# DECOMPOSING THE BID-ASK SPREAD: A CROSS-MARKET MODEL USING OPTIONS DATA


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## ABSTRACT

**We develop the cross-market model, an extension of Huang and Stoll (1997) that captures information from trade flows in the options market. The cross-market model reveals that the inclusion of information from the options market results in a significant increase in the estimated adverse information component. This increase is observed irrespective of the degree of option leverage. Further, intraday variation in stock bid-ask spread components are affected by the stock trade size and the extent of imbalance in information-based option trades.**



***JEL Classifications*: G10, G11**

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## I. Introduction

Market makers provide liquidity and facilitate trades by submitting bids indicating how much they are willing to pay for a security, and asks indicating their willingness to sell. The difference between the two prices is known as the bid-ask spread. Following Demsetz (1968) where the bid-ask spread reflects the price a trader must pay for immediate execution, a rich volume of research has emerged suggesting that the stock bid-ask spread is made up of three components relating to adverse information, inventory and order processing.[1]

Several statistical models have been developed that estimate the spread components and test implications of the theoretical models developed. These statistical models include: *covariance models* (see Roll (1984), Choi *et al*. (1988), Stoll (1989), and George *et al*. (1991)); *vector autoregressive models* (see Hasbrouck (1988, 1991)); and *trade-indicator models* (see Glosten and Harris (1988), Madhavan *et al*. (1997), and Huang and Stoll (1997)).

The seminal covariance models are highly stylized and restrictive. They were developed at a time when high frequency trading data was not commonly available for research purposes. Of the models that decompose the bid-ask spread into three separate components, the trade-indicator model of Huang and Stoll (1997) is typical. However, the original specification of this model is limited, as it focuses entirely on a

[1] Bagehot (1971), Stoll (1978), Copeland and Galai (1983), Glosten and Milgrom (1985), and Easley and O'Hara (1987) explain the bid-ask spread in terms of adverse information costs. Garman (1976), Stoll (1978), Amihud and Mendelson (1980), Ho and Stoll (1981), and Cohen *et al*. (1981) introduce inventory holding costs and Tinic (1972), and Stoll (1978) consider order processing costs.

single market for equities, and consequently ignores other relevant information flows emanating from the options market.

In reality, the stock and options markets are inter-related.[2] Black (1975) implies that some traders may be attracted to options markets. For example, several trading strategies exist for informed traders with positive (negative) news about a stock. They may choose to buy (sell) the stock, buy (sell) a call option written on the stock, or sell (buy) a put option until all information is fully reflected in security prices. Hence, adverse information about a stock may extend beyond the stock market to the options market. With this interrelatedness in mind, the current trade-indicator models developed potentially underestimate the adverse information component of the stock bid-ask spread.

Our paper addresses this omission by extending the Huang and Stoll (1997) trade-indicator model specification. The *cross-market model* developed adopts a simple structure to facilitate empirical implementation and provides a flexible framework to examine a variety of microstructure issues such as: the intra-day distribution of bid-ask spread components; the relationship between adverse selection and option leverage and the impact of stock trade size and information-based option trade flows on bid-ask spread components. The cross-market model is estimated using the underlying stocks of ten of the most active exchange-traded options in 2000 on the Australian Stock Exchange. Our cross-market model relies on information from both the stock and options markets. It captures the adverse information about a stock via the simultaneous trade flows in both the stock and options markets. Prior options literature

[2] Refer to option pricing models such as Black & Scholes (1973) where the value of the option is a function of the underlying stock price.

(see Black (1975), Anthony (1988), Figlewski (1989), Chan *et al.* (1993), and Fase (1994)) reveals evidence of information asymmetry in both the stock and options markets and supports the inclusion of an option trade indicator when modeling spread decomposition. In addition, Easley *et al*. (1998) find that the information-based option trading volume contains information about future stock price direction and identifies that the information flow from the options market to the stock market is faster. Consequently, spread decomposition models should incorporate all available information signals from both stock and options markets.

Our inclusion of an aggregate option trade indicator capturing trade flows observed in the options market is shown to significantly contribute to the measurement of the adverse information component of the stock bid-ask spread. By ignoring trade flows in the options market, previous frameworks relying solely on stock market trade flows to decompose the stock bid-ask spread understate the adverse information component of the stock bid-ask spread. Our empirical results reveal that 63.9% of the total adverse selection component of the stock spread of 12.2% is attributable to options market flow. By comparison, an implementation of Huang & Stoll (1997) yields a stock spread adverse selection component of only 8.0%. The cross-market model is then applied across intra-day sub-periods to examine inter-temporal differences of spread component estimates, as it is well known that the stock bid-ask spread varies across the trading day (see Chan *et al*. (1995a and 1995b)). We find adverse selection for the first hour of trading (14.2%) and 90 minutes before lunch (11.3%) is statistically similar, but there is a strong rise in the adverse selection component after the close of trading in the options market (16.3%) and a subsequent decline at the close of trade (12.0%). The cross-market model also takes into account variations in option leverage, as informed investors are expected to possess a higher propensity to trade highly levered options. However, tests on sub-samples based on leverage reveal that the components of the stock spread are not influenced by option leverage. Finally, the effect of trade size and option trade imbalance on the distribution of stock spread components estimated from the cross-market model is reported. This analysis considers the impact of liquidity and its consequence for spread decomposition estimates. Consistent with prior predictions, when there is significant size variation in a sequence of stock trades, the adverse selection component is higher. When trade flow is initially small in size in *t*-2 and then increases in *t*-1, inventory holding costs rise accordingly. We also observe an inverse relationship between the order processing component and trade size, with 35.5% (58.9%) of the spread attributable to order processing costs for large (small) trades. All of these extensions demonstrate the robustness of the cross-market model specification formulated to account for the interrelatedness of the stock and options markets.

## II. Developing the Cross-Market Model

The cross-market model is specified by adopting the same notation of Huang and Stoll (1997). To account for the inclusion of option securities, however, the use of superscripts of *s* and *o* are added to distinguish between stock and option variables, respectively. From Equation (1) in Huang and Stoll (1997), the change in the fundamental value of the stock, $\Delta V_t^s$, is modeled as follows:

$$\Delta V_t^s = V_t^s - V_{t-1}^s = \alpha^s \frac{S^s}{2} Q_{t-1}^s + \alpha^o \frac{S^s}{2} Q_{t-1}^o + \varepsilon_t^s , \qquad (1)$$

where,

$V_t^s$ is the unobservable fundamental value of the stock prior to bid and ask quotes posted at time *t*,

$V_{t-1}^s$ is the unobservable fundamental value of the stock prior to bid and ask quotes posted at time *t*-1,

$Q_t^s$ is the trade indicator for the stock transaction at time *t*. It is assigned a value of +1 if the trade is buyer initiated, or -1 if the trade is seller initiated,

$Q_{t-1}^o$ is the aggregate option trade indicator that summarizes the trade flows of options written on the stock observed in the *last period*. It is assigned a value of +1, 0, or -1 if the total value of positive option trades is larger than, equal to, or less than negative option trades transacted at the same time as or after the last stock trade at time *t*-1 but before the current stock trade at time *t*, respectively,[3]

$S^s$ is the constant traded bid-ask spread of the stock estimated by the model,

$\alpha^s$ is the proportion of the half-spread of the stock attributable to adverse information inferred from the trade indicator of the last stock trade, $Q_{t-1}^s$,

$\alpha^o$ is the proportion of the half-spread of the stock attributable to adverse information inferred from the aggregate option trade indicator of the last period, $Q_{t-1}^o$ and,

$\varepsilon_t^s$ is the public information shock.

Thus $\Delta V_t^s$ is a function of the private information revealed by the last stock trade, $\alpha^s \left(S^s/2\right)Q_{t-1}^s$, and the public information component, $\varepsilon_t^s$, as in Huang and Stoll (1997). Further, it also reflects the private information revealed by option trade flows observed in the last period, $\alpha^o \left(S^s/2\right)Q_{t-1}^o$.

[3] Buyer (seller)-initiated trades in calls and seller (buyer)-initiated trades in puts are classified as positive (negative) option trades that are associated with good (bad) news about the underlying stock as per Easley *et al.* (1998).

The trade sign, $Q_{t-1}^{s}$, is assumed to be random and unexpected by the stock market maker until the stock trade actually takes place in Equation (1). However, $Q_{t-1}^{s}$ may be influenced by the inventory equilibrating activities carried out by stock market makers, and the trading activities of the informed traders and option market makers. Huang and Stoll (1997) indicate that the inventory model based strategy of raising (lowering) the bid and ask quotes by market makers following the execution of a public buy (sell) order to encourage a subsequent sell (buy) order leads to a bias towards trade reversals and induces negative serial correlation in $Q_{t}^{s}$. The options-related literature also suggests that trade flows observed in the stock and options markets are related if informed traders transact in both markets. In addition, the empirical results of Kaul *et al*. (2002) indicate that option market makers use stocks to hedge their option positions. In other words, after accepting market buy orders for calls (puts), option market makers may hedge their reduced inventories in calls (puts) by buying (selling) the underlying stocks. Thus the expected value of $Q_{t-1}^{s}$ is characterized by last period's observed value, as indicated in Huang and Stoll (1997), as well as the aggregate option trade indicator, $Q_{t-2}^{o}$, summarizing the trade flows of options observed between the two consecutive stock trades at *t*-2 and *t*-1. The expected value is written as:

$$E\left(Q_{t-1}^{s} \mid Q_{t-2}^{s}, Q_{t-2}^{o}\right) = \left(1 - 2\pi^{s}\right)Q_{t-2}^{s} + \varphi^{o} Q_{t-2}^{o}, \tag{2}$$

where $\pi^{s}$ is the probability that the stock trade at *t*-1 is opposite in sign to the previous trade at *t*-2. If there are no inventory holding costs, the sign of a trade is unpredictable and $\pi^{s}$ equals 0.5. However, if market orders are influenced by the placement of the bid and ask, $\pi^s$ is expected to yield values greater than 0.5. $\varphi^o$ is the estimated coefficient of the aggregate option trade indicator. It equals zero if the trade flow in the options market does not affect the stock trade indicator. Alternatively, when $\varphi^o$ is significantly greater than zero, then either informed traders transact in both markets, or, option market makers use the underlying stock to hedge their option positions.

When option market makers have target inventory levels and use the placement of the bid and ask to induce inventory-equilibrating trades, the aggregate option trade indicator may be serially correlated. The potential presence of informed traders transacting in both markets suggests the following relationship for the expected value of $Q^o_{t-1}$ :

$$E\left(Q^o_{t-1} \mid Q^o_{t-2}, Q^s_{t-1}\right) = \left(1 - 2\pi^o\right)Q^o_{t-2} + \varphi^s Q^s_{t-1}, \tag{3}$$

where $\pi^o$ is the probability that the aggregate option trade indicator in period *t*-1 is of opposite sign to that in period *t*-2. If there is no target inventory level, the sign of the aggregate option trade indicator is unpredictable and $\pi^o$ equals 0.5. Under the inventory models, the sign of the aggregate option trade indicator is expected to reverse over time so that $\pi^o$ exceeds 0.5. $\varphi^s$ is the estimated coefficient of the stock trade indicator and equals zero if the trade flow in the stock market does not affect the option trade indicator. Alternatively, if informed traders transact in both markets, the estimated value of $\varphi^s$ should exceed zero.[4]

Once the factors affecting the stock and option trade indicators are identified, the expected component is removed to ensure that the revision in fundamental values is caused by trade innovations and unexpected public information releases. Hence Equation (1) becomes:

$$V_t^s - V_{t-1}^s = \alpha^s \frac{S^s}{2}\left[Q_{t-1}^s - \left(1 - 2\pi^s\right)Q_{t-2}^s - \varphi^o Q_{t-2}^o\right] + \alpha^o \frac{S^s}{2}\left[Q_{t-1}^o - \left(1 - 2\pi^o\right)Q_{t-2}^o - \varphi^s Q_{t-1}^s\right] + \varepsilon_t^s, \quad (4)$$

where $Q_{t-1}^s - \left(1 - 2\pi^s\right)Q_{t-2}^s - \varphi^o Q_{t-2}^o$ is the unexpected trade innovation in the stock and $Q_{t-1}^o - \left(1 - 2\pi^o\right)Q_{t-2}^o - \varphi^s Q_{t-1}^s$ the unexpected trade innovation in the option. Equation (4) is now a revised specification of Equation (1) that includes an augmented set of more timely information derived from the options market trade flow to explain the change in the fundamental value of the stock. Specifically, the cross-market model allows for the interaction between the stock and options markets and introduces an option trade innovation that reveals information about the underlying stock after the last stock trade at *t*-1, but before the latest stock trade at *t*. Equation (4) may be re-interpreted when examining information asymmetries between the stock and options markets. If informed traders transact in the options market, their trading activities are

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[4] We are grateful to Mahen Nimalendran for suggesting the use of an option trade indicator in Equation (2) and a stock trade indicator in Equation (3) to capture the interaction between the stock and options markets. In Equation (3), note that the stock trade indicator, $Q_{t-1}^s$, is a lagged variable based on the stock trade executed at time *t*-1 and observed before the aggregate option trade indicator, $Q_{t-1}^o$, which is determined by the option trades executed between the two stock trades from *t*-1 to *t*.

captured by the option trade innovation and the estimated value of $\alpha^o$ should be positive and significantly different from zero. Equation (4) differs from existing causality studies examining lead/lag relationships between the two markets in the following aspects. First, a more timely measure of *information-based* option trading volume instead of option transaction prices (see Stephan and Whaley (1990)) or plain option trading volume (see Anthony (1988)) is used to infer information about the underlying stock.[5] Second, the trading volumes in different option series written on the same underlying stock are pooled together to generate the option trade indicator and reflect the information content of the options market. Existing causality studies typically investigate the lead/lag relationship between individual option series (as if each series is independent of one another) and the underlying stock in spite of the fact that the price and volume of an individual option series may not be representative of the 'collective' information on the underlying stock.[6]

When empirically estimating the cross-market model, the unobservable change in $V_t^s$ must be removed using a process similar to Huang and Stoll (1997). The first difference of the empirical representation of the inventory models of Stoll (1978) and Ho and Stoll (1981) is combined with Equation (4) to remove $\Delta V_t^s$:

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[5] Chan *et al*. (1993) demonstrate that the use of transaction prices can bias the result towards a leading effect from common stocks to options with small deltas due to the tick size restriction.

[6] It is quite common that the price of a call (put) moves in the opposite (same) direction to that of the underlying stock. Bakshi *et al*. (2000), for example, find that when the S&P 500 index moves up and down, the index call (put) option is found to move in the opposite (same) direction in 13.9% (13.4%) of the sample observations collected at hourly intervals.

$$M_t^s = V_t^s + \beta^s \frac{S^s}{2} \sum_{i=1}^{t-1} Q_i^s \ , \qquad (5)$$

where

$M_t^s$ is the quote midpoint, or the average of the bid and ask prices at time t,

$\beta^s$ is the proportion of the half-spread of the stock attributable to inventory holding costs and,

$\sum_{i=1}^{t-1} Q_i^s$ is the measure of the cumulative inventory position from the time the market opens through the trade at time *t*-1.

Finally, to facilitate the estimation of the bid-ask spread components, the empirical representation of the cross-market model is obtained by replacing the traded spread by observed bid-ask spreads in corresponding periods:

$$\Delta M_t^s = \left(\alpha^s + \beta^s\right)\frac{S_{t-1}^s}{2} Q_{t-1}^s - \alpha^s \frac{S_{t-2}^s}{2}\left(1 - 2\pi^s\right) Q_{t-2}^s - \alpha^s \frac{S_{t-2}^s}{2} \varphi^o Q_{t-2}^o + \alpha^o \frac{S_{t-1}^s}{2} Q_{t-1}^o - \alpha^o \frac{S_{t-2}^s}{2}\left(1 - 2\pi^o\right) Q_{t-2}^o - \alpha^o \frac{S_{t-1}^s}{2} \varphi^s Q_{t-1}^s + e_t^s . \qquad (6)$$

Finally, the adverse information, inventory and order processing components of the stock bid-ask spread are measured by ($\alpha^o$ + $\alpha^s$), $\beta^s$, and [1 – ($\alpha^o$ + $\alpha^s$) - $\beta^s$], respectively. The values of these parameters, the two trade flow correlation coefficients, $\varphi^o$ and $\varphi^s$, and the two trade-sign reversal probabilities, $\pi^s$ and $\pi^o$, are obtained by simultaneously estimating Equations (2), (3) and (6).

## III. Data Description

The stock and options data are sourced from the on-line and real-time Stock Exchange Automated Trading System (SEATS) and 'CLICK'™ databases of the Australian Stock Exchange (ASX), respectively. The dataset consists of intra-day data for ten stocks with the most active exchange-traded options based on trading volume for the year 2000. All trades are time-stamped to the nearest second. Only SEATS trades recorded during normal stock market operations from 10am to 4pm are used and important feature of the ASX electronic limit order market is that buyer versus seller initiated trade indicators are directly recorded by SEATs for all trades (excluding cross trades), thus eliminating the need to rely upon a classifying algorithm such as Lee & Ready (1991). The ASX market is continuously traded and market orders are executed against limit orders, ranked on strict price-time priority. All cross trades are excluded as the trade indicator variable is not specified for this trade type. As this market opens and closes with an auction, we also exclude the opening and closing recorded trades. Several filters are applied to ensure clean data. A buyer (seller) initiated trade is removed if the transaction price is less than (greater than) the best ask (bid).[7] Further,

[7] The Australian stock market is an order-driven market whereby a market order to buy is always matched with the latest best limit order to sell. If the volume of the market order is less than or the same as that of the limit order at the top of the queue, the trade price is the best ask price. Alternatively, if the volume of the market order exceeds that of the best limit order, a number of limit orders in the queue will be matched and executed simultaneously until the market order is filled. Thus it is possible to observe a buyer initiated trade with a transaction price above the best ask or a seller initiated trade with a transaction price below the best bid price.

to ensure that the data sample is free from recording errors, trades with unusual transaction prices or quotes are also removed.[8]

In the case of option data only trades undertaken during normal trading hours (10am-12:30pm and 2pm-4pm) are retained. Further filters are applied, in particular, all opening and closing trades, cross trades, late and overnight trades are excluded, along with records with zero premiums or excessive premiums greater than $8. CLICK trades occurring on expiration dates and ex-dividend dates of underlying stock are also removed. Additionally, the far-in and far-out-of-the-money options are severely infrequently traded and these trade flows are not used to compute $Q_t^o$.[9] Finally, there must be at least a total of 50 daily trades in the retained option series to be included in the dataset.

Insert Table 1 Here

Table 1 shows the cumulative distribution of stock trades by trade size. Based on the cumulative percentages, the average trade size ranges between A$10,000-

[8] A record is considered unusual if the transaction price is greater than $100 or less than $0.10 since the stocks selected in this study have never gone beyond $100 or fallen below $0.10 during the sample period. If the difference between price and midpoint is greater than $5, if the bid price is equal to or larger than the ask price, or if the bid-ask spread is greater than $2 or 25% of the midpoint, the record is eliminated.

[9] Defining M as the difference between the stock price (strike price) and the strike price (stock price) for calls (puts) and I as the strike price interval of the stock option, an option is classified as far-out-of-the-money if M ≤ –2.5I and far-in-the-money if M > 2.5I. In the year 2000, for the sample stock options selected in this study, these two categories of options accounted for 8% of the total number of option trades.

$30,000 for individual stock in the sample. The distribution of stock trades is negatively skewed, as the majority of all trades (54.92%) are less than $15,000 in value and only a small proportion of all trades (9.75%) exceed A$100,000. Of the ten stocks selected, TLS and NAB are the most active with more than a quarter of a million trades whereas NDY is the least active, trading only 68,527 times per year.

Insert Table 2 Here

Table 2 reports the average quoted midpoint and the average bid-ask spread (calculated as a volume weighted measure) for each individual stock. The data is also presented according to trade size where a small trade is defined as less than $100,000 otherwise it is treated as a large trade. There is little difference in the size of the bid-ask spread between small and large trades on average and across individual stocks. This observation suggests that the stock market has considerable depth and that limit order traders keep bid-ask spreads narrow. Thus, traders do not necessarily wait for even narrower bid-ask spreads before submitting large market orders.

Across intraday periods, we observe a general pattern that the bid-ask spread is widest in the first hour of trading and subsequently declines throughout the day. This spread pattern is apparent in both average bid-ask spreads and for bid-ask spreads across individual firms. The Kruskal-Wallis tests of difference between average bid-ask spread for the period 10-11am is higher and significantly different from all other time periods with chi-squared values ranging from 3.94 (at 5% significance) to 14.86 (at 1% significance). Wider bid-ask spreads at the open that reflect greater price uncertainty on the NYSE and CBOE are also observed in other international markets (see Chan *et al*. (1995b)). Chan *et al*. (1995a) postulate that during the open of

NASDAQ, market-makers post wider bid-ask spreads to protect themselves from information asymmetry during price discovery. The gradual decline in bid-ask spreads during the remaining hours of trading is also consistent with Madhavan (1992) indicating that limit order traders gradually infer equilibrium prices and resolve the initial information asymmetry from transaction price histories.

However, in contrast to previous findings, the average bid-ask spread in the final hour of trading for our sample does not decline sharply as observed in the CBOE nor widen significantly as in the case of the NYSE. This is perhaps not surprising given the absence of a true market-maker on the ASX and the reduced importance of inventory holding costs.[10]

Table 3 reports the average summary statistics related to trading volume for both the stock and options data. Panel A considers the stock trading. The sample consists of a daily average of 733 trades worth A$29.2M in the 10 largest stock with active option trading. TLS has the highest share turnover in terms of number of trades and number of shares traded per day, however, NCP experiences the highest dollar value in turnover measured both in terms of total dollars transacted and the average dollar value per trade per day. MIM and NDY are the least traded stock in the sample with fewer than 428 and 272 trades per day respectively, representing a total turnover

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[10] For example, NYSE specialists are restricted from executing orders on only one side of the bid-ask spread. Chan *et al.* (1995a) suggest that severe inventory imbalances may occur towards the close. Consequently, NYSE specialist may widen bid-ask spreads approaching market close to discourage further trades that may worsen their inventory position. Alternatively, in a competitive market with multiple market-makers Chan *et al.* (1995b) argue that CBOE bid-ask spreads may narrow sharply towards the close if market markers who hold short (have excessive) inventory positions outbid each other by posting higher bids (lower asks) to restore target inventory levels.

of A$6.96M and A$4.13M respectively. The comparable options trading statistics are presented in Panel B. BHP and NAB stock options register the highest turnover in both call and put trades per day. Despite being ranked third in terms of number of trades, the total value of NCP trading is higher in calls over the sample period. NDY, MIM and QAN stock options are the least active with less than 26 call option trades and a smaller number of put trades. Average dollar values per trade for the least traded options are approximately 1/3 of the value of the highest traded options.

Insert Table 3 Here

## IV. Results

*The Cross-Market Model*

We apply the Huang and Stoll (1997) model with induced serial correlation in stock trade flows to estimate the bid-ask spread components and the probability of a stock trade reversal using individual trades.[11] Our results are presented in Table 4. The parameter estimates indicate that the portion of the spread due to adverse selection is 8.0%, while inventory holding costs amount to 25.4% of the stock spread, implying an average order processing cost of 66.6%. Although the ASX is an electronic limit

[11] Following Huang and Stoll (1997), we apply their model to another set of data that combines sequential trades with the same trade indicator, trade and quote prices. Despite observing a larger average value of $\pi^s$ at 0.85, the average value of $\alpha^s$ drops to -19.01% and the average value of $\beta^s$ rises to 0.98, thus implying that stock bid-ask spreads arise strictly as a result of inventory holding costs. Although combining trades could mitigate the positive serial correlation effect caused by broken orders, this practice could also inadvertently aggregate independent trades. Furthermore, since the Australian stock market is an order-driven market, quotes are firm, updated continuously, and known by the traders instantaneously. Thus we consider only raw data in all subsequent analyses.

order driven market without a designated stock market maker, the estimates of bid-ask spread components are similar to those reported in Huang and Stoll (1997) where adverse selection is 9.6% and inventory holding costs are 28.7% of the total bid-ask spread of NYSE stock. A significant inventory component in an order-driven market with no official market-makers is also observed in Japanese stock markets (see Lindsey and Schaede (1992)).[12] Further, the average probability of a stock trade reversal is 22.1% for the 10 ASX listed stocks with the most actively traded options. For individual firms this statistic ranges from 7.1% to 30.7% and is considerably lower than comparable NYSE evidence reported in Huang & Stoll (1997, Table 6, p.1020) where the likelihood of a stock trade reversal is 86.8%. However, given the ASX market structure, the likelihood of trade reversal is expected to be considerably lower due to the absence of formal market makers for stocks, resulting in less emphasis being placed on inventory equilibria.

Insert Table 4 Here

Table 5 presents the results of the cross-market model that incorporate trade flow information from the options market. Additional coefficient estimates are reported for the option indicator variable, $\alpha^o$, the two trade flow correlation coefficients, $\varphi^o$

[12] Japanese securities firms operating in an order-driven market engage in market-making activities by submitting quotes on the opposite side of customer's orders. Lindsey and Schaede argue that large securities firms handling a high volume of transactions from a set of diversified customers can submit simultaneous buy and sell limit orders thus setting the effective bid-ask spread. This implies that the spread of a security traded in an order-driven market may be influenced by potential inventory risk.

and $\varphi^s$, and the option trade-sign reversal probability, $\pi^o$.[13] The impact of trade flow information from the stock and option markets is disaggregated in Panel A. On average, 4.4% of the stock bid-ask spread is attributed to adverse information due to the trade flows observed in the stock market, while a further 7.8% of the stock bid-ask spread relates to trade flows observed in the options market. This result is also found at the individual stock level, where all of the $\alpha^o$ coefficients, representing the adverse information component due to the trade flows in the options market are positive and statistically different from zero at the 5% significance level. Note that the estimate of the aggregate adverse information component consisting of the sum of $\alpha^o$ and $\alpha^s$ of 12.2% is larger than the adverse selection component reported in Table 4 of 8.0%. We conclude that applying Huang and Stoll (1997) without regard for related trade flows in the options market severely underestimates the adverse information component in our dataset by 52.5%. We find that inventory holding costs and the probability of a stock trade reversal are largely unaffected by the inclusion of option trade flow data. The inventory holding costs account for 27.5% of the stock bid-ask spread and the probability of a stock trade reversal is 21.5% for the sample.[14] This statistic reveals a high level of trade persistence where the propensity that a buyer initiated trade is followed by another buyer initiated trade is 78.5%. The higher than expected trade persistence is explained by market structure differences as there is no defined market marker on the ASX stock market, consequently, there is the possibility that large trades

[13] These coefficients have been obtained from the simultaneous estimation of equations (2), (3) and (6) from Section II.

[14] This evidence is consistent with Sawtell and Woo (2004) where an implementation of Huang & Stoll (1997) on ASX share repurchases yields a trade reversal probability of 24.3%.

submitted to SEATS may be broken down into a series of small trades. What is quite revealing is that despite the lower trade reversal statistic in the stock market, the average probability of trade reversal is 48.7% in the options market which reflects the multi-dealer option market structure.

Insert Table 5 Here

The theoretical inventory model of Stoll (1978) proposes that market makers strategically place quotes to restore their optimal inventory positions. This activity is expected to induce negative serial correlation in the trade flow (i.e. trade reversal). The absence of formalized market makers in the ASX stock market would predict less serial correlation (positive) between stock trade flows on the ASX, all other things equal. In contrast, the ASX options market allows for one or more market makers who may be concerned about their inventory positions. Consequently, we expect the probability of trade persistence to be larger in the stock market compared to the options market. Our empirical results confirm that trade persistence is 1.5 times higher in the ASX stock market relative to the options market.

To allow for the prospect of cross-market interrelatedness of the trade flows in the stock and options market $\varphi^s$ is estimated to measure the impact of stock trade flows on subsequent option trading whereas $\varphi^o$ reflects the converse. The estimated average coefficient of the stock trade indicator, $\varphi^s$, is 0.7% and reflects a buyer-initiated trade in the stock market leading to a period of net positive options trading (the total value of long calls and short puts exceeding that of short calls and long puts). All $\varphi^s$ coefficients for individual stock are statistically different from zero at the 5% level of significance. This result reveals the existence of informed trading in both stock and options markets where a buy (sell) order in the stock market is followed by a period of net positive (negative) option trading. Correspondingly, the average coefficient of the option trade indicator, $\varphi^o$, is -13.4%. This negative coefficient implies that net positive (negative) option trading is followed by sell (buy) orders in the stock market. All coefficients for $\varphi^o$ for individual stock are negative and significant at 5%. The sign on the coefficient of $\varphi^o$ indicates that trade flows from the options market are negatively correlated with trade flows in the stock market.

*Stock Bid Ask Spread Components: Intra-Day Analysis*

The estimation of the cross-market model is also applied to four intra-day periods to permit an investigation of bid-ask spread components over time. Table 5 Panel B reports the intra-day distribution of stock bid-ask spread components using the cross-market model during the four intra-day periods from 10-11am, 11-12:30pm, 2-3pm and 3-4pm, respectively.

The adverse information components of the stock bid-ask spread attributed to stocks and options display similar intra-day patterns. The adverse selection component for stocks and options are 4.7% and 9.5%, respectively, for the first hour of trading from 10-11am. These coefficients decline in the next 90 minutes of trading to 3.8% and 7.5% and later increase from 2-3pm to 7.3% and 9.0% and then decline in final hour of trading to 4.1% and 7.9%, respectively. Notice that the adverse selection component due to options trade flow is higher in periods following a disruption to continuous trading in the options market, registering its highest value at the start of trading (after a long overnight trading cessation) and second highest value after the designated lunch break in the options market. However, none of these coefficients are statistically different at the 10% level of significance (Kruskal-Wallis), hence the adverse selection component is not statistically different across all sub-period comparisons.

The addition of option market trade flows provides additional explanatory power to the cross-market model. The sum of the two adverse information components, $\alpha^s + \alpha^o$, is 14.2% in the first hour of trading, 11.3% in the next 90 minutes, 16.3% during the period from 2-3 p.m., and 12.0% in the last trading hour.

The inventory component of the stock bid-ask spread is not statistically different across sub-periods, but this component does not have a particularly large range over the trading day. It takes on an initial value of 26.2% during the first hour of trading, ranges between 27.0 – 24.7% between 10 and 3pm then eventually rises to 28.9% in the final hour of trading. Finally, the average order processing component is relatively stable, ranging from 59.0% to 61.7% across the trading day.

*Stock Bid Ask Spread Components: Option Leverage and Adverse Information*

Easley *et al.* (1998) theorize that increased leverage in the options market results in more informed traders using options. However, they do not empirically test this proposition. Informed traders are expected to have a higher propensity to trade options with higher leverage (see Black (1975)) as an investment in a levered security offers the highest rate of return per dollar invested. Extending this concept to the cross-market model, we expect to find that high levered options are associated with higher adverse information components, all other things equal. The cross-market model is applied to three sub-samples that vary in terms of the degree of option leverage (low, moderate and high). For example, out-of-the-money call options and in-the-money put options are highly leveraged, whereas all at-the-money options are moderately levered and in-the-money call options and out-of-the money put options are regarded as having low leverage. Correspondingly, the influence of leverage can be incorporated in the cross-market model as follows:

$$Q_{t-1}^{s} = \left(1 - 2\pi^{s}\right)Q_{t-2}^{s} + \varphi^{o,lev}Q_{t-2}^{o,lev} + \zeta_{t-1}^{s} \tag{7}$$

$$Q_{t-1}^{o,lev} = \left(1 - 2\pi^{o,lev}\right)Q_{t-2}^{o,lev} + \varphi^{s}Q_{t-1}^{s} + \zeta_{t-1}^{o,lev} \tag{8}$$

$$\begin{aligned}\Delta M_{t}^{s} = {} & \left(\alpha^{s} + \beta^{s}\right)\frac{S_{t-1}^{s}}{2}Q_{t-1}^{s} - \alpha^{s}\frac{S_{t-2}^{s}}{2}\left(1-2\pi^{s}\right)Q_{t-2}^{s} - \alpha^{s}\frac{S_{t-2}^{s}}{2}\varphi^{o}Q_{t-2}^{o,lev} + \alpha^{o,lev}\frac{S_{t-1}^{s}}{2}Q_{t-1}^{o,lev} \\ & - \alpha^{o,lev}\frac{S_{t-2}^{s}}{2}\left(1-2\pi^{o,lev}\right)Q_{t-2}^{o,lev} - \alpha^{o,lev}\frac{S_{t-1}^{s}}{2}\varphi^{s}Q_{t-1}^{s} + e_{t}^{s}.\end{aligned} \tag{9}$$

$Q_{t-1}^{o,sl}$ is assigned a value of +1, 0, or –1 if during the period the total value of positive option trades in the next-in and further-in-the-money calls, and next-out and further-out-of-the-money puts is larger than, equal to, or less than the total value of negative option trades in the same groups of options,

$Q_{t-1}^{o,ml}$ is assigned a value of +1, 0, or –1 if during the period the total value of positive option trades in the at-the-money calls and puts is larger than, equal to, or less than the total value of negative option trades in the same groups of options, and

$Q_{t-1}^{o,ll}$ is assigned a value of +1, 0, or –1 if during the period the total value of positive option trades in the next-out and further-out-of-the-money calls, and next-in and further-in-the-money puts is larger than, equal to, or less than the total value of negative option trades in the same groups of options.[15]

The empirical results reported in Table 6 show little impact of option leverage on the distribution of common stock bid-ask spread components.[16] Panels A, B and C present the results of the cross-market model when the value of the aggregate option

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[15] Define M as the difference between the stock price (strike price) and the strike price (stock price) for calls (puts), and I as the strike price interval of the stock option. An option is classified as further-out-of-the-money if –2.5I < M ≤ –1.5I, next-out-of-the-money if –1.5I < M ≤ –0.5I, at-the-money if –0.5I < M ≤ +0.5I, next-in-the-money if 0.5I < M ≤ 1.5I, and further-in-the-money if 1.5I < M ≤ 2.5I.

[16] To ensure that option liquidity does not confound the results, if on any day there are less than 20 trades in either leverage group of options, the data collected on that day is removed from the sample. This filtering procedure explains the reduced number of observations in Table 6.

trade indicator variable, $Q_t^{o,lev}$, is based on low, medium and high leverage options, respectively. Our results show little statistical difference between the sub-samples based on option leverage, and this observation is true for both the mean statistic for the sample and for individual stock. These results contradict Easley *et al.* (1998) as the adverse information component is not significantly different according to option leverage either across the entire sample or for individual stocks.

Insert Table 6 Here

*Stock Bid Ask Spread Components: Stock Trade Size Effect*

As the cross-market model is premised on assumptions underlying Huang and Stoll (1997), it may not be realistic to assume that all trades are of the same size.[17] As a robustness check, we consider the impact of stock trade size on components of the stock spread. Two trade sizes are considered where a trade size of A$100,000 or more is classified as large, whereas all other trades are classified as small. The cross-market model accommodates variations in trade size as follows:

$$Q_{t-1}^{s,j} = \left(1 - 2\pi^{s,ij}\right)Q_{t-2}^{s,i} + \varphi^{o}Q_{t-2}^{o} + \zeta_{t-1}^{s,ij} \quad (10)$$

$$Q_{t-1}^{o} = \left(1 - 2\pi^{o}\right)Q_{t-2}^{o} + \varphi^{s,j}Q_{t-1}^{s,j} + \zeta_{t-1}^{o} \quad (11)$$

$$\Delta M_t^{s,ij} = \left(\alpha^{s,ij} + \beta^{s,ij}\right)\frac{S_{t-1}^{s,j}}{2}Q_{t-1}^{s,j} - \alpha^{s,ij}\frac{S_{t-2}^{s,i}}{2}\left(1-2\pi^{s,ij}\right)Q_{t-2}^{s,i} - \alpha^{s,ij}\frac{S_{t-2}^{s,i}}{2}\varphi^{o}Q_{t-2}^{o} + \alpha^{o}\frac{S_{t-1}^{s,j}}{2}Q_{t-1}^{o} - \alpha^{o}\frac{S_{t-2}^{s,i}}{2}\left(1-2\pi^{o}\right)Q_{t-2}^{o} - \alpha^{o}\frac{S_{t-1}^{s,j}}{2}\varphi^{s,j}Q_{t-1}^{s,j} + e_t^{s,ij} \quad (12)$$

[17] In Huang and Stoll (1997) trade volume is not directly modeled. There is evidence to suggest that trade size influences spread, see Lin *et al.* (1995) where the adverse selection component increases significantly and monotonically as stock trade size increases.

where *i* and *j* are the stock trade size categories at time *t*-2 and *t*-1, respectively. Knowledge of the stock trade indicator is required for the two previous periods and the cross-market model is then estimated across four subsets of data reflecting combinations of trade size (preserving the trade sequence) observed across two time frames, *t*-2 and *t*-1.[18]

Table 7 reveals the impact of stock trade size on the distribution of the bid-ask spread components of common stocks. Panels A-D present the results of the cross-market model for subsets of data consisting of large-small (LS), small-small (SS), small-large (SL) and large-large (LL) stock trades observed between period *t*-2 and *t*-1 respectively.

Insert Table 7 Here

Clusters of similarly sized trades do not appear to affect the adverse selection component across sub-samples to any great extent. However, when there is significant variation in trade size across consecutive trades between *t*-2 to *t*-1, the adverse selection component is higher and statistically different at 1% based on Kruskal-Wallis tests of significance, as in the case of SS-LS, SL-LS, LS-LL. This result is believed to be affected by LS trade sequences that place greater emphasis on potential inventory risks (there is a higher inventory holding cost component). The lower adverse selection component by definition will be lowered when there is a higher inventory holding cost component (and for some cases takes on negative values for individual stock). Panel A indicates for the LS sub-sample (that is a large stock trade followed by a small stock

[18] Based on the distribution of stock trades reported in Table 1, $100,000 is used as the cutoff to distinguish small and large stock trades in this study.

trade) the adverse selection component is on average -0.1%, whereas, the corresponding inventory holding cost component is 47.6%. Panels B, C and D report comparable statistics for the SS, SL and LL stock trade sizes when the adverse selection coefficients are 4.6%, 8.0% and 11.2% respectively, monotonically increasing with trade size. Correspondingly, the adverse selection component attributed to options for the same sub-samples is 7.9%, 13.0% and 9.6%. The higher adverse selection component attributed to the SL sub-group suggests that an increase in trade size from small to large increases the chance of transacting with higher levels of information asymmetry. It appears that the stock market attaches a higher probability of informed trading given large and recent stock trades.[19] These results are consistent with Lin *et al.* (1995) and the direct relationship observed between stock trade size and the adverse information component documented in Huang and Stoll (1997).[20]

We find comparably lower average inventory holding costs in the SS sub-sample (28.5%) and an appreciable increase in these costs for the LL sub-sample (43.7%). Note that both the SS and LL sub-samples are characterized by no variation in sequential stock trade size. A marginal increase in average inventory holding costs occurs when trade size varies between large and small categories, as seen exhibited by

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[19] The upstairs trade in the NYSE is similar to the special crossing in the ASX which involves a minimum consideration that ranges between $1,000,000 and $5,000,000. Details of a special cross trade are entered into SEATS only after the trade has taken place and the price may be at any agreed value regardless of the current market price. However, all cross trades are removed in this study to ensure consistency of market structure.

[20] Huang and Stoll (1997) explain that a large stock trade in the NYSE is usually pre-negotiated upstairs and preceded by transactions that convey information about the block. Consequently, a large stock trade may not contain much information to influence subsequent quotes.

the SL sub-sample (46.2%) and the LS sub-sample (47.6%). Further note that there are significantly higher inventory holding costs components when a large sized stock transaction takes place no matter the sequence of trade. Larger sized trades may be difficult to counterbalance, implying that more than one subsequent trade may be necessary to eliminate the inventory imbalance arising from the large trade. Alternatively, inventory holding costs might need to be averaged across a number of sequential trades, and may not be adequately captured across only two trading times.

Contrary to results presented in Table 5, the order processing costs fall below inventory holding costs when the stock trade sequence finishes with a large trade. Table 7, Panels C and D reveal that 32.8% and 35.5% of the stock bid-ask spread is attributed to order processing costs when the stock trade sequences are SL and LL, respectively. In Panels A and B, order processing costs are larger when the stock trade sequences are LS and SS, some 51.0% and 58.9% respectively. Hence, there is an inverse relationship between the order processing component and trade size which is expected as execution costs are generally fixed.

*Stock Bid Ask Spread Components: Option Trade Imbalance Effect*

We also study the potential impact of option trade imbalances on the distribution of stock spread components, using two option trade imbalance categories large (defined as greater than A$20,000) and small (the remainder). The modified cross-market model allowing for options trade imbalance is:

$$Q^{s}_{t-1} = (1 - 2\pi^{s})Q^{s}_{t-2} + \varphi^{o,x}Q^{o,x}_{t-2} + \zeta^{s}_{t-1} \quad (13)$$

$$Q^{o,y}_{t-1} = (1 - 2\pi^{o,xy})Q^{o,x}_{t-2} + \varphi^{s}Q^{s}_{t-1} + \zeta^{o,xy}_{t-1} \quad (14)$$

$$\Delta M_t^s = \left(\alpha^s + \beta^s\right)\frac{S_{t-1}^s}{2}Q_{t-1}^s - \alpha^s\frac{S_{t-2}^s}{2}\left(1-2\pi^s\right)Q_{t-2}^s - \alpha^s\frac{S_{t-2}^s}{2}\varphi^{o,x}Q_{t-2}^{o,x} + \alpha^{o,xy}\frac{S_{t-1}^s}{2}Q_{t-1}^{o,y}$$

$$- \alpha^{o,xy}\frac{S_{t-2}^s}{2}\left(1-2\pi^{o,xy}\right)Q_{t-2}^{o,x} - \alpha^{o,xy}\frac{S_{t-1}^s}{2}\varphi^s Q_{t-1}^s + e_t^{s,xy} \qquad (15)$$

where $x$ and $y$ are the option trade imbalance categories at time $t$-2 and $t$-1, respectively. The model is estimated for four subsets of data associated with the four option trade imbalance sequences observed at $t$-2 and $t$-1, namely small to small, small to large, large to small and large to large. The results are reported in Table 8.[21] Note that three stocks (MIM, NDY and QAN) are dropped from the sample due to data limitations.

Insert Table 8 Here

When a small imbalance in information-based option trades is followed by a large imbalance (SL) as in Table 8 Panel C, the estimated coefficient of the option trade indicator (7.8%) dominates the adverse selection component based on stock trade only (1.2%), suggesting that the majority of the adverse information component is inferred from the trade flows of the options market. However, the converse is true when a large imbalance in information-based option trades is followed by a small imbalance (LS) where the adverse selection component based on stock (13.2%) is larger by 3.5 times the adverse selection from option trading (3.8%) as reported in Panel A. These results imply that larger imbalances in information-based option trades result in a larger adverse selection component.

[21] The imbalance in information-based option trades is classified as large if it exceeds $20,000. Similar results are obtained when different cutoffs at $5,000, $10,000, and $15,000 are used to partition the data.

Recall in Table 5, we presented results of the cross-market model where the sum of the adverse selection from both options and stock markets exceeded estimates directly from an implementation of the Huang & Stoll model that did not explicitly account for trade flow in the options market. We find that the inclusion of the options trade flow is particularly important in the determination of adverse selection, as the cross-market model estimates that on average, 63.9% of the overall total adverse selection of 12.2% is attributable to options market trade flow. A more detailed analysis provided in Table 8 that takes into consideration the size of the option trade imbalance and reveals that adverse selection is influenced by the size of the option trade imbalance. For SL, options explain 86.7% of the total adverse selection component, compared with 60.9% for the SS category, but only 22.4% of the LS category. For the LL category, the adverse selection components for both stocks and options are negative in sign. This result appears to be largely a reflection of the relative importance of inventory holding risk in two stocks (NCP and CWO).

Our results also reveal that a large portion of the stock bid-ask spread is attributed to inventory holding costs when a large imbalance in information-based option trades is observed in the previous trading period. In Panel C, the average inventory component is 61.3%. This finding compares to significantly lower average inventory components of 22.2% in Panel A (for LS) and 35.3% reported in Panel B relating to SS option trade sizes. Liquidity providers for the stock market may require a larger inventory component to offset potentially larger variation in future inventory levels. Our findings are consistent with Kaul *et al*. (2002) indicating that option market makers use stocks to hedge their option positions.

## V. Summary and Conclusions

We extend the Huang and Stoll (1997) model by constructing a trade-indicator model incorporating trade flows observed in the options market to estimate the adverse selection, inventory holding costs and order processing components of stock bid-ask spreads. This research contributes to the theoretical literature in a number of important ways. The development of the cross-market model takes into account the findings of the options-related literature and improves the measurement of the adverse information component of a common stock by incorporating the trade flows observed in the options market. Our empirical findings reveal that the Huang and Stoll model routinely underestimates the adverse selection component of stock bid-ask spreads. Further, the cross-market model provides an alternative method (to the causality approach) of testing for the presence of informed trading in the options market and studying the interaction between the stock and options markets. We introduce option trade indicators to estimate the probability of a trade reversal in the stock market, and stock trade indicators to estimate the probability of trade reversal in the options market. The cross-market model characterizes interaction between the stock and options market trade flows and information. In particular, when options trade flow is explicitly included in the cross-market model, we find that the adverse selection component is higher than when this information is not used. Adverse selection is also affected by the sequence of trade size in both stock and options markets, but invariant to the level of options leverage. When options with different degrees of leverage are used to compute the aggregate option trade indicator of the cross-market model, we find little difference in the size of the estimated adverse information component of the stock bid-ask spreads associated with option trade flows, suggesting that there is no information asymmetry among options with different degrees of leverage.

The trade size of both stock and option trades are found to influence stock bid-ask spread components. When large variations in stock trade sizes occur, especially when the last trade is large, a larger estimated adverse information component of the stock bid-ask spreads is obtained. This finding suggests that the market attaches a higher probability of informed trading for a stock trade that is both recent and large in terms of trade size. Finally, the cross-market model provides a more realistic setting that portrays the inter-relatedness of both stock and options markets where potential cross-market information effects can be explored in greater detail.

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**TABLE 1. Cumulative Distribution of Stock Trades.**

| Value per trade | TLS | NAB | CWO | NCP | BHP | CBA | WMC | QAN | MIM | NDY | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| < $1000 | 4.38 | 3.99 | 4.30 | 4.47 | 4.62 | 4.35 | 4.72 | 6.79 | 7.25 | 8.37 | 5.32 |
| < 5000 | 26.83 | 18.70 | 25.90 | 14.57 | 16.27 | 20.93 | 20.67 | 41.12 | 41.19 | 43.52 | 26.97 |
| < 10000 | 46.85 | 32.85 | 45.38 | 25.15 | 30.01 | 35.09 | 39.01 | 62.81 | 64.07 | 67.34 | 44.86 |
| < 15000 | 56.28 | 45.45 | 56.41 | 33.19 | 36.79 | 45.34 | 49.26 | 72.74 | 76.29 | 77.49 | 54.92 |
| < 20000 | 62.49 | 50.46 | 63.31 | 39.52 | 46.39 | 50.57 | 57.22 | 80.41 | 81.01 | 82.59 | 61.40 |
| < 25000 | 66.27 | 57.67 | 69.87 | 46.16 | 50.79 | 54.98 | 63.09 | 83.77 | 85.42 | 86.35 | 66.44 |
| < 50000 | 78.27 | 72.01 | 84.35 | 61.03 | 67.30 | 68.96 | 80.45 | 93.11 | 92.87 | 93.86 | 79.22 |
| < 75000 | 85.14 | 80.25 | 90.91 | 70.32 | 76.47 | 77.50 | 88.61 | 96.39 | 95.96 | 96.19 | 85.77 |
| < 100000 | 88.67 | 85.02 | 94.41 | 77.43 | 87.77 | 82.96 | 92.92 | 98.19 | 97.29 | 97.84 | 90.25 |
| < 125000 | 91.21 | 90.05 | 96.70 | 84.79 | 90.70 | 87.22 | 95.24 | 98.84 | 98.53 | 98.63 | 93.19 |
| < 150000 | 93.36 | 93.70 | 97.88 | 87.75 | 92.61 | 92.42 | 96.81 | 99.20 | 98.84 | 98.94 | 95.15 |
| < 175000 | 95.21 | 94.83 | 98.54 | 90.12 | 94.64 | 93.99 | 97.98 | 99.52 | 99.13 | 99.20 | 96.32 |
| < 200000 | 96.49 | 95.78 | 98.98 | 92.23 | 97.37 | 94.91 | 98.74 | 99.77 | 99.31 | 99.41 | 97.30 |
| < 250000 | 97.58 | 97.74 | 99.51 | 96.19 | 98.29 | 96.58 | 99.30 | 99.85 | 99.63 | 99.66 | 98.43 |
| < 500000 | 99.68 | 99.74 | 99.94 | 99.45 | 99.87 | 99.54 | 99.93 | 99.98 | 99.93 | 99.95 | 99.80 |
| Total no. of trades | 334922 | 252194 | 213631 | 210038 | 207963 | 182197 | 137086 | 130133 | 107923 | 68527 | 184461 |

Note: The sample consists of ten ASX-listed common stocks with the most active exchange-traded options based on trading volume for the year 2000. The distribution is expressed in terms of cumulative percentages in each trade size category and computed from SEATS trades recorded during normal stock market operations from 10am to 4pm.

**TABLE 2. Summary Statistics on Stock Midpoint and Bid-Ask Spread.**

| Stock | Type | Trade Size | | Time Periods | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Small < $100,000 | Large >= $100,000 | All | 10–11am | 11am–12:30pm | 12:30 – 2pm | 2–3pm | 3–4pm |
| CBA | MP | 27.47 | 27.43 | 27.47 | 27.46 | 27.42 | 27.54 | 27.45 | 27.49 |
| | BAS | 0.0231 | 0.0232 | 0.0231 | 0.0302 | 0.0228 | 0.0210 | 0.0206 | 0.0209 |
| NAB | MP | 24.48 | 25.33 | 24.61 | 24.63 | 24.60 | 24.49 | 24.61 | 24.67 |
| | BAS | 0.0199 | 0.0199 | 0.0199 | 0.0266 | 0.0194 | 0.0175 | 0.0174 | 0.0175 |
| NCP | MP | 20.41 | 21.60 | 20.68 | 20.45 | 20.74 | 20.55 | 20.86 | 20.74 |
| | BAS | 0.0255 | 0.0290 | 0.0278 | 0.0375 | 0.0268 | 0.0255 | 0.0260 | 0.0233 |
| BHP | MP | 18.74 | 18.89 | 18.76 | 18.81 | 18.73 | 18.82 | 18.74 | 18.72 |
| | BAS | 0.0189 | 0.0183 | 0.0186 | 0.0249 | 0.0176 | 0.0172 | 0.0168 | 0.0164 |
| WMC | MP | 7.48 | 7.53 | 7.48 | 7.51 | 7.48 | 7.52 | 7.49 | 7.45 |
| | BAS | 0.0130 | 0.0128 | 0.0129 | 0.0153 | 0.0126 | 0.0122 | 0.0120 | 0.0124 |
| TLS | MP | 6.88 | 6.96 | 6.89 | 6.86 | 6.90 | 6.87 | 6.92 | 6.89 |
| | BAS | 0.0105 | 0.0105 | 0.0105 | 0.0113 | 0.0103 | 0.0104 | 0.0102 | 0.0102 |
| CWO | MP | 4.94 | 5.13 | 4.95 | 4.94 | 4.96 | 4.97 | 4.97 | 4.95 |
| | BAS | 0.0114 | 0.0116 | 0.0114 | 0.0130 | 0.0111 | 0.0109 | 0.0110 | 0.0109 |
| QAN | MP | 3.63 | 3.66 | 3.63 | 3.64 | 3.63 | 3.63 | 3.63 | 3.64 |
| | BAS | 0.0105 | 0.0105 | 0.0105 | 0.0110 | 0.0104 | 0.0103 | 0.0104 | 0.0103 |
| MIM | MP | 1.09 | 1.12 | 1.09 | 1.09 | 1.08 | 1.08 | 1.09 | 1.09 |
| | BAS | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 |
| NDY | MP | 0.96 | 0.99 | 0.96 | 0.96 | 0.96 | 0.96 | 0.95 | 0.96 |
| | BAS | 0.0100 | 0.0100 | 0.0100 | 0.0101 | 0.0100 | 0.0100 | 0.0100 | 0.0100 |
| Average | MP | 11.61 | 11.86 | 11.65 | 11.64 | 11.65 | 11.64 | 11.67 | 11.66 |
| | BAS | 0.0153 | 0.0156 | 0.0155 | 0.0190 | 0.0151 | 0.0145 | 0.0144 | 0.0142 |

Note: For each stock, the SEATS trades recorded during normal stock market operations from 10am to 4pm are sorted into two trade size categories and five intra-day periods to compute the volume weighted average quoted midpoint (MP) and bid-ask spread (BAS) presented above.

**TABLE 3. Summary Statistics on Stock and Option Trading Volume.**

**Panel A: Stocks**

| Stock | No. of trades per day | No. of shares traded per day | Value per day (000s) | No. of shares traded per trade | Value per trade |
|---|---|---|---|---|---|
| TLS | 1,329 | 7,622,656 | 52,414 | 5,735 | 39,437 |
| NAB | 1,001 | 1,857,492 | 46,249 | 1,856 | 46,214 |
| CWO | 848 | 4,776,334 | 23,229 | 5,634 | 27,401 |
| NCP | 837 | 2,641,143 | 55,057 | 3,156 | 65,794 |
| BHP | 825 | 2,166,290 | 40,584 | 2,625 | 49,177 |
| CBA | 729 | 1,374,788 | 37,585 | 1,886 | 51,572 |
| WMC | 544 | 2,379,931 | 17,785 | 4,375 | 32,694 |
| QAN | 516 | 2,238,783 | 8,134 | 4,335 | 15,751 |
| MIM | 428 | 6,400,581 | 6,961 | 14,945 | 16,254 |
| NDY | 272 | 4,281,841 | 4,130 | 15,746 | 15,186 |
| Average | 733 | 3,573,984 | 29,213 | 6,029 | 35,948 |

**Panel B: Options**

| Stock | No. of trades per day | | No. of contracts Traded per day | | Value per day (000s) | | No. of contracts traded per trade | | Value per trade (000s) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | call | put | Call | put | call | put | call | put | call | put |
| BHP | 106 | 76 | 1,736 | 1,272 | 1,218 | 804 | 16 | 17 | 11 | 11 |
| NAB | 96 | 83 | 1,215 | 1,358 | 826 | 946 | 13 | 16 | 9 | 11 |
| NCP | 74 | 66 | 1,097 | 904 | 1,269 | 766 | 15 | 14 | 17 | 12 |
| TLS | 83 | 53 | 2,914 | 1,805 | 766 | 561 | 35 | 34 | 9 | 10 |
| WMC | 61 | 36 | 1,330 | 841 | 469 | 273 | 22 | 23 | 8 | 7 |
| CBA | 47 | 42 | 687 | 742 | 460 | 461 | 15 | 18 | 10 | 11 |
| CWO | 49 | 36 | 1,609 | 1,055 | 560 | 326 | 33 | 29 | 11 | 9 |
| NDY | 25 | 21 | 1,042 | 1,570 | 68 | 179 | 42 | 74 | 3 | 8 |
| MIM | 24 | 12 | 939 | 626 | 81 | 66 | 39 | 54 | 3 | 6 |
| QAN | 16 | 17 | 376 | 592 | 56 | 170 | 24 | 35 | 4 | 10 |
| Average | 58 | 44 | 1,295 | 1,076 | 577 | 455 | 25 | 31 | 8 | 10 |

Note: In Panel A, the summary statistics reported for the ten ASX-listed common stocks are computed from stock trades recorded during normal trading hours from 10am to 4pm during the year 2000. In Panel B, the summary statistics reported for the ten related stock options are computed from option trades recorded during normal trading hours from 10am-12:30pm and 2pm-4pm during the year 2000.

**TABLE 4. Results of the Huang and Stoll (1997) Model with Induced Serial Correlation in Trade Flows.**

| | | $\alpha^s$ | | $\beta^s$ | | $\pi^s$ | | $\overline{R}^2$ | |
|---|---|---|---|---|---|---|---|---|---|
| Stock | Nobs | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Eq. (21) | Eq. (26) |
| TLS | 238,263 | 0.025* | 0.003 | 0.210* | 0.003 | 0.217* | 0.001 | 0.182 | 0.125 |
| NAB | 200,775 | 0.062* | 0.007 | 0.394* | 0.006 | 0.290* | 0.001 | 0.111 | 0.195 |
| BHP | 179,698 | 0.103* | 0.009 | 0.415* | 0.007 | 0.307* | 0.001 | 0.100 | 0.231 |
| NCP | 141,231 | 0.157* | 0.012 | 0.318* | 0.008 | 0.292* | 0.001 | 0.111 | 0.224 |
| CWO | 131,345 | 0.071* | 0.006 | 0.282* | 0.004 | 0.233* | 0.001 | 0.159 | 0.177 |
| CBA | 100,800 | 0.225* | 0.011 | 0.274* | 0.009 | 0.303* | 0.002 | 0.096 | 0.216 |
| WMC | 87,341 | 0.089* | 0.009 | 0.391* | 0.008 | 0.274* | 0.002 | 0.115 | 0.228 |
| MIM | 20,749 | 0.012* | 0.004 | 0.049* | 0.003 | 0.071* | 0.003 | 0.319 | 0.035 |
| NDY | 20,555 | 0.009 | 0.005 | 0.051* | 0.003 | 0.081* | 0.003 | 0.334 | 0.035 |
| QAN | 14,989 | 0.043* | 0.010 | 0.155* | 0.008 | 0.146* | 0.004 | 0.210 | 0.102 |
| Avg. | 113,575 | 0.080 | 0.008 | 0.254 | 0.006 | 0.221 | 0.002 | 0.174 | 0.157 |

Note: The bid-ask spread decomposition regression is based on the two equations, Equations 21 and 26, in Huang and Stoll (1997). Superscripts of *s* are added to the two equations for clarity of exposition:

$$E\left(Q_{t-1}^s \mid Q_{t-2}^s\right) = \left(1 - 2\pi^s\right)Q_{t-2}^s \qquad \text{(HS - 21)}$$

$$\Delta M_t^s = \left(\alpha^s + \beta^s\right)\frac{S_{t-1}^s}{2}Q_{t-1}^s - \alpha^s \frac{S_{t-2}^s}{2}\left(1 - 2\pi^s\right)Q_{t-2}^s + e_t^s. \qquad \text{(HS - 26)}$$

The stocks are listed in a descending order by the number of observations. $\alpha^s$ measures the estimated adverse information component of the stock bid-ask spread inferred from the trade flows in the stock. $\beta^s$ is the estimated inventory component of the stock bid-ask spread. $\pi^s$ is the estimated probability of a stock trade reversal.

*Significant at the 5% level (testing whether the coefficient estimates are significantly different from 0.5 for $\pi^s$, and zero for the remaining variables).

## TABLE 5. Results of the Cross-Market Model.

**Panel A: Cross-Market Estimates for Individual Stock**

| | | $\alpha^s$ | | $\beta^s$ | | $\pi^s$ | | $\alpha^o$ | | $\pi^o$ | | $\varphi^o$ | | $\varphi^s$ | | $\bar{R}^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stock | Nobs | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Eq. (2) | Eq. (3) | Eq. (6) |
| TLS | 238,263 | 0.026* | 0.003 | 0.213* | 0.003 | 0.216* | 0.001 | 0.044* | 0.009 | 0.487* | 0.001 | -0.108* | 0.008 | 0.003* | 0.0001 | 0.182 | 0.001 | 0.126 |
| NAB | 200,775 | 0.043* | 0.006 | 0.369* | 0.005 | 0.278* | 0.001 | 0.097* | 0.013 | 0.485* | 0.001 | -0.125* | 0.008 | 0.009* | 0.0001 | 0.108 | 0.002 | 0.196 |
| BHP | 179,698 | 0.065* | 0.007 | 0.419* | 0.006 | 0.291* | 0.001 | 0.078* | 0.015 | 0.487* | 0.001 | -0.122* | 0.008 | 0.012* | 0.0001 | 0.096 | 0.002 | 0.230 |
| NCP | 141,231 | 0.057* | 0.008 | 0.416* | 0.007 | 0.274* | 0.001 | 0.068* | 0.019 | 0.482* | 0.002 | -0.120* | 0.009 | 0.010* | 0.0002 | 0.106 | 0.002 | 0.224 |
| CWO | 131,345 | 0.060* | 0.005 | 0.291* | 0.004 | 0.229* | 0.001 | 0.085* | 0.014 | 0.489* | 0.002 | -0.169* | 0.011 | 0.004* | 0.0001 | 0.159 | 0.001 | 0.178 |
| CBA | 100,800 | 0.067* | 0.009 | 0.379* | 0.008 | 0.286* | 0.002 | 0.100* | 0.015 | 0.488* | 0.002 | -0.137* | 0.011 | 0.009* | 0.0002 | 0.091 | 0.001 | 0.214 |
| WMC | 87,341 | 0.059* | 0.008 | 0.401* | 0.007 | 0.265* | 0.002 | 0.110* | 0.017 | 0.485* | 0.002 | -0.180* | 0.011 | 0.009* | 0.0002 | 0.113 | 0.001 | 0.228 |
| MIM | 20,749 | 0.012* | 0.005 | 0.049* | 0.003 | 0.074* | 0.003 | 0.074* | 0.017 | 0.488* | 0.006 | -0.194* | 0.028 | 0.002* | 0.0000 | 0.323 | 0.001 | 0.038 |
| NDY | 20,555 | 0.011* | 0.005 | 0.050* | 0.003 | 0.085* | 0.003 | 0.046* | 0.014 | 0.482* | 0.005 | -0.124* | 0.024 | 0.007* | 0.0000 | 0.338 | 0.001 | 0.037 |
| QAN | 14,989 | 0.042* | 0.010 | 0.160* | 0.008 | 0.147* | 0.004 | 0.076* | 0.026 | 0.493 | 0.005 | -0.058* | 0.029 | 0.002* | 0.0003 | 0.211 | -0.000 | 0.104 |
| Avg. | 113,575 | 0.044 | 0.007 | 0.275 | 0.006 | 0.215 | 0.002 | 0.078 | 0.016 | 0.487 | 0.003 | -0.134 | 0.015 | 0.007 | 0.0001 | 0.173 | 0.001 | 0.157 |

**Panel B: Cross-Market Estimates : Intra-Day Comparison**

| | | $\alpha^s$ | | $\beta^s$ | | $\pi^s$ | | $\alpha^o$ | | $\pi^o$ | | $\varphi^o$ | | $\varphi^s$ | | $\bar{R}^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stock | Nobs | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Eq. (2) | Eq. (3) | Eq. (6) |
| 10-11 | 30,331 | 0.047 | 0.012 | 0.2623 | 0.010 | 0.187 | 0.003 | 0.095 | 0.034 | 0.487 | 0.006 | -0.149 | 0.032 | 0.007 | 0.0002 | 0.183 | 0.001 | 0.155 |
| 11-12:30 | 31,196 | 0.038 | 0.011 | 0.2699 | 0.010 | 0.212 | 0.003 | 0.075 | 0.027 | 0.486 | 0.005 | -0.135 | 0.026 | 0.007 | 0.001 | 0.148 | 0.002 | 0.154 |
| 2-3. | 21,748 | 0.073 | 0.013 | 0.2467 | 0.011 | 0.192 | 0.004 | 0.090 | 0.032 | 0.485 | 0.006 | -0.121 | 0.032 | 0.007 | 0.002 | 0.185 | 0.001 | 0.163 |
| 3-4 | 30,299 | 0.041 | 0.012 | 0.2891 | 0.011 | 0.218 | 0.004 | 0.079 | 0.029 | 0.489 | 0.005 | -0.148 | 0.028 | 0.006 | 0.001 | 0.149 | 0.001 | 0.164 |

Note: The bid-ask spread decomposition regression is based on the cross-market model represented by Equations (2), (3) and (6). In Panel A, all individual trades are considered when both markets are open and the results are presented for individual stocks listed according to the number of recorded trades throughout the day. Panel B reports intraday patterns for 4 sub-periods (the first hour of stock trading 10-11am; 11am-12:30pm; 2-3pm and the last hour of trading from 3-4pm). The sum of $\alpha^s$ and $\alpha^o$ measures the total estimated adverse information component of the stock bid-ask spread inferred from the trade flows in the stock and options markets. $\beta^s$ is the estimated inventory component of the stock bid-ask spread. $\pi^s$ is the estimated probability of a stock trade reversal. $\pi^o$ is the estimated probability that the aggregate option trade indicator reverses in sign between two consecutive periods. $\varphi^o$ and $\varphi^s$ are the estimated coefficients of the aggregate option trade indicator and stock trade indicator, respectively.

*Significant at the 5% level (testing whether the coefficient estimates are significantly different from 0.5 for $\pi^s$ and $\pi^o$, and zero for the remaining variables).

**TABLE 6. Results of the Cross-Market Model - Leverage and Adverse Information.**

| | | $\alpha^s$ | | $\beta^s$ | | $\pi^s$ | | $\alpha^{o,lev}$ | | $\pi^{o,lev}$ | | $\varphi^{o,lev}$ | | $\varphi^s$ | | $\overline{R}^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Panel A: Low Leverage Options are Used to Determine the Values Assigned to $Q_t^{o\ lev}$** | | | | | | | | | | | | | | | | | | |
| Stock | Nobs | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Eq. (7) | Eq. (8) | Eq. (9) |
| TLS | 166,781 | 0.026* | 0.004 | 0.206* | 0.003 | 0.205* | 0.001 | 0.034 | 0.017 | 0.496* | 0.001 | -0.114* | 0.009 | 0.001* | 0.000 | 0.189 | 0.000 | 0.123 |
| NAB | 157,394 | 0.042* | 0.006 | 0.371* | 0.006 | 0.273* | 0.001 | 0.066* | 0.023 | 0.494* | 0.001 | -0.124* | 0.009 | 0.003* | 0.000 | 0.108 | 0.001 | 0.195 |
| BHP | 155,094 | 0.065* | 0.007 | 0.415* | 0.007 | 0.287* | 0.001 | 0.056* | 0.028 | 0.496* | 0.001 | -0.122* | 0.008 | 0.004* | 0.000 | 0.098 | 0.000 | 0.228 |
| NCP | 107,476 | 0.037* | 0.008 | 0.421* | 0.008 | 0.268* | 0.002 | 0.047 | 0.030 | 0.494* | 0.001 | -0.122* | 0.010 | 0.003* | 0.000 | 0.106 | 0.001 | 0.219 |
| CWO | 58,056 | 0.045* | 0.007 | 0.279* | 0.006 | 0.213* | 0.002 | 0.000 | 0.037 | 0.500 | 0.002 | -0.153* | 0.017 | 0.001* | 0.000 | 0.165 | 0.000 | 0.165 |
| WMC | 51,209 | 0.059* | 0.010 | 0.394* | 0.009 | 0.254* | 0.002 | 0.075* | 0.033 | 0.495* | 0.002 | -0.182* | 0.014 | 0.004* | 0.000 | 0.115 | 0.001 | 0.225 |
| CBA | 48,690 | 0.057* | 0.012 | 0.376* | 0.011 | 0.285* | 0.002 | 0.075* | 0.029 | 0.495* | 0.002 | -0.142* | 0.015 | 0.005* | 0.000 | 0.085 | 0.001 | 0.207 |
| QAN | 5,931 | 0.054* | 0.015 | 0.143* | 0.011 | 0.117* | 0.005 | 0.091 | 0.059 | 0.494 | 0.006 | -0.111* | 0.049 | 0.001* | 0.000 | 0.223 | 0.000 | 0.095 |
| MIM | 4,003 | 0.016 | 0.011 | 0.052* | 0.007 | 0.060* | 0.005 | 0.098 | 0.074 | 0.489 | 0.007 | -0.166* | 0.069 | 0.001 | 0.004 | 0.303 | -0.000 | 0.041 |
| NDY | 3,704 | 0.006 | 0.009 | 0.042* | 0.007 | 0.060* | 0.005 | 0.035 | 0.068 | 0.488* | 0.006 | -0.211* | 0.060 | 0.004 | 0.004 | 0.307 | -0.002 | 0.031 |
| Avg. | 75,834 | 0.041 | 0.009 | 0.270 | 0.007 | 0.202 | 0.003 | 0.058 | 0.040 | 0.494 | 0.003 | -0.145 | 0.026 | 0.003 | 0.001 | 0.170 | 0.000 | 0.153 |
| **Panel B: Medium Leverage Options are Used to Determine the Values Assigned to $Q_t^{o\ lev}$** | | | | | | | | | | | | | | | | | | |
| TLS | 166.781 | 0.027* | 0.004 | 0.206* | 0.003 | 0.206* | 0.001 | 0.040* | 0.014 | 0.495* | 0.001 | -0.114* | 0.009 | 0.001* | 0.000 | 0.189 | 0.000 | 0.123 |
| NAB | 157,394 | 0.042* | 0.006 | 0.371* | 0.006 | 0.273* | 0.001 | 0.064* | 0.024 | 0.493* | 0.001 | -0.124* | 0.009 | 0.004* | 0.000 | 0.108 | 0.001 | 0.195 |
| BHP | 155,094 | 0.065* | 0.007 | 0.415* | 0.007 | 0.287* | 0.001 | 0.053* | 0.026 | 0.495* | 0.001 | -0.122* | 0.008 | 0.005* | 0.000 | 0.098 | 0.001 | 0.228 |
| NCP | 107,476 | 0.038* | 0.008 | 0.421* | 0.008 | 0.268* | 0.002 | 0.027 | 0.032 | 0.493* | 0.001 | -0.122* | 0.010 | 0.004* | 0.000 | 0.106 | 0.001 | 0.219 |
| CWO | 58,056 | 0.045* | 0.007 | 0.279* | 0.006 | 0.213* | 0.002 | 0.040 | 0.029 | 0.495* | 0.002 | -0.154* | 0.017 | 0.002* | 0.000 | 0.165 | 0.000 | 0.166 |
| WMC | 51,209 | 0.059* | 0.010 | 0.394* | 0.009 | 0.250* | 0.002 | 0.095* | 0.039 | 0.497 | 0.002 | -0.183* | 0.014 | 0.004* | 0.000 | 0.115 | 0.000 | 0.226 |
| CBA | 48,690 | 0.058* | 0.012 | 0.376* | 0.011 | 0.285* | 0.002 | 0.066 | 0.037 | 0.495* | 0.002 | -0.143* | 0.015 | 0.005* | 0.000 | 0.085 | 0.001 | 0.207 |
| QAN | 5,931 | 0.053* | 0.015 | 0.144* | 0.011 | 0.116* | 0.005 | 0.056 | 0.068 | 0.500 | 0.005 | -0.104* | 0.049 | 0.001* | 0.000 | 0.223 | 0.000 | 0.096 |
| MIM | 4,003 | 0.010 | 0.011 | 0.055* | 0.007 | 0.059* | 0.005 | 0.056 | 0.071 | 0.497 | 0.008 | -0.181* | 0.067 | -0.001 | 0.003 | 0.302 | 0.000 | 0.041 |
| NDY | 3,704 | 0.007 | 0.009 | 0.040* | 0.007 | 0.062* | 0.005 | 0.058 | 0.053 | 0.498 | 0.007 | -0.212* | 0.060 | 0.001 | 0.005 | 0.309 | -0.002 | 0.032 |
| Avg. | 75,834 | 0.040 | 0.009 | 0.270 | 0.007 | 0.202 | 0.003 | 0.055 | 0.039 | 0.496 | 0.003 | -0.146 | 0.026 | 0.003 | 0.001 | 0.170 | 0.000 | 0.153 |

(Continued)

## TABLE 6. Continued.

**Panel C: High Leverage Options are Used to Determine the Values Assigned to $Q_t^{o\ lev}$**

| | | $\alpha^s$ | | $\beta^s$ | | $\pi^s$ | | $\alpha^{o,lev}$ | | $\pi^{o,lev}$ | | $\varphi^{o,lev}$ | | $\varphi^s$ | | $\bar{R}^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stock | Nobs | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Eq. (7) | Eq. (8) | Eq. (9) |
| TLS | 166,781 | 0.026* | 0.004 | 0.206* | 0.003 | 0.205* | 0.001 | 0.038* | 0.014 | 0.494* | 0.001 | -0.114* | 0.009 | 0.001* | 0.000 | 0.189 | 0.000 | 0.123 |
| NAB | 157,394 | 0.042* | 0.006 | 0.371* | 0.006 | 0.273* | 0.001 | 0.059* | 0.022 | 0.494* | 0.001 | -0.124* | 0.009 | 0.004* | 0.000 | 0.108 | 0.001 | 0.195 |
| BHP | 155,094 | 0.066* | 0.007 | 0.415* | 0.007 | 0.287* | 0.001 | 0.062* | 0.025 | 0.495* | 0.001 | -0.122* | 0.008 | 0.006* | 0.000 | 0.098 | 0.001 | 0.228 |
| NCP | 107,476 | 0.038* | 0.008 | 0.422* | 0.008 | 0.268* | 0.002 | 0.029 | 0.025 | 0.493* | 0.001 | -0.123* | 0.010 | 0.005* | 0.000 | 0.106 | 0.001 | 0.219 |
| CWO | 58,056 | 0.045* | 0.007 | 0.278* | 0.006 | 0.213* | 0.002 | 0.050 | 0.034 | 0.496* | 0.002 | -0.153* | 0.017 | 0.001* | 0.000 | 0.165 | 0.000 | 0.166 |
| WMC | 51,209 | 0.059* | 0.010 | 0.394* | 0.009 | 0.253* | 0.002 | 0.055 | 0.033 | 0.494* | 0.002 | -0.183* | 0.014 | 0.003* | 0.000 | 0.115 | 0.001 | 0.225 |
| CBA | 48,690 | 0.057* | 0.012 | 0.376* | 0.011 | 0.285* | 0.002 | 0.067* | 0.034 | 0.495* | 0.002 | -0.143* | 0.015 | 0.004* | 0.000 | 0.085 | 0.001 | 0.207 |
| QAN | 5,931 | 0.052* | 0.015 | 0.144* | 0.011 | 0.117* | 0.005 | 0.178* | 0.078 | 0.502 | 0.003 | -0.115* | 0.050 | 0.004* | 0.000 | 0.223 | -0.001 | 0.096 |
| MIM | 4,003 | 0.012 | 0.011 | 0.055* | 0.007 | 0.059* | 0.005 | 0.066 | 0.070 | 0.489 | 0.007 | -0.184* | 0.069 | 0.001 | 0.003 | 0.302 | 0.002 | 0.041 |
| NDY | 3,704 | 0.006 | 0.009 | 0.043* | 0.007 | 0.059* | 0.005 | 0.045 | 0.066 | 0.490 | 0.007 | -0.215* | 0.060 | -0.001 | 0.003 | 0.307 | 0.002 | 0.033 |
| Avg. | 75,834 | 0.040 | 0.009 | 0.270 | 0.008 | 0.202 | 0.003 | 0.065 | 0.040 | 0.494 | 0.003 | -0.148 | 0.026 | 0.003 | 0.001 | 0.170 | 0.001 | 0.153 |

Note: The bid-ask spread decomposition regression is based on the cross-market model represented by Equations (7), (8) and (9). The model is applied to examine the impact of option leverage on the distribution of common stock bid-ask spread components. Panels A, B, and C present the results when the value of the aggregate option trade indicator variable, $Q_t^{o,lev}$, is based on low, medium and high leverage options, respectively. The sum of $\alpha^s$ and $\alpha^{o,lev}$ is the total estimated adverse information component of the stock bid-ask spread due to the trade flows in both the stock and options markets. $\beta^s$ is the estimated inventory component. $\pi^s$ is the estimated probability of a stock trade reversal. $\pi^{o,lev}$ is the estimated probability that the aggregate option trade indicator reverses in sign between two consecutive periods. $\varphi^{o,lev}$ and $\varphi^s$ are the estimated coefficients of the aggregate option trade indicator and stock trade indicator, respectively.

*Significant at the 5% level (testing whether the coefficient estimates are significantly different from 0.5 for $\pi^s$ and $\pi^{o,lev}$, and zero for the remaining variables).

**TABLE 7. Results of the Cross-Market Model – Stock Trade Size and Bid-Ask Spread Components.**

| | | $\alpha^{s,ij}$ | | $\beta^{s,ij}$ | | $\pi^{s,ij}$ | | $\alpha^{o}$ | | $\pi^{o}$ | | $\varphi^{o}$ | | $\varphi^{s,j}$ | | $\overline{R}^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stock | Nobs | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Eq. (10) | Eq. (11) | Eq. (12) |
| **Panel A: Large to Small Stock Trades (LS)** | | | | | | | | | | | | | | | | | | |
| NAB | 24,052 | -0.027 | 0.020 | 0.538* | 0.020 | 0.304* | 0.003 | 0.065 | 0.039 | 0.485* | 0.004 | -0.135* | 0.022 | 0.009* | 0.0004 | 0.076 | 0.002 | 0.225 |
| TLS | 22,715 | -0.045* | 0.010 | 0.385* | 0.010 | 0.210* | 0.003 | 0.073* | 0.030 | 0.488* | 0.005 | -0.056* | 0.026 | 0.006* | 0.0002 | 0.178 | 0.001 | 0.178 |
| NCP | 21,541 | 0.033 | 0.021 | 0.551* | 0.020 | 0.286* | 0.003 | 0.017 | 0.059 | 0.484* | 0.004 | -0.128* | 0.023 | 0.008* | 0.0004 | 0.085 | 0.002 | 0.252 |
| BHP | 18,645 | 0.020 | 0.022 | 0.578* | 0.022 | 0.293* | 0.004 | 0.046 | 0.049 | 0.489* | 0.004 | -0.130* | 0.024 | 0.013* | 0.0005 | 0.079 | 0.002 | 0.271 |
| CBA | 14,164 | -0.012 | 0.031 | 0.564* | 0.031 | 0.331* | 0.004 | 0.113* | 0.041 | 0.486* | 0.005 | -0.192* | 0.028 | 0.010* | 0.0005 | 0.051 | 0.001 | 0.257 |
| CWO | 6,392 | 0.022 | 0.024 | 0.481* | 0.023 | 0.222* | 0.006 | 0.073 | 0.073 | 0.489* | 0.003 | -0.285* | 0.051 | 0.008* | 0.0004 | 0.129 | 0.001 | 0.234 |
| WMC | 5,610 | -0.008 | 0.032 | 0.596* | 0.033 | 0.258* | 0.006 | 0.060 | 0.056 | 0.485* | 0.007 | -0.249* | 0.045 | 0.017* | 0.0006 | 0.097 | 0.004 | 0.268 |
| MIM | 693 | 0.010 | 0.029 | 0.114* | 0.021 | 0.034* | 0.008 | -0.327* | 0.150 | 0.447* | 0.025 | -0.070 | 0.132 | -0.007 | 0.0092 | 0.475 | 0.010 | 0.069 |
| Avg. | 14,227 | -0.001 | 0.024 | 0.476 | 0.022 | 0.242 | 0.005 | 0.015 | 0.062 | 0.481 | 0.007 | -0.156 | 0.044 | 0.008 | 0.0015 | 0.146 | 0.003 | 0.219 |
| **Panel B: Small to Small Stock Trades (SS)** | | | | | | | | | | | | | | | | | | |
| TLS | 187,325 | 0.023* | 0.003 | 0.183* | 0.003 | 0.209* | 0.001 | 0.038* | 0.009 | 0.487* | 0.002 | -0.111* | 0.009 | 0.002* | 0.0001 | 0.188 | 0.001 | 0.106 |
| NAB | 145,578 | 0.046* | 0.006 | 0.323* | 0.006 | 0.263* | 0.001 | 0.101* | 0.015 | 0.486* | 0.002 | -0.117* | 0.010 | 0.009* | 0.0002 | 0.119 | 0.002 | 0.172 |
| BHP | 138,222 | 0.060* | 0.007 | 0.397* | 0.007 | 0.284* | 0.001 | 0.082* | 0.018 | 0.486* | 0.002 | -0.124* | 0.009 | 0.011* | 0.0002 | 0.101 | 0.002 | 0.215 |
| CWO | 117,583 | 0.059* | 0.005 | 0.279* | 0.004 | 0.225* | 0.001 | 0.080* | 0.015 | 0.489* | 0.002 | -0.165* | 0.011 | 0.003* | 0.0001 | 0.164 | 0.001 | 0.170 |
| NCP | 89,348 | 0.044* | 0.009 | 0.360* | 0.008 | 0.258* | 0.002 | 0.070* | 0.026 | 0.481* | 0.002 | -0.111* | 0.011 | 0.009* | 0.0003 | 0.118 | 0.002 | 0.183 |
| WMC | 75,113 | 0.058* | 0.008 | 0.388* | 0.008 | 0.261* | 0.002 | 0.109* | 0.018 | 0.486* | 0.002 | -0.171* | 0.012 | 0.008* | 0.0002 | 0.117 | 0.001 | 0.220 |
| CBA | 67,231 | 0.069* | 0.009 | 0.306* | 0.008 | 0.256* | 0.002 | 0.076* | 0.019 | 0.490* | 0.002 | -0.122* | 0.013 | 0.008* | 0.0003 | 0.114 | 0.001 | 0.173 |
| MIM | 19,265 | 0.011* | 0.005 | 0.048* | 0.003 | 0.077* | 0.003 | 0.079* | 0.017 | 0.488* | 0.006 | -0.187* | 0.028 | 0.003* | 0.0000 | 0.312 | 0.001 | 0.038 |
| Avg. | 104,958 | 0.046 | 0.007 | 0.286 | 0.006 | 0.229 | 0.002 | 0.079 | 0.017 | 0.487 | 0.002 | -0.139 | 0.013 | 0.007 | 0.0002 | 0.154 | 0.001 | 0.160 |
| **Panel C: Small to Large Stock Trades (SL)** | | | | | | | | | | | | | | | | | | |
| NAB | 24,076 | 0.032 | 0.020 | 0.593* | 0.020 | 0.300* | 0.003 | 0.093* | 0.034 | 0.481* | 0.004 | -0.183* | 0.025 | 0.014* | 0.0003 | 0.080 | 0.003 | 0.280 |
| TLS | 22,739 | 0.050* | 0.013 | 0.400* | 0.012 | 0.254* | 0.003 | 0.050 | 0.030 | 0.493 | 0.004 | -0.148* | 0.027 | 0.005* | 0.0001 | 0.121 | 0.000 | 0.211 |
| NCP | 21,560 | 0.037 | 0.021 | 0.603* | 0.021 | 0.297* | 0.003 | 0.076* | 0.039 | 0.479* | 0.004 | -0.122* | 0.024 | 0.015* | 0.0004 | 0.076 | 0.004 | 0.287 |
| BHP | 18,665 | 0.327* | 0.025 | 0.326* | 0.025 | 0.315* | 0.004 | 0.181* | 0.040 | 0.487* | 0.005 | -0.121* | 0.026 | 0.016* | 0.0003 | 0.063 | 0.003 | 0.293 |
| CBA | 14,179 | 0.040 | 0.032 | 0.660* | 0.032 | 0.332* | 0.004 | 0.114* | 0.047 | 0.489* | 0.005 | -0.144* | 0.030 | 0.013* | 0.0004 | 0.052 | 0.002 | 0.316 |
| CWO | 6,398 | 0.055* | 0.027 | 0.483* | 0.027 | 0.261* | 0.006 | 0.146* | 0.055 | 0.491 | 0.008 | -0.188* | 0.056 | 0.005* | 0.0003 | 0.090 | 0.001 | 0.246 |
| WMC | 5,626 | 0.079* | 0.035 | 0.551* | 0.035 | 0.283* | 0.006 | 0.178* | 0.059 | 0.489 | 0.008 | -0.312* | 0.051 | 0.014* | 0.0006 | 0.073 | 0.002 | 0.288 |
| MIM | 691 | 0.021 | 0.026 | 0.079* | 0.020 | 0.052* | 0.009 | 0.203 | 0.143 | 0.495 | 0.025 | -0.522* | 0.185 | 0.001 | 0.0081 | 0.424 | 0.000 | 0.060 |
| Avg. | 14,242 | 0.080 | 0.025 | 0.462 | 0.024 | 0.262 | 0.005 | 0.130 | 0.056 | 0.488 | 0.008 | -0.218 | 0.053 | 0.010 | 0.0013 | 0.122 | 0.002 | 0.248 |

(Continued)

**TABLE 7. Continued.**

**Panel D: Large to Large Stock Trades (LL)**

| | | $\alpha^{s,ij}$ | | $\beta^{s,ij}$ | | $\pi^{s,ij}$ | | $\alpha^{o}$ | | $\pi^{o}$ | | $\varphi^{o}$ | | $\varphi^{s,j}$ | | $\overline{R}^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stock | Nobs | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Eq. (10) | Eq. (11) | Eq. (12) |
| NCP | 8,782 | 0.248* | 0.034 | 0.395* | 0.032 | 0.274* | 0.005 | 0.261* | 0.065 | 0.484* | 0.007 | -0.211* | 0.038 | 0.011* | 0.0006 | 0.079 | 0.002 | 0.302 |
| NAB | 7,069 | 0.274* | 0.041 | 0.409* | 0.040 | 0.309* | 0.006 | 0.148* | 0.060 | 0.486* | 0.007 | -0.127* | 0.045 | 0.005* | 0.0005 | 0.052 | 0.001 | 0.317 |
| TLS | 5,484 | 0.054* | 0.023 | 0.444* | 0.019 | 0.172* | 0.005 | 0.040 | 0.056 | 0.490* | 0.005 | -0.161* | 0.065 | 0.012* | 0.0005 | 0.193 | 0.002 | 0.259 |
| CBA | 5,226 | 0.017 | 0.059 | 0.657* | 0.059 | 0.353* | 0.007 | 0.216* | 0.078 | 0.477* | 0.010 | -0.211* | 0.050 | 0.009* | 0.0006 | 0.028 | 0.001 | 0.332 |
| BHP | 4,166 | 0.076* | 0.039 | 0.604* | 0.039 | 0.251* | 0.007 | 0.090 | 0.080 | 0.495 | 0.010 | -0.097 | 0.056 | 0.016* | 0.0010 | 0.084 | 0.002 | 0.310 |
| WMC | 992 | 0.053 | 0.063 | 0.531* | 0.065 | 0.248* | 0.015 | -0.098 | 0.082 | 0.450* | 0.021 | -0.117 | 0.121 | 0.028* | 0.0014 | 0.058 | 0.015 | 0.266 |
| CWO | 972 | 0.102 | 0.069 | 0.432* | 0.067 | 0.259* | 0.015 | 0.109 | 0.128 | 0.498* | 0.001 | -0.410* | 0.096 | 0.016* | 0.0005 | 0.049 | 0.003 | 0.256 |
| MIM | 100 | 0.075 | 0.099 | 0.022 | 0.021 | 0.016* | 0.011 | 0.003 | 0.046 | 0.459 | 0.095 | -0.436 | 0.296 | -0.013 | 0.0263 | 0.672 | -0.015 | -0.039 |
| Avg. | 4,099 | 0.112 | 0.053 | 0.437 | 0.043 | 0.235 | 0.009 | 0.096 | 0.074 | 0.480 | 0.019 | -0.221 | 0.096 | 0.010 | 0.0039 | 0.152 | 0.002 | 0.250 |

Note: The bid-ask spread decomposition regression is based on the cross-market model represented by Equations (10), (11) and (12). The model is applied to examine the impact of stock trade size on the distribution of bid-ask spread components of common stocks. Panels A, B, C, and D present the results for subsets of data consisting of large to small (LS), small to small (SS), small to large (SL) and, large to large (LL) stock trades observed in the last two periods, respectively. A small stock trade is defined as less than $100,000 otherwise it is treated as a large trade. The sum of $\alpha^{s,ij}$ and $\alpha^{o}$ measures the total estimated adverse information component of the stock bid-ask spread due to the trade flows observed in the stock and options markets. $\beta^{s,ij}$ is the estimated inventory component and $\pi^{s,ij}$ is the estimated probability of a stock trade reversal. $\pi^{o}$ is the estimated probability that the aggregate option trade indicator reverses in sign between two consecutive periods. $\varphi^{o}$ and $\varphi^{s,j}$ are the estimated coefficients of the aggregate option trade indicator and stock trade indicator, respectively.

*Significant at the 5% level (testing whether the coefficient estimates are significantly different from 0.5 for $\pi^{s,ij}$ and $\pi^{o}$, and zero for the remaining variables).

**TABLE 8. Results of the Cross-Market Model – Information-Based Option Trade Imbalance and Bid-Ask Spread Components.**

| | | $\alpha^s$ | | $\beta^s$ | | $\pi^s$ | | $\alpha^{o,xy}$ | | $\pi^{o,xy}$ | | $\varphi^{o,x}$ | | $\varphi^s$ | | $\overline{R}^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stock | Nobs | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Eq. (13) | Eq. (14) | Eq. (15) |
| **Panel A: Large to Small Option Trade Imbalance (LS)** | | | | | | | | | | | | | | | | | | |
| BHP | 2,818 | 0.019 | 0.192 | 0.412* | 0.191 | 0.467* | 0.010 | -0.006 | 0.088 | 0.493* | 0.003 | -0.077* | 0.019 | 0.014* | 0.0004 | 0.001 | 0.004 | 0.203 |
| NAB | 2,754 | 0.009 | 0.137 | 0.366* | 0.136 | 0.443* | 0.010 | 0.015 | 0.095 | 0.490* | 0.003 | -0.072* | 0.019 | 0.007* | 0.0005 | 0.003 | 0.005 | 0.178 |
| NCP | 1,937 | 0.057 | 0.162 | 0.317* | 0.162 | 0.459* | 0.011 | 0.028 | 0.081 | 0.489* | 0.003 | -0.114* | 0.023 | 0.007* | 0.0007 | -0.004 | 0.005 | 0.177 |
| TLS | 1,703 | 0.032 | 0.075 | 0.169* | 0.072 | 0.405* | 0.012 | 0.018 | 0.070 | 0.499 | 0.003 | -0.077* | 0.024 | -0.008* | 0.0001 | 0.013 | 0.000 | 0.092 |
| CWO | 1,239 | 0.076 | 0.149 | 0.194 | 0.145 | 0.454* | 0.014 | -0.022 | 0.114 | 0.497 | 0.003 | -0.112* | 0.029 | -0.011* | 0.0002 | 0.004 | 0.002 | 0.116 |
| CBA | 1,138 | 0.724* | 0.252 | -0.267 | 0.247 | 0.428* | 0.015 | 0.178* | 0.081 | 0.503 | 0.004 | -0.023 | 0.023 | -0.002* | 0.0007 | -0.014 | 0.000 | 0.230 |
| WMC | 1,013 | 0.010 | 0.120 | 0.366* | 0.120 | 0.457* | 0.015 | 0.056 | 0.102 | 0.490* | 0.005 | -0.206* | 0.031 | 0.005* | 0.0008 | -0.002 | -0.001 | 0.174 |
| Avg. | 1,800 | 0.132 | 0.155 | 0.222 | 0.153 | 0.445 | 0.012 | 0.038 | 0.090 | 0.494 | 0.003 | -0.097 | 0.024 | 0.002 | 0.0005 | 0.000 | 0.002 | 0.167 |
| **Panel B: Small to Small Option Trade Imbalance (SS)** | | | | | | | | | | | | | | | | | | |
| TLS | 234,756 | 0.026* | 0.003 | 0.213* | 0.003 | 0.214* | 0.001 | 0.047* | 0.010 | 0.488* | 0.001 | -0.114* | 0.008 | 0.002* | 0.0001 | 0.185 | 0.001 | 0.126 |
| NAB | 195,061 | 0.044* | 0.006 | 0.367* | 0.005 | 0.275* | 0.001 | 0.101* | 0.014 | 0.489* | 0.001 | -0.133* | 0.009 | 0.008* | 0.0001 | 0.110 | 0.001 | 0.195 |
| BHP | 173,854 | 0.066* | 0.007 | 0.415* | 0.006 | 0.287* | 0.001 | 0.086* | 0.017 | 0.488* | 0.002 | -0.132* | 0.009 | 0.010* | 0.0001 | 0.099 | 0.002 | 0.230 |
| NCP | 137,238 | 0.056* | 0.008 | 0.415* | 0.007 | 0.271* | 0.001 | 0.054* | 0.021 | 0.483* | 0.002 | -0.122* | 0.010 | 0.009* | 0.0002 | 0.109 | 0.002 | 0.223 |
| CWO | 128,801 | 0.060* | 0.005 | 0.289* | 0.004 | 0.226* | 0.001 | 0.094* | 0.016 | 0.489* | 0.002 | -0.180* | 0.012 | 0.003* | 0.0001 | 0.162 | 0.001 | 0.177 |
| CBA | 98,443 | 0.068* | 0.009 | 0.377* | 0.008 | 0.284* | 0.002 | 0.096* | 0.017 | 0.488* | 0.002 | -0.157* | 0.012 | 0.008* | 0.0002 | 0.093 | 0.001 | 0.214 |
| WMC | 85,250 | 0.060* | 0.008 | 0.399* | 0.007 | 0.262* | 0.002 | 0.111* | 0.018 | 0.488* | 0.002 | -0.182* | 0.012 | 0.009* | 0.0002 | 0.116 | 0.001 | 0.227 |
| Avg. | 150,486 | 0.054 | 0.007 | 0.353 | 0.006 | 0.260 | 0.001 | 0.084 | 0.016 | 0.488 | 0.002 | -0.146 | 0.010 | 0.007 | 0.0001 | 0.125 | 0.001 | 0.199 |
| **Panel C: Small to Large Option Trade Imbalance (SL)** | | | | | | | | | | | | | | | | | | |
| BHP | 2,823 | -0.048 | 0.089 | 0.794* | 0.092 | 0.358* | 0.003 | 0.020 | 0.033 | 0.438* | 0.030 | 0.029 | 0.060 | 0.014* | 0.000 | 0.001 | 0.004 | 0.203 |
| NAB | 2,750 | -0.050 | 0.080 | 0.639* | 0.081 | 0.342* | 0.003 | 0.103* | 0.026 | 0.389* | 0.033 | -0.086 | 0.070 | 0.007* | 0.001 | 0.003 | 0.005 | 0.178 |
| NCP | 1,936 | 0.375* | 0.105 | 0.407* | 0.103 | 0.336* | 0.004 | 0.174* | 0.041 | 0.369* | 0.035 | -0.083 | 0.069 | 0.007* | 0.001 | -0.004 | 0.005 | 0.177 |
| TLS | 1,701 | -0.060 | 0.061 | 0.462* | 0.060 | 0.325* | 0.002 | 0.016 | 0.021 | 0.392* | 0.040 | -0.083 | 0.084 | -0.008* | 0.000 | 0.013 | 0.000 | 0.092 |
| CWO | 1,242 | -0.108 | 0.079 | 0.638* | 0.076 | 0.310* | 0.002 | 0.054 | 0.034 | 0.527 | 0.059 | -0.097 | 0.096 | -0.011* | 0.000 | 0.004 | 0.002 | 0.116 |
| CBA | 1,140 | -0.055 | 0.135 | 0.601* | 0.133 | 0.368* | 0.004 | 0.092* | 0.043 | 0.532 | 0.044 | 0.080 | 0.086 | -0.002* | 0.001 | -0.014 | 0.000 | 0.230 |
| WMC | 1,013 | 0.028 | 0.106 | 0.748* | 0.101 | 0.317* | 0.004 | 0.085 | 0.044 | 0.344* | 0.043 | -0.172* | 0.087 | 0.005* | 0.001 | -0.002 | -0.001 | 0.174 |
| Avg. | 1,801 | 0.012 | 0.094 | 0.613 | 0.092 | 0.337 | 0.003 | 0.078 | 0.035 | 0.427 | 0.040 | -0.059 | 0.079 | 0.002 | 0.001 | 0.000 | 0.002 | 0.167 |

(Continued)

## TABLE 8. Continued.

**Panel D: Large to Large Option Trade Imbalance (LL)**

| | | $\alpha^s$ | | $\beta^s$ | | $\pi^s$ | | $\alpha^{o,xy}$ | | $\pi^{o,xy}$ | | $\varphi^{o,x}$ | | $\varphi^s$ | | $\bar{R}^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stock | Nobs | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Eq. (13) | Eq. (14) | Eq. (15) |
| NAB | 210 | 0.282 | 0.191 | 0.252 | 0.189 | 0.339* | 0.030 | 0.051 | 0.072 | 0.262* | 0.011 | -0.097 | 0.062 | -0.006 | 0.014 | 0.020 | 0.188 | 0.269 |
| BHP | 203 | 0.356 | 0.339 | 0.031 | 0.327 | 0.378* | 0.030 | -0.235* | 0.071 | 0.289* | 0.012 | -0.009 | 0.061 | 0.084* | 0.017 | 0.002 | 0.136 | 0.126 |
| NCP | 120 | -4.478 | 3.995 | 5.093 | 4.001 | 0.509 | 0.012 | 0.091 | 0.096 | 0.332* | 0.016 | -0.082 | 0.072 | 0.148* | 0.017 | 0.001 | 0.122 | 0.521 |
| TLS | 103 | 0.000 | 0.123 | 0.229* | 0.105 | 0.455 | 0.043 | 0.037 | 0.038 | 0.279* | 0.026 | 0.339* | 0.079 | 0.119 | 0.081 | 0.015 | 0.177 | 0.077 |
| CBA | 79 | 0.474* | 0.187 | -0.003 | 0.220 | 0.600* | 0.040 | 0.064 | 0.107 | 0.248* | 0.025 | 0.363* | 0.078 | -0.052* | 0.019 | -0.025 | 0.172 | 0.315 |
| WMC | 65 | 0.094 | 0.240 | 0.071 | 0.218 | 0.392 | 0.056 | 0.046 | 0.057 | 0.290* | 0.020 | -0.134 | 0.092 | 0.022 | 0.016 | 0.003 | 0.111 | -0.004 |
| CWO | 63 | -0.730 | 0.380 | 1.454* | 0.380 | 0.366* | 0.030 | -0.312* | 0.103 | 0.263* | 0.022 | -0.277* | 0.066 | 0.075* | 0.018 | 0.042 | 0.026 | 0.429 |
| Avg. | 120 | -0.572 | 0.779 | 1.018 | 0.777 | 0.434 | 0.034 | -0.037 | 0.078 | 0.281 | 0.019 | 0.015 | 0.073 | 0.056 | 0.026 | 0.008 | 0.133 | 0.248 |

Note: The bid-ask spread decomposition regression is based on the cross-market model represented by Equations (13), (14) and (15). The model is applied to examine the impact of information-based option trade imbalance on the distribution of stock bid-ask spread components. Panels A, B, C, and D present the results for subsets of data consisting of large to small (LS), small to small (SS), small to large (SL), and large to large (LL) option trade imbalances observed in the last two periods, respectively. The option trade imbalance in a period embedded by two stock trades is measured by the difference between the values of positive and negative option trades in the same period. The imbalance is classified as large if the amount exceeds $20,000 and small otherwise. The sum of $\alpha^s$ and $\alpha^{o,xy}$ measures the total estimated adverse information component of the stock bid-ask spread due to the trade flows observed in the stock and options markets. $\beta^s$ is the estimated inventory component and $\pi^s$ is the estimated probability of a stock trade reversal. $\pi^{o,xy}$ is the estimated probability that the aggregate option trade indicator reverses in sign between two consecutive periods. $\varphi^{o,x}$ and $\varphi^s$ are the estimated coefficients of the aggregate option trade indicator and stock trade indicator, respectively.

*Significant at the 5% level (testing whether the coefficient estimates are significantly different from 0.5 for $\pi^s$ and $\pi^{o,xy}$, and zero for the remaining variables).