mendelson, 1980; Ho & Stoll, 1980; Stoll, 1978, 1989). More precisely, these studies emphasise, in the spirit of Demsetz (1968), real economic sources expended to execute trades, namely order processing costs, inventory costs as well as market power. Other researchers focused on the component of the spread that arises when liquidity suppliers deal with informed traders. In this regard, the quoted spread provides liquidity suppliers with protection against losses when dealing with superior information traders (Kyle, 1985; Easley & O'Hara, 1987; Glosten & Milgrom 1985; and Glosten 1994) and when dealing with those who are quick to act on new information by trading on posted quotes before they are changed (Copeland & Galai 1983). However as Stoll (1989, 2000) has shown, the empirical decomposition of the spread reveals that order processing costs, inventory costs and asymmetric information costs are the three components of the spread. Indeed, the market maker must quote a spread that maximises his profit from transactions from the two types of investors mentioned before, while allowing his portfolio to earn a return compatible with its level of risk.

With regard to options markets, the study by Khoury et al. (1991) presents a complete decomposition of the quoted bid-ask spread of options into its determinants. Of all the factors affecting option bid-ask spread, the option price (representing the capital invested in the specialist's inventory), the continuity of the option market, and whether the option is in-the-money or not (reflecting the degree of transmission of the underlying security's liquidity characteristics to the option) show up as the most important determinants of bid-ask spreads. Their results also reveal that the specific risk of the option is overshadowed by that of its underlying security and that the volume of transactions and the continuity of the options market seem to characterise its level of activity which has a negative effect on the spread[3]. Similarly, by extending Ho and Stoll's model (1983) to an option pricing framework, Berkman (1992) also finds evidence on the Amsterdam Stock exchange of a negative relationship between the absolute bid-ask spread and trading activity and a positive relationship with the value of the option, its delta, and with the return volatility of the underling security.

[3] It should be mentioned that the authors noted that the Mahalanobis distance allows them to identify four strata of concentration in the residuals of a bid-ask spread regression based on volume of transactions.

Examining the quoted spread on the S&P 100 Index Options, George and Longstaff (1993) find that it is positively related to the option's price and remaining days to maturity and negatively related to its delta and its level of trading activity. With respect to trading activity, the authors suggest that the option's remaining term to maturity and nearness-to-money are the determinants of the level of activity in options markets. In their analysis they find a negative relationship between the level of activity in options and both their term-to-maturity and nearness-to-money. Pinder (2003) in his analysis of the Australian options market, reports a positive relationship between end-of-day quoted bid-ask spreads and the option's remaining term-to-maturity which may reflect the negative relationship between term-to-maturity and level of trading. He also finds evidence of a negative relationship between the quoted spread and the option's value and its implied volatility, and a negative relationship with the level of its trading activity. On the other hand, he reports a positive relationship between an option's delta, measured in absolute terms, and its quoted bid-ask spread. This last result confirms that of Berkman for the Amsterdam Stock Exchange but contradicts the findings of George and Longstaff for the S&P 100 options market.

Consistent with the notion that in contestable markets, competitive pricing is expected to reduce the equilibrium price to the level of marginal cost, several studies have compared the bid-ask spread of stocks traded in different market structures. The results invariably show that spreads tend to decrease under competition associated with different market designs or with multiple listings (Huan & Stoll, 2001; Stoll, 2000; Chou, 2005). In regards to options markets, Neal (1987) compared the quoted bid-ask spread of AMEX options interlisted on a second exchange, to that of options traded only on AMEX. His model specifies that option spread is function of its daily transactions volume, its price calculated as the average between the bid and the ask prices, the implicit volatility of its underlying security, whether the option is interlisted or not, and whether its price is higher than 0.50$ or not. The results of the study show that interlisting of options indeed reduces their bid-ask spread. However, as the volume of transaction increases, the reduction in the spread grows smaller until it becomes negligible[4]. Using the same variables in a constrained and an unconstrained model, and a statistical procedure adapted to panel data, Khoury & Fischer (2000) find that the bid-ask spread of Montreal options interlisted in U.S. markets are narrower than those of noninterlisted options. Their study also reveals a positive and significant relationship between spreads on the one hand and options prices and implied volatilities[5] on the other, as well as a negative, though non significant, relationship with the number of transactions. In another paper, Neal (1992) finds that for low volume options, spreads are narrower on an exchange structured around specialists than on an exchange designed around competitive market makers. The opposite is true for options with relatively high volume of transactions. These results are consistent with the theoretical results of the model by Grossman and Miller (1988). Pinder (2003), on the other hand, finds that spreads are narrower when market makers are obliged to maintain a continual presence in the market.

[4] The volatility of the volume of transactions makes it impossible to estimate with any reasonable precision the level of transactions after which interlisting has no impact on the bid-ask spread. Nevertheless, the author suggested that 1 500 options per day is the threshold after which competition no longer reduces the bid-ask spread.

[5] It is interesting to note that option risk was also proxied by the variance of its quotes in this study. The results show that the coefficient of this measure of volatility is also positive and highly significant.

II- **Data and methodology**

The recent introduction of PIP provides a timely testing ground for order execution process innovations. In the context of this new process, specific contracts can be traded either through PIP or through more conventional channels, which allows for a model design that controls for the contracts' trading media. In addition, although only a restricted list of member firms may initiate a PIP, other order flow providers can access the process indirectly through those firms. This provides accessibility for all investors to potential price improvements. Overall, 14.42% of our sampled transactions were executed using PIP. By concentrating on the transactions of a single exchange any distorting effects arising from differences between exchanges is also minimized. An alternative sample design would have been to compare transactions on BOX to the national best bid and offer quotes (NBBO), in order to assess the equilibrium effect of PIP on the overall options market in the U.S. Though interesting, this issue falls however outside the scope of this paper. It should also be noted that all contracts in the sample of this study included both PIPed and non-PIPed transactions for the same secutity. Futhermore, as will be specified later on, the estimation methodology adopted in the paper adjusts for the panel nature of the data which also includes contract specific effects.

To estimate the impact of PIP we have used data of actual transactions and quoted spreads graciously provided by the Boston Options Exchange. A sample of 10 854 transactions was selected, which includes the most traded contracts in the 10 days preceding the third Friday of December 2004[6]. It should be noted that the proprietary nature of the dataset limits its availability. The month of December 2004 was selected because it is the month with the highest level of average direct orders PIPed in the last quarter of the first year of BOX operations. This sample represents all BOX transactions in this time frame for which all required data are available. The option contracts in the sample exhibit an average spread immediately preceding the transactions of 0.084$. Minimum and maximum quoted spreads are 0.05$ and 2.60$ respectively.

Quoted spreads were then matched with each transaction and analyzed using a variation of typical inventory based models. As mentioned in Neal (1987), using quoted spreads assumes that they remain valid representations of the markets expectations at any given time. Alternatively, a more restrictive assumption can be used, namely that quoted spreads remain valid so long as they are unchanged. Although the sample emphasizes contracts that are most traded on any given day, quoted spreads could become invalid if the time between the last quote and the order's execution is excessively long. The sample design will therefore limit the delay between quoted spreads and actual transactions to a maximum of 15 minutes. Upon inspection, only 17 observations do not meet this criterion. Furthermore, the sample is filtered to exclude zero bid price and positive ask price quotes which represent approximately 2% of total observations. Such observations truncate the distribution and bias the spread towards zero.

[6] The number of specific contracts included in the sample varies from 150 to 250 for each of the sampled working days. All transactions relating to these contracts are included in the initial sample. The final sample is obtained by excluding 593 observations due to lack of control data availability. Unreported descriptive statistics show that excluded observations do not materially differ from included ones.

Two separate models are used to analyze the impact of PIP as a market microstructure innovation on BOX. The first model seeks to determine the effect of PIP on options spreads after controlling for other factors previously uncovered in the literature as follows:

$$\text{Spread / price} = \text{intercept} + \beta_1 \text{ volume} + \beta_2 \text{ volume} * \text{DTT} + \beta_3 \text{ price} + \beta_4 \text{ price} * \text{DNP} + \beta_5 \text{ volatility} + \beta_6 \text{ DTT} + \beta_7 \text{ M} + \beta_8 \text{ T} + \varepsilon \quad (1)$$

where

Spread = quoted ask price – quoted bid price
Volume = total daily trading volume per contract
DTT = 1 if the matched transaction uses PIP and 0 otherwise
Price = average of bid and ask prices
DNP = 0 if option price is greater than 50 cents and 1 otherwise[7]
Volatility = implied standard deviation of the underlying stock return[8]
M = is the absolute value of the underlying stock price minus the option's strike price
T = remaining number of days until the option expires

Volume, a measure of market liquidity, is expected to have a reducing effect on quoted spreads since order flow providers should be more willing to accept lower profits in the presence of greater potential trading volume. As discussed earlier, higher option prices are indicative of higher inventory costs and thus lead to wider quoted spreads. Lower priced options involve smaller inventory costs and a greater proximity to prices' lower bound of 0$.

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[7] Consistent with Neal (1987), this variable controls for the potential masking of competitive effects due to low price option spreads. Indeed, given the discreetness of quoted prices and the fact that lower priced options are more likely to be quoted closer to the lower bound of bid and ask prices, these options are more likely to be affected by the minimum tick size.

[8] Implied volatility is measured using Black and Scholes option pricing model based on the settlement price of the stock, the average of the bid and ask prices, the remaining time to maturity and the daily 3 month treasury bill rate.

Spreads are thus more likely to be positively related to price although less so for lower priced options. Alternatively, market uncertainty measured by implied volatility, denotes order flow provider risk, which is expected to be associated with related to wider quoted spreads. The nearness-to-money ($|S - K|$) as defined in equation (1) and time-to-maturity provide alternative measures of order flow provider risk and have been shown to be negatively related to trading activity, which in turn should lead to larger quoted spreads. On the other hand, nearness-to-money and time to maturity are positively related to the option price, which leads, by construction, to smaller proportional quoted spreads. The net impact of these two variables will thus depend on the trade off between the trading activity effect and the price effect.

Apart from its impact on options spreads, PIP can also be analyzed through its impact on order execution quality as measured by the cost of trading. This second aspect is important since transactions could take place inside the quoted spreads which reduces their validity as a measure of real spreads. Moreover, the significance of the results based on quoted spreads may be further reduced if wider quoted spreads lead to more transactions being executed within such quotations. On the other hand, the examination of execution quality also brings into focus the working of non-price competition.

Neal's (1987) paper introduces a measure of order execution quality defined for each transaction by:

$$Z = 2 * [\text{Transaction price} - (\text{bid} + \text{ask})/2] / (\text{ask} - \text{bid}). \qquad (2)$$

One of the spurious effects of equation (2) is that larger quoted spreads, other things equal, necessarily result in better execution quality as measured by Z. To avoid this effect an alternative measure of execution quality is defined as follows:

$$Y = 2 * [\text{Transaction price} - (\text{bid} + \text{ask})/2] / [(\text{bid} + \text{ask})/2]. \qquad (3)$$

Equation (3) uses the last quoted bid and ask prices before each transaction is executed. More specifically, the measure uses bid and ask quotes immediately before the transaction is executed for non-PIP trades and the bid and ask quotes immediately before the PIP is initiated for PIP transactions. It should be noted that the Y variable in equation (3) measures the effective spread proportional to the option's quoted mid price. Transactions executed at the bid or ask prices will result in an absolute value of Y equal to the percentage spread. Transaction prices closer to mid price will result in an absolute value of Y closer to zero. The average of absolute values of Y for non-PIPed transactions is 0.0898, while it stands at 0.0600 for PIPed transactions (difference test; $t = 12.19$). The impact of PIP on the absolute values of Y is then estimated using the model:

$$\begin{aligned} \text{Abs}\,[Y] = {} & \text{intercept} + \beta_1 \text{ volume} + \beta_2 \text{ volume} * \text{DTT} + \beta_3 \text{ price} \\ & + \beta_4 \text{ price} * \text{DNP} + \beta_5 \text{ volatility} + \beta_6 \text{ DTT} + \beta_7 \text{ M} + \beta_8 \text{ T} + \varepsilon \qquad (4) \end{aligned}$$

Thus the absolute value of Y is regressed on the same variables that determine the option spread in model (1). This specification of model (4) follows from the definition of Y which represents the effective spread in proportion to the option's mid price.

III – Empirical Results

Effect of PIP on quoted spreads

The empirical analysis begins with an examination of the PIP effect on quoted spreads at the time of the transaction. The effect on transaction quality, where transactions are compared to spreads immediately before their execution, is then analyzed in order to estimate both the PIP's overall impact and its impact relative to alternative parameterizations of transactions volume. More specifically, the model specified in equation 3 is first estimated as expressed in the equation. Model parameters are then allowed to vary according to the size of individual transactions and according to the overall daily volume per contract. The unconstrained specifications of equation 3 provide indications as to how the PIP effect varies for each volume cluster. It should be noted that all models are corrected for a second order autoregressive process to obtain consistent estimates of the standard errors[9]. Where appropriate, parameter standard errors are adjusted according to White (1980) which assumes heteroskedastic error terms of unknown form.

Table I presents the results of the PIP effect on spreads. These results are consistent with anticipated price improvements effects and previous empirical research. The negative coefficient estimates on price is to be expected since spreads are defined in proportion to prices. Interestingly, the price impact on low priced option proportional spreads is positive likely

[9] The estimated autoregression coefficients are less than 0.1 for the second lag and after.

reflecting the incidence of the minimum tick size constraint. Table I also reveals that quoted proportional spreads are positively related to the implicit volatility of the underlying security, which provides a proxy for market risk. These findings are consistent with previous studies such as those of Neal (1992), Berkman (1992), Khoury and Fischer (2000), and Pinder (2003).

TABLE I approximately here

Daily volume of transactions, as a measure of market liquidity, is also negatively related to option proportional spreads. This result is consistent with the existing literature. The table also shows that the negative effect of volume on spreads is less pronounced for quoted proportional spreads associated with PIP transactions although this result is not statistically significant. This observation constitutes a preliminary indication that PIP may provide additional price improvements in highly liquid markets when spreads are less sensitive to increases in daily transaction volume. Neal (1987) shows that beyond a certain threshold, spreads are less sensitive to variations in volume.

Results in table I also show that the quoted proportional spread is negatively related to transactions for which a PIP is initiated. Overall, PIPed transactions are associated with a proportional spread that is 3.22% narrower than that of non PIPed transactions, other things equal. This result leads us to suspect that market makers may be compensating their PIP-related losses by widening quoted spreads on options that are less likely to be PIPed. In equilibrium, it is possible that the net effect on investors in general may be negligible since market makers can adjust equilibrium quoted spreads to reflect their anticipation of PIP related losses. However, the impact of PIP on the quality of execution of related transactions remains an interesting avenue of investigation for market structure considerations.

Other results show that option proportional spreads are negatively related to the remaining time to maturity. This result is to be expected since the remaining time to maturity is positively related to option prices which, in turn, are negatively related to the measure of proportional spreads by construction. This shows that the price effect dominates the trading activity effect when the possibility of PIPed transactions exists. This in turn explains the apparent contradiction between our findings and those of Chan and Pinder (2000) and Pinder (2003) who define the spread in their model on an absolute rather than proportional basis. Table I also shows that option proportional spreads are positively related to the nearness-to-money measure. This result is consistent with that of George and Longstaff (1993) who show that nearness-to-money is positively related to trading activity and thus to investor interest in the option. As the option attracts a larger investor base, order flow providers are more likely to maintain continuous quotes on the option, which, as demonstrated in Chan and Pinder (2000) and Pinder (2003), results in narrower spreads. This shows that, in our model, for the nearness-to-money variable whose absolute value increases as the price of the underlying security moves further away from the strike price, the trading activity effect seems to dominate the price effect.

Persistency of PIP-related spread changes

It is also interesting to examine the persistency of spread changes following a PIP-related order execution by analyzing the percentage change in quoted spreads before and after a transaction is executed. More specifically, for non-PIP order executions the last quoted spread before the order is subtracted from the first quoted spread after the transaction is executed and this difference is then divided by the last quoted spread before the transaction. For PIP order executions, the last quoted spread before the PIP is initiated is subtracted from the first quoted spread after the transaction is executed and this difference is then divided by the last quoted spread before the PIP is initiated. Table II indicates that spreads immediately after PIP order executions, revert in the median to the level immediately before the transaction. The median relative change in quoted spreads is 0.00 for PIPed order executions and -0.50 for non PIPed order executions. Table II also provides additional evidence of spreads' lack of sensitivity to PIP order executions. Results indicate that the common effect is more than fully offset by PIP. The observed reversion effect decreases with spread and daily volume. The table also shows that the relative change in spreads following order executions is negatively related to price and to the quality of trade executions while it is positively related to volume, spreads immediately before the order execution, and the combined effect of implied volatility and spreads.

Table II approximately here

Effect of PIP on transaction execution quality

Table III presents the results of the constrained model specified in equation 4. As the results show, the quoted absolute spreads are positively related to the measure of transaction quality. Larger spreads are thus associated, on average, with poorer subsequent transaction quality. The financial literature suggests that larger spreads, other thing equal, may be market makers' reaction to the presence of informed or speedy traders, which in turn could explain that they would be less likely to make additional price concessions in order executions.

Table III approximately here

The average effect of daily volume of transactions on execution quality is somewhat less obvious. Results show that it is not possible to conclude that the average effect on the daily number of transactions, as a proxy for market liquidity, has a statistically significant effect on the quality of order execution. This may result from the sample design, which biases towards more liquid contracts where additional volume may have less marginal impact on order execution quality. However, the marginal effect of volume on PIP transactions is negative and statistically significant. This means that although overall market liquidity does not affect execution quality on average for the most liquid contracts in a statistically significant manner, additional volume leads to better execution quality when a PIP is initiated.

Table III also shows that the measure of quality of order execution is negatively related to the PIP indicator variable. More specifically, the average marginal price improvement associated with PIP is 1.49% of the option price immediately before the transaction. This represents an improvement of almost 0.037$ when compared to the average price of 2.483$. Results also indicate that order flow providers are willing to improve the execution price even more when the market liquidity is greater. Intuitively, order flow providers may be more willing to execute orders at better prices when market liquidity gives them an opportunity to make up foregone profits on reduced execution prices. However, the results show that for most liquid contracts this is only true for PIP transactions where order flow providers may face competing bids in addition to those usually available through conventional trading channels. Indeed, table III shows that for the most liquid contracts, the volume variable is only significant for PIP-related transactions where it results in additional price improvements.

Other results also show that transaction quality is positively related to implied volatility of the underlying security returns[10]. This finding is consistent with that of Stoll (2000), which indicates that there are more opportunities for price improvements in volatile stocks. This positive effect of volatility remains even after controlling for its potential effects on both spread and volume. In addition, results show that the option's price is negatively related to the Y measure. This finding is expected by construction. A more interesting result is that for low priced options, higher quoted option prices lead to poorer transaction quality. This finding

[10] The negative effect of volatility remains present when the sample is filtered to include only the transactions where the implicit volatility of the underlying returns is between 20% and 60%.

contradicts that of Stoll (2000) for the stock market, where the opportunity for price improvement is greater for low priced stocks.

The nearness-to-money of the option is also positively related to the Y measure, meaning that the more the option is in the money the better the quality of order execution[11]. This result is not surprising since the nearness-to-money measure we use is negatively related to the option's trading activity. This means that as the price of the underlying security moves closer to the strike price and trading activity increases accordingly, as shown by George and Longstaff (1993), order flow providers will tend to provide quotes more frequently than otherwise, thus reducing their spread. Similar observations have been made by Pinder (2003).

A further contention based on the findings reported earlier in this paper is that the observed effects may not be homogeneous across all trades. For example, results show that the average effect of transaction volume on execution quality is somewhat unclear. In order to explore this ambiguity in greater depth, the model is redefined to include the combined effects with different volume clusters. The analysis thereby segregates each of the previously observed effects either according to the number of contracts being traded or according to overall daily volume per contract.

The first segregation focuses on the marginal effects for each determinant conditional on four clusters of trade size. More specifically, the overall transactions are classified according to the number of contracts in each trade.

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[11] Unreported results show that this effect positive is present even after controlling for the combined effect with quoted spreads.

Small trades (TRADEVOL5) are defined as those where 5 contracts or less are traded and represent 16.42% of the final sample, medium trades (TRADEVOL10) are those where 6 to 10 contracts are traded and represent 34.26% of overall trades, large trades (TRADEVOL50) are those where 11 to 50 contracts are traded and represent 12.82% of the sample, while very large trades (TRADEVOL51+) with more than 50 contracts represent 16.35% of the final sample. Table IV presents the results of this first segregation.

Table IV approximately here

The major findings of this table are first that the price improvement associated with PIP is smallest for small trades of 5 contracts and less where it stands at 1.26% of the quoted price immediately preceding the transaction and increases gradually with trade size until it reaches 3.07% for very large trades of 51 contracts and more. In dollar terms the price improvement ranges from 0.031$ for small trades to 0.076$ for large trades when compared to average prices. Secondly, consistent with constrained results relating to the impact of price on execution quality, the segregated results show that this impact is positive and significant. Furthermore, the combined price effect for small prices is also negative and significant. Thirdly, the impact of quoted spreads on execution quality is statistically significant, except for very large trades.

Just as important is the question of the extent to which informed and uniformed traders benefit from PIP related price improvements. If we assume that smaller trades of 5 contracts or less are more heavily weighted towards uninformed traders while very large trades of 500 contracts and more are more heavily weighted towards informed trades, it is possible to infer the extent to which these two categories of traders are affected by PIP. As shown in Table IV, informed traders seem to benefit to a larger extent from PIP related price improvements than uninformed traders. At first sight, this result may seem counterintuitive, since it could be expected that order flow providers would face less asymmetric information risk when dealing with uninformed traders than with informed traders, and would therefore be more inclined to offer PIP related price improvements to the former group. Our result is however consistent with the finding of Table III mentioned earlier to the effect that in the presence of greater volume, order flow providers may be more willing to offer price concessions related to PIP as they can make up foregone profits through additional volume.

The constrained results of table III were also segregated according to 5 daily volume clusters. These clusters are contract specific and are defined as very small volume days of 150 contracts or less, small volume days of 151 to 200 contracts, medium volume days of 201 to 250 contracts, large volume days of 251 to 500 contracts, and very large volume days of more than 500 contracts. The clusters represent 16.35%, 16.23%, 14.34%, 24.40%, and 28.16% of the overall sample respectively. The results of this segregation are presented in the appendix. The major finding of interest resulting from this segregation is that the price improvement effect of PIP is most pronounced for very large volume days representing 2.86% of quoted prices immediately before the transaction and declines for lower volume days to almost 1.27% for very low volume days. This result confirms the previous findings of table III where PIP related price improvement shows an additional positive impact on execution quality. On the other hand, the impact of spread on execution quality increases with the daily volume.

It is worth noting that the findings that price improvement generated by PIP increases with the size of trades and the degree of daily liquidity contradict those reported in earlier studies for price improvement opportunities that are not generated through competitive processes similar to that of PIP. For example, Chordia and Subrahmanyam (1995) reported that improvement opportunities on the NYSE decline with the size of trade and that they first increase and then decrease with order size for non-NYSE market makers who pay for order flow. In this sense, PIP represents a competitive innovation different from previous price improvement market processes.

IV – Conclusion

This study examines the impact of an options market innovation arising from the Price Improvement Process introduced by the Boston Options Exchange on options spreads, the quality of order execution as measured by the cost of trading and the offering of price improvements to informed and uninformed traders on that venue. The process provides an interesting opportunity to study the impact of an innovative competitive trading structure on market transactions in the venue that introduced the innovation. The study uses a variation of inventory based bid-ask spread models to estimate the impact of the new process using a large sample of 10 864 orders that were executed in December 2004.

The main findings of the paper are first that the price improvement generated by PIP averages 1.49% of quoted prices on the Boston Options Exchange. This finding point to the fact that the order execution quality on BOX is enhanced in the presence of PIP and that the average price improvement falls within the minimum tick size. Secondly, the PIP-related price improvement ranges from a low of 1.26% of quoted prices for small trades of 5 contracts and less to a high of almost 3.07% for very large trades of more than 50 contracts. This result indicates that PIP-related price improvements affect informed traders more than uninformed traders, which is consistent with the notion that order flow providers may be more willing to offer price concessions when they can make up foregone profits on greater volume. Thirdly, daily liquidity has a marked impact on the extent of the PIP related price improvement. Thus, the marginal liquidity-related improvement ranges from 1.27% of quoted prices for very low liquidity days where 150 and less contracts are traded to a high of 2.86% for very high liquidity days where more than 500 contracts are traded. All this evidence supports the conclusion that PIP-related price improvement is sensitive to market liquidity.

Thus it seems that when price improvement is generated through a competitive bidding process that is not limited by the tick size, as in PIP, the gain to investors comes at the expense of the market maker's inventory cost represented by the bid-ask spread. The findings also lead us to suspect that market makers may integrate the likelihood of potential PIP-related losses in their equilibrium quoted spreads in general. Furthermore, the improvement generated by PIP takes place after all other price improvement possibilities associated with conventional channels are exhausted and market makers are more willing to provide price improvements the more markets are uncertain and are less willing when the option is closer to the money. On the other hand, PIP related price improvement is associated with larger volume of transactions and days of greater liquidity, which provides market makers with the opportunity to make up for lower execution prices. In the same vein, the impact of PIP appears to be temporary since spreads immediately after a PIP order execution revert to the level immediately before the transaction. This new evidence has not been observed before in studies of markets that do not operate with this new competitive trading structure. As a whole, these findings provide a better understanding of the implications of the competitive trading structures in options markets.

To conclude, it is interesting to note that some market participants have voiced reservations regarding potential harmful effects of PIP-like processesses on the price discovery function of option markets as well as on the transparency and liquidity of their transactions.[12] As time goes by, it would be interesting to see if the financial market as a whole integrates PIP related effects into the general equilibrium of spreads within the context of an efficient price discovery process.

[12] See for example : http://www.sec.gov/rules/sro/cboe/cboe200560/mhinerfeld110805.pdf

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TABLE I - Effect of PIP on quoted spreads

This table provides results for model (1) that estimates the impact on quoted spreads during order execution proportional to the average of the option's bid and ask prices. The model regressors include *Volume*, the total daily trading volume per contract, *DTT*, an indicator variable equal to 1 if the matched transaction uses the price improvement process and 0 otherwise, *Price*, the average of bid and ask prices, *DNP*, an indicator variable equal to 0 if option price is greater than 50 cents and 1 otherwise, *Volatility*, the implied standard deviation of the underlying stock return, *M*, the absolute value of the underlying stock price minus the option's strike price, *T*, the remaining number of days until the option expires.

	Parameter	p-value
Constant	0.1331	0.0000
VOLUME	-7.56E-06	0.0001
VOLUME*DTT	1.55E-06	0.6163
PRICE	-0.0108	0.0000
PRICE*DNP	0.4265	0.0000
VOLATILITY	5.43E-08	0.0069
DTT	-0.0322	0.0000
T	-5.82E-05	0.0000
M	0.0025	0.0000

Sample: 10 864; Adjusted R^2 : 27.30%

TABLE II - Effect of PIP on Spread Persistency

This table provides results for a model that estimates the impact the the percentage change in quoted spreads before and after a transaction is executed. More specifically, for non-PIP order executions the last quoted spread before the order is subtracted from the first quoted spread after the transaction is executed and this difference is then divided by the last quoted spread before the transaction. For PIP order executions, the last quoted spread before the PIP is initiated is subtracted from the first quoted spread after the transaction is executed and this difference is then divided by the last quoted spread before the PIP is initiated. The model regressors include *Volume*, the total daily trading volume per contract, *DTT*, an indicator variable equal to 1 if the matched transaction uses the price improvement process and 0 otherwise, *Price*, the average of bid and ask prices, *DNP*, an indicator variable equal to 0 if option price is greater than 50 cents and 1 otherwise, *Volatility*, the implied standard deviation of the underlying stock return, *M*, the absolute value of the underlying stock price minus the option's strike price, *T*, the remaining number of days until the option expires.

	Parameter	p-value
Constant	-0.2576	0.0014
VOLUME	6.70E-05	0.0000
VOLUME*DTT	-3.46E-05	0.0009
PRICE	-0.0156	0.0000
PRICE*DNP	-0.0449	0.2625
SPREAD	2.4843	0.0003
SPREAD*DTT	-0.1253	0.8538
VOLATILITY	-9.76E-08	0.4480
VOLATILITY*SPREAD	1.82E-06	0.0368
VOLATILITY*VOLUME	-4.81E-11	0.4861
DTT	0.2759	0.0000
T	-2.76E-05	0.5537
M	-0.0005	0.6864

Sample: 10 864; Adjusted R^2 *: 25.41%*

TABLE III - Effect of PIP on order execution quality

This table provides results for model (4) that estimates the impact on the absolute value of the transaction quality measure, where the measure is equal to the effective spread immediately before the trade execution divided by the average between the bid and ask prices. The model regressors include *Volume*, the total daily trading volume per contract, *DTT*, an indicator variable equal to 1 if the matched transaction uses the price improvement process and 0 otherwise, *Price*, the average of bid and ask prices, *DNP*, an indicator variable equal to 0 if option price is greater than 50 cents and 1 otherwise, *Volatility*, the implied standard deviation of the underlying stock return, *M*, the absolute value of the underlying stock price minus the option's strike price, *T*, the remaining number of days until the option expires.

	Parameter	p-value
Constant	0.0717	0.0000
VOLUME	8.28E-07	0.6076
VOLUME*DTT	-5.41E-06	0.0142
PRICE	-0.0095	0.0000
PRICE*DNP	0.2677	0.0000
SPREAD	0.2275	0.0000
SPREAD*DTT	-0.0048	0.9003
VOLATILITY	-1.53E-07	0.0000
VOLATILITY *SPREAD	1.44E-06	0.0000
VOLATILITY *VOLUME	1.51E-10	0.0000
DTT	-0.0298	0.0000
T	-3.82E-05	0.0000
M	0.0021	0.0000

Sample: 10 864; Adjusted R^2 *: 25.93%*

TABLE IV - Effect of PIP on order execution quality

Unconstrained Model Segregated by Trade Volume Clusters

This table provides results for an unconstrained version of model (4) that estimates the impact on the absolute value of the transaction quality measure, where the measure is equal to the effective spread immediately before the trade execution divided by the average between the bid and ask prices. Each of model (4) effects is the segregated according to trade size by multiplying each regressor by one of the following segregating variables *TRADEVOL5*, defined as those transactions where 5 contracts or less are traded, *TRADEVOL10*, the transactions where 6 to 10 contracts are traded, *TRADEVOL50*, the transactions where 11 to 50 contracts are traded, *TRADEVOL51+*, the transactions with more than 50 contracts.The model regressors include *Volume*, the total daily trading volume per contract, *DTT*, an indicator variable equal to 1 if the matched transaction uses the price improvement process and 0 otherwise, *Price*, the average of bid and ask prices, *DNP*, an indicator variable equal to 0 if option price is greater than 50 cents and 1 otherwise, *Volatility*, the implied standard deviation of the underlying stock return, *M*, the absolute value of the underlying stock price minus the option's strike price, *T*, the remaining number of days until the option expires.

	Parameter	p-value
TRADEVOL5	0.0597	0.0000
TRADEVOL10	0.0492	0.0000
TRADEVOL50	0.0917	0.0000
TRADEVOL51+	0.1079	0.0000
VOLUME*TRADEVOL5	3.19E-07	0.9242
VOLUME*TRADEVOL10	6.79E-06	0.1298
VOLUME*TRADEVOL50	-1.01E-06	0.6358
VOLUME*TRADEVOL51+	-7.90E-06	0.0126
VOLUME*DTT*TRADEVOL5	-1.68E-06	0.6626
VOLUME*DTT*TRADEVOL10	-9.97E-06	0.0854
VOLUME*DTT*TRADEVOL50	-8.33E-06	0.0267
VOLUME*DTT*TRADEVOL51+	4.11E-06	0.4998
PRICE*TRADEVOL5	-0.0079	0.0000
PRICE*TRADEVOL10	-0.0099	0.0000
PRICE*TRADEVOL50	-0.0087	0.0000
PRICE*TRADEVOL51+	-0.0106	0.0000
PRICE*DNP*TRADEVOL5	0.2170	0.0000
PRICE*DNP*TRADEVOL10	0.2812	0.0000
PRICE*DNP*TRADEVOL50	0.2535	0.0000
PRICE*DNP*TRADEVOL51+	0.2271	0.0000
SPREAD*TRADEVOL5	0.2642	0.0000
SPREAD*TRADEVOL10	0.2702	0.0000
SPREAD*TRADEVOL50	0.1261	0.0051
SPREAD*TRADEVOL51+	0.2494	0.2338

TABLE IV- followed

Effect of PIP on order execution quality

Unconstrained Model Segregated by Trade Volume Clusters

SPREAD*DTT*TRADEVOL5	-0.0070	0.9086
SPREAD*DTT*TRADEVOL10	-0.1401	0.0149
SPREAD*DTT*TRADEVOL50	0.0210	0.7810
SPREAD*DTT*TRADEVOL51+	0.1779	0.4366
VOLATILITE*TRADEVOL5	8.78E-09	0.6417
VOLATILITE*TRADEVOL10	9.82E-08	0.1353
VOLATILITE*TRADEVOL50	9.92E-08	0.0000
VOLATILITE*TRADEVOL51+	6.86E-08	0.0818
DTT*TRADEVOL5	-0.0251	0.0002
DTT*TRADEVOL10	-0.0086	0.2726
DTT*TRADEVOL50	-0.0286	0.0088
DTT*TRADEVOL51+	-0.0615	0.0078
T*TRADEVOL5	-2.77E-05	0.1013
T*TRADEVOL10	3.53E-05	0.0988
T*TRADEVOL50	-8.19E-05	0.0000
T*TRADEVOL51+	-0.0003	0.0000
M*TRADEVOL5	2.59E-05	0.7472
M*TRADEVOL10	0.0027	0.0000
M*TRADEVOL50	0.0025	0.0000
M*TRADEVOL51+	0.0040	0.0003

Sample: 10 864; Adjusted R^2 : 27.83%

APPENDIX - Effect of PIP on order execution quality

Unconstrained Model Segregated by Daily Number of Trades Clusters

This table provides results for an unconstrained version of model (4) that estimates the impact on the absolute value of the transaction quality measure, where the measure is equal to the effective spread immediately before the trade execution divided by the average between the bid and ask prices. Each of model (4) effects is the segregated according to total daily volume by multiplying each regressor by one of the following segregating variables: *TOTALVOL150,* transactions where the total daily number of trades is 150 contracts or less, *TOTALVOL200,* transactions where the total daily number of trades is between 151 to 200 contracts, *TOTALVOL250*, transactions where the total daily number of trades is between 201 to 250 contracts, *TOTALVOL500*, transactions where the total daily number of trades is between 251 to 500 contracts, *TOTALVOL501+*, transactions where the total daily number of trades is greater than 500 contracts. The model regressors include *Volume*, the total daily trading volume per contract, *DTT*, an indicator variable equal to 1 if the matched transaction uses the price improvement process and 0 otherwise, *Price*, the average of bid and ask prices, *DNP*, an indicator variable equal to 0 if option price is greater than 50 cents and 1 otherwise, *Volatility*, the implied standard deviation of the underlying stock return, *M*, the absolute value of the underlying stock price minus the option's strike price, *T*, the remaining number of days until the option expires.

TOTALVOL150	0.0554	0.0259
TOTALVOL200	0.0187	0.5935
TOTALVOL250	0.0564	0.1307
TOTALVOL500	0.0933	0.0000
TOTALVOL501+	0.0772	0.0000
VOLUME*TOTALVOL150	0.0001	0.4335
VOLUME*TOTALVOL200	0.0002	0.2282
VOLUME*TOTALVOL250	2.89E-05	0.8601
VOLUME*TOTALVOL500	-1.65E-05	0.6412
VOLUME*TOTALVOL501+	3.47E-07	0.8819
VOLUME*DTT*TOTALVOL150	-8.03E-05	0.8001
VOLUME*DTT*TOTALVOL200	-0.0003	0.4124
VOLUME*DTT*TOTALVOL250	-0.0015	0.0354
VOLUME*DTT*TOTALVOL500	4.83E-05	0.5163
VOLUME*DTT*TOTALVOL501+	1.62E-06	0.5307
PRICE*TOTALVOL150	-0.0114	0.0000
PRICE*TOTALVOL200	-0.0079	0.0000
PRICE*TOTALVOL250	-0.0087	0.0000
PRICE*TOTALVOL500	-0.0103	0.0000
PRICE*TOTALVOL501+	-0.0172	0.0000
PRICE*DNP*TOTALVOL150	0.2362	0.0000
PRICE*DNP*TOTALVOL200	0.3473	0.0000
PRICE*DNP*TOTALVOL250	0.2207	0.0000
PRICE*DNP*TOTALVOL500	0.2938	0.0000
PRICE*DNP*TOTALVOL501+	0.1881	0.0000

APPENDIX - Followed

Effect of PIP on order execution quality

Unconstrained Model Segregated by Daily Number of Trades Clusters

SPREAD*TOTALVOL150	0.2663	0.0000
SPREAD*TOTALVOL200	0.2647	0.0000
SPREAD*TOTALVOL250	0.1782	0.0001
SPREAD*TOTALVOL500	0.1643	0.0123
SPREADTOTALVOL501+	0.1721	0.1597
SPREAD*DTT*TOTALVOL150	0.0590	0.4624
SPREAD*DTT*TOTALVOL200	-0.1718	0.1221
SPREAD*DTT*TOTALVOL250	-0.1293	0.2137
SPREAD*DTT*TOTALVOL500	-0.0182	0.8309
SPREAD*DTT*TOTALVOL501+	0.2448	0.1088
VOLATILITY*TOTALVOL150	7.14E-08	0.0768
VOLATILITY*TOTALVOL200	3.19E-08	0.0107
VOLATILITY*TOTALVOL250	-7.75E-08	0.0021
VOLATILITY*TOTALVOL500	3.37E-08	0.3560
VOLATILITY*TOTALVOL501+	4.09E-07	0.0001
DTT*TOTALVOL150	-0.0254	0.5145
DTT*TOTALVOL200	0.0386	0.5735
DTT*TOTALVOL250	0.3315	0.0491
DTT*TOTALVOL500	-0.0533	0.0710
DTT*TOTALVOL501+	-0.0572	0.0000
T*TOTALVOL150	-8.41E-05	0.0000
T*TOTALVOL200	4.34E-05	0.0489
T*TOTALVOL250	-9.34E-05	0.0000
T*TOTALVOL500	6.50E-06	0.6618
T*TOTALVOL501+	-0.0001	0.0000
M*TOTALVOL150	0.0022	0.0002
M*TOTALVOL200	0.0004	0.0094
M*TOTALVOL250	0.0037	0.0000
M*TOTALVOL500	0.0007	0.0022
M*TOTALVOL501+	0.0132	0.0009

Sample: 10 864; Adjusted R^2 *: 30.75%*