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Introducing Contemporaneous Open-Outcry and E-Trading at the Chicago Board of Trade

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Abstract

This study uses a vector error correction (VEC) model to examine price-volume relationships between open outcry and e-trading at the Chicago Board of Trade. We test whether equilibrium price corrections on one system are independent of the other, and whether this price behavior is more sensitive to changes in screen-based volume as opposed to open outcry volume. Error correction terms capture an asymmetric price adjustment process led by open outcry trading. Open outcry volume (market depth) also results in price discovery by dampening price volatility on both markets. These aspects of market microstructure are relevant in identifying how newly introduced e-trading systems operate in relation to established open outcry systems, and how e-trading systems may affect the economic performance of futures exchanges generally.

Keywords: Market liquidity; Bid-ask spreads; Open outcry; Screen-based trading

1. Introduction

Stigler [15] reminds us that competition motivates market participants to provide goods and services skillfully and economically, and at times experiment with new ways of doing business. This behavior is exemplified by The Chicago Board of Trade's (CBOT) advancement of e-trading platforms–innovations which gained early acceptance in Europe and have since transformed the mechanics of futures trading. Some exchanges have used e-trading systems to extend trading hours; examples include the Chicago Board of Trade's Project A® and a/c/e™ electronic trading systems (Ulibarri [16]), the New York Mercantile Exchange's ACCESS® system (Ulibarri [17]), and the Automated Pit Trading system once used at the London International Fin- ancial Futures Exchange (LIFFE). In other applications futures exchanges adopted e-trading systems exclusively; examples include EUREX, the elec- tronic German-Swiss exchange which formed with the merger between the Deutch Terminbose (DTB) and the Swiss Options and Financial Futures Exchange (SOFFEX); and the newly formed Euronext.liffe (2001), which merged the derivatives markets of

Amsterdam, Brussels, LIFFE, Lisbon and Paris under a single electronic trading platform, LIFFE CONNECT®.

Clearly the development of e-trading at European exchanges changed the organization of the global futures industry. As a leading player in the industry, the Chicago Board of Trade (CBOT) was the first US derivatives exchange to adopt e-trading when it launched its Project A platform in 1994. Over the next four years Project A served as an after-hours market without much growth in contract volume. On the contrary, the growth of e-trading volume at European exchanges more than doubled[1]. Thus to position itself in the emerging technological revolution CBOT launched its "side-by-side" trading platform in September 1998 by extending Project A hours to run con- currently with the boisterous open outcry auction.

The purpose of this study is to examine the early performance of CBOT's side-by-side markets at promoting "price discovery"--the process by which markets attempt to find equilibrium prices, thereby enabling market makers to exchange contracts more economically (Schreiber and Schwartz, [12]). A number of papers have considered price discovery across electronic and open outcry futures markets, particularly between the German Bund futures contract which was traded electronically at the DTB and through open outcry at LIFFE[2].

For example, Shyy and Lee [13] present evidence that the DTB's automated price movements Granger cause LIFFE's open outcry price movements. This finding is surprising given that the average daily trading volume on LIFFE was about two or three times that of DTB, or 91,674 contracts compared to 39,300 contracts.[3] On the contrary, Kofman and Moser [8] report bi-directional causality between the two Bund markets and suggest there may be more information-based trading on the DTB. Pirrong [10]

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[1] Early studies by Baptiste et al. [1], Sarkar and Tozzi [14], and Price Waterhouse [11] found global use of electronic trading systems (from eight systems in 1990 to about forty in 1997, with electronic trading volume increasing from 7 percent in 1989 to 18 percent in 1996).

[2] Footnote 7 briefly describes organizational changes and restructuring at LIFFE pursuant to the evolution of e-trading at European exchanges.

[3] Shyy and Lee [13] use an error correction model to test Granger causality, finding that price movements on the DTB caused price movements in LIFFE (the methodology is discussed below in section 3). Interestingly, the t-values for lagging variables suggest the price transmission process was very fast, with only the one-minute lag variable for DTB having signiicant impact on LIFFE price movements. The authors are surprised by the finding of a unidirectional lead from the DTB to LIFFE given LIFFE exhibited a significantly larger trading volume in Bund futures than the DTB.

meanwhile, presents evidence that market liquidity and depth were greater on the DTB's e-trading system than LIFFE's open outcry market. In retrospect, the evidence presented by both Pirrong and Shyy & Lee corresponds with LIFFE's decision to switch from open outcry to its current e-trading plat- form, LIFFE CONNECT®.

Meanwhile, little is known about the relationship between e-trading and open-outcry at US derivatives exchanges; in particular, the process of price discovery and the attending role of market depth. The present study focuses on price discovery at the CBOT over a sampling period dominated by open outcry trading (1998-1999). Assuming open outcry auctions play a leader-ship role in determining price equilibrium, the study tests for a one-way causal relationship between sides. The importance of market depth (trading volume) in determining price adjustment behavior is also examined, with specific focus on how volume surprises on one side of the platform impact the other. These aspects of market microstructure are of interest to financial economists in terms of understanding how the emergence of e-trading im-pacts the simultaneous operation of open outcry auctions, and how this inter-action conditions the economic performance of futures exchanges generally.

This study provides three extensions over previous work in comparing electronic and open outcry markets. First, this research deviates from the European-based studies by examining the price-effects from e-trading during the first year of side-by-side operations. Secondly, by focusing on the opera- tion of the CBOT side-by-side trading platform, this study tests price-volume relationships between systems operating contemporaneously at a common exchange. Thirdly, a vector error correction (VEC) framework is used to ex- amine the economic effects of market depth in explaining price-volume rela- tionships across trading systems. This econometric framework yields testable implications concerning the impacts of market depth on price volatility, and the leadership role of open outcry auctions during the early stages of e-trading.

The remainder of the paper is organized as follows. Section 2 reviews some of the institutional background behind the development of e-trading networks at the CBOT. Section 3 describes a study data set for examining causal relationships in the price discovery process and the attending role of market depth. Section 4 applies a VEC framework in testing price-volume behavior in the side-by-side market platform, followed by a summary of findings and concluding remarks.

2. CBOT E-Trading Platforms

In 1994, the CBOT introduced its first e-trading platform, Project A. This trading system used an electronic order-entry and order-matching system for exchanging futures contracts and options on futures contracts. As on other e-trading platforms, trade execution on Project A required three prin- cipal components: i) remote computer terminals from where customer orders are submitted and trade confirmations are received; ii) a centralized host computer which processed/executed trades; and iii) a network linking the various terminals to the host computer and the host computer to the clear- inghouse[4]. Incoming orders on Project A get routed and processed electroni- cally by the host computer using a trade execution algorithm subject to rules establishing their priority. For example, the Project A algorithm matched bids with offers according to priority rules over price and time of entry: or- ders that "made the market" (beating the best bid or ask prices) were given priority over orders that were "at the market" or within one tick of the market.

Beginning September 1998, the CBOT began operating Project A con- currently alongside its open outcry auction of T-bond futures. Each market was treated as a separate exchange: orders entered into on Project A could not be filled in the open outcry auction, and vice-versa. However, transac- tions on either market could offset each other at the end of the trading day through the clearing function, then provided by the Board of Trade Clearing Corporation. Despite Project A's potential to enhance technical efficiencies and process orders at a lower cost, it remained an auxiliary market relative to the much deeper open outcry auction.

The literature offers various possible reasons for the dominance of open outcry over the study period. Sarkar and Tozzi [14] for example, suggest floor traders could have executed large or complex trades more easily than e-traders, e.g. "stop loss orders" or various types of "spread trades[5]". More- over, Pirrong [10] suggests floor traders could have had better information as to the direction of the market given their observations of incoming order flow and eye-to-eye awareness of extant buying and selling positions.

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[4] Lati [9] reports that futures exchanges received 95.4% of their trades through electronic routing systems in the year 2000; the preferred media by which customers communicate with e-trading systems.

[5] These orders were more difficult to enter electronically on early e-trading platforms and typically required more "handling". For example, executing "stop loss" orders entails buying or selling a contract when it reaches a specified price, while executing "spread" trades in- volves simultaneously buying and selling of two different futures contracts.

Conversely, e-orders are generally entered anonymously, with no one trader knowing who is entering a bid or an offer. In this sense e-trading on Project A may have generated less information regarding the "feel" of the market or the motiva- tions of potential counterparties. In addition, Pirrong [10] observes that e-traders must explicitly withdraw old quotes from their screens, which is rela- tively time consuming and increases exposure to adverse selection risk. Such market frictions are consistent with the perception that highly active con- tracts, such as CBOT's 30-year T-bond futures, may have been traded more efficiently in open outcry auctions (Kharouf [7]).

While the above arguments would explain the relative popularity of open outcry over the 1998-1999 study period, they do not explain why e-trading was the dominant means of exchange in Europe (at France's Matif, Ger- many's DTB and the UK's LIFFE), or why the CBOT would continue deve- loping its e-trading platforms despite their apparent drawbacks. Perhaps these questions are better answered by considering the actions taken by CBOT to increase the distribution of its e-traded products; specifically, its decision to replace Project A (August 2000) with the a/c/e-alliance platform (alliance/cbot/eurex), giving CBOT direct entry into Europe. The a/c/e plat- form set up a common network for e-trading of derivatives between CBOT and EUREX, then the world's leading e-futures market. The "implicit mer- ger" between organizations supported the growth of e-traded products at the CBOT.[6] Indeed, by 2003, the a/c/e-alliance platform accounted for over 70% of all U.S. Bond futures trading, a far cry from the Project A experience (see Figure 1).

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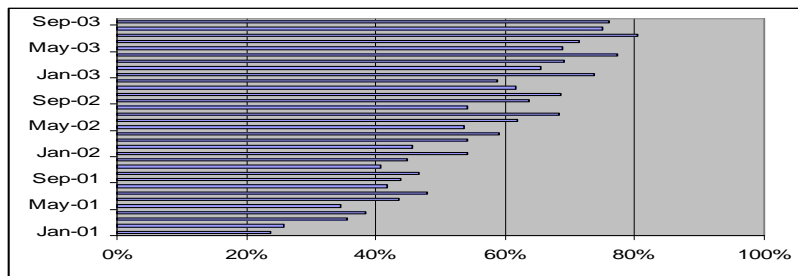
[6] The term "implicit merger" was first introduced by Domowitz [3]. The present use of the term signifies an economic organization with infrastructure capacity to market a larger array of products or handle a larger volume of trade at lower cost.

Figure 1 T-Bond E-Trading as % of Total Trading

The a/c/e platform was scheduled to operate through 2008. However, in early 2002, the market structure of Europe's futures industry shifted with the reorganization of LIFFE and its takeover by Euronext (creating Euronext liffe) [7]. These developments enabled LIFFE to begin marketing its proprietary e-trading technologies. Soon after, CBOT ended its alliance with EUREX (effective January 2004) and opened e-cbot® under a licensing agreement with Euronext.liffe[8]. The new trade network gives CBOT a direct market for its products at 556 locations in 26 countries worldwide, creating the world's most widely accessible e-trading platform.

Fundamentally, the development of e-trading platforms at the CBOT is mindful of Schumpeter's concept of *Creative Destruction*: the process by which technological innovation and organizational change combine in redefining the boundaries of competition[9]. Of present interest is the assimilation and performance of e-trading vis-à-vis the operation of side-by-side markets. To this end, the remainder of this paper studies the price-volume behavior between Project A and the open outcry auction. The notion that trade volume conditions price discovery is a feature of the study. Deep markets, such as CBOT's open outcry auction of T-bonds, tend to have relatively low price volatility in the sense that prices move little in response to increased trade volume. On the contrary, thin markets such as Project A tend to have greater price volatility. Anticipating results the study finds price volatility tends to decrease symmetrically in both markets due to increased volumes of open outcry trading, thus underscoring the value of contemporaneous trading in the early development of CBOT's e-trading system.

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[7] Euronext.liffe formed in 2001 following the purchase of LIFFE by Euronext, a consortium of various European derivatives markets, including: Amsterdam, Brussels, LIFFE, Lisbon, and Paris. To motivate its purchase, LIFFE adopted a for-profit ownership structure and separated its technology business from its trading business; steps which created market value.

[8] The newest platform is powered by LIFFE CONNECT® software and Sun Microsystems infrastructure. Among its notable features, LIFFE CONNECT® software provides for the calculation of "implied pricing," "best-price quotations" and "dynamic pricing limits" which move automatically with the market thus reducing the potential for mis-trades.

[9] Creative Destruction signifies a process which, "incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. . . . (With) every piece of business strategy acquir(ing) its true significance only against the background of that process and within the situation created by it….(With) competition (created) from the new commodity, the new technology, the new source of supply, the new type of organization…" From Capitalism, Socialism and Democracy (New York: Harper, 1975) [orig. pub. 1942], pp. 82-85

3. Study Data

Study data for CBOT futures contracts on 30-year US treasury bonds is provided by the CBOT Market Information Department for the period October 1, 1998 thru August 5, 1999. The data cover 211 trading days and include separate trade volume and price information for the Project A and open outcry daytime sessions (7:20 am to 2:00 pm Chicago time). The CBOT identifies contracts traded through open outcry by the ticker symbol US, and those traded on Project A by the ticker symbol ZB. Accordingly, the study denotes open outcry trade volume and average daily price as USVOL and USP, and Project A trade volume and average daily price as ZBVOL and ZBP. Table 1 reports their sample statistics.

The average daily price levels in open outcry (USP) and Project A (ZBP) have similar means, standard deviations, and coefficients of variation (CV). On the contrary, both the means and standard deviations of the trading volumes vary significantly between sessions. Project A volume (ZBVOL) averages approximately 2 percent of open outcry volume (USVOL) and exhibits significantly more dispersion about the mean (CV = 0.73 compared to CV = 0.38). Figure 2 plots the price-volume time series.

Both price series trend downward over the study period, akin to random walk models with stochastic drift. Consequently, each series {USP} and {ZBP} appears to be a non-stationary stochastic process (or unit root process)[10]. Confirmation of the random walk price behavior is given by Dickey-Fuller (D-F) tests for unit roots. Here the D-F τ-statistics of

Table 1 Sample Statistics

n = 211 trading days	Mean	Max	Min	S.D.	CV	D-F τ*
Open outcry price level USP	122,766	134,188	113,781	5,266	0.0429	-1.32
Project A price level ZBP	122,779	134,125	113,813	5,264	0.0429	-1.29
Open outcry volume USVOL	338,730	760,417	85,571	130,126	0.3842	
Project A volume ZBVOL	6,426	33,897	0	4,702	0.7317	

* The Mackinnon critical values for rejection of unit roots are 3.4634. Accordingly, the τ-statistics indicate the price series have unit roots (i.e. they are non-stationary stochastic processes).

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[10] Formally, a stochastic process {X_t} which follows a random walk is referred to in the time series literature as a non-stationary stochastic process (or unit root process), i.e. its mean and/or variance change over time.
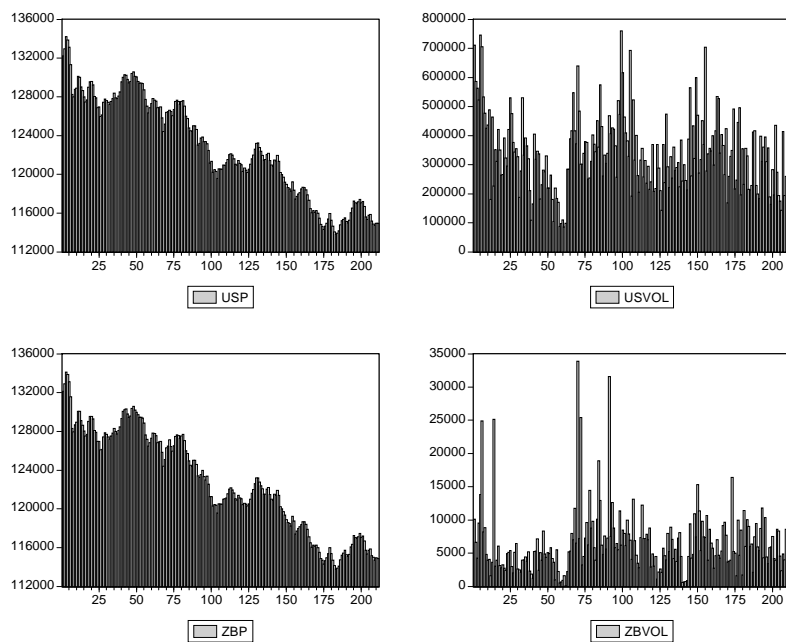
Figure 2 Price-Volume Data for 30-Year T-Bond Futures Traded
Electronically (ZBP-ZBVOL) and through
Open Outcry (USP-USVOL).

-1.32 and -1.29 do not exceed the Mackinnon critical value of 3.4634, suggesting that both series are unit root processes and thus non-stationary. This is an important feature insofar as modeling the interrelationship between market prices.

4. VEC Framework

The absence of arbitrage between the Project A and open outcry markets implies the price series USP and ZBP cannot drift apart in a persistent man- ner[11]. Thus, while each series is individually non-stationary,

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[11] Suppose not, and that T-bond futures are trading at 120-20 through open outcry and 120-31 on Project A. In the absence of transaction costs, an arbitrageur could simultaneously buy 100 contracts in the pit and sell them on Project A for a risk-free profit of $F(Pe - Pp) = 100[$ 120-31 - 120-20]. Clearly, the incentives for increased selling on Project A and buying in the open outcry auction would result in the absence of arbitrage opportunities across the side-by-side platform.

the two series are certain to be cointegrated in the sense of Engel-Granger [5]; that is, a stationary linear combination of the two price series may exist as defined by the cointegrating regression $USP_{t-1} = \beta\, ZBP_{t-1} + \eta_t$, where η_t is a stationary stochastic process with zero-mean and finite variance. In economic terms, this cointegrating regression establishes an "equilibrium-type relationship" between prices on Project A and the open outcry auction. On average the two markets will tend to be in equilibrium as defined by the mathematical expec- tation $E[\eta_t] = 0$. On the contrary, deviations from equilibrium (or "equili- brium errors") are implied by $\eta_t \neq 0$. For modeling purposes, such deviations are assumed to be corrected by adjustments in one or both price series based on the following error correction mechanism:

$$\Delta USP_t = \gamma_{us}\,(USP_{t-1} - \beta\, ZBP_{t-1}) + \mu_{us} \quad = \gamma_{us}\,(\eta_{t-1}) + \mu_{us} \qquad (1)$$

$$\Delta ZBP_t = \gamma_{zb}\,(USP_{t-1} - \beta\, ZBP_{t-1}) + \mu_{zb} \quad = \gamma_{us}\,(\eta_{t-1}) + \mu_{us} \qquad (2)$$

where γ_{us} and γ_{zb} are price-response parameters and μ_{us} and μ_{zb} are random shocks specific to each market.

Convergence towards price equilibrium requires that at least one of the price-response parameters be significantly different from zero. For example, if $\gamma_{us} < \gamma_{zb} \leq 0$ then deviations from equilibrium (i.e. "equilibrium errors" where $\eta_{t-1} \neq 0$) will be followed primarily by equilibrating price changes in the open outcry auction. In this case, open outcry prices are said to be rela- tively more price-responsive compared to Project A prices. On the contrary, if $\gamma_{zb} < \gamma_{us} \leq 0$ then equilibrium price adjustments will occur primarily on Pro- ject A. Given this error-correction process, a vector error correction (VEC) model is specified by extending equations (1a) and (1b) to include lagged changes in average daily price levels (ΔUSP_{t-k} and ΔZBP_{t-k}), and daily trade volumes (USVOL and ZBVOL), yielding the following reduced-form VEC model:

$$\Delta USP_t = c_1 + \gamma_{us}(\eta_{t-1}) + \sum (a_{1,k}\Delta USP_{t-k}) + \sum (b_{1,k}\Delta ZBP_{t-k}) + \Phi_{us}USV + \Phi_{zb}ZBV + \mu_{us} \qquad (3)$$

$$\Delta ZBP_t = c_2 + \gamma_{zb}(\eta_{t-1}) + \sum (a_{2,k}\Delta USP_{t-k}) + \sum (b_{2,k}\Delta ZBP_{t-k}) + \Phi_{us}USV + \Phi_{zb}ZBV + \mu_{zb} \qquad (4)$$

where $\eta_{t-1} = USP_{t-1} - \beta\, ZBP_{t-1}$ represent deviations from the cointegrating equilibrium, and Φ_{us} and Φ_{zb} are volume parameters capturing the effects of market depth on price behavior, i.e. price-volume causality across the trading platform. Accordingly, the VEC allows testing competing hypotheses of price-volume effects on the market microstructure.

Symmetrical price responsiveness to changes in open outcry volume is implied by Φ_{us} having the same sign in both reduced form equations. For example, negative (positive) signs are indicative that increased open outcry volume dampens (increases) price volatility in both markets. On the contrary, an asymmetrical price response pattern to changes in floor volume is implied by Φ_{us} having mixed signs in both reduced form equations. Similar interpretations apply in examining price responsiveness relative to changes in e-traded volume.

Because each regression equation has the same number of lagged endogenous variables, ordinary least-squares (OLS) estimation of each equation separately yields efficient parameter estimates. Ultimately, each equation was estimated using $k = 4$ lags in each of the endogenous prices series (ΔUSP and ΔZBP), covering daily trade activity over a one-week period[12]. OLS estima- tion of the reduced-form VAR using four lags on each endogenous variable yields 12 parameter estimates per equation. These parameters include a con- stant term (c_1 or c_2); an error-correction term describing the responsiveness of price levels to deviations from their cointegrating equilibrium (γ_{us} or γ_{zb}); eight parameters describing the intertemporal significance of lagged changes in the price levels, i.e. the autoregressive components ($a_{1,k}$, $b_{1,k}$ or $a_{2,k}$, $b_{2,k}$); and the two volume terms (Φ_{us} and Φ_{zb})[13]. Table 2 reports the parameter estimates.

Price adjustment towards equilibrium requires at least one of the price-response parameters be statistically different from zero. Here, the relatively large (absolute) value $|\gamma_{us}| = |-2.3905|$ points to the responsiveness of open outcry prices to the previous day's deviation from long-run equilibrium. On the other hand, the smaller (absolute) value $|\gamma_{zb}| = |-0.6366|$ implies Project A prices are relatively unresponsive to the previous day's equilibrium error. Consequently the signs and values of the price-response parameters suggest open outcry tends to drive long-run price equilibrium across markets. This asymmetric price adjustment process is a fundamental feature of the price-setting mechanism over the study period, consistent with leadership role of

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[12] The Aikaiki information criteria (AIC) supports a model with 4 lags in each of the price series (AIC = 21.38). Longer lag lengths of $k = 16, 12, 8$ did not significantly reduce the sum of squared residuals, while unnecessarily increasing losses in degrees of freedom. See Enders [4] pg. 88 for further discussion of this and other model selection criteria.

[13] Of course, the OLS regression results also provide estimates of the reduced form-residuals and elements in the reduced-form covariance matrix.

open outcry auctions in the early phase of side-by-side trading. Procedures for testing Granger causality are discussed next[14].

Table 2 VEC Parameter Estimates

Variable		Lag USP equation ($R^2 = 0.23$)			ZBP equation ($R^2 = 0.31$)	
	(i=)	Coeff.	t-val.		Coeff.	t-val.
USP_{t-I}	1	2.7877	2.6913		2.1808	2.2287
	2	1.7684	2.0004		1.3153	1.5749
	3	0.7766	1.1261		0.4123	0.6328
	4	0.4357	0.9817		0.1719	0.4101
ZBP_{t-I}	1	-2.4868	-2.3973		-1.8749	-1.9134
	2	-1.8419	-2.0917		-1.3866	-1.6668
	3	-0.7989	-1.1758		-0.4201	-0.6544
	4	-0.6405	-1.5196		-0.3900	-0.9798
Error Correction Terms (price-response coeff.) γ_{us} and γ_{zb}		-2.3905	-2.0468		-0.6366	-0.5771
Open Outcry Volume Φ_{us}		-0.0005	-2.345	-0.0004		-2.2050
Project A Volume Φ_{zb}		0.0006	0.0763	0.0032		0.4055
VEC Pairwise Granger Causality Tests – Null Ho:					P-value	
ΔUSP_{t-i} does not Granger Cause ZBP_t ΔZBP_{t-i} does not Granger Cause USP_t					0.0782 0.1064	

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[14] The discussion which follows is based on techniques outlined in Enders [4] pgs. 367 and 371. The reader is referred to this reference for further discussion of Granger causality test procedures in the context of VEC time-series models.

in ex- plaining long-term market price adjustments ($\Phi_{zb} = 0.0006$, t = 0.0763 and $\Phi_{zb} = 0.0032$, t = 0.4055). On the contrary, the parameter estimates for open outcry volume are negative and statistically significant in both equations ($\Phi_{us} = -0.0005$, t = -2.345 and $\Phi_{us} = -0.0004$, t = -2.2050). Thus, price volatility tends to decrease symmetrically in both markets due to increasing volumes of open outcry trading. These results strengthen the market leadership role of open outcry auctions in determining price equilibria on the side-by-side trading platform over the first year of operations.

5. Concluding Remarks

This study of CBOT's Project A and open outcry markets casts doubt on the belief that e-trading systems are invariably superior to open outcry markets, particularly in the early phase of contemporaneous trading wherein the majority of trades continue to stop at the desk for hand delivery to the pit. The case study of CBOT interest rate futures allows examining daily price-volume data for contracts which were simultaneously traded at a common futures exchange during the early phase of side-by-side trading. The study assumes the dynamics of this data are well described by a simple time series model in which cointegrated pricing and market depth contribute to price discovery. Two inferences may be drawn from these measurement procedures.

First, there is clear evidence of an interdependent market structure between open outcry and screen-based trading with open outcry singularly responsible for maintaining price equilibrium. Second, both price responsiveness and market depth are fundamental in explaining the relative importance of open outcry trading in reducing price volatility and restoring the price equilibrium relationships. Both of these arguments suggest open outcry auctions performed a price leadership role during the early phase of side-by-side trading at the CBOT.

The findings in this study build on previous research by identifying the joint importance of price responsiveness and market depth in explaining the lead-role of open outcry sessions in the price discovery process. Unlike Shyy and Lee [11], who find one-way causality from electronic to open outcry markets, our results are suggestive that screen-based and open outcry mar- kets may initially be interdependent in maintaining equilibrium price rela- tionships. Also, in contrast to the bi-directional causality found by Kofman and Moser [7], we find that open outcry takes a leadership role by deepening the overall market and restoring long-run price equilibrium across

trading sy- stems. Furthermore, Pirrong [8] finds an asymmetrical impact of volume on price volatility which suggests a scarcity of market-making capacity in the open outcry market (LIFFE) compared to the screen-based market (DTB). Conversely, the present study finds open outcry volume having a symme- trical dampening effect on price volatility across markets, implying the ab- sence of any resource constraints on market-making capacity.

These interpretations are subject to at least two major qualifications. First, any interpretation of price behavior across screen-based and open out-cry markets is conditional on the time period of analysis and information variables included in the analysis. In this study, we examine the early phase of side-by-side trading with price and volume measured on a day-by-day basis. This research design gives an alternative representation of market dynamics relative to the ones examined in the various LIFFE-DTB studies. Second, the present study maintains trade volume is exogenous with respect to the residual terms in the reduced form model. While this assumption avoids the simultaneity issues posed by a more complex model specification, it may oversimplify the relationship between the error correction process and the contemporaneous price-volume relationships between markets. Finally, it is hoped that this study makes a contribution in the area of e-trading and e-business generally.

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