TRADING VOLUME, BID–ASK SPREAD, AND PRICE VOLATILITY IN FUTURES MARKETS

GEORGE H. K. WANG*
JOT YAU

In this study, we examined the relations between trading volume, bid–ask spread, and price volatility on four financial and metal futures. Hausman's (1978) tests of specification confirmed that trading volume, bid–ask spread, and price volatility are jointly determined. We estimated the parameters and elasticities of trading volume, bid–ask spread, and price volatility in a three-equation structural model, using the generalized method of moments (GMM) procedure. Results indicate that there was a positive relationship between trading volume and price volatility but an inverse relationship between trading volume and bid–ask spread after we controlled for other factors. Furthermore, results show that price volatility had a positive relationship with bid–ask spread and a negative relationship with lagged trading

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*Correspondence author, Director of Market Research, Division of Economic Analysis, U.S. Commodity Futures Trading Commission, 3 Lafayette Centre, 1155 21st Street NW, Washington, DC 20581; e-mail: gwang@cftc.gov

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- *George H. K. Wang is the Director of Market Research in the Division of Economic Analysis at the Commodity Futures Trading Commission and is an Adjunct Finance Faculty Member in the Robert H. Smith School of Business, University of Maryland, College Park, Maryland.*
- *Jot Yau is an Associate Professor of Finance in the School of Management at George Mason University in Fairfax, Virginia.*

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volume. In addition, we found that the ordinary least-squares parameter estimates of each equation model were often severely underestimated in comparison with those consistent estimates obtained from the GMM estimation. Results from this study have important policy implications. Our results indicate that a transaction tax, which is analogous to a greater bid–ask spread, will reduce trading volume, although the reduction is not as great as we previously estimated.

INTRODUCTION

Trading volume (TV), bid–ask spread (BAS), and price volatility are among the most heavily studied variables in the microstructure literature of financial markets because their behaviors are of concern to many groups of people. Traders, speculators, hedgers, and arbitrageurs alike are interested in extracting information from these variables to know how their reaction to new information and interaction can be used in predicting future prices. Policymakers and regulators are interested in knowing how changes in these variables impact the market activity and its regulation.

A case in point is the discussion on a user fee or transaction tax on futures transactions periodically brought up on the Capitol Hills in the United States. Advocates of such a transaction tax argue that it would increase the government revenue significantly as it has done in Japan, Germany, and the United Kingdom. Hence, proponents argue that such a transaction tax would increase government revenues that could be used to fund the Commodity Futures Trading Commission (CFTC). Those who oppose argue that a tax on securities transactions would increase the cost of capital, reduce market liquidity, and diminish security value. In addition, a securities transaction tax could drive trading in some securities to overseas markets not burdened by taxation, a major concern of the futures exchanges.[1] Before one can properly evaluate the pros and cons of a transaction tax, one must first answer a more general question: What impact would an increase in transaction costs have on market activity in terms of TV and price volatility? This is the question we address in this article.

Extant literature that provides some possible answers to the previous question includes those studies on (a) the relationship between TV and price volatility, (b) the relationships between BAS and TV within theories of BASs, and (c) the relationship between BASs and observed price vol-

[1]For a review of arguments, see Schwert and Seguin (1993).

atility.[2] One common feature of the earlier studies is the assumption that the variables specified in the model are exogenous to one another. For example, Benston and Hagerman (1974) applied the ordinary least-squares (OLS) method to estimate the determinants of BASs with TV, price volatility, and other variables as explanatory variables. Similarly, in identifying the determinants of TV in the metal futures markets, Martell and Wolf (1987) used price volatility as one of the explanatory variables in a single equation of TV estimated by OLS, whereas price volatility is a function of TV and BAS. Likewise, in Chiang and Venkatesh's (1988) study of the effect of insider and institutional holdings on the BAS, volume was considered an exogenous variable in an OLS regression. On close examination of the evidence from previous studies, one can reasonably infer that some of the variables, such as TV, BAS, and price volatility, are not exogenous to each other. Recently, empirical studies have begun to analyze the economic relationship in a two-equation simultaneous structural model between volume and volatility (e.g., Foster, 1995), BAS and intraday price volatility (Wang, Michalski, Jordan, & Moriarty, 1994), BAS and volume (Berkman, 1992), and BAS and trading rates (George & Longstaff, 1993). Empirical results from the two-equation simultaneous structural model seem to support our conjecture that TV, BAS, and price volatility are pairwise endogenously determined. Thus, the critical empirical question that helps solve the controversy on how these variables affect the market activity hinges on accurate estimation of these variables with respect to one another. Producing consistent estimates requires proper model specification. This leads us to investigate the relationship of TV, BAS, and price volatility in a three-equation simultaneous structural model.

Our work contributes to extant literature in a number of dimensions. First, we examined the relationships in the futures markets, after confirming them with a battery of Hausman's (1978) specification tests, in a three-equation simultaneous structural model. The specification of our model explicitly accommodates the endogeneity of the three variables—TV, BAS, and price volatility—which has not been recognized by previous studies. Specifically, we studied (a) the relations between TV and BAS conditioning on price volatility, (b) the relations between price volatility and BAS conditioning on TV, and (c) the relations between price volatility

[2]See the section entitled Literature on the Relations of TV, Price Volatility, and BAS for the literature review on (a) the relationship between TV and price volatility, (b) the relationship between BASs and TV, and (c) the relationship between BASs and price-observed price volatility. Some of these studies were done on equities, bonds, and options.

and TV conditioning on BAS. Second, we explicitly model persistence in TV, price volatility, and BAS.[3] Third, we demonstrate that the generalized method of moments (GMM) estimation procedure produces consistent estimates of elasticities (coefficients), in contrast to the OLS used commonly in previous studies, which has produced inconsistent estimates. Fourth, we show that the methodological improvements over previous studies of the volume–volatility, volume–BAS, and price volatility-BAS relations have significant economic and policy implications. The approach proposed in this study should be of particular interest to researchers, policymakers, and regulators because it provides a methodology for obtaining reliable estimates of major determinants of TV, BAS, and price volatility.

For a sample of two financial futures (Standard & Poor's [S&P] 500 and deutsche mark [DM]) and two metal futures (gold and silver), specification tests of our three-equation structural model confirmed that TV, BAS, and price volatility are jointly determined. Results also indicate that a positive relationship exists between TV and intraday price volatility (IV), whereas an inverse relationship exists between TV and BAS after we control for other factors. In addition, evidence indicates that price volatility is positively related to BAS and negatively related to lagged TV. Furthermore, we found that the OLS parameter estimates of our model were often severely underestimated in comparison with the estimates obtained by GMM. This suggests to us that instrumental variable estimators should be used in cases where explanatory variables are endogenously determined with the dependent variable in the equation.

Finally, we found empirically that for the S&P 500 and DM futures, if TV is the dependent variable, only the BAS (not the price volatility) is the endogenous explanatory variable in the simultaneous equations system.

The rest of the article proceeds as follows: In the section entitled Literature on the Relations of TV, Price Volatility, and BAS, we review the literature on the relations of TV, price volatility, and BAS. In the section entitled Empirical Specification of the Model, we present the specification of the empirical model. We present the data and methodology in the section entitled Data and Methodology. We present and discuss the results in the section entitled Empirical Results. We conclude the article with the Summary and Conclusions section.

[3]Persistence in volume and volatility has been reported in the literature. For examples, see Lamoureux and Lastrapes (1990), Bessembinder and Seguin (1993), and Foster (1995).

LITERATURE ON THE RELATIONS OF TV, PRICE VOLATILITY, AND BAS

Extant literature and empirical studies on the relations of TV, price volatility, and BAS can be grouped into studies on (a) the relations between TV and price volatility, (b) the relations between BAS and TV within theories of BASs, and (c) the relations between BAS and observed price volatility.

TV and Price Volatility

Explanations for the documented relationship between TV and volatility have revolved around two main theories: the sequential information model (SIM) and the mixture of distributions hypothesis (MDH).[4] The SIM allows a number of incomplete equilibria to be reached before the final equilibrium is found, whereas the MDH assumes that the final equilibrium is immediately attained. The primary implication of the SIM is that a sequential reaction to information suggests that asset price volatility is potentially forecastable with knowledge of TV. The MDH provides a model that implies a positive contemporaneous relationship between TV and price volatility, with the relationship being a function of the mixing variable, defined as the rate of information arrival.

Previous empirical research on the relationship between TV and price volatility has noted that in general there is a strong contemporaneous positive relationship between volume and price volatility in the futures markets.[5] Within the Granger causality framework, results from testing these two theories are often mixed.[6]

Blume, Easley, and O'Hara (1994) provided a new model that is based on the primary assumption that traders receive pricing signals of differing precision or quality. They purported that volume provides information on the precision and dispersion of information signals when price alone does not. Their model implies that volume can be used to forecast future price movements because traders condition their price expectations on volume as well as price. Foster's (1995) findings seem to concur with Blume et al.'s model implication that volume and price volatility are simultaneously determined. However, he concluded that volume by itself

[4]Literature on the SIM includes Copeland (1976); Jennings, Starks, and Fellingham (1981); and Smirlock and Starks (1984). Previous work on the MDH includes Clark (1973), Epps and Epps (1976), Tauchen and Pitts (1983), and Harris (1987).
[5]Previous articles in this area include Clark (1973); Cornell (1981); Tauchen and Pitts (1983); Garcia, Leuthold, and Zapata (1986); Grammatikos and Saunders (1986); Foster (1995) and others.
[6]See Karpoff (1987) for an excellent review of previous studies on the relationship between TV and price changes in both futures and stock markets.

is not an adequate proxy for the rate of information; lagged volume also plays a role.

Martell and Wolf (1987) applied OLS to study major determinants of TV in the metal futures markets, using the daily and monthly data. They concluded that TV is not only a function of volatility but also of open interest (OI), interest rates, exchange rates, and other variables.

BASs, Transaction Costs, and TV

The inventory cost model, asymmetry information model, and order processing model are the three theories of determinants of BASs.[7] Although there are differences in their theoretical arguments, they all conclude that BASs are positively related to price volatility and negatively related to TV.

In earlier empirical studies, Demsetz (1968) examined the impact of transaction costs on transaction rates (i.e., the number of transactions over a given time period) of the New York Stock Exchange (NYSE) stocks, and Epps (1976) estimated the elasticities of TV of NYSE stocks with respect to transaction costs. The results of both studies on equities are consistent with the expectation that trading activity is inversely related to trading costs.

Benston and Hagerman (1974) concentrated on explaining the determinants of quoted BASs across securities. On the basis of OLS regression results, they concluded that BASs are positively related to price volatility and negatively related to competition in market making, such as the number of market makers trading in the security and the number of transactions.

Berkman (1992) found that BASs and TV in the European Options Exchange in Amsterdam were negatively related in a two-equation simultaneous equation system after he controlled for other factors. Also, George and Longstaff (1993) found a negative relationship between transaction rates and BASs for the S&P 100 index options market in a two-equation structural model. Wang, Yau, and Baptiste (1997) found a negative relationship between BAS and TV for seven futures contracts in a two-equation simultaneous equation model.

BASs and Price Volatility

Roll (1984), French and Roll (1986), Glosten (1987), and others derived a relationship between the standard deviation of equilibrium price

[7]See Stoll (1978) for a discussion on the inventory cost model. See Bagehot (1971) and Copeland and Galai (1988) for the information asymmetry model, and see Demestz (1968) and Tinic (1972) for the order processing model.

changes and the BAS for a particular data-generating process. Cohen, Maier, Schwartz, and Whitcomb (1986) reviewed previous empirical studies of the relationship between transaction price volatility and BASs in securities markets. In general, these studies found a positive relationship between transaction price volatility and BASs when price change was measured over short intervals (e.g., daily). The relationship became insignificant for price changes measured over longer intervals (e.g., monthly). Recently, Amihud and Mendelson (1987) demonstrated the existence of a positive relationship at the closing hour of the NYSE. None of these empirical studies controlled for the information effect on volatility.

Harris (1987) incorporated both liquidity and information effects and found an inverse relationship between transaction price volatility and liquidity. However, liquidity was not measured directly by the BAS but by a set of hypothesized explanatory variables.

Wang et al. (1994), using direct estimates of the BAS, examined the intraday relationship of BASs and price volatility in the S&P 500 index futures market and controlled for information and liquidity effects. They found that BASs and price volatility are jointly determined and positively related.

As we review the existing literature and empirical evidence to date on the major determinants of TV, BAS, and price volatility, these three variables, namely, TV, BAS, and price volatility, appear to be jointly determined.

EMPIRICAL SPECIFICATION OF THE MODEL

In this article, we propose a three-equation structural model to examine the joint determinants of TV, BAS, and price volatility in the futures markets. The explanatory variables are drawn from previous studies:

TV = *f* [Changes in the Reservation Price of Speculators, Changes in the Expected Physical Position of Hedgers, Transaction Costs (Including BASs and Other Fixed Fees), OI, Lagged Trading Volume)] (1)

BAS = *f* [Price Risk, TV, Number of Market Makers in the Pit, Settlement Price (SP) of Futures, and Lagged BAS] (2)

$$\text{Price Volatility} = f\,[\text{TV, BAS, Lagged TV, and Lagged Price Volatility}] \qquad (3)$$

In Equation 1, the TV equation, we specified the TV as a function of changes in the reservation price of speculators, changes in the expected physical position of hedgers, transaction costs (including BASs and other fixed fees), surrogate information variable, OI, and lagged TV.

Martell and Wolf (1987) suggested that changes in the reservation prices of interday and intraday speculators are their main motivation for trading. Because speculators adjust their reservation price by observing the IV, we used the IV, measured by the price range (i.e., high price − low price), as a proxy for changes in the reservation price. We expected the IV to be positively related to TV in accordance with the MDH.

Changes in the expected physical position of hedgers is another major determinant of TV. Changes in this determinant of TV are usually attributable to a change in the information set available to hedgers. However, because factors affecting the information set vary with the nature of the asset, it is impossible to incorporate all the relevant information variables in a single model.[8] Hence, we adopted lagged OI (OI_{t-1}) and 3-month Treasury bill (3TB) rates in this study as surrogates for the information variables that affect changes in the expected physical position of hedgers. Lagged OI is the total number of outstanding contracts in the futures market lagged one period. We expected it to a have positive impact on TV. We expected the 3TB rates to be inversely related to TV, reflecting the opportunity cost of holding inventory.

Transaction cost is believed to impact TV adversely. Higher transaction costs would decrease the opportunity for market participants to make profitable trades, thus leading them to search for alternative trading vehicles with lower transaction costs. As a result, TV would decrease.

The BAS, the variable component of the transaction costs, has been included in Equation 1 as the transaction cost because other components (e.g., commission, fees, taxes) are stable over the trading period. Hence, we expected TV to be negatively related to the size of the BAS.

In Equation 2, the BAS equation, we specified the BAS as a function of the price risk (or volatility–risk measure), TV, number of market makers in the pit, SP of futures, and lagged BAS. These determinants were found to be significant in previous studies. The BASs used in this study were the mean of daily realized BASs estimated from the intraday time and sales data. The methodology of computing realized BASs was that of the

[8]See Martell and Wolf (1987).

CFTC, which has been used in other studies (e.g., Wang et al., 1994) and controls for information and liquidity effects.[9] Because the realized BAS is the mean size of price reversals, one is not always sure that the magnitude of a price reversal will always equal the BAS, particularly in the markets where new information may cause the market price to overreact in the initial price movement or in the reversal.

Transaction price changes (i.e., the price risk) imply two types of risk for market makers. First, market makers may bear nonsystematic risk because of underdiversification in the assets they hold. Second, large price changes may be correlated with the presence of information traders, and dealers must increase the BAS to compensate for expected losses when trading opposite to informed traders. Hence, IV, used as a proxy for the price risk in Equation 2, is expected to have a positive impact on the BAS.

If TV is considered a measure of market liquidity, as TV increases there is more opportunity for market makers to offset the undesirable positions of their inventories and, hence, reduce their price risk. Thus, BASs will decrease. Therefore, we expected a negative relationship between BASs and TV in Equation 2.

The results of previous studies (Chan, Chung, & Johnson, 1995; Ho & Stoll, 1983) suggest that the degree of competition in market making affects the behavior of BASs. We used the number of market makers trading in the pit during the day as our proxy for competition among market makers. We expected this to be negatively related to the size of the BAS. A large number of market makers would tend to keep the spread at a minimum as they compete for trades. However, the number of market makers in the trading pit was highly correlated with TV; subsequently, it was dropped from our estimation equation.

We employed the daily SP of the futures contract to control for the effect of the measurement scale for the same contract with different price levels and maturities.

In Equation 3, the price volatility equation, we specified the observed price volatility as a function of the TV, BAS, lagged TV, and 1-day lagged variable of itself. It has been suggested in previous studies that both TV and BASs are expected to impact price volatility positively. The greater

[9]The realized BASs were estimated as follows: (a) an empirical joint price distribution of ΔP_t and ΔP_{t-1} during a daily interval was created, (b) the subset of price changes that exhibited price continuity (i.e., a positive change followed by another positive change) was discarded, (c) absolute values of the price changes that were price reversals were taken, and (d) the mean of absolute values obtained in the third step was computed. For a further discussion of alternative estimators of the BAS for intraday futures prices, see Bhattacharya (1983); Thompson and Waller (1988); Wang, Michalski, Jordan, and Moriarty (1990); Wang et al. (1994); Ma, Peterson, and Sears (1992); and Ding (1999).

the TV is, the greater the possibility is that prices will move into higher or lower regions, thus creating greater volatility. In addition, the changes in volume may be caused by a third mixing variable, the information arrival, which will increase volatility according to the MDH. Similarly, when the BAS widens, it may be attributable to orders from informed traders that can affect the market makers unfavorably, prompting them to widen the BAS to protect their position, which eventually leads to greater transaction price movements because of bid–ask bounce.

At this point, a note on the lagged variable is warranted. A partial adjustment model was specified in each equation to take into account the distributed lags (persistence) effect in the dependent endogenous variable. Thus, the lagged term of the dependent endogenous variable in each equation was entered as an explanatory variable in the model.

Moreover, we employed the fixed effect model to pool daily time series of the cross-sectional data. In this model, dummy variables (D_is, where $i = 1$ and 2 for the first and second deferred contracts, respectively) are used to capture the effects of changing intercepts, nonconstant variance of the error terms arising from different maturity months, or both.[10]

The empirical model is written as follows:

$$\begin{aligned} \mathrm{TV}_{it} = {} & \beta_{10} + \beta_{12}\mathrm{BAS}_{it} + \beta_{13}\mathrm{IV}_{it} + \beta_{14}3\mathrm{TB}_{it} + \beta_{15}\mathrm{OI}_{it-1} \\ & + \beta_{16}\mathrm{TV}_{it-1} + D_i\mathrm{s} + e_{1it} \end{aligned} \tag{4}$$

$$\begin{aligned} \mathrm{BAS}_{it} = {} & \alpha_{20} + \alpha_{22}\mathrm{TV}_{it} + \alpha_{23}\mathrm{IV}_{it} + \alpha_{24}\mathrm{SP}_{it} \\ & + \alpha_{25}\mathrm{BAS}_{it-1} + D_i\mathrm{s} + e_{2it} \end{aligned} \tag{5}$$

$$\begin{aligned} \mathrm{IV}_{it} = {} & \delta_{30} + \delta_{32}\mathrm{TV}_{it} + \delta_{33}\mathrm{BAS}_{it} + \delta_{34}\mathrm{TV}_{it-1} \\ & + \delta_{35}\mathrm{IV}_{it-1} + D_i\mathrm{s} + e_{3it} \end{aligned} \tag{6}$$

where TV_{it} is the TV of ith contract on the tth day; TV_{it-1} is TV_{it} lagged 1 day; BAS_{it} is the mean of intradaily realized BASs of the ith contract on the tth day; BAS_{it-1} is BAS_{it} lagged 1 day; IV_{it} is the intraday price volatility of the ith contract on the tth day; IV_{it-1} is IV_{it} lagged 1 day; $3\mathrm{TB}_{it}$ is the average 3TB rates; OI_{it-1} is the OI of the ith contract on the tth day lagged 1 day; SP_{it} is the SP of the ith contract on the tth day; D_is are dummy variables to reflect differences in contract months for a futures commodity, $i = 1$ or 2 (e.g., $D_1 = 1$ for observations belonging to

[10]Furthermore, the empirical results of the dummy variables in the price volatility equation are a byproduct of testing the effects of maturity on price volatility (i.e., the Samuelson effect).

the first deferred contract at time *t* and zero otherwise); and e_{1it}, e_{2it}, and e_{3it} are the error terms of Equations 4 through 6, respectively.[11]

DATA AND METHODOLOGY

Data

The sample for this study was based on the following futures contracts:

1. Two financial futures contracts, including the (a) S&P 500 index futures (Chicago Mercantile Exchange [CME]) for the contract months March, June, September, and December and (b) DM (CME) for the contract months January, March, April, June, July, September, October, and December.
2. Two metal futures contracts, including (a) silver (Commodity Exchange [COMEX]) for the contract months January, March, May, July, September, and December and (b) gold (COMEX) for the contract months February, April, June, August, October, and December.

These futures were selected primarily because they are the most actively traded futures in their own categories, so the problem of infrequent trading was minimized.

The first contract of each maturity month was the nearby contract, and the other two were deferred contracts. The inclusion of two or three contracts with differing maturity from each category was made to ensure that a representative cross-sectional sample was obtained of the futures market with maximum variations in BASs and price volatility, which allowed reliable estimation of the relative importance of each explanatory variable in determining the TV in different futures markets. Thus, the daily time series of cross-sectional data (i.e., nearby and first and second deferred contracts) of these futures from the CME and the COMEX over the time period from January 2, 1990 to April 29, 1994 formed the sample for estimating the parameters of the model.

The time and sales intraday data from the two exchanges were used to estimate the daily mean of realized BASs, IV, and average SP level. The computerized trade reconstruction intraday data from each exchange is used to construct a measure of daily trade volume for the nearby and

[11]Each equation in our model was either exactly identified or overidentified because the number of predetermined variables excluded from the equation of our interest was at least equal to or greater than the number of endogenous variables included less one (see Johnston, 1984, p. 455).

deferred contracts. Daily OI for each contract was obtained from the CFTC database for the time period under study.

Empirical Methodology

Before we proceeded to the estimation process, we took the following precautions to mitigate the econometric problems that frequently plague the time series data. First, all variables in Equations 4 through 6 were transformed into log form. This enabled us to stabilize the variance of the error terms and approximate error terms toward a symmetric distribution. Also, coefficients could be readily interpreted as the elasticities of TV, realized BASs, and price volatility with respect to their explanatory variables.

Second, to avoid any spurious relationship among the variables because of the presence of a unit root in the time series, we applied the augmented Dickey–Fuller test (ADF) to test for differenced stationarity. Results from ADF tests form the basis for deciding whether the model should be estimated in level or first difference form. The empirical results of the ADF tests are reported in Table I. We found that the time series of TV, BASs, price volatility, and OI were free of unit root problems for the nearby and deferred contracts, whereas the 3TB rates and futures SPs had a unit root. After the first difference was taken, the 3TB rates and futures SPs were reduced to stationary time series. On the basis of these results, we estimated our three-equation model in level form for all variables, except for the 3TB rates and futures SPs in first difference form.

Finally, to confirm the specification of our model that TV, BAS, and price volatility were de facto endogenous (i.e., they all were simultaneously determined in the system), we formally applied the specification test of Hausman (1978) to our three-equation system in two ways.[12]

We first tested the null hypothesis (H_0) that BAS and price volatility are exogenous variables in the TV equation; the alternative hypothesis, H_A, suggests that one of them is not. The *F* test (based on the augmented regression approach) was used to test the hypothesis. The test procedure was as follows. First, the residuals, $\hat{e}_1$ and $\hat{e}_2$, were obtained from the OLS regressions of BAS and price volatility on the rest of the predeter-

[12]The basic idea of Hausman's (1978) specification error test is to compare the statistical difference between two estimators obtained from alternative specifications. The first estimator was efficient and consistent under the H_0, so that there was no specification error, but was inconsistent under the H_A, so that there was specification error. The second estimator was consistent under both hypotheses but less efficient under the H_0. The Hausman test provides a test statistic to examine the difference between the estimates of these two estimators. The rejection of the H_0 suggests the presence of a certain type of specification error.

TABLE I

Empirical Results of Augmented Dickey–Fuller (ADF) Tests on the Stationarity of Time Series Data

	$ln\ (TV_i)$	$ln\ (IV_i)$	$ln\ (BAS_i)$	$ln\ (OI_i)$	$ln\ (3TB_i)$	$ln\ (SP_i)$
Standard & Poor's 500 index futures						
Nearby	−8.216	−7.104	−8.542	−8.599	0.158	−2.505
First deferred	−7.752	−7.225	−7.366	−7.851	—	−2.534
Second deferred	−6.211	−5.401	−6.418	−4.950	—	−3.191
All contracts	−8.848	−9.987	−9.223	−8.388	—	−2.577
Deutsche mark futures						
Nearby	−8.836	−5.519	−9.676	−5.310	0.158	−2.364
First deferred	−8.164	−5.893	−7.753	−8.009	—	−2.380
Second deferred	−7.277	−4.415	−6.463	−4.717	—	−3.029
All contracts	−8.641	−9.250	−9.659	−6.344	—	−4.257
Silver futures						
Nearby	−8.447	−6.067	−7.423	−8.212	0.158	−1.063
First deferred	−7.246	−5.088	−9.038	−8.875	—	−1.350
Second deferred	−7.282	−5.680	−6.668	−6.822	—	−2.130
All contracts	−12.448	−9.749	−12.519	−13.029	—	−3.473
Gold futures						
Nearby	−8.923	−5.071	−7.253	−8.843	0.158	−2.229
First deferred	−7.513	−4.311	−6.812	−7.976	—	−2.082
Second deferred	−5.445	−4.883	−6.336	−4.439	—	−2.616
All contracts	−12.513	−8.167	−11.130	−13.456	—	−4.137

Note: The critical values of the ADF tests at the 1% and 5% significance levels are −3.96 and −3.41, respectively (see Fuller, 1996, p. 642).

mined variables in our three-equation model, respectively. Second, the TV equation (Equation 4) was estimated by OLS after the subscripts $\hat{e}_1$ and $\hat{e}_2$ were added as explanatory variables. Third, the F test was used to test the H_0 that $\theta_1 = \theta_2 = 0$, where θ_1 and θ_2 are coefficients of $\hat{e}_1$ and $\hat{e}_2$. The F-test results are presented as Case 1 in Table II. All F statistics were significant, and the H_0 was rejected at the 1% level for all futures contracts. The rejection of H_0 suggests that BAS, price volatility, or both were not exogenous; they should be treated as endogenous variables in the estimation of coefficients of the TV equation (Equation 4). Hence, the instrumental variable estimation method, which produces consistent estimates, instead of the OLS estimation procedure, should be used in estimating the parameters of the TV equation. Following the same procedure, we next tested the H_0 that TV, price volatility, or both were exogenous in the BAS equation (Equation 5). We repeated the test to see if BAS, TV, or both were exogenous in the price volatility equation (Equation 6) or not. These tests enable us to determine whether we have a

TABLE II

Results of the Hausman's Specification Test on the Trading-Volume Equation

Contract	(1) F Test (Augmented Regression Approach)	(2) χ^2	(3) χ^2
Standard & Poor's 500 index futures	4.96[a] (2,2213)	637.67[a]	0.639
Deutsche mark futures	24.70[a] (2,2289)	1120.64[a]	0.006
Silver futures	24.93[a] (2,2821)	18.28[a]	81.63[a]
Gold futures	29.99[a] (2,2853)	101.710[a]	32.07[a]

Note: For Case 1, in the null hypothesis H_0 the bid–ask spread and price volatility are exogenous in the trading-volume equation; in the alternative hypothesis H_A, they are not. For Case 2, in H_0 the bid–ask spread is exogenous if the price volatility is endogenous in the trading-volume equation; in H_A, the bid–ask spread is endogenous. For Case 3, in H_0 the price volatility is exogenous if the bid–ask spread is exogenous in the trading-volume equation; in H_A, bid–ask spread is endogenous. The percentage points of F with 2 and ∞ degrees of freedom for $\alpha = 0.05$ and $\alpha = 0.01$ are 3.0 and 4.61, respectively. The percentage points of chi square with 1 degree of freedom for $\alpha = 0.05$ and $\alpha = 0.01$ are 3.84 and 6.63, respectively.

[a]Significance at the 1% level. The numbers in parentheses are the degrees of freedom for the numerator and denominator, respectively.

TABLE III

Results of the Hausman's Specification Test on the Bid–Ask-Spread Equation

Contract	(1) F Test (Augmented Regression Approach)	(2) χ^2	(3) χ^2
Standard & Poor's 500 index futures	50.62[b] (2,2313)	4.59[a]	6.90[b]
Deutsche mark futures	78.09[b] (2,2289)	127.59[b]	665.92[b]
Silver futures	38.03[b] (2,2821)	33.06[b]	87.68[b]
Gold futures	65.00[b] (2,2853)	49.08[b]	3.6

Note: For Case 1, in the null hypothesis H_0, the trading volume and price volatility are exogenous in the bid–ask-spread equation; in the alternative hypothesis H_A, they are not. For Case 2, in H_0 the price volatility is exogenous if the price volatility is endogenous in the in the bid–ask-spread equation, in H_A, the price volatility is endogenous. For Case 3, in H_0 the trading volume is exogenous if the price volatility is exogenous in the bid-ask-spread equation; in H_A, the trading volume is endogenous. The percentage points of F with 2 and ∞ degrees of freedom for $\alpha = 0.05$ and $\alpha = 0.01$ are 3.0 and 4.61, respectively. The percentage points of chi square with 1 degree of freedom for $\alpha = 0.05$ and $\alpha = 0.01$ are 3.84 and 6.63, respectively.

[a]Significance at the 5% level. [b]Significance at the 1% level. The numbers in parentheses are the degree of freedom for the numerator and denominator, respectively.

three-equation simultaneous equations system or not. Results for the BAS equation (Equation 5) and the price volatility equation (Equation 6) are presented as Case 1 in Tables III and IV, respectively. Similar to the results for the TV equation, the F tests rejected the H_0 in all cases, confirming empirically that TV, price volatility, and BAS were endogenously determined in the simultaneous equations system. However, we still did not know which one or whether both of the two explanatory variables is endogenous in the system.

TABLE IV

Results of the Hausman's Specification Test on the Price-Volatility Equation

Contract	*(1) F Test (Augmented Regression Approach)*	*(2)* χ^2	*(3)* χ^2
Standard & Poor's 500 index futures	530.8[b] (2,2313)	335.99[a]	304.68[b]
Deutsche mark futures	225.62[b] (2,2289)	409.85[b]	482.35[b]
Silver futures	299.51[b] (2,2821)	405.75[b]	387.64[b]
Gold futures	369.99[b] (2,2853)	102.10[b]	243.6

Note: For Case 1, in the null hypothesis H_0 the bid–ask spread and trading volume are exogenous in the price-volatility equation; in the alternative hypothesis H_A, they are not. For Case 2, in H_0 the bid–ask spread is exogenous if the trading volume is endogenous in the price-volatility equation; in H_A, the bid–ask spread is endogenous. For Case 3, in H_0 the trading volume is exogenous if the bid–ask spread is exogenous in price-volatility equation; in H_A, the trading volume is endogenous if the bid–ask spread is endogenous in the price-volatility equation. The percentage points of F with 2 and ∞ degrees of freedom for $\alpha = 0.05$ and $\alpha = 0.01$ are 3.0 and 4.61, respectively. The percentage points of chi square with 1 degree of freedom for $\alpha = 0.05$ and $\alpha = 0.01$ are 3.84 and 6.63, respectively.

[a]Significance at the 5% level. [b]Significance at the 1% level. The numbers in parentheses are the degrees of freedom for the numerator and denominator, respectively.

Thus, in the second test we wanted to find out which one of the two explanatory variables, if any, was exogenous in each equation. Hence, we assumed one of the three explanatory variables was exogenous, whereas the other two were endogenous in the system. For instance, we first tested the H_0 that BAS was exogenous if price volatility was endogenous in the TV equation; the H_A was that BAS was endogenous. If the test result failed to reject the H_0, this would suggest that we could empirically treat BAS as an exogenous variable in the TV equation. In other words, a two-equation system (i.e., TV and price volatility in Equations 4 and 6) would be practically adequate in producing consistent estimates for the TV equation. If we rejected the H_0, the BAS should be treated as endogenous in the TV equation. This second test would provide additional evidence for whether previous studies of two-equation models for volume–price volatility, volume–BAS, and price volatility–BAS suffered from simultaneity bias.

The second test proceeded as follows:

1. The parameters of the TV equation were estimated by the two-stage least squares (2SLS) under the assumption that the H_0 was true.
2. The parameters of the TV equation were estimated by 2SLS under the assumption that the H_A was true.
3. The m statistic, which is distributed as chi square with one degree of freedom, was calculated (see Maddala, 1992, pp. 511–512):

$$m = \frac{\hat{q}^2\hat{r}^2}{(1 - r^2)\hat{V}_0}$$

where $\hat{q}$ is equal to $\hat{\beta}_1 - \hat{\beta}_0$, $\hat{\beta}_0$ is the estimate of BASs obtained in Step 1, $\hat{\beta}_1$ is the coefficient estimate of BASs obtained in Step 2, $\hat{r}^2$ is the R^2 of the reduced form equation for BASs, and $\hat{V}_0$ is the variance of $\hat{\beta}_0$.

Results are presented as Case 2 in Table II for the TV equation. The chi-square tests rejected the H_0 for all futures contracts.

Similarly, we applied the test, assuming this time that price volatility was exogenous if BAS was endogenous in the TV equation. Results are presented as Case 3 in Table II. The chi-square tests failed to reject the H_0 for the S&P 500 futures and DM futures, whereas they rejected the H_0 for the silver and gold futures. When the results of Case 3 are combined with those from Cases 1 and 2, it appears that in estimating the relationship between TV, BAS, and price volatility for silver and gold futures, the three explanatory variables must be considered simultaneously because they were shown to be endogenous. However, for S&P 500 and DM futures, if TV is the concern of estimation, BAS must be treated as endogenous, whereas price volatility can be treated empirically as exogenous.

The same chi-square tests were applied to Equations 5 and 6, and the results are reported as Cases 2 and 3 in Tables III and IV. Results for the BAS and price volatility equations were all statistically significant, except for the gold futures, where the chi-square test for Case 3 in the BAS equation was barely significant at the 5% level.

Our empirical findings suggest a caveat to the interpretation of the results from some of the previous studies (e.g., Benston & Hagerman, 1974; Chiang & Venkatesh, 1988) on BASs, price volatility, and TV. Because OLS was usually the estimation procedure used in these studies, they may have suffered from simultaneous equations bias, yielding inconsistent coefficients. Furthermore, although a simultaneous equations approach was assumed in some of the previous studies (e.g., Berkman, 1992; Foster, 1995; George & Longstaff, 1993), they did not formally test for specification errors, so their results may have been prone to specification errors.

On the basis of the results obtained from the specification tests, we adopted a simultaneous equations model in the following analysis. The GMM procedure, an instrumental variable method suggested by Hansen (1982), was used to estimate the parameters of our three-equation model. The optimal weighted matrix used in the estimation was the estimated

TABLE V

Empirical Results on the Trading-Volume, Bid–Ask-Spread and Price-Volatility Equations of Standard & Poor's 500 Index Futures (Chicago Mercantile Exchange) from January 2, 1990 to April 29, 1994[a]

Variable	*ln* (TV_{it})	*ln* (BAS_{it})	*ln* (IV_{it})
Constant	−2.136[b] (−6.67)	−0.581[b] (−3.54)	−0.094 (−0.33)
ln (TV_{it})	—	−0.273[b] (−22.67)	1.204[b] (8.10)
ln (BAS_{it})	−0.776[b] (−5.37)	—	2.808[b] (7.85)
ln (IV_{it})	0.487[b] (8.95)	0.923[b] (6.68)	—
∇ln (SP_{it})	—	−0.284[b] (−5.15)	—
ln (BAS_{it-1})	—	0.194[b] (5.20)	—
∇ln $(3TB_t)$	−0.645 (0.57)	—	—
ln (OI_{it-1})	0.514[b] (9.42)	—	—
ln (TV_{it-1})	0.369[b] (16.65)	—	−0.318[b] (−4.5)
ln (IV_{it-1})	—	—	−0.236[b] (−2.78)
D_1	0.139[a] (2.26)	0.379[b] (5.96)	−0.537[b] (−4.28)
D_2	0.236[a] (2.36)	0.115[b] (4.62)	−0.797[b] (−3.91)
R^2	0.94	0.79	0.04

Note: Each equation is estimated by the generalized method of moments. Definitions of variables are listed in the third section. Numbers in parentheses are *t* statistics. ∇ denotes the first difference operator.
[a]Significance at the 5% level. [b]Significance at the 1% level.

consistent covariance matrix under the serially correlated and hetero-skedastic error process (as proposed by Newey & West, 1987). The merit of this procedure is that it provides a set of consistent estimates of parameters as well as corresponding standard errors for each of the parameter estimates under serially correlated and heteroskedastic error terms of our simultaneous equations model.

EMPIRICAL RESULTS

The empirical results for Equations 4 through 6 are reported in Tables V through VIII.

TV Equation

In the TV equation, the coefficients of the BASs were negatively related to the TV and were statistically significant at the 1% level for all four futures. These negative coefficients can be interpreted as the short-run estimates of the elasticity of TV with respect to the BASs for the futures contracts studied. For example, Table V shows that the TV for the S&P 500 index futures will decrease 0.776% for each 1% increase in BAS (column 2, variable #3). Similar elasticities of TV with respect to BASs

TABLE VI

Empirical Results on the Trading-Volume, Bid–Ask-Spread and Price-Volatility Equations of Deutsche Mark Futures (Chicago Mercantile Exchange) from January 2, 1990 to April 29, 1994[a]

Variable	*ln* (TV_{it})	*ln* (BAS_{it})	*ln* (IV_{it})
Constant	−4.1610[b] (−6.88)	−1.207[b] (−2.63)	3.182[b] (3.64)
ln (TV_{it})	—	−0.265[b] (−21.14)	0.794[b] (11.08)
ln (BAS_{it})	−1.301[b] (−11.19)	—	1.554[b] (9.43)
ln (IV_{it})	0.696[a] (10.91)	0.632[b] (8.20)	—
∇ln (SP_{it})	—	−0.178[b] (−5.45)	—
ln (BAS_{it-1})	—	0.178[b] (7.32)	—
∇ln ($3TB_t$)	−3.634[b] (−2.98)	—	—
ln (OI_{it-1})	0.276[b] (8.47)	—	—
ln (TV_{it-1})	0.368[b] (13.29)	—	−0.249[b] (−5.56)
ln (IV_{it-1})	—	—	−0.018 (0.47)
D_1	0.008 (0.13)	0.035 (0.97)	0.073 (1.11)
D_2	−0.038 (−0.36)	0.118[a] (2.00)	0.186 (1.74)
R^2	0.92	0.80	0.10

Note: Each equation is estimated by the generalized method of moments. Definitions of variables are listed in the third section. Numbers in parentheses are *t* statistics. ∇ denotes the first difference operator.
[a]Significance at the 5% level. [b]Significance at the 1% level.

TABLE VII

Empirical Results on the Trading-Volume, Bid–Ask-Spread and Price-Volatility Equations of Silver Futures (Commodity Exchange) from January 2, 1990 to April 29, 1994[a]

Variable	*ln* (TV_{it})	*ln* (BAS_{it})	*ln* (IV_{it})
Constant	0.198[a] (2.04)	0.359[b] (3.03)	−0.706[b] (−6.81)
ln (TV_{it})	—	−0.202[b] (−18.72)	0.598[b] (16.91)
ln (BAS_{it})	−0.895[b] (−3.00)	—	1.263[b] (13.19)
ln (IV_{it})	0.515[b] (3.06)	0.508[b] (9.64)	—
∇ln (SP_{it})	—	−0.003 (−0.34)	—
ln (BAS_{it-1})	—	0.118[b] (5.39)	—
∇ln ($3TB_t$)	−1.758[a] (−2.01)	—	—
ln (OI_{it-1})	0.282[b] (5.03)	—	—
ln (TV_{it-1})	0.494[b] (20.14)	—	−0.268[b] (−8.73)
ln (IV_{it-1})	—	—	0.124[b] (3.82)
Trend	−0.016[a] (−2.21)	—	—
D_1	−0.282[a] (−4.84)	−0.128[b] (−1.67)	0.145[b] (4.04)
D_2	−0515[b] (−6.02)	−0.159[b] (−5.96)	0.253[b] (6.46)
R^2	0.71	0.31	0.21

Note: Each equation is estimated by the generalized method of moments. Definitions of variables are listed in the third section. Numbers in parentheses are *t* statistics. ∇ denotes the first difference operator.
[a]Significance at the 5% level. [b]Significance at the 1% level.

TABLE VIII

Empirical Results on the Trading-Volume, Bid–Ask-Spread, and Price-Volatility Equations of Gold Futures (Commodity Exchange) from January 2, 1990 to April 29, 1994[a]

Variable	$\ln(TV_{it})$	$\ln(BAS_{it})$	$\ln(IV_{it})$
Constant	0.198 (0.23)	0.213[b] (3.84)	−0.087 (−1.38)
$\ln(TV_{it})$	—	−0.241[b] (−23.73)	0.278[b] (7.78)
$\ln(BAS_{it})$	−1.314[a] (−2.32)	—	0.538[b] (5.31)
$\ln(IV_{it})$	0.434 (1.63)	0.589[b] (12.53)	—
$\Delta\ln(SP_{it})$	—	−0.197 (−0.19)	—
$\ln(BAS_{it-1})$	—	0.129[b] (6.27)	—
$\Delta\ln(3TB_t)$	−0.184 (−0.11)	—	—
$\ln(OI_{it-1})$	0.462[b] (8.31)	—	—
$\ln(TV_{it-1})$	0.31[b] (2.60)	—	0.093[b] (−3.73)
$\ln(IV_{it-1})$	—	—	0.269[b] (7.81)
Trend	−0.213 (−1.14)	—	—
D_1	−0.188[a] (−2.56)	−0.037 (−1.33)	0.021 (0.76)
D_2	−0.575[b] (−6.48)	−0.014 (−0.47)	0.021 (0.85)
R^2	0.83	0.39	0.24

Note: Each equation is estimated by the generalized method of moments. Definitions of variables are listed in the third section. Numbers in parentheses are *t* statistics. Δ denotes the first difference operator.
[a]Significance at the 5% level. [b]Significance at the 1% level.

can be found in Tables VI through VIII for DM (−1.301), silver (−2.028), and gold (−1.314) futures, respectively. They all suggest that TV will decline when BASs, a major component of transaction cost, increases. The estimates of the long-run elasticity of TV with respect to BASs are presented in Table IX. They are all elastic and range from −1.230 for the S&P 500 index futures to −2.058 for the DM futures.

The coefficients of IV were all positive and statistically significant at the 1% level for all four futures contracts. This result is as expected and is consistent with the empirical findings of Cornell (1981), Tauchen and Pitts (1983), Martell and Wolf (1987), and others. In addition, this is consistent with the theory that an increase in price volatility will change the reservation price of speculators and increase the demand for risk transfer by hedgers. Both effects should lead to a higher volume. The short-run elasticities of TV with respect to price volatility were all less than one, except for silver futures (1.386).

It was expected that the regression coefficient for the changes in the 3TB rates would be negatively related to TV. In general, higher short-term interest rates increase the cost of carry in the cash or spot assets or commodities, reduce the hedging needs in the futures market, and reduce speculative trade by making alternative investments more attractive.

TABLE IX

Elasticities of the Trading Volume with Respect to the Bid–Ask Spread in Futures Markets

Futures	*Short-Run Estimate*	*Long-Run Estimate*[a]
Financial futures		
Standard & Poor's 500 index futures	−0.776	−1.230
Deutsche mark futures	−1.301	−2.058
Metals futures		
Silver futures	−0.895	−1.598
Gold futures	−1.314	−1.907

[a]Long-run estimate = (short-run estimate)/[1 − coefficient ln (TV_{it-1})].

Thus, a reduction in speculative and hedging activities in the futures markets would lower TV. An inverse relationship was, therefore, anticipated. However, the resulting coefficients of the changes in 3TB rates were mixed. The coefficients for the S&P 500 (0.645) and silver (0.821) futures were positive, whereas those for DM and gold futures were, as expected, negative but statistically weak.

The coefficients of OI lagged one period (OI_{it-1}; hereafter, OI) were all positive and statistically significant at the 1% level for all futures, except for silver. High OI indicates more trades are likely to occur in the future. We observed that the coefficients of TV with respect to OI were less than 0.514, albeit close to zero for silver.

All of the coefficients of lagged TV (TV_{it-1}) were positively significant at the 1% level. Also, the sizes of the coefficients for the four futures were quite similar; all were between 0.3 and 0.4. The significance in the coefficients of lagged volume agrees with the extant literature that persistence in volume exists. Once again, empirical evidence lends support to our partial adjustment model specification.

Thus far, there are two observations about the empirical results that are noteworthy. First, our results support the notion that the degree of elasticity of a particular futures contract depends on the availability of close substitutes in the form of domestic and overseas futures contracts. Thus, it makes much sense for the elasticities of the TV of S&P 500 and DM futures to be lower when the silver and gold futures trading are available in many foreign countries. Second, given our results, the elasticity estimates used by the Congressional Budget Office (1992)—for example, the −0.26 estimates of Epps (1976), who used stock market data—seriously underestimate current market elasticities. Hence, the Congressional Budget Office study overestimates potential revenue from user's fees. However, Edwards's (1992) assumed elasticity of less than -5.0 in his simulation of the impact of a user's fee on the S&P 500 index futures was not supported by our findings either. It appears that the magnitude of the elasticity has been overestimated, whereas the potential tax revenue has been underestimated.

BAS Equation

Coefficient estimates of the explanatory variables on the BAS equation are presented in column 3 of Tables V through VIII. The coefficients of TV were negative and statistically significant at the 1% level for all four futures. These result are consistent with those of Benston and Hagerman (1974). The associated coefficients were no smaller than -0.273. This means that a 10% increase in TV will result in a no more than 2.73% drop in the BAS.

The coefficients of price volatility (IV) were significantly positive for all four futures. This result was as expected because an increase in price volatility implies two types of risk for the market markers as mentioned before. In terms of magnitude, the elasticities of BASs with respect to price volatility were higher for financial futures (S&P 500 = 0.923 and DM = 0.632) than those for the metals (silver = 0.508 and gold = 0.589).

Changes in the daily SP are employed to control for the effect of different price levels of contracts with differing maturities. The coefficients for the change in SP were all negative; those for financial futures but not those for the metals were statistically significant.

The coefficients of lagged BASs (BAS_{it-1}) were invariably small but positively significant at the 1% level. This suggests that the dynamic adjustment of the BAS is not usually completed in a 1-day period for the selected futures.

These results of the effect of TV on the BAS equation have important implications for the recent proposal on creating a two-tiered system by the futures exchanges: one for the professional and institutional traders and the other for retail customers. The purpose of creating a two-tiered market is to allow the market for professionals to be exempt from federal regulations.[13] A tiered market, splitting up the current TV into the professional and retail markets, will drive up the BAS and reduce market liquidity in both markets, hurting the retail market more, other things being equal. Because the TV of professional traders is expected to be

[13]See the *Wall Street Journal* ("Senate to Hear," 1997) for a discussion of this proposal.

much greater than that of retail customers, a split-up of the futures markets into tiers would take away the volume needed for a liquid market for retail customers, widening the BAS in the retail customer futures market. Thus, the creation of professional futures markets, despite many advantages arising thereof, will inevitably impose negative externalities to futures customer trading in the retail market. From the public policy perspective, this deserves careful consideration of the costs and benefits of deregulation. Results from this study provide estimates of the cost of externalities in terms of loss of market liquidity as measured by the widening BAS.

Price Volatility Equation

Results of the price volatility equation are presented in column 4 of Tables V through VIII. The coefficients for both TV and BAS are positively significant at the 1% level for all four futures. From the estimated price volatility equation, we can decompose the sources of change in the observed price volatility into two components: (a) the information component approximated by TV and (b) the intraday liquidity component represented by BASs. As expected, increases in TV had positive impacts on price volatility. This is also consistent with results in well-documented literature. Likewise, our finding that a positive relationship exists between BASs and observed price volatility is also consistent with results reported by Wang et al. (1994). This finding can be interpreted to indicate that an increase in liquidity (i.e., narrowing BASs) will reduce price volatility conditioned on a given level of TV.

The coefficients for lagged TV (TV_{it-1}) were negative and significant at the 1% level for all four futures. This is consistent with Foster (1995), who found that lagged volume was significant in explaining price volatility in crude oil futures. It implies that knowledge of current volume could be used to explain futures price variability. This is in stark contrast to contemporaneous volume, whose coefficients are positive for all futures. A negative coefficient implies that an increase in lagged TV (as a measure of liquidity) reduces the current price volatility, conditioned on the current TV and the BAS. Our results are also consistent with Bessembinder and Seguin (1993), who found that the lagged OI variable (interpreted as a measure of liquidity) results in a negative and significant coefficient on price volatility. The coefficients of lagged price volatility (IV_{it-1}) were significantly positive for the metals and positive for the DM futures but insignificantly negative for the S&P 500 futures. These results suggest that there is a persistence effect in price volatility. Furthermore, our re-

TABLE X

A Comparison of the Estimated Coefficients of Explanatory Endogenous Variables in the Trading-Volume Equation by the Generalized Method of Moment (GMM) and Ordinary Least-Squares (OLS) Procedures

Contracts	*GMM Estimates*[a]	*OLS Estimates*[a]
Standard & Poor's 500 index futures		
ln (BAS_{it})	−0.776 (−5.37)	−0.363 (−11.64)
ln (IV_{it})	0.487 (8.95)	0.445 (15.82)
Deutshe mark futures		
ln (BAS_{it})	−1.301 (−11.19)	−0.628 (−18.51)
ln (IV_{it})	0.696 (10.91)	0.523 (19.11)
Silver futures		
ln (BAS_{it})	−2.028 (−6.46)	−0.234 (−7.65)
ln (IV_{it})	1.386 (9.41)	0.570 (23.62)
Gold futures		
ln (BAS_{it})	−1.314 (−2.32)	−0.270 (−10.94)
ln (BAS_{it})	0.434 (1.63)	0.449 (19.11)

[a]Numbers in parentheses are corresponding *t* statistics. For two-side tests, the percentile of $t(\alpha = 0.05)$ is equal to 1.96, and the percentile of $t(\alpha = 0.01)$ is equal to 2.576.

sults do not support the findings by Lamoureux and Lastrapes (1990) that the incorporation of TV in the price volatility equation would remove the significance of the lagged price volatility term on price volatility.[14] In fact, our results indicate that both contemporaneous and lagged volume help explain price volatility.

Instrumental Variable (GMM) Estimates Versus OLS Estimates

Finally, we tried to assess how large the simultaneity bias would have been had we not used the instrumental variable approach but OLS instead. Therefore, we estimated each of the three equations with OLS. We first present the comparison of GMM estimates versus OLS estimates of the two selected explanatory endogenous variables, BAS and IV, in the TV equation, which are presented in Table X. Most of the OLS estimates were severely underestimated in comparison with the corresponding GMM estimates.[15] For example, the OLS coefficients of the BAS in the

[14]Lamoureux and Lastrapes' (1990) results suffered from simultaneity bias because price volatility and TV are jointly determined.

[15]The magnitude of simultaneity bias depends on the magnitude of the correlation between the exploratory endogenous variable and the error term of the equation (see Johnston, 1984, chap. 11).

TABLE XI

A Comparison of the Estimated Coefficients of Explanatory Endogenous Variables in the Bid–Ask-Spread Equation by the Generalized Method of Moment (GMM) and Ordinary Least-Squares (OLS) Procedures

Contracts	*GMM Estimates*[a]	*OLS Estimates*[a]
Standard & Poor's 500 index futures		
ln (TV_{it})	−0.273 (−22.67)	−0.213 (−26.69)
ln (IV_{it})	0.923 (6.68)	0.342 (15.41)
Deutsche mark futures		
ln (TV_{it})	−0.265 (−21.14)	−0.211 (−27.39)
ln (IV_{it})	0.632 (8.20)	0.312 (18.55)
Silver futures		
ln (TV_{it})	−2.02 (−18.72)	−0.144 (−23.22)
ln (IV_{it})	0.508 (9.64)	0.274 (16.78)
Gold futures		
ln (TV_{it})	−0.241 (−23.73)	−0.189 (−27.01)
ln (IV_{it})	−0.589 (−12.53)	0.369 (19.84)

[a]Numbers in parentheses are corresponding t statistics. For two-side tests, the percentile of $t(\alpha = 0.5)$ is equal to 1.96, and the percentile of $t(\alpha = 0.01)$ is equal to 2.576.

TV equation were uniformly smaller (about two to eight times) than their GMM counterparts. Estimated elasticities based on OLS seem to suggest that TVs were all inelastic to BASs, but in fact they were elastic in the long run, as indicated by the GMM estimates. The comparison of GMM and OLS estimates for the BAS and price volatility equations are presented in Tables XI and XII, respectively. In general, similar patterns of OLS underestimation were observed in these two equations as in the TV equation.

SUMMARY AND CONCLUSIONS

In this study, the relations among TV, BAS, and price volatility of four financial and metal futures were examined. After a battery of Hausman's (1978) tests of specification, we confirmed that TV, BAS, and price volatility are jointly determined. We estimated the parameters and elasticities of TV, BAS, and price volatility in a three-equation structural model using the GMM procedure. Results indicate that there is a positive relationship between TV and IV but an inverse relationship between TV and BAS after other factors are controlled. Furthermore, results show that price volatility has a positive relationship with BAS and a negative relationship with lagged TV. In addition, we demonstrated that the OLS parameter esti-

TABLE XII

A Comparison of the Estimated Coefficients of Explanatory Endogenous Variables in the Price-Volatility Equation by the Generalized Method of Moment (GMM) and Ordinary Least-Squares (OLS) Procedures

Contracts	*GMM Estimates*[a]	*OLS Estimates*[a]
Standard & Poor's 500 index futures		
ln (BAS_{it})	2.808 (7.85)	0.296 (14.17)
ln (TV_{it})	1.204 (8.10)	0.188 (15.09)
Deutsche mark futures		
ln (BAS_{it})	1.554 (9.43)	0.418 (17.34)
ln (TV_{it})	0.794 (11.08)	0.244 (18.44)
Silver futures		
ln (BAS_{it})	1.263 (13.19)	0.342 (17.34)
ln (TV_{it})	0.598 (16.91)	0.286 (26.32)
Gold futures		
ln (BAS_{it})	0.538 (5.31)	0.329 (19.83)
ln (TV_{it})	0.278 (7.78)	0.266 (23.67)

[a]Numbers in parentheses are corresponding t statistics. For two-side tests, the percentile of $t(\alpha = 0.05)$ is equal to 1.96, and the percentile of $t(\alpha = 0.01)$ is equal to 2.576.

mates of each equation model were often severely underestimated in comparison with their consistent estimators obtained from the GMM estimation. Results from this study have important policy implications on two recent proposals: (a) the imposition of a transaction tax and (b) a two-tiered futures market for professionals and retail investors. For both proposals, accurate estimates of elasticities of BAS and TV with respect to each other are provided by this study.

Our results indicate that a transaction tax, which is analogous to a greater BAS, will reduce TV, although the reduction is not as great as previously estimated. In contrast, a tiered market, splitting up the current TV into the professional and retail markets, will drive up the BAS and reduce market liquidity in both markets, hurting the retail market more, other things being equal.

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