# THE RELATIVE EFFICIENCIES OF PRICE EXECUTION BETWEEN THE SINGAPORE EXCHANGE AND THE TAIWAN FUTURES EXCHANGE

**ROBIN K. CHOU***
**JIE-HAUN LEE**

Both the Singapore Exchange (SGX) and the Taiwan Futures Exchange (TAIFEX) offer future contracts based on Taiwan's stock-market indices. TAIFEX reduced the transaction tax from 5 basis points to 2.5 basis points on May 1, 2000. Hence, empirical tests are performed on the differences in trading costs and information transmissions between SGX and TAIFEX for the sample periods both before and after the tax reduction. It is shown that the reduction in the transaction tax greatly improves the efficiencies of price execution. Due to the structural differences between these two

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*Correspondence author, Department of Finance, National Central University, Chung-Li, 320, Taiwan, R.O.C.; e-mail: rchou@cc.ncu.edu.tw

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■ *Robin K. Chou is an Assistant Professor in the Department of Finance at National Central University in Chung-Li, Taiwan, R.O.C.*

■ *Jie-Haun Lee is a Professor in the Department of Finance at National Chengchi University, in Taipei, Taiwan, R.O.C.*

markets, the trading costs and speed of information transmissions also are different. The results also provide implications for the relative efficiencies of different market structures.  Jrl Fut Mark 22: 173–196, 2002

## INTRODUCTION

Many countries impose some form of transaction tax on securities trading. The influences of imposing a security transaction tax have been subject to extensive discussions by both academics and regulatory agencies. As Schwert and Seguin (1993) have pointed out, proponents of a transaction tax argue that it usually serves as a significant source of revenue and decreases the price volatility by discouraging speculative or noise trading. Opponents argue that the benefits of a transaction tax are likely to be outweighed by its potential costs. They say that a transaction tax would increase the cost of capital, reduce market liquidity, and bring down securities' values. Most importantly, in a competitive environment of international financial markets, a transaction tax could drive trading in some securities to overseas markets without such taxes.

Fleming, Ostdiek, and Whaley (1996) argued that the relative rates of price discovery in the stock, futures, and options markets are due to differences in trading costs. They found empirical results supporting the trading-cost hypothesis, that is, that markets with lower trading costs tend to lead those with higher trading costs in price discovery. Wang and Yau (2000) examined the relationships among trading volume, bid ask spread, and price volatility in futures markets. They indirectly inferred from their results that a transaction tax, which is similar to a greater bid ask spread, will reduce trading volume. However, a reduction in an explicit trading cost, such as the transaction tax, may do more than just reduce traders' out-of-pocket costs. It is likely that a decrease in the transaction tax would not only reduce the explicit trading cost, but also would lower the implicit trading cost, such as the bid ask spread, and the degree of information asymmetry. The efficiency of price discovery would benefit greatly from the simultaneous reductions in both explicit and implicit trading costs.

Other than the trading-cost hypothesis, differences in market structures also are likely to induce differences in efficiency of price discovery. Optimal market design has long been an important issue for both academics and practitioners. The desirable characteristics of an ideal market design should include an efficient price-discovery process without excessive costs of trade execution and price volatility. Research on the relative efficiencies of different markets has drawn much attention in recent literature. For example, many studies have concluded that the spreads on the New York Stock Exchange (NYSE) are larger than on NASDAQ.[1] Although structural differences between these two markets may be able to explain the wider spread on NASDAQ,[2] the debate is still far from conclusive.

This study takes advantage of a rare opportunity of transaction tax reduction on the Taiwan Futures Exchange (TAIFEX) to test directly the trading-cost hypothesis. TAIFEX reduced its transaction tax from 5 basis points to 2.5 basis points on May 1, 2000, and we propose that this is likely to have an impact on the rate of price discovery and other market quality measures. The Singapore Exchange (SGX) also provides trading on the Taiwan index futures without a transaction tax. As previously mentioned, a market imposing a transaction tax may drive trading to an overseas market without the burden of such taxes. Thus, the relative efficiencies of SGX and TAIFEX, which operate under completely different market and tax structures, are compared to examine the influences of the transaction tax and market structures on the process of price discovery.

The samples employed to accomplish this study are the Taiwan stock index futures traded on the SGX[3] and TAIFEX.[4] The Chicago Mercantile Exchange (CME) and SGX began offering futures contracts on the Dow Jones Taiwan Stock Index[5] and Morgan Stanley Capital International Taiwan Stock Index (MSCI-TW),[6] respectively, starting January 9, 1997. Since then, TAIFEX started futures trading on the Taiwan Stock Exchange (TSEC) Weighted Index[7] on July 21, 1998; the

[1]Christie and Schultz (1994) concluded that the market makers on NASDAQ implicitly collude to maintain wider spreads. Barclay (1997) and Bessembinder and Kaufman (1997) both concluded that the average execution costs are greater for trades on NASDAQ-listed firms than on NYSE-listed firms.

[2]Demsetz (1997), Godek (1996), Ho and Macris (1985), and Huang and Stoll (1996) all argued that, due to structural differences between the NYSE and NASDAQ markets, trading costs are expected to be higher and the spreads are expected to be wider on NASDAQ.

[3]The futures contract initially was traded on the Singapore International Money Exchange (SIMEX), which merged with the Singapore Exchange (SGX) on December 1, 1999.

[4]The major stock market in Taiwan is the Taiwan Stock Exchange (TSEC). The TSEC is an automated batch-call market, which operated from 9:00 am to noon before December 31, 2000. Starting in 2001, the trading hours have been extended to 1:30 pm.

[5]Dow Jones and Co., Inc. developed the Dow Jones Taiwan Stock Index to represent the market for Taiwan stocks that readily are accessible to investors worldwide. The index is a capitalization-based index of 113 highly capitalized and actively traded stocks listed on the Taiwan Stock Exchange (as of January 9, 1999).

[6]The MSCI Taiwan Stock Index contains 65% of the market capitalization of Taiwan stock markets. The ratio rose to 80%, effective on November 30, 2000, and finally to 100% on May 31, 2001.

[7]The TSEC Weighted Index is a market-value weighted index covering all of the TSEC listed stocks, excluding preferred stocks, full-delivery stocks, and newly listed stocks, which are listed for less than one calendar month.

Hong Kong Futures Exchange (HKFE) also commenced trading of the HKFE Taiwan Index futures and options contracts on May 26, 1998. The booming market for futures trading on Taiwan stock indices offers a unique opportunity to examine the relative efficiencies of different market structures in trading futures with similar underlying indices.

This study will test various measures of market efficiency such as the quoted spread, effective spread, and realized spread for periods before and after the tax reduction. The approach of comparing market efficiencies of SGX and TAIFEX that trade similar index futures has the advantage over the approach of testing markets that trade different assets because any differences in market efficiencies that are due to differences in assets traded have been controlled partially. SGX is the most active market for Taiwan index futures and TAIFEX is the local market. This should be an interesting setting for empirical studies.

It is shown that the quoted (effective) half-spread on SGX is 1.20 (1.16) basis points lower than on TAIFEX before the tax reduction. However, after the tax reduction, the quoted (effective) spread on SGX is 0.95 (0.42) basis points higher than on TAIFEX. The change of differences in implicit trading costs is due to the increased liquidity on TAIFEX and the decreased information asymmetry on TAIFEX. Due to structure differences, the realized spreads on SGX always are higher than on TAIFEX for periods both before and after the tax reduction. The information content of trades on TAIFEX also increases significantly after the tax reduction. From these empirical results, it is shown that the reduction in transaction tax and differences in market structures have great influences on the relative efficiencies of price execution.

The rest of the article is organized as follows. The next section explains the institutional differences between SGX and TAIFEX. The section following presents the data. After the data has been presented, the research methodology will be discussed, followed by a presentation of the empirical results. The final section offers our conclusions.

## INSTITUTIONAL DESCRIPTIONS OF SGX AND TAIFEX

The trading mechanisms of SGX and TSEC are quite different. SGX employs multiple trading mechanisms that include a centralized trading floor with an open-outcry system and an Electronic Trading System (ETS). The MSCI-TW index futures are traded on the open-outcry system of SGX from 8:45 am to 12:15 am, while the ETS offers the same contract from 2:45 pm to 7:00 pm. On ETS, all trades are matched automatically by the electronic system, which also provides an opportunity for cross-exchange transactions. However, most trades are concentrated in the morning session when the contracts are traded under the open-outcry system and when the Taiwan Stock Exchange is open.

In an open-outcry system, all future trades have to go through the exchange. The *pit runners* in the trading pit make competitive bids and offers by gestures. An investor initiates an order and submits it to his/her broker. The broker routes the order to a member firm on SGX, and a pit runner of the member firm discloses the contents of the order, such as price and size. If the order is matched, information on the trade, such as time, price, and number of contracts traded, will be recorded and sent to the investor via the same route by which the order comes. Thus, in an open-outcry system, the trading pit is a centralized location for matching orders. Only members of the exchange can participate in the trading-pit activities.

TAIFEX operated under an automated batch-call system from 9:00 am to 12:15 pm before 2001. There are no market makers in the market. Investors, through the help of brokers, submit orders to the automated trading system. The market sets a single transaction price that will clear the largest number of buy and sell orders periodically.[8] The buy (sell) orders with higher (lower) limit prices than the set transaction price will be executed at the transaction price. Thus, TAIFEX is a limited order-driven call market.

Both markets use price-limit systems. The price limits on TAIFEX are ±7% of the previous day's close. There are three stages of price limits on SGX. The first limits are ±7% of the previous day's close. If the prices remain at the ±7% limit for more than 10 min, the price limit is relaxed to ±10%. If the prices remain at the ±10% limit for another 10 min, the price limit is relaxed again to ±15% of the previous day's close.

The trading unit on TAIFEX is the index value of the TSEC Weighted Index × 200 New Taiwan Dollars (NT$), while the trading unit on SGX is the index value of the MSCI-TW index × 100 U.S. Dollars (US$). The available future contract delivery dates on TAIFEX are the consecutive two months following the current month and the three consecutive quarter months of March, June, September, and December. The delivery dates on SGX are similar to those of TAIFEX,

[8]The orders matched every 20 seconds on the TAIFEX before December 6, 1999. Since then, the time length has been reduced to 10 seconds between each call.

except all four consecutive quarter months of March, June, September, and December are available.

Except for these institutional differences, explicit trading costs such as transaction fees, taxes, and margin requirements are also likely to influence the efficiencies of trade execution. Before April 30, 2000, TAIFEX charged a transaction tax of 5 basis points on each trade. The tax rate fell to 2.5 basis points starting May 1, 2000. All MSCI-TW futures trades on SGX are tax free.

SGX uses the Standard Portfolio Analysis of Risk (SPAN) to calculate the margin requirement. The SPAN system covers 99% of one day's possible variation in future prices. TAIFEX computes the price variation in a specific period and requires a margin that will cover at least 99.7% of one day's variation in future prices. For example, on December 1, 1999, the second month of our data set, the margin requirements were US$3,000 and NT$140,000 on SGX and TAIFEX, respectively. On June 1, 2000, one month after the transaction tax reduction on TAIFEX, the margin requirements became US$3,700 and NT$90,000, respectively.

## DATA

The data for the TAIFEX and SGX Taiwan index futures are retrieved from the Reuters Terminal. The index future prices are taken from the contracts with the closet date to maturity. The prices that are within 5 days to maturity of the futures contract are excluded because the futures prices will converge to the spot prices; this will likely introduce biases in our tests. The variables include minute-by-minute futures index prices, trading volume, and bid and ask quotes.

The sample period is from November 1, 1999 to October 30, 2000. A set of trade and quote prices is filtered because they are likely to be erroneous or may not reflect the true trading cost that investors will face in the market.[9] The trades and quotes that are time stamped outside the regular TSEC trading hours, from 9:00 am to noon, are also excluded.

The tests are performed on two subsets of data. The first subset is from November 1, 1999 to April 30, 2000, and the second subset period is from May 1, 2000 to October 31, 2000, which corresponds to the date of the TAIFEX tax reduction on May 1, 2000. One of our major interests in this article is to test the influences of tax reduction on the efficiencies of price executions.

[9]Observations are excluded if either the bid or ask is non-positive or the difference between the ask and bid is non-positive.

## RESEARCH METHODOLOGY

### Variance Ratio Test

To test the relative pricing errors between these two markets, the variance ratio test developed by Cochrane (1988) and Lo and MacKinlay (1989) is used to examine price reversals or continuations. If markets are efficient in processing information, then the prices are expected to be unpredictable; thus, the variance ratios are close to one. However, if the market overreacts, then the price tends to reverse. Such price reversals induce negative autocorrelations in index futures returns.[10] If the degree of market overreaction is higher, then more negative autocorrelations are expected.

Let $VR(K)$ be the ratio of a $K$-period return variance to a one-period return variance times $K$, that is,

$$VR(K) = \frac{\mathrm{Var}[R_t(K)]}{K \cdot \mathrm{Var}[R_t]}, \tag{1}$$

where $R_t(K)$ is a $K$-period return and $R_t$ is a one-period return at time $t$. In this article, $R_t(K)$ denotes returns over 5- or 15-min intervals and $R_t$ represents the minute-by-minute return.

According to Cochrane (1988) and Lo and MacKinlay (1989), $VR(K)$ can be expressed as the following function:

$$VR(K) \approx 1 + \frac{2(K-1)}{K}\rho_1 + \frac{2(K-2)}{K}\rho_2 + \cdots + \frac{2}{K}\rho_{K-1} \tag{2}$$

where $\rho_K$ is the $K$-lag autocorrelation in stock returns. Function $VR(K)$ will be less than unity if transaction returns contain errors due to the bid–ask spread or market overreaction. As Roll (1984) and Kaul and Nimalendran (1990) have pointed out, bid–ask spread bounces also may cause price reversals. To exclude bid–ask spread errors, variance ratios based on bid prices are estimated to distinguish between the relative impacts of bid–ask bounces and pricing errors on the index futures returns.

### Measures of Trading Costs

The first measure of trading costs used is the quoted half-spread, which measures half of the difference between the quoted bid and ask prices.

[10]See, for example, DeBondt and Thaler (1985), Delong, Shleifer, Summers, and Waldman (1990), Shefrin and Statman (1985), and Kaul and Nimalendran (1990).

Because the measure of trading costs for a single trade is expected while the entire difference between bid and ask prices measures a round-trip trading cost, the quoted spread is divided by two. All of the measures of trading costs reported in our study are in relative terms and in basis points. The relative quoted half-spread ($QS$) is calculated as

$$QS_{it} = \frac{10000(A_{it} - B_{it})}{2M_{it}}, \tag{3}$$

where $A_{it}$ is the quoted ask price for index future $i$ at time $t$, $B_{it}$ is the quoted bid price for index future $i$ at time $t$, and $M_{it}$ is the mid-point of quoted ask and bid prices.

The quoted half-spreads are likely to be biased estimators of the trading costs because trades do not always occur at the quoted prices. This will make the quoted spread a biased measure of trading costs.

To overcome this bias, a second measure of trading costs, the effective half-spread, is computed. It measures the difference between the actual traded price and the mid point of the quoted bid and ask prices and provides a better measure of the actual trading costs. The relative effective half-spread ($ES$) is calculated as

$$ES_{it} = \frac{10000D_{it}(P_{it} - M_{it})}{M_{it}}, \tag{4}$$

where $P_{it}$ is the transaction price for index future $i$ at time $t$, and $M_{it}$ is the mid point of bid–ask prices of the quotes concurrent with the current transaction. The term, $D_{it}$, is an indicator variable, which is $-1$ if $P_{it} < M_{it}$ (a customer sell order) or 1 if $P_{it} > M_{it}$ (a customer buy order).

Glosten and Milgrom (1985) show that the spread includes a component for compensating the dealer's loss to potentially better-informed traders. After a customer's buy (sell) order, which refers to a trade that occurs at the ask (bid) or between quoted mid-point and ask (bid), the asset value tends to increase (decrease). This permanent increase or decrease represents the market's assessment of information conveyed by the trade, that is, the price impact or information asymmetry component of a trade. The information asymmetry component will not equal the entire effective half-spread unless all the trades in the market are information motivated.

There is generally a price reversal after each trade, and the difference between the effective spread and the information asymmetry component is the gross profit to dealers, or the realized half-spread. To gauge the extent of information trading on SGX and TAIFEX, the effective half-spread is decomposed further into the realized half-spread and information asymmetry component. Following Huang and Stoll (1996), the price reversal after trades, which represents the market-making revenue net of losses to better-informed traders, is measured as the realized spread. Transaction prices of 1, 15, and 30 min after the current trade are used as the proxies of the index futures' post-trade economic values. The information asymmetry component ($IA$) and realized spread ($RS$) are calculated as

$$IA_{it} = \frac{10000D_{it}(P_{it+n} - M_{it})}{M_{it}} \tag{5}$$

$$RS_{it} = \frac{10000D_{it}(P_{it} - P_{it+n})}{M_{it}}, \tag{6}$$

where $P_{it+n}$ is the trade price at least $n$ min (1, 15, or 30 min) after the trade at time $t$. Note that the effective half-spread is the sum of the information asymmetry component and realized spread.

To further understand the intraday pattern of trading costs and the possible relation between order size and trading costs, the intraday trading costs and trading costs by order size also are calculated. Specifically, a trading day is broken into six 30-min trading periods and the trading costs between SGX and TAIFEX during each trading period are compared. Trades are then divided into four order-size groups, that is, for trades of contract size <20, between 20 and 30, between 30 and 40, and >40. The categories are chosen to make the number of trades in each group as close as possible in these two markets. The trades are classified not by the order size of the current trade, but by the average trade size during each of the 15-min trading periods[11] to account for the order-splits strategies and noise in trading volume.

The trading cost measures of SGX and TAIFEX are compared by applying the time-series regression model, which adjusts for autocorrelations in residuals to account for possible autocorrelations in the data. The $t$ statistics for testing the equality of sample means reported in the tables are obtained from the time-series regression model assuming 5 lags of autocorrelation.[12]

[11]The average trading volume during each of the twelve 15-min trading periods from 9:00 am to noon is computed. All trades are classified by the average order size of the 15-min period it belongs to.

[12]We thank the referee for suggesting this test. The time-series regression model is also estimated, assuming 10 and 15 lags of autocorrelation in trading cost measures. The results are qualitatively similar.

## Information Transmission Test

The differences in trading costs will likely lead to differences in the speed and amount of information reflected in the transaction prices on SGX and TAIFEX. If one of the exchanges is more efficient in processing information than the other, then a lead–lag relation between the index future prices of these two markets is expected. To test this hypothesis and study the cause of the possible lead–lag relation between SGX and TAIFEX, the Granger causality test [namely, the Vector Error Correction (VEC) model] is performed.

The VEC model is a restricted vector-autocorrelation-regression (VAR) model that has cointegration restrictions built into the specification so that it is designed for use with nonstationary series that are known to be cointegrated. The reason for using the VEC model is that price levels generally are nonstationary. Because these two series are based on Taiwan's stock indices, which are highly correlated, a possible cointegrated relation between them is likely.

Engle and Granger (1987) showed that a linear combination of two or more nonstationary series may be stationary. If such a stationary linear combination exists, then the nonstationary time series are said to be cointegrated. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship between the variables.

In order to test for the information transmission speed between these two markets using a VEC model, tests for unit roots and cointegration are performed first. This article uses the augmented Dickey–Fuller (ADF) test to detect the existence of unit roots in price series. The specification of the ADF approach is as follows:

$$\Delta y_t = \mu + \gamma y_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta y_{t-i} + \varepsilon_i, \tag{7}$$

where $\Delta$ denotes the differencing operator, $y_t$ is either the price series of SGX or TAIFEX, $\mu$, $\gamma$, and $\delta$ are regression coefficients, $p$ is the selected number of lags, and $\varepsilon_i$ is the noise term. This specification is then used to test:

$H_0$: $\gamma = 0$, $y$ has a unit root and is nonstationary
$H_1$: $\gamma < 0$, $y$ does not have a unit root and is stationary.

If $H_0$ cannot be rejected, then $y$ is nonstationary. The ADF test then is conducted again on the second difference of $y_t$ to test if the first difference of $y_t$ is stationary. The specification of the ADF test is then:

$$\Delta^2 y_t = \mu + \gamma \Delta y_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta^2 y_{t-i} + \varepsilon_i, \tag{8}$$

where $\Delta^2$ denotes the second-order differencing operator. The hypothesis test is similar to that of the previous test on the first difference. Higher-order tests can be carried out similarly if the test of second difference still yields nonstationarity.

If both price series of the SGX and TAIFEX futures are nonstationary, then the following model can be used to test whether they are cointegrated:

$$S_t = \mu + \beta T_t + u_t \tag{9}$$

$$\Delta \hat{u}_t = \gamma \hat{u}_{i-1} + e_t, \tag{10}$$

where $S_t$ is the SGX price series and $T_t$ is the TAIFEX price series at time $t$. The term $\hat{u}_t$ is the estimated residual from eq. (10). The hypothesis test is as follows:

$H_0$: $\gamma = 0$, $u$ has a unit root and $S_t$ and $T_t$ are not cointegrated
$H_1$: $\gamma < 0$, $u$ does not have a unit root and $S_t$ and $T_t$ are cointegrated.

The VEC specification restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing a wide range of short-run dynamics. The cointegration term is known as the error-correction term because the deviation from the long-run equilibrium is corrected gradually through a series of partial short-run adjustments. The specification of the VEC model is as follows:

$$\Delta S_t = \delta + \gamma(S_{t-1} - \mu - \beta T_{t-1}) + \sum_{i=1}^{p} \beta_{Si} \Delta S_{t-i} + \sum_{i=1}^{p} \beta_{Ti} \Delta T_{t-i} + \varepsilon_i \tag{11}$$

$$\Delta T_t = \delta' + \gamma'(S_{t-1} - \mu - \beta T_{t-1}) + \sum_{i=1}^{p} \beta'_{Si} \Delta S_{t-i} + \sum_{i=1}^{p} \beta'_{Ti} \Delta T_{t-i} + \varepsilon'_i, \tag{12}$$

where $S_t$ and $T_t$ are the index futures prices of SGX and TAIFEX, respectively. The second term is the error-correction term and $\gamma$ and $\gamma'$

are the speed of error correction. Hence, the coefficients, $\beta$s and $\beta'$s, indicate the direction and strength of information transmissions between SGX and TAIFEX.

## EMPIRICAL RESULTS

In this section, the pricing errors, the differences in trading costs, and the pattern of information transmissions between SGX and TAIFEX are examined. Possible explanations for these empirical results are also provided.

Index futures trades on SGX are tax free while TAIFEX charged a transaction tax of 5 basis points before May 1, 2000, and 2.5 points afterwards. It is plausible that this reduction in the transaction tax will have a great impact on the relative efficiencies between SGX and TAIFEX because it affects all traders in the markets, and, as will be shown, a drop of 2.5 basis points in tax is almost as large as the effective half-spreads on these two exchanges.[13]

### Trading Volume, Return Variance, and Variance Ratio Test

Table I shows the trading volume and return variances of SGX and TAIFEX. Both the trading volume and return volatilities exhibit a U-shaped intraday pattern, which is well documented in the literature. The trading volume of SGX is greater than TAIFEX in both sample periods, with the difference becoming smaller. This indicates that although SGX is an offshore market for Taiwan stock index futures, it is more active than the local market. However, the trading volume on TAIFEX almost doubled in the second period while that on SGX only increased mildly. This is likely to be explained by the reduction in the transaction tax because the explicit trading cost on TAIFEX is much smaller in the second period and the traders are more willing to direct their order flows to TAIFEX.

The return variances of SGX are greater than those of TAIFEX for both periods. The differences in return variance are larger in the second

[13]This article also tries to compare other explicit costs, such as a broker's commission on SGX and TAIFEX. The index futures brokers indicate that the transaction fees are negotiable and vary quite noticeably. It generally is lower for institutional traders. Thus, it is difficult to compare nonstandardized transaction costs. However, a reduction in the transaction tax would certainly impact all traders in the markets.

**TABLE I**
Differences in Trading Volume and Return Variance

| | *First Period* | | | *Second Period* | | |
|---|---|---|---|---|---|---|
| | *SGX* | *TFEX* | *Diff.* | *SGX* | *TAIFEX* | *Diff.* |
| *Panel A: Volume* | | | | | | |
| All Observations | 33.37 | 11.57 | 21.80*** | 38.11 | 22.65 | 15.46*** |
| 09:00~09:30 | 28.63 | 14.45 | 14.18*** | 34.12 | 28.35 | 5.77*** |
| 09:30~10:00 | 34.91 | 11.64 | 23.27*** | 38.00 | 22.88 | 15.12*** |
| 10:00~10:30 | 31.89 | 9.78 | 22.10*** | 38.47 | 18.03 | 20.44*** |
| 10:30~11:00 | 31.61 | 8.97 | 22.64*** | 35.91 | 18.05 | 17.86*** |
| 11:00~11:30 | 32.53 | 9.86 | 22.67*** | 37.08 | 19.33 | 17.75*** |
| 11:30~12:00 | 35.71 | 13.64 | 22.07*** | 39.04 | 25.58 | 13.46*** |
| *Panel B: Return Var.* ($10^{-4}$) | | | | | | |
| All Observations | 0.0150 | 0.0112 | 0.0039** | 0.0198 | 0.0120 | 0.0078*** |
| 09:00~09:30 | 0.0403 | 0.0308 | 0.0094*** | 0.0507 | 0.0241 | 0.0266*** |
| 09:30~10:00 | 0.0172 | 0.0092 | 0.0080*** | 0.0145 | 0.0091 | 0.0053*** |
| 10:00~10:30 | 0.0081 | 0.0063 | 0.0018 | 0.0113 | 0.0075 | 0.0038*** |
| 10:30~11:00 | 0.0069 | 0.0062 | 0.0007 | 0.0114 | 0.0080 | 0.0034*** |
| 11:00~11:30 | 0.0082 | 0.0066 | 0.0016** | 0.0136 | 0.0086 | 0.0050*** |
| 11:30~12:00 | 0.0106 | 0.0090 | 0.0016 | 0.0183 | 0.0153 | 0.0030*** |

Note. The range of the first period is from November 1, 1999–April 30, 2000, and the range of the second period is from May 1, 2000–October 31, 2000. Trading volume is the 1-min average number of contracts traded, and the return variance is the minute-by-minute transaction return variance. Superscripts *** and ** denote the significance level of 1% and 5%, respectively, for the Wilcoxon signed rank test, where the differences are zero. The trading day is divided into six 30-min trading sessions, as indicated in the first column.

period. After the transaction-tax reduction, the return variance of TAIFEX remains fairly stable. TAIFEX seems to have absorbed the increased volume quite well because the increase in trading volume on TAIFEX in the second period does not inflate the return variance. Table II shows that price reversals on SGX are more significant than on TAIFEX in both periods; this is likely to contribute to the higher variances on SGX. Another interesting observation is that the 5-min return on TAIFEX shows strong continuation in both periods. The momentum in 5-min returns may be related to the differences in the speed of information adjustments and transmissions between SGX and TAIFEX, which will be studied later.

## Implicit Trading Costs

Quoted and effective half-spreads on SGX and TAIFEX for the two subperiods are calculated. Tables III and IV present relative quoted half-spreads (in basis points) classified by trading time and trade size,

**TABLE II**
Variance Ration Test

| | *SGX* | *TAIFEX* | *Difference* |
|---|---|---|---|
| *Panel A: First Period* | | | |
| $K = 5$ | 1.0522 | 1.1779*** | −0.1257 |
| $K = 15$ | 0.8492* | 1.1076 | −0.2582* |
| *Panel B: Second Period* | | | |
| $K = 5$ | 0.9525 | 1.3237*** | −0.3712*** |
| $K = 15$ | 0.9600 | 1.0613 | −0.1013 |

Note. The range of the first period is from November 1, 1999–April 30, 2000, and the range of the second period is from May 1, 2000–October 31, 2000. Variance ratio is calculated as

$$VR(K) = \frac{\mathrm{Var}[R_t(K)]}{K \cdot \mathrm{Var}[R_t]},$$

where $R_t(K)$ are $K$-min returns and $R_t$ are 1-min returns at time $t$. $K$ is either 5 or 15 min, as indicated in the table. Superscripts *** and * denote the significance level of 1% and 10%, respectively, for the Wilcoxon signed rank test, where the variance ratios are 1 or the differences are 0.

**TABLE III**
Quoted Half-Spread (Basis Points) by Trading Time

| | *Quoted Half-Spreads* | | |
|---|---|---|---|
| | *SGX* | *TAIFEX* | *Difference* |
| *Panel A: First Period* | | | |
| All Observations | 2.5552 | 3.7594 | −1.2042*** |
| 09:00~09:30 | 2.8115 | 4.2979 | −1.4864*** |
| 09:30~10:00 | 2.6385 | 3.5910 | −0.9525*** |
| 10:00~10:30 | 2.4790 | 3.5452 | −1.0635*** |
| 10:30~11:00 | 2.3928 | 3.5535 | −1.1607*** |
| 11:00~11:30 | 2.4868 | 3.6379 | −1.1511*** |
| 11:30~12:00 | 2.5712 | 3.9273 | −1.3561*** |
| *Panel B: Second Period* | | | |
| All Observations | 4.1393 | 3.1863 | 0.9530*** |
| 09:00~09:30 | 6.0218 | 3.6138 | 2.4080* |
| 09:30~10:00 | 3.5668 | 2.9012 | 0.6656*** |
| 10:00~10:30 | 3.6672 | 2.9770 | 0.6902*** |
| 10:30~11:00 | 3.7515 | 2.9501 | 0.8014*** |
| 11:00~11:30 | 3.7276 | 3.1488 | 0.5788** |
| 11:30~12:00 | 3.8126 | 3.4577 | 0.3549 |

Note. The range of the first period is from November 1, 1999–April 30, 2000, and the range of the second period is from May 1, 2000–October 31, 2000. The percentage quoted half-spread ($QS$) is calculated as

$$QS_{it} = \frac{10000(A_{it} - B_{it})}{2M_{it}},$$

where $A_{it}$ is the quoted ask price for index future $i$ at time $t$, $B_{it}$ is the quoted bid price for index future $i$ at time $t$, and $M_{it}$ is the midpoint of the quoted ask-and-bid prices. Superscripts ***,**, and * denote the significance level of 1%, 5%, and 10%, respectively, for the autocorrelation consistent test of the equality of sample means. The trading day is divided into six 30-min trading sessions, as indicated in the first column.

**TABLE IV**
Quoted Half-Spread (Basis Points) by Trading Size

| | *Quoted Half-Spreads* | | |
|---|---|---|---|
| | *SGX* | *TAIFEX* | *Difference* |
| *Panel A: First Period* | | | |
| All Contract Size | 2.5540 | 3.7649 | −1.2109*** |
| ≤20 | 2.4944 | 3.6156 | −1.1212*** |
| 20~30 | 2.4143 | 4.5380 | −2.1237*** |
| 30~40 | 2.6168 | 4.2839 | −1.6671*** |
| ≥40 | 2.6590 | 4.6515 | −1.9925*** |
| *Panel B: Second Period* | | | |
| All Contract Size | 4.1523 | 3.1919 | 0.9609*** |
| ≤20 | 2.7265 | 2.8169 | −0.0904 |
| 20~30 | 3.1415 | 3.0691 | 0.0724 |
| 30~40 | 3.5222 | 3.5735 | −0.0513 |
| ≥40 | 5.4849 | 4.4514 | 1.0335 |

Note. The range of the first period is from November 1, 1999–April 30, 2000, and the range of the second period is from May 1, 2000–October 31, 2000. The percentage quoted half-spread ($QS$) is calculated as

$$QS_{it} = \frac{10000(A_{it} - B_{it})}{2M_{it}},$$

where $A_{it}$ is the quoted ask price for index future $i$ at time $t$, $B_{it}$ is the quoted bid price for index future $i$ at time $t$, and $M_{it}$ is the midpoint of the quoted ask-and-bid prices. Superscript *** denotes the significance level of 1% for the autocorrelation consistent test of the equality of sample means. The sample is divided into four groups according to order size (in number of contracts), as indicated in the first column.

respectively, and Tables V and VI present relative effective spreads in similar formats. A few interesting observations can be made from the quoted spreads.

First, the size of average quoted spreads is generally smaller than that of the effective spread. This is to be expected because it is not rare for trades to take place between quoted prices. Second, by Tables III and V, both the size of quoted and effective spreads exhibits U-shaped intraday patterns. Third, by Tables IV and VI, the spread size usually increases with order size. As will be shown in the next section, this is due to the higher information content of larger trade size because the information asymmetry components increase as the trade size increases. Fourth, by checking across Tables III to VI, it can be seen that spreads on SGX during the first period are smaller than those on TAIFEX, while the opposite is true during the second period. This is an interesting finding because, as the transaction tax on TAIFEX decreases, the implicit trading costs on TAIFEX also fall relatively to those on SGX. The decrease in transaction tax and the increase in liquidity on TAIFEX in the second period are

**TABLE V**
Effective Half-Spread (Basis Points) by Trading Time

| | *Effective Half-Spreads* | | |
|---|---|---|---|
| | *SGX* | *TAIFEX* | *Difference* |
| *Panel A: First Period* | | | |
| All Observations | 2.1284 | 3.2912 | −1.1628*** |
| 09:00~09:30 | 2.6687 | 3.6916 | −1.0229*** |
| 09:30~10:00 | 2.0766 | 3.1244 | −1.0478*** |
| 10:00~10:30 | 1.9912 | 3.1175 | −1.1263*** |
| 10:30~11:00 | 1.9212 | 3.1797 | −1.2585*** |
| 11:00~11:30 | 2.0585 | 3.1951 | −1.1366*** |
| 11:30~12:00 | 2.1532 | 3.4711 | −1.3179*** |
| *Panel B: Second Period* | | | |
| All Observations | 3.1607 | 2.7388 | 0.4219*** |
| 09:00~09:30 | 3.5860 | 3.0361 | 0.5499** |
| 09:30~10:00 | 2.7715 | 2.4809 | 0.2906** |
| 10:00~10:30 | 2.8809 | 2.5808 | 0.3001 |
| 10:30~11:00 | 2.7449 | 2.5770 | 0.1679 |
| 11:00~11:30 | 3.0111 | 2.7229 | 0.2882 |
| 11:30~12:00 | 3.1388 | 2.9817 | 0.1571 |

Note. The range of the first period is from November 1, 1999–April 30, 2000, and the range of the second period is from May 1, 2000–October 31, 2000. The percentage effective half-spread ($ES$) is calculated as

$$ES_{it} = \frac{10000D_{it}(P_{it} - M_{it})}{M_{it}},$$

where $P_{it}$ is the transaction price for index future $i$ at time $t$, and $M_{it}$ is the midpoint of bid–ask prices of the quotes concurrent with the current transaction. $D_{it}$ is an indicator variable, which is −1 if $P_{it} < M_{it}$ (a customer sell order) or 1 if $P_{it} > M_{it}$ (a customer buy order). Superscripts *** and ** denote the significance level of 1% and 5%, respectively, for the autocorrelation consistent test of the equality of sample means. The trading day is divided into six 30-min trading sessions, as indicated in the first column.

likely to be the major contributing factors in reducing the trading costs of TAIFEX.

Liquidity traders have incentives to trade more often or to direct their order flows to TAIFEX as the transaction tax decreases. On the other hand, informed traders are also more likely to release their information due to decreased explicit costs and increased number of trades from liquidity traders. Overall, the market liquidity and efficiency improve and the spread size becomes smaller. A 2.5 basis-point reduction in the transaction tax (a drop of 100%) on TAIFEX not only doubles the trading volume, but also significantly reduces the traders' implicit trading costs.

From the regulatory agencies' point of view, revenues from the transaction tax remain nearly unchanged, while both the explicit and implicit trading costs faced by investors decrease significantly. These results lend

**TABLE VI**
Effective Half-Spread (Basis Points) by Trading Size

| | *Effective Half-Spreads* | | |
|---|---|---|---|
| | *SGX* | *TAIFEX* | *Difference* |
| *Panel A: First Period* | | | |
| All Contract Size | 2.1279 | 3.2958 | −1.1679*** |
| ≤20 | 1.7998 | 3.1802 | −1.3804*** |
| 20~30 | 1.8772 | 3.8468 | −1.9696*** |
| 30~40 | 2.2655 | 5.3734 | −3.1079*** |
| ≥40 | 2.5874 | 4.1556 | −1.5682*** |
| *Panel B: Second Period* | | | |
| All Contract Size | 3.1665 | 2.7456 | 0.4209*** |
| ≤20 | 1.9063 | 2.4288 | −0.5225*** |
| 20~30 | 2.2179 | 2.5972 | −0.3793*** |
| 30~40 | 2.8975 | 3.0756 | −0.1781 |
| ≥40 | 4.1751 | 4.0030 | 0.1721* |

Note. The range of the first period is from November 1, 1999–April 30, 2000, and the range of the second period is from May 1, 2000–October 31, 2000. The percentage effective half-spread ($ES$) is calculated as

$$ES_{it} = \frac{10000 D_{it}(P_{it} - M_{it})}{M_{it}},$$

where $P_{it}$ is the transaction price for index future $i$ at time $t$, $M_{it}$ is the midpoint of bid–ask prices of the quotes concurrent with the current transaction. $D_{it}$ is an indicator variable, which is −1 if $P_{it} < M_{it}$ (a customer sell order) or 1 if $P_{it} > M_{it}$ (a customer buy order). Superscripts *** and * denote the significance level of 1% and 10%, respectively, for the autocorrelation consistent test of the equality of sample means. The sample is divided into four groups according to order size (in number of contracts), as indicated in the first column.

support for the trading-cost hypothesis by Fleming et al. (1996). Furthermore, it also shows that a reduction in the transaction tax is a Pareto-optimal improvement.

The trading cost is only one of the indicators in gauging market efficiency. Other related measures of market quality, such as the degree of information asymmetry and the speed of information compounded into prices, also may be affected by the reduction in the transaction tax. This is the issue to which we now turn.

## Realized Spread and Information Asymmetry

By examining information asymmetry components of spreads in this section, we expect to gain a better understanding of the relation between the change in liquidity and information asymmetry. Tables VII and VIII show the relative realized spread and information asymmetry components of the spread (in basis points) by using traded prices 15 min after the current trades as proxies for post-trade economic values of the index

**TABLE VII**
Realized Spread and Information Asymmetry (Basis Points) by Trading Time—15-Min Classification

| | *Realized Spreads* | | | *Information Asymmetry* | | |
|---|---|---|---|---|---|---|
| | *SGX* | *TAIFEX* | *Diff.* | *SGX* | *TAIFEX* | *Diff.* |
| *Panel A: First Period* | | | | | | |
| All Observations | 1.5272 | 1.3521 | 0.1751 | 0.5481 | 1.9148 | −1.3667** |
| 09:00~09:30 | 2.1510 | 1.7130 | 0.4380 | 0.3468 | 1.8977 | −1.5509 |
| 09:30~10:00 | 1.3879 | 0.8778 | 0.5101 | 0.6614 | 2.2342 | −1.5728 |
| 10:00~10:30 | 0.8303 | 1.0886 | −0.2583 | 1.1451 | 2.0287 | −0.8836 |
| 10:30~11:00 | 2.9339 | 0.9311 | 2.0028* | −1.0492 | 2.2601 | −3.3093*** |
| 11:00~11:30 | 1.0107 | 1.8461 | −0.8354 | 1.0269 | 1.3513 | −0.3244 |
| 11:30~12:00 | 0.5132 | 1.8545 | −1.3413 | 1.5602 | 1.5796 | −0.0194 |
| *Panel B: Second Period* | | | | | | |
| All Observations | 1.8624 | 1.1879 | 0.6745 | 1.1104 | 1.5151 | −0.4047 |
| 09:00~09:30 | 2.2616 | 1.9251 | 0.3365 | 1.7968 | 1.1107 | 0.6861 |
| 09:30~10:00 | 2.9308 | −0.1697 | 3.1005** | −0.1474 | 2.6473 | −2.7947** |
| 10:00~10:30 | 3.0502 | 0.4665 | 2.5837** | −0.2661 | 2.1118 | −2.3779* |
| 10:30~11:00 | 2.4482 | 2.8196 | −0.3714 | 0.2500 | −0.2435 | 0.4935 |
| 11:00~11:30 | 0.6157 | 1.5529 | −0.9372 | 2.3680 | 1.1678 | 1.2002 |
| 11:30~12:00 | −1.8346 | 0.0001 | −1.8347 | 4.5587 | 2.9379 | 1.6208 |

Note. The range of the first period is from November 1, 1999–April 30, 2000, and the range of the second period is from May 1, 2000–October 31, 2000. The information-asymmetry component (*IA*) and realized spread (*RS*) are calculated as

$$IA_{it} = \frac{10000D_{it}(P_{it+n} - M_{it})}{M_{it}}$$

$$RS_{it} = \frac{10000D_{it}(P_{it} - P_{it+n})}{M_{it}},$$

where $P_{it+n}$ is the trade price 15 min after the trade at time $t$, and $M_{it}$ is the midpoint of bid–ask prices of the quotes concurrent with the current transaction. Note that the effective half-spread is the sum of the information-asymmetry component and realized spread. Superscripts ***, **, and * denote the significance level of 1%, 5%, and 10%, respectively, for the autocorrelation consistent test of the equality of sample means. The trading day is divided into six 30-min trading sessions, as indicated in the first column.

futures.[14] Table VII classifies trades by time and Table VIII classifies trades by order size. Overall, the realized spread is higher and the information asymmetry component is smaller on SGX for both testing periods. From Table VII, comparing all observations across two sample periods, it is found that the information asymmetry components on TAIFEX decreased quite significantly from the first to the second period. The decrease is likely due to the decreased transaction tax and increased liquidity on TAIFEX.

[14]The results of using prices 5 min afterwards should provide reliable estimates because 1 min seems too short for the index futures prices to revert back to their economic value and 30 min seems too long to prevent other compounding factors from affecting index prices. The calculations by using the traded prices 1 and 30 min after the current prices as proxies also are repeated. The results are qualitatively similar and available upon request.

**TABLE VIII**
Realized Spread and Information Asymmetry (Basis Points) by Trading Size—15-Min Classification

| | *Realized Spreads* | | | *Information Asymmetry* | | |
|---|---|---|---|---|---|---|
| | *SGX* | *TAIFEX* | *Diff.* | *SGX* | *TAIFEX* | *Diff.* |
| *Panel A: First Period* | | | | | | |
| All Contract Size | 1.5272 | 1.3533 | 0.1739 | 0.5482 | 1.9163 | −1.3681** |
| ≤20 | 1.4244 | 1.5100 | −0.0856 | 0.3583 | 1.6477 | −1.2894 |
| 20~30 | 1.9305 | −2.1042 | 4.0347*** | −0.0698 | 5.9644 | −6.0342*** |
| 30~40 | 1.1796 | 10.0700 | −8.8904** | 1.0602 | −4.4042 | 5.4644 |
| ≥40 | 1.2798 | −3.4927 | 4.7725 | 1.2200 | 7.9109 | −6.6909 |
| *Panel B: Second Period* | | | | | | |
| All Contract Size | 1.8716 | 1.1928 | 0.6788 | 1.1115 | 1.5158 | −0.4043 |
| ≤20 | 0.8359 | 1.6792 | −0.8433 | 1.0604 | 0.7384 | 0.3220 |
| 20~30 | 2.3370 | 0.0692 | 2.2678** | −0.1265 | 2.5156 | −2.6421*** |
| 30~40 | 1.8349 | 0.9404 | 0.8945 | 1.0133 | 2.1078 | −1.0945 |
| ≥40 | 1.6652 | 2.7755 | −1.1103 | 2.4487 | 1.1572 | 1.2915 |

Note. The range of the first period is from November 1, 1999–April 30, 2000, and the range of the second period is from May 1, 2000–October 31, 2000. The information-asymmetry component (*IA*) and realized spread (*RS*) are calculated as

$$IA_{it} = \frac{10000D_{it}(P_{it+n} - M_{it})}{M_{it}}$$

$$RS_{it} = \frac{10000D_{it}(P_{it} - P_{it+n})}{M_{it}},$$

where $P_{it+n}$ is the trade price 15 min after the trade at time $t$, and $M_{it}$ is the midpoint of bid–ask prices of the quotes concurrent with the current transaction. Note that the effective half-spread is the sum of information-asymmetry component and realized spread. Superscripts *** and ** denote the significance level of 1% and 5%, respectively, for the autocorrelation consistent test of the equality of sample means. The sample is divided into four groups according to order size (in number of contracts), as indicated in the first column.

Since SGX and TAIFEX are competing markets for the Taiwan stock index futures, it is not surprising that as the transaction tax falls and relative trading volume increases on TAIFEX, both the realized spread and information asymmetry increase on SGX. The increase of information asymmetry on SGX is especially significant and is likely due to the drop in explicit transaction costs on TAIFEX. Hence, a significant amount of liquidity trading moves from SGX to TAIFEX.

The size of the realized spread on SGX is greater than that on TAIFEX for both periods. This can be explained by the differences in market structures between SGX and TAIFEX. SGX is a continuous market with market makers. The member firms, which post bid and ask prices actively, bear the costs of providing liquidity and thus require higher realized spreads to be compensated for possible information losses. TAIFEX is a batch auction market where the trades are matched by the price that will clear the largest number of orders. The bid and ask prices are ex-post reference prices from the limit order book. The immediate participants of auction markets are thus all traders in the market. They usually do not play the role of liquidity providers actively and hence do not require as large a realized spread as the quote providers on SGX.

From Table VII, the realized spread and information asymmetry do not exhibit strong intraday patterns. The realized spreads in Table VIII, classified by trading size, also do not show obvious patterns. For the information asymmetry components classified by trading size, there is a tendency for a larger trade to carry more information because the information asymmetry usually increases with order size.

To summarize, the quoted and effective spreads on TAIFEX are significantly smaller than those on SGX in the second period, while the opposite is true for the first period. This is likely due to the reduced transaction tax and resulting increased liquidity on TAIFEX. The change of differences in quoted and effective spread can be broken up into relative changes in realized spreads and information asymmetry.

The test of realized spreads shows that the realized spreads of SGX are larger than those on TAIFEX and the differences become larger in the second period due to the decreased relative liquidity on SGX. This can be explained by the differences in market structures. Finally, the information asymmetry on TAIFEX decreases relatively to that on SGX. The relative increase of the realized spread on SGX and the decrease of information asymmetry on TAIFEX both contribute to lower implicit trading costs on TAIFEX in the second period.

## Information Transmissions

In order to further test the information processing efficiencies of SGX and TAIFEX and to understand the possible causes of the change of differences in trading costs, the VEC framework is employed to test the information transmissions between these two exchanges. The augmented Dickey–Fuller test is carried out, and it is concluded that both SGX and TAIFEX index future prices contain a unit root[15] in both sample periods; that is, they are integrated with degree of one [an $I(1)$ process]. After first differencing, the existence of unit roots in both series is rejected. For both periods, the cointegration test[16] shows that the SGX and TAIFEX

[15]To save space, the table of the unit root test is omitted. For price levels, the test of unit roots cannot be rejected by the critical value tabulated by MacKinnon (1991). After first differencing, the hypotheses of the existence of unit roots are rejected under the 0.01 significance level.

[16]The cointegration test results also are omitted to make the study concise. The results of the unit root test and cointegration test are available upon request.

index futures series are cointegrated, which is not surprising considering that both are based on Taiwan stock indices, which are highly correlated.

After confirming these two future price series are $I(1)$ and cointegrated, the Granger causality test is performed to examine the information processing efficiencies and transmissions between SGX and TAIFEX. Table IX shows the coefficients of the Granger causality test. Five lags are selected to fit the model. It is unlikely for the price series to

**TABLE IX**

Granger Causality Test (Vector Error-Correction Model)

| | *Dependent Variable* | | | *Dependent Variable* | |
|---|---|---|---|---|---|
| *Coefficient* | *SGX* | *t-Stats* | *Coefficient* | *TAIFEX* | *t-Stats* |
| *Panel A: First Period* | | | | | |
| $\gamma$ | −0.0005 | −0.75935 | $\gamma'$ | 0.0270** | 2.2061 |
| $\beta_{S1}$ | −0.0394*** | −3.6677 | $\beta'_{S1}$ | 6.2171*** | 30.9343 |
| $\beta_{S2}$ | −0.0476*** | −4.2124 | $\beta'_{S2}$ | 3.6548*** | 17.2803 |
| $\beta_{S3}$ | −0.0185 | −1.6060 | $\beta'_{S3}$ | 1.4631*** | 6.7908 |
| $\beta_{S4}$ | −3.0305*** | −2.6868 | $\beta'_{S4}$ | 1.4343*** | 6.7373 |
| $\beta_{S5}$ | 0.0061 | 0.5468 | $\beta'_{S5}$ | 0.9519*** | 4.5835 |
| $\beta_{T1}$ | 0.0066*** | 11.6249 | $\beta'_{T1}$ | −0.1862*** | −17.4626 |
| $\beta_{T2}$ | 0.0050*** | 8.5812 | $\beta'_{T2}$ | −0.0352*** | −3.2038 |
| $\beta_{T3}$ | 0.0018*** | 3.0380 | $\beta'_{T3}$ | −0.0142 | −1.2912 |
| $\beta_{T4}$ | 0.0012** | 2.1790 | $\beta'_{T4}$ | −0.0210** | −1.9671 |
| $\beta_{T5}$ | −0.0008 | −1.5281 | $\beta'_{T5}$ | −0.0461*** | −4.6462 |
| $F$-statistic | 18.8241 | | | 119.1000 | |
| *Panel B: Second Period* | | | | | |
| $\gamma$ | −0.0014 | −1.3382 | $\gamma'$ | 0.0282 | 1.4330 |
| $\beta_{S1}$ | −0.0155 | −1.5050 | $\beta'_{S1}$ | 6.8392*** | 35.8104 |
| $\beta_{S2}$ | −0.0807*** | −7.4001 | $\beta'_{S1}$ | 2.8916*** | 14.3024 |
| $\beta_{S3}$ | −0.0966*** | −8.7951 | $\beta'_{S1}$ | 1.1824*** | 5.8093 |
| $\beta_{S4}$ | −0.0855*** | −7.8822 | $\beta'_{S1}$ | 0.7221*** | 3.5930 |
| $\beta_{S5}$ | −0.0202* | −1.9357 | $\beta'_{S1}$ | 1.0313*** | 5.3314 |
| $\beta_{T1}$ | 0.0115*** | 20.5447 | $\beta'_{T1}$ | −0.1028*** | −9.9560 |
| $\beta_{T2}$ | 0.0072*** | 12.4621 | $\beta'_{T2}$ | −0.0627*** | −5.8454 |
| $\beta_{T3}$ | 0.0041*** | 7.1038 | $\beta'_{T3}$ | −0.0597*** | −5.5610 |
| $\beta_{T4}$ | 0.0018*** | 3.1847 | $\beta'_{T4}$ | −0.0450*** | −4.2759 |
| $\beta_{T5}$ | −0.0008 | 1.4870 | $\beta'_{T5}$ | −0.0420*** | −4.3127 |
| $F$-statistic | 62.9420 | | | 144.3257 | |

Note. The first period is from November 1, 1999–April 30, 2000, and the second period is from May 1, 2000–October 31, 2000. The specification of the VEC model is as follows:

$$\Delta S_t = \delta + \gamma(S_{t-1} - \mu - \beta T_{t-1}) + \sum_{i=1}^{p} \beta_{Si}\Delta S_{t-i} + \sum_{i=1}^{p} \beta_{Ti}\Delta T_{t-i} + \varepsilon_i$$

$$\Delta T_t = \delta' + \gamma'(S_{t-1} - \mu - \beta T_{t-1}) + \sum_{i=1}^{p} \beta'_{Si}\Delta S_{t-i} + \sum_{i=1}^{p} \beta'_{Ti}\Delta T_{t-i} + \varepsilon'_i,$$

where $S_t$ and $T_t$ are the future index levels of SGX and TAIFEX, respectively. The second term is the error-correction term and $\gamma$ and $\gamma'$s are the speed of the error correction. $\beta'$s indicate the direction and strength of information transmissions between SGX and TAIFEX. Superscripts ***, **, and * denote the significance level of 1%, 5%, and 10%, respectively.

lag each other for more than 5 min because these two price series are based on highly correlated indices and an arbitrage opportunity may arise if the series are out of sync for an extended period of time.

Table IX shows that, based on the $F$ values, all tests are significant. The term $\beta_T$ ($\beta'_S$) represents the information flows from TAIFEX (SGX) to SGX (TAIFEX) when the futures prices of SGX (TAIFEX) are treated as dependent variables. Although the information transmits bilaterally between SGX and TAIFEX, it can be seen by examining the $t$-statistics in Table IX, the relative strength of information transmissions from SGX to TAIFEX is much higher in the first period. In the second period, the strength of information transmissions from SGX to TAIFEX remains about the same, while the strength from TAIFEX to SGX increases quite noticeably. This indicates that the information efficiencies of TAIFEX increase from the first to the second period. This is likely due to decreased explicit and implicit transaction costs on TAIFEX, which enhance the liquidity and information content of TAIFEX trades.

The impact of market frictions such as the transaction tax is shown to be quite significant in this study. To put it in perspective, a decrease of 2.5 basis points in the transaction tax is almost as large as the effective half-spread for both SGX and TAIFEX, and its influences are certainly not to be ignored. The results also provide direct evidence supporting the trading-cost hypothesis. As the trading cost drops, the efficiency of the market increases.

## SUMMARY AND CONCLUSION

This article has studied the relative efficiencies of price execution between SGX and TAIFEX in terms of transaction costs, variances, and information transmissions. It is found that the transaction tax has a great impact on the implicit trading costs and information processing efficiencies. After the reduction of the transaction tax on TAIFEX on May 1, 2000, the quoted spreads, effective spreads, and speed of information incorporated into prices all improved significantly compared to those on SGX.

In the first sample period of which the transaction tax is higher on TAIFEX, the quoted and effective spreads of SGX are both smaller than those on TAIFEX. After the transaction tax fell from 5 basis points to 2.5 basis points, which is a decrease of similar magnitude to the size of the effective half-spread of the two markets, the trading volume on TAIFEX almost doubled and the quoted and effective spreads of TAIFEX became significantly smaller than those on SGX. To further test whether the reduction in implicit trading costs is related to the decrease in transaction tax, the effective spreads are decomposed into realized spread and information asymmetry components. Overall, the results show that the transaction tax delays the price-discovery process and increases both the explicit and implicit trading costs.

Due to the reduced transaction tax, both liquidity traders and informed traders have incentives to trade more often on TAIFEX in the second period. This is evident by the decrease in the degree of information asymmetry on TAIFEX from the first to the second sample period. TAIFEX is a batch auction market without active dealer participation. The realized spread on such a market naturally would be less than an open-outcry system employed by SGX because member firms on SGX provide quotes actively and hence bear the costs of providing liquidity.

In both sample periods, there exist bilateral information transmissions between SGX and TAIFEX. However, as the transaction tax fell on TAIFEX, the amount of information and the speed of information transmissions also improved. TAIFEX, an order-driven market, allows traders to submit orders directly to the market and trade with other market participants. This structure has the advantage of a larger trader base and less costs of intermediation. Even with the presence of a transaction tax on TAIFEX in the second period, the implicit costs have been lower than those on SGX. It is conjectured that if the transaction tax on TAIFEX falls further, the efficiencies of price execution on TAIFEX would significantly surpass those on SGX.

There are few articles that examine empirically the impacts of a transaction tax on the performance of futures markets. The results in this study shed light on how explicit trading costs such as a transaction tax will influence the efficiencies of price execution on futures markets. It is shown that a reduction in the transaction tax greatly improves the efficiency of the futures market. Furthermore, there has been much interest in comparing the efficiencies of different market structures. The study of the relative efficiencies of order-driven versus quote-driven markets is still in its early stage, and the results are far from conclusive. However, as our empirical results show, an order-driven market is likely to provide traders with better price execution because of the larger base of market participants and lower costs of intermediation.

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