Transparency in OTC Equity Derivatives Markets: a Quantitative Study

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Abstract

We study trade-transparency in over-the-counter (OTC) equity derivatives markets, performing two related experiments. The first consists of a statistical study: we analyze a very large dataset of reported OTC transactions to the MarkitServ database and seek to correlate the trade prices with the prices of analogous derivatives listed in exchanges or with model prices derived from the latter ("fair value prices"). The second part consists in conducting Live Quote Experiments, in which we partner with two firms to request firm live quotes from multiple dealers. Quotes are requested for a list of transactions that we designed beforehand. The dealers involved did not know that this was an experiment and returned with two-way quotes on the list of trades, which were recorded along with contemporaneous quotes from listed markets corresponding to similar strikes and maturities.

The statistical study indicates that (i) price-to-fair-value discrepancies are found to be within one or two bid-offer spreads with 95% confidence. (ii) Transactions involving end-users are no further away from fair value than analogous dealer-to-dealer trades on average. Thus the statistical study suggests that end-users trading with dealers are not at a significant informational disadvantage.

Live quote experiments give even better results in this direction. They indicate only very minor dispersion of quotes among dealers (i.e. most dealers quote similar prices) and tight bid-ask spreads. Discrepancies between dealer quotes and contemporaneous listed implied volatilities are less than 1%, when considering all the data and products pooled together.

The results indicate a very reasonable level price-discovery in OTC equity derivatives markets, due to the strong link that exists between OTC prices and information available from listed options exchanges.

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1 Introduction and Executive Summary

Unlike other asset classes such as interest-rate and credit derivatives, equity derivatives are traded over-the counter and also in exchanges. There are, nevertheless, significant differences between OTC trading and exchange trading in these products. Listed derivatives are centrally cleared and prices are quoted continuously during trading sessions. They are highly standardized in terms of expiries and maturities, which range from one month up to a maximum of two years in some cases. Liquidity in exchange-traded options is limited to a few hundred contracts in most cases and concentrated in near-term contracts.[1] The over-the-counter market, on the other hand, is an institutional market in which end-users (hedge funds, asset-managers and large corporations) trade through dealers in bilateral transactions which are highly customized in terms of maturities, contingencies and trade sizes. OTC trades are much larger than ones which can be executed in exchanges. The existence of listed markets brings about the issue of the linkage between the two co-existing markets and the extent to which information available in listed markets contributes to price-discovery in OTC markets.

This study addresses the price-transparency and efficiency of OTC equity derivatives markets from the latter viewpoint. We do this in two ways: first, using a very large cross-section of reported OTC trades, we collect statistics on trade sizes and compare reported transaction prices with model prices for the

[1] While US listed options maturities generally do not exceed two years, in Europe five-year maturities are not uncommon, and the Eurostoxx 50 option goes out to 10 years. This primarily allows OTC trades to be given up (novated) to the clearing-house, since the order-book liquidity is concentrated in the near-term contracts.

same contracts calculated from information available in listed markets. Second, we conduct two Live Quote Experiments (LQEs) in which we use anonymous firms to request quotes on a selected list of OTC transactions to a group of dealers. This LQE is conducted in anonymous fashion so the quotes that we receive from the dealers represent realistic price levels in the OTC market. We then compare the collected quotes with contemporaneous Bloomberg data and among themselves. The goal of the two experiments is to evaluate by different means the level of price transparency, or price-discovery, which is available on the OTC market in equity derivatives.

1.1 Statistical Study

The data analyzed in the statistical study consists of a large collection of reported trades involving three types of OTC Equity Derivatives (OTCEDs): share options, index options and equity variance swaps.[2] It encompasses a wide cross-section of trades from MarkitServ during the period of June 1 to August 31, 2010 spanning 3 major currencies (Yen, Euro and US Dollar). Options were both equity index options and equity share options on selected stocks. We analyzed 14,965 trades of which 13,827 were index trades (options and variance swaps) and 1138 were single-share option trades. For each trade, information about whether the trade was dealer-to-dealer or dealer-to-end-user was provided by MarkitServ.

We performed a trade-by-trade comparison of the reported prices and prices that would be obtained from Bloomberg (BB) end-of-day (EOD) exchange-data. In the case of options on single-shares or on indexes, we built implied volatility surfaces from the BB data by interpolating and extrapolating implied volatilities. This allowed us to create model prices for bespoke options with custom strike prices and expirations.

For the analysis of variance swaps, we constructed a fair-value formula following the standard theoretical model [2], [3], which uses market-implied volatilities as inputs (implied volatility skew). Reported prices and model prices were converted into implied volatilities allowing for comparison of prices in the same economic units.

Statistical tests and confidence intervals for the differences in implied volatilities (reported versus model) per trade were made in the following categories and by currency: (a) index options, (b) single-share options, (c) variance swaps, (d) pooled data for *all trades* (dealer-dealer and dealer-end user) and (e) pooled data for *trades between dealers and end-users.*

We found that at the 95% confidence level, the difference between OTC and BB/model volatilities *for options* is between 1 and 2 volatility points in most cases. Given that actual bid/ask spreads may range from 1 to 3 implied volatilities according to the underlying asset, and that there is a delay between "screen" and EOD volatility marks, the results indicate that the discrepancies

[2]According to [1] and sources therein, such contracts correspond to the majority of OTCEDs in terms of notional volumes traded.

are reasonable. Therefore, we conclude that, statistically, the reported OTC prices are consistent with contemporaneous listed market information.

Variance contracts show wider discrepancies than options. In fact, for variance swaps, the OTC market seems to be *biased upward* by 1 or 2 volatility points relative to the model values, both for bid and ask quotes. This suggests that the OTC market demands and pays premium above FV for variance swaps, presumably due to the fact that full hedging of variance contracts with options is infeasible for liquidity reasons, *i.e.* the lack of depth in listed deep-out-of-the-money options, and transaction costs.

In all the currencies studied, we observe consistently that dealer-to-end-user trades are closer to fair-value than dealer-to dealer trades or, at least, that the prices at which end-users trade are not "worse" (comparing with listed volatilities) than the prices in dealer-to-dealer trades.

1.2 Live Quote Experiments

We conducted live experiments, which consisted in mimicking real OTC trading with the assistance of anonymous firms which are active participants in the OTC market. First, we determined in collaboration with ISDA members a list of plausible trades that we would like to submit to the dealer markets. These trades were designed in terms of size, strikes and maturities in such a way that they could be plausibly requested by an end-user to a dealer. Then, with the assistance of two buy-side firms, we requested firm two-way quotes from 3 to 4 dealers chosen by us. Finally, we collected the quotes as well as the contemporaneous screens showing implied volatilities for listed options on the same underlying assets ("Bloomberg OMON"). We collected for 18 OTC trades and with 3 to 4 dealers for each trades. Using the data, we assessed (i) the dispersion in quotes across dealers and (ii) the proximity of these quotes to Bloomberg OMON.

The results of the Live Quote Experiments show that the dispersion of mid-quotes for all dealers pooled across all trades is 0.30%, which means that the quotes of different dealers are typically within 0.30% in volatility terms. The average dealer bid/ask spread is 0.89% which is similar to the average order-book bid/ask spreads observed on the Bloomberg screen for listed products. The average difference between mid-market dealer quotes and mid-market Bloomberg OMON is 0.40%. These results show that there is little dispersion among dealer quotes for these OTC products and they are close to the OMON values as well. Even though the agreement is better for index products than for single-share options and variance swaps, we find that the OTC prices and listed prices are highly consistent, and hence that end-users consulting listed options screens such as Bloomberg OMON can achieve a significant degree of information about prices at which they can could transact in the over-the-counter market. This strong link between listed markets and OTC markets in equity derivatives contributes significantly to price transparency.

2 Statistical Study

2.1 Markit Data

Markit provided us with a large database of reported trades corresponding to the period June 1 to August 31, 2010. This data consists of trades reported to MarkitServ in OTC equity options and variance swaps. Table 1 provides an overview of the transactions that were analyzed in the study in terms of sample size. For simplicity, we restricted ourselves to the three major currencies where OTC equity derivatives are traded: JPY, EUR and USD. As the reader can see, we analyzed approximately 15,000 trades. Table 2 shows the different entries that were provided by Markit for each transaction. Aside from the price and transaction time, we have information on the size of the trades and whether a given trade is an inter-dealer trade or a dealer-to-end-user trade.

Before analyzing trades in terms of fair value, we "scrubbed" the sample to eliminate data-entry errors and certain trade-reporting idiosyncrasies. For example, when reporting conversion trades (buy a put and sell a call with the same strike) or "reverse conversions", which have two legs, counterparties often tend to report a premium of 1 for each leg rather than the actual price. Usually, these legs are executed simultaneously, so conversions could in principle be "detected" by searching for pairs of transactions on a equal amount of puts and calls executed at the same time. In this paper, we preferred not to analyze this kind of spread trade because it was not reported clearly as such in the data as a single transaction. Since this could lead to errors, we eliminated all option trades that reported a premium of exactly 1 currency unit or zero premium.

To calculate implied volatilities for the option deals, we downloaded daily closing prices and quoted dividend yields for the underlying assets from publicly available sources (Bloomberg or Yahoo!Finance). We then computed the implied volatilities of all the options transacted after removing the aforementioned "unit-premium" or "zero-premium" deals. We then further cleaned the data by removing transactions for which the implied volatility could not be calculated. This is a well-known approach for detecting data-entry errors and option prices which are inconsistent with the value of the underlying security.[3] In the cases when dividends were not readily available using public data sources, we assumed that dividends were zero.

2.2 Trade Size

An often stated assumption is that OTC trades are larger than trades in listed markets. To verify this, we collected descriptive statistics for trade size from the Markit data, for both options and variance swap trades. For simplicity, we normalized all option trades to dollar notionals and all variance swap trades to

[3] Aside from data-entry errors, other sources of bad data could be due to asynchronicity of EOD underlying prices and deals transacted in the middle of the day, in the case of deep in- or out-of-the-money options.

OTC Transaction Data from MarkitServ

Currency	Contract	Dealer-to-Dealer	Dealer-to-end-user	Total
USD	Index Option	1508	84	1592
USD	Share Option	20	28	48
USD	Variance Swap	1844	448	2292
USD	All Contracts	3372	560	3932
EUR	Index Option	386	134	520
EUR	Share Option	586	282	868
EUR	Variance Swap	270	198	468
EUR	All Contracts	1242	614	1856
JPY	Index Option	8427	58	8485
JPY	Share Option	214	8	222
JPY	Variance Swap	276	194	470
JPY	All Contracts	8917	260	9177
All curr.	Index Option	10321	276	10597
All curr.	Share Option	820	318	1138
All curr.	Variance Swap	2390	840	3230
All curr.	All Contracts	13531	1434	14965

Table 1: Description and number of trades corresponding to each category of OTC derivatives considered in the statistical study. We examined the data across three major currencies and among single-share options, index options and index variance swaps. We also classified trades according to whether they were dealer-to-dealer or dealer-to-end-user.

Example of a transaction report from MarkitServ

Field Name	Sample Data
Party A	Bank
Party B	Bank
Tenor (Days)	37
Converted Notional (USD)	19,764,885.41
Month Reference	2
Submit (Month/Year)	Jun-10
Trade Count	1
Application ID	12934020
Submit Date	6/1/2010
Trade Date	6/1/2010
End Date	
Option Exp Date	7/8/2010
Product	Equity Index Option
Currency	USD
Settlement Currency	USD
Equities Description	S&P 500 Index
RIC	.SPX
Related Exchange ID	All Exchanges
Strike Price	1020
Vega Notional	
Variance Amount	
Variance Strike	
Option Quantity	113571429
Submission Date/Time	01-JUN-10 12.49.13.580958 AM
Option Entitlement	1
Option Type	P
Index Multiplier	1
Premium Amount	1135714

Table 2: The left-hand column provides the standard entries for MarkitServ OTC equity derivatives. The identities of the counterparties were replaced by "Bank" or "End-user" to make the data anonymous. Notice that these entries cover both options and variance swaps. For the latter, a "Vega Notional", "Variance Amount" and "Variance Strike" would be specified instead of "Strike Price" and "Premium Amount".

dollar-vega notionals. Dollar-vega corresponds to the sensibility in dollars for a move of 1% in implied volatility for the underlying asset.

Table 3 contains information about trade notional sizes for OTC options. The average deal is approximately for 10 million dollars notional. However, the distribution is fat-tailed and deals of 80-100 Million dollars are fairly common (less than 2.5 standard deviations from the mean). This can be compared with exchange-traded options markets. In single share options, a exchange trade for 1000 contracts, or 100,000 shares is a very large trade. At $40 per share, this represents only a 4 million dollar trade. Similar considerations apply to indexes albeit with higher notionals (*e.g.* 20,000,000 USD). Clearly, the data in table 3 shows that the OTC options market is a market for block trades in options and that, in this sense, it has no equivalent in the listed exchanges. This is particularly true for EMEA and Asia, as discussed in the qualitative study [1].

Trade-Size Statistics For OTC Options

Sample Statistic	Notional Value (in USD 1 Million)
Average	19
Median	10
Standard Deviation	38
Maximum	1132
10th Largest	679
Kurtosis	305*
Skewness	13*

Table 3: Descriptive statistics for trade sizes in OTC options and index options. The median deal is of the order of USD 10 million. Note however that the distribution is extremely fat-tailed and lepto-kurtotic. For example, the largest 10 trades exceed 679 million USD, and a deal which is 2 standard deviations above the mean corresponds approximately to a 86 million USD notional. Values with asterisks are dimensionless (kurtosis and skewness).

Table 4 shows statistical sizes for variance swaps. As before, standard sizes range from 100K to 300K in vega, but we observe instances of much larger trades. The variance swap market has no counterpart in the listed derivatives exchanges except for a contract traded in CBOE which is small and illiquid.

Trade-Size Statistics For OTC Variance Swaps

Sample Statistic	Vega Notional (in USD 100K)
Average	1.3
Median	1.0
Mode	1.0
Standard Deviation	1.1
Maximum	10.0
10th largest	7.5
Kurtosis	9
Skewness	2

Table 4: Descriptive statistics for notionals in OTC index variance swaps. The notional is measured as a dollar vega, in units of 100k dollars. Average deals are of the order of 100K USD vega, but the distribution is highly fat-tailed and the maximum 10 deals are between 750K and 1MM dollar vega. Values with asterisks are dimensionless.

2.3 Bloomberg Data

To proxy screen prices for exchange-traded derivatives in the statistical study, we used end-of-day (EOD) option implied volatilities from Bloomberg. The volatilities were downloaded using Bloomberg's $BDH()$ function and specifying three moneyness values (90%, 100% (at-the-money) and 110%) and standard maturities up to 2 years.[4] Using the downloaded Bloomberg data, we constructed interpolated volatility surfaces $\sigma(K,T)$ for each underlying and for each trading day over the period of interest. These volatility surfaces were used to price options on arbitrary strikes and maturities by interpolation of the latter quantities.[5] To define implied volatilities outside the range of available strikes/maturities, we considered a constant interpolation (in K) of the volatility surface for each maturitity T and a constant interpolation (in T) for maturities which fell beyond the available data. This surface was used as a model to price all options trades.

For pricing variance swaps, we considered the classical formula used by exchanges and OTC dealers for pricing variance contracts.[6]

[4] In several cases, we were only able to obtain partial information (shorter maturities).

[5] Suppose that K_1 and K_2 are strikes for which we have data and which are the nearest to K with $K_1 < K < K_2$. Similarly, assume that we have data for maturities T_1 and T_2 which are the nearest to T such that $T_1 < T < T_2$. We define the interpolated implied volatility $\sigma(K,T)$ by the formula

$$\sigma^2(K,T) = \frac{T_2 - T}{T_2 - T_1}\left(\frac{K_2 - K}{K_2 - K_1}\sigma^2(K_1,T_1) + \frac{K - K_1}{K_2 - K_1}\sigma^2(K_2,T_1)\right) + \frac{T - T_1}{T_2 - T_1}\left(\frac{K_2 - K}{K_2 - K_1}\sigma^2(K_1,T_2) + \frac{K - K_1}{K_2 - K_1}\sigma^2(K_2,T_2)\right). \quad (1)$$

[6] The formula is a discrete version of the well-known representation of the fair-value variance

Thus, for both options and variance swaps, we generated two sets of numbers associated with each trade: (i) an implied volatility from transactional data and (ii) an implied volatility from interpolated/extrapolated Bloomberg data.

2.4 Testing for the differences in implied volatilities

Once we have generated the reported and model implied volatilities for each deal we can test statistically for the mean of the difference between the two volatilities. We performed this test in a pooled fashion (all trades) and in various sub-categories: by currency, type of contract and whether the contract was traded between dealers or between a dealer and an end-user. The idea of hypothesis testing is to make a judgment, given the data, on whether or not we can reject the fact that the OTC prices and the model prices are similar up to bid/ask spreads.[7]

2.4.1 Japan

The estimates for the differences between OTC implied volatilities and model implied volatilities are in the Midpoint column of Table 5. This table also contains 95% confidence intervals on the difference obtained from the data. We also display the width of the confidence interval. Except for the case of Variance Swaps, the differences between implied volatility discrepancy occurred in the variance swap category. We believe that this is due to the fact that the market prices variance swaps slightly higher than the theoretical formula due to the fact that one needs to extrapolate the implied volatility curve to strikes far away from the money to evaluate the fair value. In the present study, we extended the implied volatility curve for a given maturity as a constant, using the closest strike. This may result in a low bias for our fair value estimator of variance-swap volatility.

For pooled data (when we consider all JPY trades in the same sample) the 95% confidence interval is $[-1.27, -0.54]$. Although the interval appears to be biased lower, we should take into account the bid-ask spreads in implied volatilities as well. Bid-ask spreads in singles-share deals can be up to 3 implied volatilities. Typical bid-ask spreads in index options and variance swaps can be approximately one IV or sometimes more.

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as a portfolio of puts and calls on the same underlying asset, *viz.*

$$\sigma^2_{VS,T} = \frac{2e^{rT}}{T}\left[\int_0^F P(T,K)\frac{dK}{K^2} + \int_F^\infty C(T,K)\frac{dK}{K^2}\right],$$

where r is the interest rate, F is the forward price, and $P(T,K)$ and $C(T,K)$ represent respectively the fair values of puts and calls with strike K and maturity T. These fair values are computed using a discretized grids (see for instance [2], [3]) and the fair-values for puts and calls are computed from a parabolic approximation of the volatility surface $\sigma(K,T)$ with 5 strikes.

[7] Bid-ask spreads for options range from 0.5 to 2 basis points according to the underlying, the strike and maturity, with indexes and large-cap stocks corresponding to the smallest spreads.

Another interesting observation has to do with the difference between considering all trades versus just dealer/end-user trades. We found that, in the latter case, we cannot reject that the difference between OTC vol and model vol is different from zero at 95% confidence, even without taking bid-ask spread considerations into effect. Thus, the data suggests that end-users will get prices which are consistent with publicly disseminated data, which is consistent with high pre-trade transparency.

Confidence Intervals for the Difference between reported OTC implied volatilities and model implied volatilities using Bloomberg data: JPY

Trade Characteristics	Mid-point	Low Endpoint	High Endpoint	Width
Index Options	-1.25	-1.65	-0.84	0.8
Single Share Options	-1.96	-2.9	-1.03	1.86
Variance Swaps	2.16	1.78	2.54	0.76
All Trades	-0.9	-1.27	-0.54	0.74
Only Dealer - Enduser	0.52	-0.07	1.1	1.16

Table 5: The values correspond to the 95% confidence intervals for the difference between OTC implied volatility and listed implied volatility for JPY-denominated OTC derivatives. The first column represents the midpoint of the interval, which is the average difference between the trade implied volatility and the model implied volatility. All values are in percentage points (volatility points).

2.4.2 Eurozone

The tests for Euro-denominated products yield similar results, which are displayed in Table 6. For all *options* (index, single-name) we find that mid-point for the confidence interval is less than 1 implied volatility. Thus, with 95% confidence, we cannot reject the hypothesis that the difference is zero once we take into account bid-ask spreads.

As with the JPY trades, variance swaps are different and the trades price approximately 2 volatility points above the classical pricing formula [3], [2]. The 95% confidence interval for variance swaps IV differences is $[1.82, 2.61]$, suggesting a difference between our model and the way that the market quotes. Consultations with OTC traders suggest that factors that may raise the fair value of the variance swap are anticipations of large moves in the index and the impossibility of hedging variance swaps with deep-out-of-the-money options, particularly for large trades.

The confidence interval associated with the entire EUR data set is $[-0.44, 0.33]$, which contains the value zero. Therefore, we cannot reject globally that the difference between OTC volatilities and theoretical volatilities is zero, even before taking into account bid/offer spreads.

Confidence intervals for the Difference between reported OTC implied volatilities and model implied volatilities using Bloomberg data: EUR

Trade Characteristics	Mid-point	Low Endpoint	High Endpoint	Width
Index Options	-0.38	-0.79	0.03	0.82
Single Share Options	-0.66	-1.3	-0.2	1.28
Variance Swaps	2.22	1.82	2.61	0.8
All Trades	0.66	0.35	0.97	0.61
Only Dealer - Enduser	-0.06	-0.44	0.33	0.38

Table 6: The values reported correspond to the 95% confidence intervals for the difference between OTC implied volatility and listed implied volatility for Euro-denominated OTC derivatives. All values are in percentage points (volatility points).

2.4.3 United States

The results for the United States OTC data is similar to the previous ones, but we observe larger differences between reported trades and theoretical values. In the case of single-share options and variance swaps, these difference exceed one IV, so we need to take into account transaction costs to justify such differences.

Other sources for errors in the data are (i) the correct evaluation of dividends for long-dated options and (ii) the difference between the implied volatilities at the time that the trade was reported and the implied volatilities at the close

Confidence Intervals for the Difference between reported OTC implied volatilities and model implied volatilities using Bloomberg data: USD

Trade Characteristics	Mid-point	Low Endpoint	High Endpoint	Width
Index Options	-1.33	-1.62	-1.04	0.58
Single Share Options	-1.80	-3.07	-0.52	2.48
Variance Swaps	3.00	2.92	3.07	0.16
All Trades	1.78	1.64	1.78	0.28
Only Dealer - Enduser	1.40	1.01	1.4	0.8

Table 7: The values reported correspond to the 95% confidence intervals for the difference between OTC implied volatility and listed implied volatility for Euro-denominated OTC derivatives. All values are in percentage points (volatility points).

3 Live Quote Experiments

The second part of the study analyzes live quotes from major dealers over the course of the trading day, measuring the discrepancies from one dealer to another and also comparing the results with contemporaneous option volatilities from exchanges. We designed and conducted a Live Quote Experiment (LQE) which was conducted with the assistance of two buy-side, end-user, firms (Firm 1 and Firm 2, hereafter). Each firm is an active participant in the OTC equity derivatives markets, although they have different characteristics.

The LQE consisted in the elaboration of a list of trades in equity options and variance swaps by Finance Concepts in consultation with ISDA. We then conducted an experiment in which a Firm requested two-way markets in each of the products to series of major dealers, nearly in simultaneous fashion. The maturities that we chose for options did not correspond to an exact option expiration date and ranged from 1 to 2 years. Transaction sizes were chosen to be consistent with the typical sizes for options and variance swaps in the OTC market (5,000 contracts, 100,000 vegas); see Tables 3, 4. When the dealers returned with bid/offer quotes (both in terms of price and volatility) we recorded them as well as the Bloomberg OMON screen of the nearest maturity.

During these experiments, members of Finance Concepts and/or ISDA were present in the trading floor next to the trader to ensure the confidentiality of the experiment and therefore that the quotes reflected actual market conditions.

The list of trades given to the two firms were different (see Tables 8 and 9). One of the reasons is that one firm is an active participant in the variance swaps market and the other is not, trading mostly OTC equity options. Thus, to prevent any possible "tipping off" of dealers, we gave each firm trades which corresponded approximately to the business that they would otherwise conduct on a regular basis. The experiments were conducted in a period of approximately 2 hours for each of the firms on different days.

The experiment with Firm 1 took slightly longer than Firm 2 because Firm 1 had to split the experiment into the NY morning session and an evening session with its Asia trader. All requests for quotes for Firm 1 were conducted via Bloomberg Instant Messenger (IM). Firm 2 used a combination of voice and IM. The typical waiting time between request for quotes and a response from a dealer was up to or less than 5 minutes. In cases in which dealers did not respond for more than 20 minutes, we did not record the quotes.

Trades submitted by Firm 1 for the Live Quote Experiment

Trade ID	Underlying	Expiration	Share Amt.	Type	Strike (% moneyness)
1	US Semicond.	12/5/2011	500,000	Call	105
2	US Retail	2/16/2012	100,000	Put	92
3	SPX Index	12/5/2011	85,000	Call	88
4	EUR Cell. Telecom	12/5/2011	500,000	Call	100
5	EUR Integr. Telecom	2/16/2012	100,000	Put	86
6	SX5E Index	12/5/2011	85,000	Call	95
7	JPY Electronics	12/6/2011	50,000	Call	84
8	JPY Itegr. Telecom	3/16/2012	10,000	Put	97
9	NK225 Index	12/6/2011	85,000	Call	125
10	SPX Index	7/20/2011	100,000 vega	Variance Swap	1,300*
11	SX5E Index	8/20/2011	100,000 vega	Variance Swap	1,250*
12	NK225 Index	8/20/2011	10,000,000 vega	Variance Swap	1,000*

Table 8: There were a total of 12 OTC trades: 6 single-share options, 3 index options and 3 variance swaps. We considered the three major markets (USD, EUR, JPY). The expiration dates are not standard dates and the notionals are consistent with typical sizes transacted over the counter. Share names were removed to preserve the anonymity of the parties involved. Option strikes are expressed in percentage of the share/index price. (*) Variance swap strikes are quoted in $(\text{volatility})^2$.

Trades submitted by Firm 2 for the live quote experiment

Trade ID	Underlying	Expiration	Share Amt.	Type	Strike (% moneyness)
13	EUR Manufact.	12/7/2011	42,000	Call	110
14	EUR Cell. Telecom	12/7/2011	23,300	Call	115
15	SX5E Index	12/7/2011	1,425,000	Call	115
16	US Financial	12/7/2011	1,000,000	Call	115
17	US Software	12/7/2011	1,000,000	Call	112
18	SPX	12/7/2011	25,000,000	Call	115

Table 9: Firm 2 priced 4 single-share options and 2 index options in the US and Europe. Share names were removed to preserve the anonymity of the parties involved. Option strikes are expressed in percentage of the share/index price.

3.1 Results

From the output of the LQEs, we can determine two things:

- the *dispersion* between dealer quotes and
- how well the latter quotes agree with the volatilities disseminated from exchanges.

The results and analysis are tabulated as follows. In Table 10 we display the results of the LQE with Firm 1. This experiment involved 4 dealers and 12 different trades (4 in the USD, 4 in Europe and 4 in Asia). In Table 11, we display the results of the LQE with Firm 2. Finally in Table 12, we collect statistics on the 18 trades and analyze the dispersion of the quotes and how well they agree with Bloomberg OMON.

Based on the results of the LQEs, we computed statistics for each trade across dealers and compared with Bloomberg data. We also compare the size of spreads and differences with BB data for all trades together.

The results show that (i) dealer quotes present little dispersion, and (ii) dealer quotes agree with BB OMON volatilities with a high degree of accuracy (see Table 11).

Live Quote Experiment for Firm 1

Trade ID	Dealer 1		Dealer 2		Dealer 3		Dealer 4		Bloomberg	
	Bid	Offer	Bid	Offer	Bid	Offer	Bid	Offer	Bid	Offer
1	26.8	27.5	27.2	28.5	26.5	27.5	27.2	27.8	27.0	27.2
2	21.9	22.5	21.8	22.9	21.6	22.1	22.2	22.4	22.5	22.9
3	24.1	24.5	24.4	24.7	24.3	24.5	24.5	24.8	23.5	24.7
4	22.6	23.7	22.7	24.4	22.4	24.4	-	-	24.4	26.7
5	28.0	29.2	28.8	30.3	26.7	29.2	-	-	25.0	28.5
6	23.9	24.1	24.1	24.6	24.0	24.3	-	-	24.2	24.5
7	29.25	31.25	30.4	32.57	30	33	-	-	28.6	30.14
8	19.05	21.3	20.27	22.4	18.5	20.9	-	-	-	-
9	17.85	18.35	18.15	18.6	17.9	18.4	-	-	-	-
10	24.1	24.7	24.2	24.9	24.15	24.65	24.15	24.85	24*	24*
11	29.7	30.5	29.3	30.3	-	-	29.55	30.35	28*	28*
12	25.9	26.5	26.2	27	26.2	27	-	-	26*	26*

Table 10: Results of the LQE for Firm 1. The first 9 trades correspond to options (single-share and index). The last 3 trades correspond to variance swaps. Each trade was shown to 4 dealers who returned with bid/offer quotes in price and implied volatilities. Here, we report the quotes in volatility terms. The last two columns correspond to the contemporaneous Bloomberg volatilities from the Bloomberg Options Monitor (OMON). The latter were interpolated in case the strike was not expliclitly traded. We used the closest expiry in listed options to compare with OTC trades. In the case of variance swaps, we used the classical reconstruction formula using a basket of options [3], [2]. Calculated variance swap volatilities are denoted with an asterisk.

Live Quote Experiment for Firm 2

Trade ID	Dealer 1		Dealer 2		Dealer 3		Bloomberg	
	Bid	Offer	Bid	Offer	Bid	Offer	Bid	Offer
13	23.90	25.10	26.05	26.69	25.89	26.21	24.4	26.5
14	20.20	21.80	21.72	23.10	21.84	22.04	21.0	21.6
15	19.60	19.80	19.41	19.58	19.04	19.23	19.3	19.7
16	36.10	38.30	36.50	36.50	36.40	37.80	35.5	36.3
17	24.25	24.40	24.85	25.57	23.95	25.24	24.6	25.1
18	16.45	16.70	16.50	-	16.44	16.64	16.2	16.5

Table 11: Same as table 10. Notice that Firm 2 did not price variance swaps and only 3 dealers were used. The exercise with Firm 2 did not involve variance swaps nor JPY trades.

Summary of Live Quote Tests

Trade ID	average mid-mkt	stdev mid-mkt	avg. spread	OTC bestbid	OTC bestoffer	BB OMON mid-mkt	BB OMON spread	Diff av. mid-mkt	Diff av. spread
1	27.4	0.39	0.88	27.2	27.5	27.1	0.22	0.3	0.66
2	22.2	0.22	0.62	22.2	22.1*	22.7	0.36	-0.5	0.26
3	24.5	0.14	0.31	24.5	24.5	24.1	1.17	0.4	-0.86
4	23.4	0.19	1.58	22.7	23.7	25.5	2.27	-2.2	-0.68
5	28.7	0.79	1.75	28.8	29.2	26.7	3.50	2.0	-1.75
6	24.1	0.17	0.29	24.1	24.1	24.4	0.34	-0.2	-0.05
7	31.1	0.72	2.39	30.4	31.3	29.4	1.54	1.7	0.85
8	20.4	0.84	2.26	20.3	20.9	-	-	-	-
9	18.2	0.15	0.48	18.2	18.4	-	-	-	-
10	24.5	0.09	0.60	24.2	24.7	24.0	0.00	0.4	0.60
11	30.0	0.21	0.14	29.7	30.3	28.0	0.00	2.0	0.14
12	26.5	0.23	0.73	26.2	26.5	26.0	0.00	0.5	0.73
13	25.6	1.00	0.72	26.1	25.1*	25.5	2.10	0.2	-1.38
14	21.8	0.72	1.06	21.8	21.8	21.3	0.63	0.5	0.44
15	19.4	0.29	0.19	19.6	19.23*	19.5	0.42	0.0	-0.23
16	36.9	0.38	1.20	36.5	36.5	35.9	0.75	1.0	0.45
17	24.7	0.45	0.72	24.9	24.4*	24.9	0.58	-0.1	0.14
18	16.5	0.04	0.15	16.5	16.6	16.3	0.34	0.2	-0.19
Pooled	-	**0.30**	**0.89**	-	-	-	**0.89**	**0.4**	**-0.06**

Table 12: The first column represents the average mid-market quote across the different dealers participating in the LQE for each trade. The second column represents the standard deviation of the mid-quotes across dealers. This is a direct measure of trade dispersion. In all the trades, the standard deviation was less than, or equal, to one volatility. If we pool this across all data, we find that the average standard deviation of mid-quotes across dealers for all trades considered is 0.3 volatilities, which means that trades are very similarly priced across dealers. The average spread across dealers is 0.98%, and the largest spreads always correspond to single-share options. Spreads are known to be higher for single-share options due to fact that these are less liquid. Columns 5 and 6 display the best bid and best offer corresponding to the dealers that were polled.[9] The Bloomberg volatilities have similar behavior in terms of spreads, as seen by looking at column 8. Column 9 displays the differences between the average mid-market quote for dealers and the Bloomberg OMON volatilities. The average difference is 0.4%, which is less than the average spread. Therefore, in aggregate, the LQE shows negligible differences between OTC quotes and BB OMON. Column 10 shows the difference between the average spreads in OTC and in listed markets for the trades considered. This difference is -0.06 over all the data, so it is negligible.

4 Conclusions

The statistical data analysis shows that, at the 95% confidence level, the difference between OTC and and BB/model volatilities *for options* is between 1 and 2 volatility points in most cases. Given that actual bid/ask spreads may range from 1 to 3 implied volatilities according to the underlying asset, and that there is a delay between "screen" and EOD volatility marks, the results indicate that the discrepancies are reasonable. Therefore, we conclude that, statistically, the reported OTC prices are consistent with contemporaneous listed market information.

Variance contracts show wider discrepancies than options. In fact, for variance swaps, the OTC market seems to be *biased upward* by 1 or 2 volatility points relative to the model values. This suggests that the OTC market demands a premium above FV for variance swaps, presumably due to the fact that full hedging of variance contracts with options is infeasible for liquidity reasons, *i.e.* the lack of depth in listed deep-out-of-the-money options, and transaction costs.[10]

In all the currencies studied, we observe consistently that dealer-to-end-user trades are closer to fair-value than dealer-to dealer trades or, at least, that the prices at which end-users trade are not "worse" (comparing with listed volatilities) than the prices in dealer-to-dealer trades.

The results of the Live Quote Experiments show that the dispersion of mid-quotes for all dealers pooled across all trades is 0.30%, which means that the quotes of different dealers are typically within 0.30% in volatility terms. The average dealer bid/ask spread is 0.89% which is similar to the average spreads observed on the Bloomberg screen for listed products. The average difference between mid-market dealer quotes and mid-market Bloomberg OMON is 0.40%. These results show that there is little dispersion among dealer quotes for these OTC products and they are close to the OMON values as well. Even though the agreement is better for index products than for single-share options and variance swaps, we find that the OTC prices and listed prices are highly consistent, and hence that end-users consulting listed options screens such as Bloomberg OMON can achieve a significant degree of information about prices at which they can could transact in the over-the-counter market. This strong linkage between listed markets and OTC markets in equity derivatives contributes significantly to price transparency.

References

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