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The Information Transmission between the Stock Market and the Options Market—The Case of IBM

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Abstract

This paper investigates the behavior of information transmission between IBM stock and its option. We adopt the intradaily data constituted of quoted bid and ask prices of the stock and options markets in our empirical tests. By using intradaily quotes, we can avoid data bias problems existing within the trade prices. We analyze the lead/lag relationship between the stock quotes and the option quotes, and provides information explanation ability of each quoted price. We also delineate the impulse response behaviors of each quoted price. The results show that in terms of information explanation capability and the time length of impacts of innovations on other variables, the stock quotes perform well and have great effects on option quotes, however the reverse is not valid. Meanwhile, the stock quotes lead the options quote while the option asks change have very minor effects on the stock quotes.

Keywords: Lead-Lag, VAR, Bid-Ask Spread, Information Transmission

Introduction

The information flow affecting options should have impacts on their underlying assets. This is obvious when we observe the traditional Black-Scholes option-pricing model. In a frictionless and rational exchange environment, price of a stock and its derivatives should simultaneously reflect the same information contents. Otherwise, it will provide investors with arbitrage opportunities to exploit profits without incurring any transaction costs. Hasbrouck (1995) proposes an idea of "one security", which means that securities and their derivatives are closely linked by arbitrage or short-term equilibrium consideration. If a stock and its options share the same information simultaneously, they would then seem to be as redundant assets in the markets since buying either one would result in same returns to investors. Extending Kyle (1985) model to continuous sequential trade model, Back (1993) models the strategic trading behaviors of different participants in both the options and stock markets[1]. He finds that few liquidity traders in the options market have certain reasons, such as transaction cost consideration, to trade in the options market. The differences regarding liquidity traders in the options and stock markets generate imperfect correlation of liquidity trades between two markets, which then induces stock prices and option prices to behave differently from each other. In equilibrium, the option price would convey different information from the stock prices. This is why options are not redundant assets in the economic environment and therefore can not be replicated by stocks and bonds.

Biais and Hillion (1994) also investigated the redundancy problem of options considering the models with three different kinds of liquidity traders, i.e., short position trader, long position trader, and non-trading trader. By marking liquidity trades endogenously, Biais and Hillion show that introduction of options would complete the financial market and prevent the market from being shut down due to higher information asymmetry problems. Meanwhile, they also indicate that the informed traders would try to adopt mixed strategies to mimic trading behaviors of liquidity traders in order to camouflage their trades. Hence, the informational revelation in the market could be less than what it should be when there are no options. Sheikh and Ronn (1994) find that there exist systematic intradaily patterns for adjusted call and put returns. And those patterns are different from intradaily pattern of stock returns. Consequently, they argue that their evidence is in favor of Back's (1993), that the presence of informed trades in options may induce some components unique to option returns.

Manaster and Rendleman (1982) using daily individual option data find that the

[1] Back (1993) develops a model showing that options convey different information from stocks and therefore options would not be redundant assets since options would enlarge the state spaces spanning by stocks only.

implied stock prices calculated from the option pricing model contain information beyond those in the underlying stock prices and conclude that the option prices tend to lead the stock prices for at least one day. Moreover, using daily individual option data, Anthony (1988) finds that although the results illustrate option volumes lead underlying stock volumes, the conclusion is weak due to several reasons, such as earlier closing of the stock market, unlimited issuance of options. In fact, using daily data could not give us satisfactory understanding about the causality relationship between options and stocks since the information could be reflected very fast in both markets without one-day delay. Criticizing the research drawbacks in Manaster and Rendleman (1982), Vijh (1987) indicates that since there are upward biases in the day-end option prices owing to the bid-ask influences, it is no surprise that Manaster and Rendleman find higher implicit stock prices than corresponding stock prices. Vijh suggests that it is better to use finer data[2], such as intradaily data, to overcome these difficulties to obtain more convincible empirical results. Stephan and Whaley (1990) investigate the lead/lag relationship between the options and the underlying stocks adopting intradaily data. After correcting the bid-ask induced serial correlation, they find that the individual stock prices tend to lead the underlying options prices for up to 45 minutes. Chan, Chung and Johnson (1993) find, however, that the findings in the Stephan and Whaley could be spurious because of the use of transaction data. Instead, using quoted prices, Chan, Chung and Johnson uncover that stocks lead options by fifteen minutes. However, this stock lead seems spurious because of larger ticks in the option prices. Therefore, they conclude that there is no lead/lag relationship between options and stocks. Since the previous studies using the fixed interval method (mostly, 15 minutes or 30 minutes), it is possible that some information within the interval could not be found because of the averaging effects. Therefore, Finucane (2000) adopt flexible time interval method to re-investigate the lead/lag relationship between individual options and stocks. Using midpoints of intradaily quoted prices, they find that stocks do lead options even when changing the time frames of price differences. Therefore, from empirical findings in the past, we could not obtain a consistent conclusion about the information transmission

[2] Easley, O'Hara and Srinivas (1994) classify the option trading volumes by "positive news" and "negative news" and find that these classified option volumes lead stock price changes, which are opposite to the findings of Vijh (1990).

relationship between the stock and the options markets.

In this paper, we use intradaily quoted bid and ask prices of the IBM stock and its options to investigate the lead/lag relationship between stock and options. Using quote data can overcome several trade price biases behaviors and provide more insight regarding market makers' behaviors of the information transmission process. Meanwhile, besides the lead/lag relationship, we analyze the response of quoted price in reaction to an innovation of other quoted price. The findings of this paper are consistent with Stephan and Whaley (1990) and Finucane (2000) that the stock prices are more informative than the option prices.

The structure of this paper proceeds as follows: Section 2 describes our data bases and research methodology. Section 3 presents and discusses the empirical results. And Section 4 concludes our study.

Data and Methodology

1. Data Description

Most previous studies use daily data and suffer deficiency on detecting instant information transmission behavior between the stock and options markets. Meanwhile, Vijh (1987) mentions that using daily data would ignore the upward biases in the day-end option prices owing to the bid-ask price influences. By using finer data, such as Stephan and Whaley (1990) and Chan, Chung and Johnson (1993), can not yet reveal the influences of the market making behaviors on the quoted prices in both markets. Moreover, Easley and O'Hara (1992) mention that the transaction prices would be biased indicators of the "true" underlying price. That is because non-trading intervals contain information on which market makers and market participants would depend on and thus revise their believes. They suggest that the quoted series are better data sets since quote changes in a continuous way and do not suffer sampling problems as transaction prices do. Based on reasons mentioned above, we use finer data set, i.e., intradaily data, and include the bid and ask prices of both markets to investigate how market making behaviors of both markets would affect the patterns of quoted prices.

We use IBM as our research object since it is the most actively traded security in the stock and options markets and non-synchronicity of trading IBM would be small. We retrieve the stock quote data from the NYSE TQRQ (Trades, Quotes, Reports, and Quotes) database and the call option quote data from the Berkeley Option Data Base (BODB). Meanwhile, we adopt a data screening procedure to eliminate unreasonable data, such as zero quoted prices and abnormal quoted prices.[3] The sample period covers 41 trading days from November to December 1990.

2. Research Methodology

Like Chan, Chung, Johnson (1993) and Finucane (2000), we calculate the implied hedge ratio, δ_t, using American (Binomial) dividend adjusted call pricing model with two input prices, the mid-points of prevailing quoted stock prices and the mid-points of quoted call option prices. Meanwhile, we divide trading hours of a trading day into 78 5-minute intervals from 9:30 to 16:00.[4] From the Black-Scholes option pricing model, we could find that the stock price change has a linear relationship with the call option price change as follows.

$$\Delta C_1 = \delta_t \Delta S_t \tag{1}$$

where ΔC_t is the call option price change at time t, ΔS_t is the stock price change at time t, and δ_t is the hedge ratio, i.e., the delta value or price sensitivity, at time t. According to equation 1, any simultaneous change in the stock (call) price would induce the call (stock) price to change in proportional.

Since our primary objective is to understand the information transmission relationship between the stock and options markets, there are four price series used, stock bid, stock ask, call option bid, and call option ask, as input variables. Firstly, following equation 1, we construct four variables for each 5-minute interval: (1) the equivalent option bid change (EOB), which is equal to the product of the hedge ratio and the stock bid price change, i.e., $EOB_t = \delta_t \times \Delta stock\ bid\ \ price_t$, (2) the

[3] Abnormal quoted prices would be defined as the prices exceeding the moving average price of previous 10 quotes by 150%.

[4] The trading hours for the CBOE are from 9:30 to 16:10 (EST) while the trading hours for the NYSE are form 9:30 to 16:00. Therefore, we choose the overlapping trading hours, 9:30 to 16:00, as our daily trading time interval.

equivalent option ask change (EOA) which is equal to the product of the hedge ratio and the stock ask price change, i.e., $EOA_t = \delta_t \times \Delta\, stock\ ask\ price_t$, (3) the option bid change, OB_t,and (4) the option ask change, OA_t. Then, the information transmission relationship between the stock prices and options prices can be represented like a VAR equation:

$$Y_t = c + \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \Phi_3 Y_{t-3} + \ldots\ldots\ldots\ldots + \Phi_p Y_{t-i} + e_t \quad (1)$$

where $Y_t = (EOB_t, EOA_t, OB_t, OA_t)'$, Φ_i is the parameter matrix for the period $t-i$, and $e_t \sim i.i.d.N(0,\Omega)$.

Empirical Results

1. Stationarity of Input Variables and the Lag Structure

Before going to the estimation of equation 2, we employ the Augmented Dickey-Fuller and Phillips-Perron unit root tests to examine whether the variables are stationary or not. Panel A of Table 1 reports the estimation results of the Augmented Dickey-Fuller unit root tests of 5 lags with and without the time trend.[5] We find that under the lag one variables, α_1, coefficients of the four variables are significantly different from zero under Cases 1 and 2. This signifies that there are no unit roots in those four variables. Meanwhile, in Panel B, the results of the Phillips-Perron unit root tests also point out that the coefficients of lag one variables in Cases 1 and 2 are significantly different form zero. Therefore, the four variables, equivalent option bid change (EOB), equivalent option ask change (EOA), option bid change (OB), and option ask change (OA), are considered stationary.

[5] We also perform both unit root tests with the number of lags above 5 and obtain the same results as the models with 5 lags.

Table 1 Unit Root Tests

Panel A: *Augmented Dickey-Fuller Test*

	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
Case 1: Without Trend				
$\alpha_1 = 0$ (-2.57)	-25.25*	-25.28*	-25.76*	-25.94*
$\alpha_0 = \alpha_1 = 0$ (3.78)	318.88*	319.45*	331.84*	336.31*
Case 2: With Trend				
$\alpha_1 = 0$ (-3.13)	-25.31*	-25.34*	-25.78*	-25.95*
$\alpha_0 = \alpha_1 = \alpha_2 = 0$ (4.03)	213.56*	214.09*	221.54*	224.53*
$\alpha_1 = \alpha_2 = 0$ (5.34)	320.33*	321.13*	332.30*	336.79*

Panel B: *Phillips-Perron Test*

	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
Case 1: Without Trend				
$\alpha_1 = 0$ (-2.57)	-57.85*	-57.24*	-59.48*	-58.91*
$\alpha_0 = \alpha_1 = 0$ (3.78)	1673.40*	1638.10*	1769.10*	1735.10*
Case 2: With Trend				
$\alpha_1 = 0$ (-3.13)	-57.88*	-57.27*	-59.49*	-258.91*
$\alpha_0 = \alpha_1 = \alpha_2 = 0$ (4.03)	1116.70*	1093.20*	1179.60*	1156.90*
$\alpha_1 = \alpha_2 = 0$ (5.34)	1675.10*	1639.80*	1769.40*	1735.40*

Numbers in the parentheses of the first column represent the critical values at 10% level
Numbers in the column are the test statistics for each unit root test.
*: represents the test statistics is significant different from zero at 10% level.

Since the variables are stationary, we continue to find the optional lag length for equation 2. Panel A of Table 2 presents the AIC (Akaike's Information Criterion) values[6] for the estimated model with one to eight lags. It is obvious that the AIC value of the model with eight lags has the smallest value. Therefore, model with eight lags seems to be suitable for us. To reconfirm our lag structure derived from the AIC values, we perform the likelihood ratio test advanced by Sims (1980) to examine whether the model with eight lags is significantly different from other models which are less than eight. The chi-square test results shown in Panel B of Table 2 make disclose that models with eight lags are optimal for our estimation since the chi-square tests are all significantly different from zero. Consequently, the empirical results shown in the following sections are based on the model with eight lags.

Table 2 AIC Values and Likelihood Ratio Tests

Panel A: *AIC values*

Lags	AIC
8	-22.8027
7	-22.7953
6	-22.7853
5	-22.7712
4	-22.7399
3	-22.6938
2	-22.6142
1	-22.4455

Panel B: *Likelihood Ration Tests*

Comparative Lag Structure	Chi-Square	Freedom	Upper-Tail Probability
8/1	1349.8949	112	0.0000
8/2	785.5775	96	0.0000
8/3	502.4402	80	0.0000
8/4	325.1517	64	0.0000
8/5	194.8035	48	0.0000
8/6	116.6921	32	0.0000
8/7	55.0803	16	0.0000

[6] We also calculate the AIC values for number of lags more than eight and find that AIC values changes insignificantly.

2. The Lead and Lag Relation Ship Within and Between the Stock Quote Changes and Option Quote Changes

The maximum likelihood estimation results of equation 2 with eight lags are shown in Table 3. Case 1 of Panel A displays the estimation results for the equivalent option bid changes (EOB). We discover that the coefficients of lagged EOBs are significantly less than zero, meaning that the current EOB would be affected by it own negative lagging effect. The negative effects of lagged EOBs reflect the fact that largely positive bid price changes in earlier periods would gradually mitigate by future equivalent options bid price changes. This signifies that effects generated by information in earlier periods would gradually decrease as time elapses. Same argument can be applied to the negative change of the equivalent option bid price in the previous periods. Furthermore, the absolute magnitudes of the coefficients of lagged EOBs are larger in later periods than in much earlier ones. This points out that the more recent information events would cause a large reversion of the current EOB changes. That is, most of the information contents in recent periods would be incorporated instantly and therefore the current EOB would not have to adjust toward their information contents. However, the market makers should smooth out those changes, especially for more recent periods, in order to reduce impacts of the information getting to an orderly market.[7]

The effects of equivalent option ask price (EOA) changes are also significant. The F-tests reveal the important causal effects from the lagged EOAs. All the coefficients of EOAs are significantly positive and the EOAs with small lags have much more impacts on the current EOB. The result demonstrates that quoted prices in stock market tend to move in a parallel way. That is, the stock bid and ask prices would move in the same direction implied by information flow in the stock market. Stoll (1989) explains that the bid and ask prices would move in the same direction, except that the true price of information asymmetry effect would be different from the original quote while inventory control effect would stay the same as the original quote. Therefore, the positive relationship between EOB and EOA verifies quotation practice of the specialist. In general, the specialist would adjust quoted bid and ask

[7] The NYSE rule 104 requires that specialists maintain a fair and orderly market and price continuity.

prices upward (downward) to reflect positive (negative) information.

On the other hand, information transmission from options market to stock market does not seem very significant. The F-tests of the causality relationship between the option bid and equivalent option bid prices is insignificantly different from zero. This denotes that we can not reject the hypothesis that option bid prices do not have impacts on equivalent option bid prices. Meanwhile, we find that nearly all except the lagged one option ask changes do not hold significant effects on EOB. Stephan and Whaley (1990) move forward that the individual stock prices tend to lead corresponding options for up to 45 minutes. Finucane (2000) also obtain the same conclusion when adopting adjustable time intervals. Therefore, non-existence impacts on EOB from option bid and asks changes confirm their findings, such that there is no lead of the option prices to stock prices. To justify our prediction that the options market contains small information impacts on the stock market, we can examine Case 2 of Panel A in Table 3. As in the EOB case, we uncover that the current EOA changes would be affected more by its own lagged effects of up to four lags and coefficients of the lags are negative. As in the EOB, information impacts in earlier periods would gradually diminish, and eventually the ask price in the stock market would adjust toward a price implied by those information and smooth out the price impacts of earlier information events. In the meantime, we also discover that coefficients of lagged EOBs are significantly positive of up to four lags. These positive coefficients of lagged EOBs in EOA equation reflect the same results as in the previous EOB equation, that specialist in stock market tend to positively (negatively) adjust the quoted bid and ask prices in reaction to the positive (negative) information.

As for the effects of the option bid changes (OB) and the option ask changes (OA), the F-tests of whether all the coefficients of OBs are equal to zero is not significantly different from zero. Moreover, nearly all except lag one OAs are also insignificantly different from zero. These results confirm the empirical results in the EOB equation that information in options market does not have any apparent effects on stock quotes. Biais and Hillion (1994) propose that the option trades may provide little predictive power on stock prices. That is because the insiders mimicking trading behaviors of liquidity traders possibly adopt unusual trading strategies, which causes option prices not to move in parallel with the underlying stock prices even under the same information environment. Back (1993) also proves that the stock prices would react most to stock orders than options orders, because of imperfect correlation of liquidity trades between the stock and options markets. And this causes imperfect correlation of options price and underlying stock prices. Therefore, our results of EOB and EOA equations are consistent with findings of Vijh (1990) that options prices do not have significant predictive power on future evolution of stock prices.

The estimation results of OB equation are shown in Case 3 of Panel B in Table 3. We could find that the coefficients of OB lags are very significantly less than zero, which is consistent with the results of the previous EOB and EOA equations. This means that the negative coefficients of its own lags indicate that market markers in options market would also try to reduce and smooth out impacts of previous option bid changes. In the meantime, the higher absolute magnitudes of OB lags in most recent periods also demonstrate that since the information contents in each period have been incorporated instantly when information events happened, market makers would try to smooth out the those impacts, especially for the most recent information events. Furthermore, coefficients of the lagged option ask changes (OA) are significantly positive up to four lags. This also confirms that market makers in the options market would adjust their quoted bid and ask prices upward (downward) in reaction to positive (negative) information.

Regarding the effects of correspondent stock quotes, we will find that coefficients of lagged equivalent option ask changes are significantly positive up to five lags in contrast to insignificant coefficients of OB lags in the EOA equation. This indicates that option bid changes would react positively to changes in the lagged stock ask prices. It also reflects findings of previous studies (Stephan and Whaley (1990), Fleming, Ostdiek and Whaley (1994), and Finucane (2000)) that individual stock prices do have predictive power about the option prices but the option price does not. There are three significantly negative coefficients of EOB lags although F-tests do not reject all coefficients of EOB lags are equal to zero. The positive relationship between the EOB lags and the current OB might indicate that higher buy demands in the stock market causing increases in the stock ask price would decrease the market sales of the call options and raise the options bid price. Some of the negative coefficients of EOB lags illustrate that the leverage advantage in trading options would attract short sale traders of stock market when they want to do large short sales of stocks but are restricted by short-sale constraint in the stock market. Therefore, the market sale of stocks would and the stock bid would decrease as well when the short sale traders heavily trade in the options market.

As for the estimation results, we find that the coefficients of OA lags are significantly negative, which indicates that market makers in the options market would try to reduce and smooth out impacts of previous option ask changes as we find in the OB equation. Moreover, the significantly positive coefficients of OB lags are consistent our findings in the OB equation that market makers in the options market would adjust their quoted bid and ask prices upward (downward) in reaction to positive (negative) information. In the meantime, the significant positive coefficients of EOA lags and negative coefficients of EOB lags point out that the stock market do affect options market but the reverse is not true. And the positive relationship between EOA lags and the current OA indicate that higher market buy demand in the stock market causing positive changes in the stock ask prices would increase a higher market buy demand in the options market and thus the option ask price would go up. On the other hand, the negative coefficients of EOB lags means that the lower market sale of stocks causing increase in stock bid prices would decrease limit sales of the options and the ask price.

Table 3 The Estimated Coefficients

Panel A: *The Options Market*

Case 1: The coefficients of the EOB equation

	Equivalent Option Bid Change		Equivalent Option Ask Change		Option Bid Change		Option Ask Change	
Lag	Coefficient	Upper Probability	Coefficient	Upper Probability	Coefficient	Upper Probability	Coefficient	Upper Probability
1	-0.5031	0.0000	0.4669	0.0000	-0.0052	0.8863	0.103489	0.0036
2	-0.3644	0.0000	0.3399	0.0000	0.0221	0.6143	0.023371	0.5838
3	-0.3171	0.0000	0.3132	0.0000	0.0334	0.4815	-0.00425	0.9262
4	-0.2106	0.0000	0.2025	0.0001	0.0253	0.6033	-0.05295	0.2604
5	-0.2315	0.0000	0.1972	0.0001	-0.0214	0.6604	0.010011	0.8316
6	-0.1849	0.0002	0.1548	0.0018	-0.0197	0.6777	0.031445	0.4938
7	-0.1212	0.0076	0.1734	0.0001	0.0045	0.9185	-0.02553	0.5501
8	-0.1026	0.0047	0.1140	0.0021	0.0117	0.7467	-0.00036	0.9921
F-test	24.9422	0.0000	22.2273	0.0000	0.3069	0.9637	2.0456	0.0378

F-test is to test the hypothesis that all coefficients of the column is equal to zero.

Case 2: The coefficients of the EOA equation

	Equivalent Option Bid Change		Equivalent Option Ask Change		Option Bid Change		Option Ask Change	
Lag	Coefficient	Upper Probability	Coefficient	Upper Probability	Coefficient	Upper Probability	Coefficient	Upper Probability
1	0.2617	0.0000	-0.3066	0.0000	-0.0296	0.4197	0.117411	0.0010
2	0.1869	0.0000	-0.2415	0.0000	-0.0001	0.9980	0.065523	0.1274
3	0.1351	0.0062	-0.1516	0.0023	0.0255	0.5938	0.002998	0.9483
4	0.1355	0.0081	-0.1467	0.0044	0.0265	0.5902	-0.0683	0.1495
5	0.0257	0.6153	-0.0582	0.2580	-0.0527	0.2827	0.040867	0.3889
6	-0.0305	0.5374	0.0037	0.9412	-0.0553	0.2460	0.048802	0.2917
7	-0.0159	0.7284	0.0714	0.1193	-0.0004	0.9937	-0.01387	0.7471
8	-0.0337	0.3555	0.0553	0.1376	0.0272	0.4574	-0.02217	0.5379
F-test	7.1806	0.0000	9.8605	0.0000	0.9883	0.4429	3.0377	0.0021

F-test is to test the hypothesis that all coefficients of the column is equal to zero.

Panel B: *The Options Market*

Case 3: The coefficients of the OB equation

	Equivalent Option Bid Change		Equivalent Option Ask Change		Option Bid Change		Option Ask Chang	
Lag	Coefficient	Upper Probability	Coefficient	Upper Probability	Coefficient	Upper Probability	Coefficient	Upper Probability
1	-0.0043	0.9257	0.1661	0.0003	-0.5091	0.0000	0.401535	0.0000
2	-0.0833	0.1473	0.1440	0.0121	-0.3766	0.0000	0.358513	0.0000
3	-0.1269	0.0412	0.1139	0.0686	-0.2600	0.0000	0.251525	0.0000
4	-0.0888	0.1678	0.0817	0.2079	-0.1617	0.0090	0.127117	0.0332
5	-0.1394	0.0306	0.1135	0.0800	-0.1343	0.0298	0.091019	0.1277
6	-0.1446	0.0204	0.0732	0.2436	-0.0620	0.3019	0.05687	0.3293
7	-0.0221	0.7017	0.1004	0.0819	-0.1087	0.0501	0.083118	0.1251
8	-0.0207	0.6524	0.0500	0.2859	-0.0229	0.6195	0.019324	0.6699
F-test	1.3968	0.1925	2.0515	0.0372	15.8678	0.0000	10.9393	0.0000

F-test is to test the hypothesis that all coefficients of the column is equal to zero.

Panel B: *The Options Market*

Case 4: The coefficients of the OA equation

	Equivalent Option Bid Change		Equivalent Option Ask Change		Option Bid Change		Option Ask Change	
Lag	Coefficient	Upper Probability	Coefficient	Upper Probability	Coefficient	Upper Probability	Coefficient	Upper Probability
1	-0.0286	0.5451	0.169033	0.0003	0.1999	0.0000	-0.29026	0.0000
2	-0.1516	0.0094	0.1816	0.0018	0.1810	0.0013	-0.17047	0.0019
3	-0.1828	0.0038	0.1640	0.0098	0.1637	0.0075	-0.15841	0.0074
4	-0.1603	0.0143	0.1547	0.0189	0.1824	0.0038	-0.21119	0.0005
5	-0.2453	0.0002	0.2022	0.0022	.01347	0.0319	-0.17455	0.0040
6	-0.2491	0.0001	0.1663	0.0091	0.1453	0.0172	-0.13705	0.0207
7	-0.0918	0.1168	0.1632	0.0054	0.0433	0.4423	-0.06835	0.2144
8	-0.0508	0.2767	0.0582	0.2216	0.0714	0.1270	-0.07653	0.0966
F-test	2.9467	0.0028	2.7398	0.0052	3.1180	0.0016	5.837	0.0000

F-test is to test the hypothesis that all coefficients of the column is equal to zero

3. The Information Proportions in the Stock Market and the Options Market

From the previous section, we know that the information transmission is unidirectional from the stock market to options market. Therefore, it is intuitively to expect that forecast error variances of quoted bid and ask those quote innovations of the stock rather than that of the options market should explain prices in stock market.

Case 1 of Table 4 reports the proportions of the forecast error variances of EOBs explained by each variable. It is obvious that the EOB can explain itself by over 90% for every forecast period. And the EOA explains more than 5% but less than 7% of the forecast error variances of future EOBs for each period. The option bid and asks changes would not explain more than 2% of the forecast error variances of future EOBs for each period. Therefore, from the variance decomposition results of forecast error variances of EOBs, we confirm that option prices will not contain much information about the stock bid prices. But it seems that the stock ask price does not explain much when compared with the stock bid prices themselves.

The decomposition of forecast error variances of EOAs is presented in the Case 2 of Table 4. We would see that the forecast error variances of EOAs can be explained by EOA itself by almost 25% while the EOB can explain the forecast error variances of EOAs by about 73%. The OBs and OAs explain the forecast error variances of EOBs by fewer than 1.5%. Hence, it is very clear that the stock quotes explain themselves more than the option quotes as we find in the Case 1 of EOB. In contrast to variance decomposition results of EOB, the equivalent option bid change explain the forecast error variances of EOAs more than EOA itself by around 48%. Result of this and the EOB case above might suggest that information contents contained in the EOB could be more informative than in the EOA. The reason that EOB plays an informative role could be due to the following scenario: the specialists cast much notice on market sale side. And this is reflected in the trading activities at the stock bid prices since the heavy market sale trades at the bid price would cause the stock prices to plunge in higher probability. A number of researchers[8] have found

[8] Pagan and Schwert (1990), Engle and Ng (1991), Nelson (1991), and Bollerslev, Chou, and Kroner (1992).

the asymmetric reaction behavior in the stock market that negative information shocks seem to increase the stock price volatility more than positive information shocks. Therefore, the specialists in the stock market would asymmetrically incorporate more information of the bid side than the of the ask side.

Regarding the forecast error variance decomposition of the option bid change (OB), Case 3 of Table 4 indicates that OB can explain itself by about 65% while the percentage explanation of OA about the forecast error variances of OB is around 2.5%. This finding is similar to the result we find in the Case 1 of EOB. On the other hand, the equivalent option bid change has the second highest explanation power of around 30%. Observing the estimation results of the OB equation in Case 3 of Table 3, we find that there are three significant coefficients of lagged EOBs. This indicates that the EOB can explain some variation of OB compared to five significant coefficients of EOA and four significant coefficients of OA. This finding gives us much more assertions about the conjecture that market markers in the options market would place more weights on the information contents of the bid side either in stock or option market than on the ask side. In the meantime, percentages of explanation of EOA and of OA about the forecast error variances of EOB are all around 2.5%, which are far below the proportions of explanation of EOB and OB.

Case 4 of Table 4 reports the results of forecast error variance decomposition of OAs. We find that OA explains itself by around 15% in each forecast period while the percentage of explanation of OB is around 52%. This result again reveals the asymmetric reaction of the market makers to the bid side information and therefore this behavior of market makers would produce higher explanation power of OB over that of OA itself. We also see that the equivalent option bid change (EOB) has higher explanation power of around 30% while the equivalent option bid change explains forecast error variances of EOA by only about 2%. Not only do those findings tell us that the market makers notice negative information more greatly than positive information but also those information contents in stock market do affect price evolution of options prices. Therefore, combining findings of the forecast error variances of OB and OA, we understand that the stock market do transmit information to the options market but not the reverse.

Table 4 Accounting Information Proportion of Forecast Error Variances

Panel A: *The Stock Market*

Case 1: Information Proportions of Forecast Error Variances of EOB

Forecast Step	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
1	93.1849	5.7793	0.7881	0.2477
2	93.1043	5.7768	0.8706	0.2483
3	92.8831	5.8901	0.9774	0.2495
4	92.6829	5.9480	1.0682	0.3010
5	92.6367	5.9542	1.1010	0.3081
6	92.6278	5.9493	1.0998	0.3231
7	92.4275	5.9921	1.1909	0.3895
8	92.3964	5.9891	1.2169	0.3976
9	92.2624	6.1241	1.2151	0.3984
10	92.2459	6.1357	1.2164	0.4019
11	92.2443	6.1356	1.2167	0.4034

Case 2: Information Proportions of Forecast Error Variances of EOA

Forecast Step	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
1	73.7980	25.2666	0.6081	0.3273
2	79.5580	25.1865	0.9266	0.3289
3	73.5093	25.1901	0.9502	0.3504
4	73.3347	25.1232	1.1192	0.4229
5	73.2595	25.0692	1.1322	0.5391
6	73.2887	25.0252	1.1476	0.5385
7	73.2285	25.0056	1.1500	0.6159
8	73.2325	24.9987	1.1529	0.6159
9	73.1786	25.0338	1.1521	0.6356
10	73.1785	25.0333	1.1525	0.6357
11	73.1777	25.0333	1.1527	0.6364

Numbers in each column, except the forecast step column, represent the percentage

Panel B: *The Option Market*

Case 3: Information Proportions of Forecast Error Variances of OB

Forecast Step	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
1	29.7881	2.1402	65.6899	2.3818
2	29.7787	2.2291	65.5678	2.4245
3	29.8106	2.2453	65.5175	2.4266
4	29.5128	2.2457	65.4473	2.4942
5	29.9504	2.2568	65.2893	2.5034
6	30.2601	2.2553	64.9812	2.5034
7	30.3357	2.2524	64.8906	2.5213
8	30.3432	2.2513	64.8479	2.5577
9	30.3338	2.2796	64.8293	2.5573
10	30.3345	2.2799	64.8066	2.5790
11	30.3363	2.2799	64.8049	2.5790

Case 4: Information Proportions of Forecast Error Variances of OA

Forecast Step	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
1	29.3787	2.1793	52.5465	15.9855
2	29.3334	2.3505	52.4588	15.8574
3	29.3438	2.3588	52.4406	15.8568
4	29.3331	2.3553	52.3649	15.9467
5	29.6027	2.3706	52.1622	15.8645
6	29.8581	2.3736	51.9613	15.8071
7	29.9096	2.3703	51.9402	15.7800
8	29.9024	2.3837	51.9242	15.7898
9	29.8988	2.3956	51.8865	15.8191
10	19.9053	2.3963	51.8807	15.8476
11	29.9068	2.3969	51.8787	15.8476

Numbers in each column, except the forecast step column, represent the percentage

4. Innovation Transmission Process Within and Between the Stock Market and the Option Market

From the results of previous sections, we have understood the transmission mechanism between the stock market and the options market. To get more insights about this transmission mechanism, we examine the dynamic response pattern of each four variables to innovations in a specific one using impulse response functions. The stimulation of impulse response function is very sensitive to the ordering of the variables. Therefore, results shown here are estimated by putting specific shock (innovation) variable on the first order without changing orders of others rest of variables.[9] The estimation results are shown in Table 5.

Case 1 of Table 5 details the responses of each variable in each period to one tick down innovation of the EOB, i.e., the EOB is reduced by $-\frac{1}{8}$, on day 0. Figure 1 present graphical patterns of responses of each variable. By examining Figure 1 and Case 1 of Table 5, we discover that one tick down innovation of EOB causes decrease of EOA by –0.33 at the first 5 minutes, followed by 0.004 at 10 minutes and 0.004 on 15 minutes. The fluctuation of EOA would cease at 40 minutes. As for the responses of OB, we find that the OB responds to innovation of EOB by 0.001 at the first five minutes, followed by 0.006 at 10 minutes, and 0.009 on 15 minutes and ceases at about 40 minutes. The response of OA to the innovation of EOB is 0.004 at the first 5 minutes, followed by 0.011 at 10 minutes, and 0.006 at 15 minutes and ceases to fluctuate at about 40 minutes. From the response patterns of each variable other than EOB, we notice that EOA respond much negatively than other variables. This pattern is expected since EOB and EOA are coming from the stock market. Regarding the responses of OB and OA, we observe that their responses are not strong, yet they are affected by the innovation of EOB.

Case 2 of Table 5 shows the impulse response results of variables in reaction to

[9] Here, we take OA innovation as an example. In the original orders, we put four variables as the following: (1) the equivalent option bid change (EOB), (2) the equivalent option ask change (EOA), (3) the option bid change (OB), and(4) the option ask change (OA). For the impulse response function to the innovation of the OA, we change the orders of variables in the VAR system as follows: (1) the option ask change (OA), (2) the equivalent option bid change (EOB), (3) the equivalent option ask change (EOA),and the option bid change (OB).

one tick up of EOA, i.e., the EOA increases by $\frac{1}{8}$. We find that EOBs are most responsive to the innovation of EOA. The responses of EOB are 0.58 at the first 5 minutes, but decline very quickly at 10 minutes, which reveals that specialist in stock market adjusts bid price quickly in response to the shock of the ask change, unlike the slow adjustment of ask price in reaction to innovation of the bid price. This substantiates the previous results that specialist is more concerned about the negative information than the positive information. As for the responses of OB and OA, we find that they respond more to the innovation of EOA larger at the first 5 minutes, and then drop very quickly to cease fluctuation at about 15 minutes. Therefore, from the response patterns of OA and OB in reaction to innovations of EOB and EOA, we identify that effects of the innovation of EOB would last longer than of innovation of EOA.

The responses of each variable to the one tick down innovation of OB are shown in Case 3 of Table 5. We find that the variable with higher response to the innovation of OB in the first 5 minutes is OA. , which is consistent with our expectation The responses of OA are –0.025 in the first 5 minutes and decrease very quickly afterwards. In addition, small responses of EOA and EOB to innovation of OB confirm our previous results that information contents are higher in stock market than in options market. On the other hand, we find that the OB responds to innovation highly and quickly. The higher responses of EOB and EOA at the first 5 minutes are much more striking than EOB and EOA in reaction to the innovation of OB. We can take a glance at Cases 1 and 2 of Table 3 and uncover that the lagged one OA has significant positive coefficients in EOB and EOA equations. This denotes that the OA has some lagged effects in influencing the current EOB and EOA. That is why we uncover higher responses of EOB and EOA to the innovation of OA. This implies that information of the ask price in options market would cause the specialist in stock market to adjust his quotes because positive changes in option ask prices may entail good news to the underlying security. However that is not true for the option bid price changes.

Table 5 Impulse Responses of Innovations

Panel A: *The Stock Market*

Case 1: The Responses of One Tick down of the EOB

Time Ahead (minute)	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
0	-0.125	0.000	0.000	0.000
5	0.063	-0.033	0.001	0.004
10	-0.001	0.004	0.006	0.011
15	0.009	0.003	0.009	0.006
20	-0.005	-0.002	0.000	0.003
25	0.010	0.010	0.010	0.014
30	0.003	0.008	0.008	0.007
35	0.002	0.000	-0.006	-0.010
40	-0.001	-0.001	-0.002	-0.004
45	-0.011	-0.006	-0.005	-0.005
50	0.002	-0.002	-0.002	0.000
55	0.000	0.000	-0.001	0.000

Case 2: The Responses of One Tick down of the EOA

Time Ahead (minute)	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
0	0.000	0.125	0.000	0.000
5	0.058	-0.038	0.021	0.021
10	-0.003	-0.001	0.009	0.013
15	0.008	0.003	0.004	0.003
20	-0.006	-0.002	-0.001	0.002
25	0.005	0.006	0.007	0.008
30	-0.001	0.004	-0.003	-0.004
35	0.008	0.005	0.003	0.000
40	0.000	0.001	0.001	-0.004
45	-0.010	-0.006	-0.006	-0.004
50	0.003	-0.002	-0.001	0.001
55	0.000	0.000	0.000	0.001

Panel B: *The Stock Market*

Case 3: The Responses of One Tick down of the OB

Time Ahead (minute)	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
0	0.000	0.000	-0.125	0.000
5	0.001	0.004	0.064	-0.025
10	-0.004	-0.006	0.005	-0.002
15	-0.003	-0.005	-0.004	-0.003
20	-0.002	-0.001	-0.005	-0.008
25	0.005	0.010	0.001	0.002
30	0.003	0.001	-0.003	-0.002
35	-0.002	-0.006	-0.009	0.010
40	0.000	-0.001	-0.007	-0.004
45	-0.001	0.003	-0.001	0.006
50	0.001	0.000	0.004	-0.002
55	-0.001	-0.001	0.000	-0.001

Case 4: The Responses of One Tick down of the OA

Time Ahead (minute)	Equivalent Option Bid (EOB)	Equivalent Option Ask (EOA)	Option Bid (OB)	Option Ask (OA)
0	0.000	0.000	0.000	0.125
5	0.013	0.015	0.050	-0.036
10	-0.001	0.001	0.007	0.001
15	0.001	-0.004	-0.002	-0.003
20	-0.006	-0.007	-0.009	-0.011
25	0.002	1.009	-0.005	-0.004
30	0.003	-0.001	-0.004	-1.002
35	-0.007	-0.007	0.005	0.005
40	0.002	0.000	0.006	-0.004
45	-0.001	0.004	-0.001	0.007
50	0.002	0.000	0.005	-0.001
55	-0.001	-0.001	0.000	-0.001

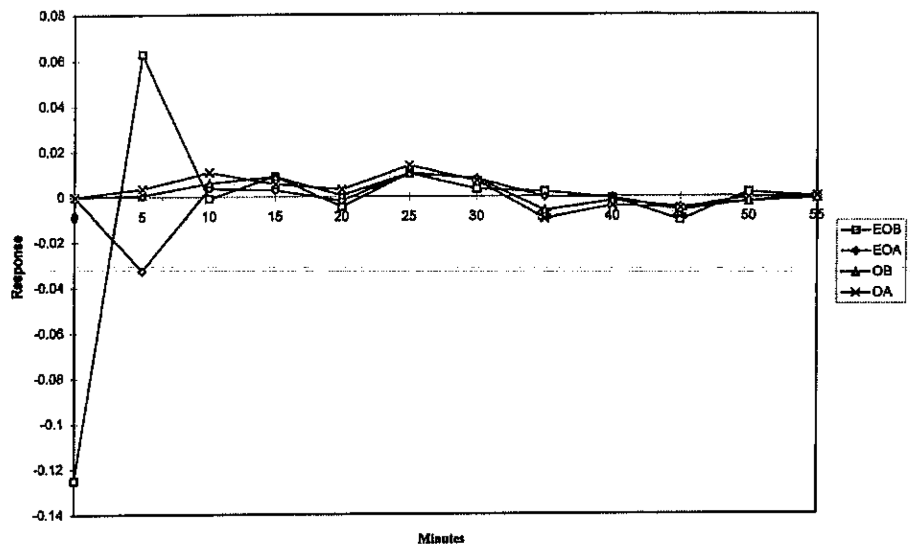

Figure 1 The Impulse Responses to the One Tick Down Innovation of EOB

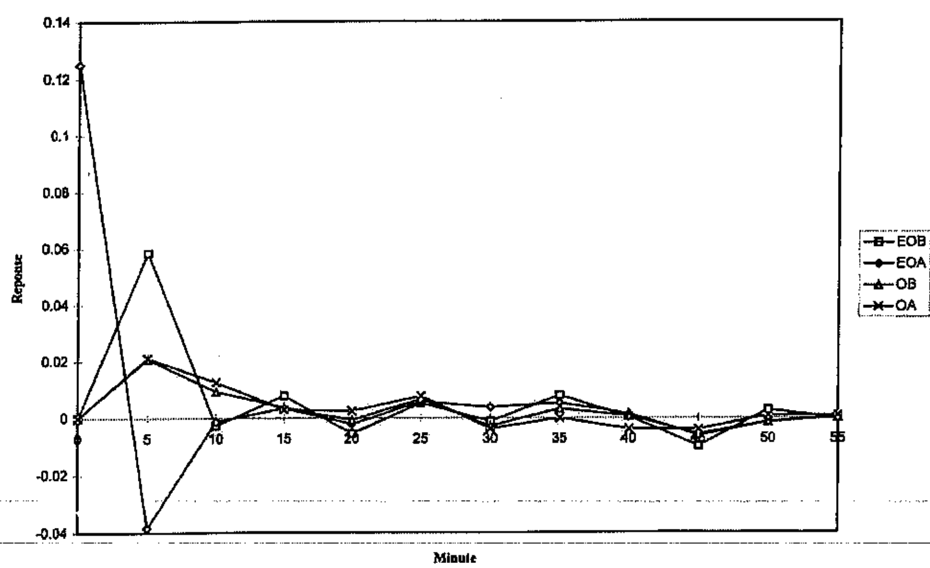

Figure 2 The Impulse Responses to One Tick Up Innovation of EOA

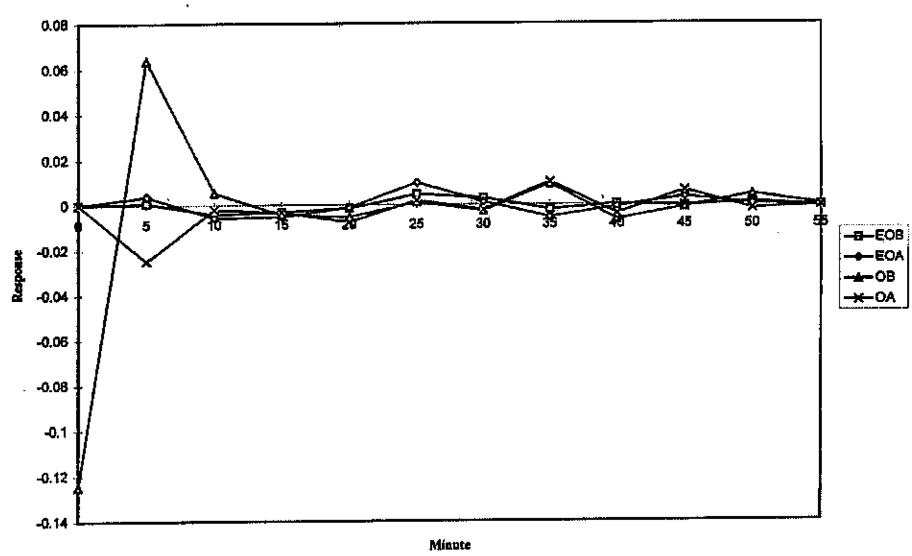

Figure 3 The Impulse Responses to the One Tick Down Innovation of OB

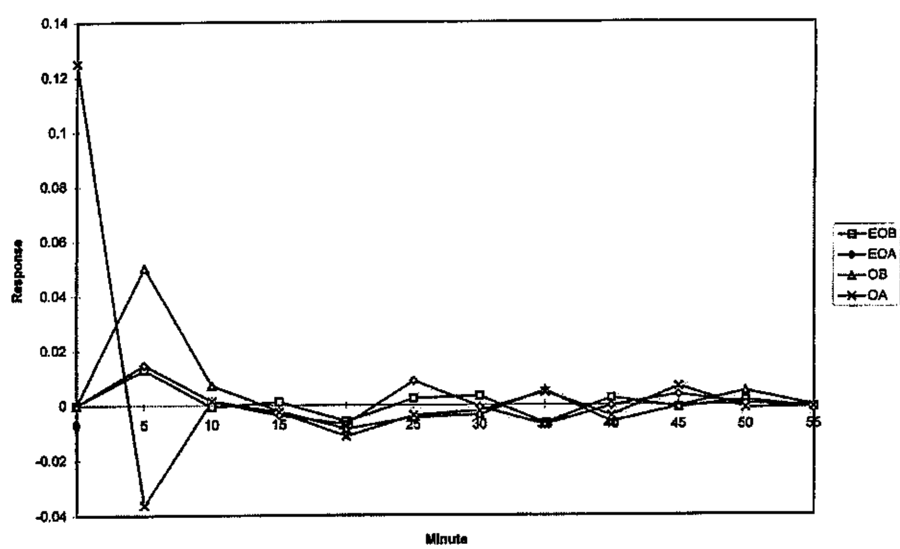

Figure 4 The Impulse Responses to the One Tick Up Innovation of OA

Summary and Conclusions

We use the intradaily IBM quoted prices to inspect information transmission behavior between the stock and the options market. The use of quoted prices can assist us in avoiding upward biases in the day-end option prices owing to the bid-ask price influences, and shun from suffering the loss of information on trade prices owing to the non-trading problems, as well as revelation influences of market making behaviors on the quoted prices. We also investigate the explanation capability of each quoted price in predicting forecast error variances of other quoted prices and identify the information responses of each quoted price in reaction to the innovations of other quoted prices.

Consistent with the findings of Stephan and Whaley (1990) and Finucane (2000), the stock quotes tend to enclose more information than the option quotes. That is, the stock quotes, either quoted bid or ask prices, will affect the option quotes. However, the reverse is not true. On the other hand, we detect a very weak effect of the option ask prices on the stock quotes, which implies that positive changes in option ask price may signal good news to the underlying security.

We also discover that market makers in both markets tend to pay more notices on the bid side information than the ask side since larger market sale orders would trade at the bid prices. This confirms the findings of the previous studies that negative information shocks seem to increase stock price volatility more than positive information shocks. Above and beyond, we also find that innovation effects of stock quotes, either quoted bid price or quoted ask price, will have an effect on other variables much longer than the option quotes. Therefore, our findings demonstrate that the stock market would carry more information than the options market. The information transmission mechanism should be unidirectional from the stock market to the options market and the options market has little or no effects on the stock market.

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