A FURTHER LOOK AT TRANSACTION COSTS, SHORT SALE RESTRICTIONS, AND FUTURES MARKET EFFICIENCY: THE CASE OF KOREAN STOCK INDEX FUTURES

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Persistent underpricing in the Korean stock index futures market is documented and alternative explanations are examined. No-arbitrage pricing bands are computed using alternative sets of transaction costs and short sale restrictions faced by different investor groups. We find that a substantial portion of the mispricing can be explained by these factors, though a high incidence of mispricing remains after accounting for costs faced by the marginal trader group—the KSE exchange members. We also observe frequent underpricing of futures during

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periods of downward market trends. This is attributed in part because of unique restrictions on short sales and accounting conventions in the Korean market. In addition, tests of alternative futures pricing models are conducted that provide mixed results. Though we do not reject the standard cost-of-carry model, an equilibrium pricing model provides reasonable explanatory power. Further, use of the cost-of-carry model does not appear to be driving the findings of persistent underpricing. Jrl Fut Mark 19: 153–174, 1999

INTRODUCTION AND OVERVIEW

On May 3, 1996 futures trading began in Korea when the Korea Stock Exchange (KSE) launched a contract on the Korea Stock Price Index 200 (KOSPI 200). Initially, the futures remained fairly priced relative to the underlying index through the first contract expiration in June 1996. Subsequently, the futures trading has exhibited persistent underpricing, suggesting short arbitrage opportunities. In fact, the underpricing at times has been so large that the futures has traded below that of the index.

The purpose of this study is to examine the pricing performance of this contract during its available trading history. To our knowledge, this is the first such study of the Korean futures market. Two important questions addressed include "Why are mispricing rates so high?" and "What factors explain the persistent underpricing?" Thus this article attempts to shed additional light on earlier studies of futures mispricing by closely examining the important role of transaction costs and short sale restrictions. Adding to the empirical interest in examining this particular contract is that the Korean stock market has exhibited, as have many of the Pacific Rim economies during the period of our investigation, a notable decline in value.

The literature on futures pricing offers several potential explanations for observed pricing irregularities. For example, the pricing models often used in analyzing futures prices are perhaps more appropriate for pricing forward contracts, as noted by Cox, Ingersoll, and Ross (1981) and French (1983). Studies pertaining to stock index futures note the differential taxation between stocks and futures (Cornell & French, 1983), a transitory phenomenon caused by unfamiliarity with a new market (Figlewski, 1984), dividend uncertainty (Peters, 1985), unequal borrowing and lending rates (Gould, 1988), differences between futures and forward contracts (MacKinlay and Ramaswamy, 1988), and position limits (Brennan & Schwartz, 1990). However, Modest (1984), Cornell (1985), and Yadav and Pope (1990) suggest that in practice most of these factors have little impact on the pricing of futures contracts.

Other studies note the importance of short-sale restrictions and transactions costs. Modest and Sundaresan (1983) note that short sellers often receive less than full use of the proceeds. Also, a short seller must pay dividends on the shares borrowed—and if the proceeds of the short sales are not available for investment, a short arbitrage becomes profitable only when the futures price is below that of the index by an amount greater than the dividends to be paid. Modest (1984) and Brenner, Subrahmanyam, and Uno (1990) argue that transaction costs are the most important factor affecting the futures underpricing. Moreover, Puttonen, and Martikainen (1991) claim that, in the presence of short sale restrictions, different transaction costs should be employed.

For a number of reasons, the Korean market provides an interesting setting for further investigating the role of transactions costs and short sale restrictions on index futures pricing.

1) As mentioned, the Korean stock market has generally declined since the introduction of the futures trading.

2) During the initial months of the futures trading, there were no mechanisms in place for selling stocks short. Subsequently, on 2 September 1996 the Korea Securities Depository (KSD) introduced a stock loan system enabling institutional investors to borrow stocks from others through the KSD. The maximum period of the loan is limited to six months, and the borrowing fee is a flat rate of 1.8% of the proceeds with 1.5% going to the lender, 0.15% to the KSD, and 0.15% to the Korea Securities Finance Corporation. Despite its adoption, there has been little short index arbitrage activity in the market. Borrowers have not found the 1.8% fee to be prohibitly expensive, but potential lenders have indicated that their 1.5% fee is inadequate compensation for the added selling pressure placed on their shareholdings by allowing them to be sold into a generally falling market.

3) Lenders of shares to the KSD may call their stocks back upon five days' notice. Thus traders establishing a short arbitrage position by borrowing stocks cannot be certain they will be able to maintain their position.

4) Accounting rules in Korea to accommodate stock lending are in transition. At present, shares held in inventory are accounted for at book value (that is, purchase price), thus allowing firms to avoid recognition of inventory losses that would otherwise arise in a declining market environment if market values were used instead. Also, the current tax system treats both purchased and borrowed shares similarly. Further, borrowers must realize losses first on any stocks they hold in inventory. Together,

these rules provide disincentives for most securities companies to engage in short selling, given the largely declining market environment.

When computing theoretical futures prices, we initially utilize a cost-of-carry model and incorporate transaction costs in somewhat more realistic detail than do most prior studies that analyze index futures pricing. For example, Brenner et al. (1990) combine all transaction costs into the price of the stock index. Modest and Sundaresan (1983), Lim (1992), and Yadav and Pope (1990) simply add and subtract transaction costs of stocks and futures to and from the theoretical futures price. In this article, alternative sets of transaction costs reflecting those faced by different trader groups are used to construct no-arbitrage pricing bands.

Our principal findings are that a substantial portion of the futures underpricing can be explained by transaction costs. However, transaction costs alone are not sufficient to account for the persistent underpricing. We find that much of the underpricing is observed during periods of downward market price changes. We attribute this to restrictions on short sales combined with accounting conventions. Further, tests of alternative futures pricing models provide mixed support for the cost-of-carry model as an appropriate model for futures price determination. An equilibrium pricing model developed by Hemler and Longstaff (1991) is also found to have explanatory power. Still, use of the cost-of-carry model does not appear to be driving the findings of futures mispricing.

STOCK INDEX FUTURES PRICING: TRANSACTION COSTS AND SHORT SALES RESTRICTIONS

In the absence of transaction costs and restrictions on short sales, the theoretical price of a stock index futures contract can be determined using a cost-of-carry relationship. The cost-of-carry consists of the financing costs less the dividends-cum-interest to be received from the stocks comprising the index:

$$F_t^* = P_t \cdot e^{r(T-t)} - D(t, T) \tag{1}$$

where F_t^* is the time t theoretical price of the stock index futures, P_t is the index value at time t; $D(t,T)$ is the future value of dividends to be paid on the underlying asset from t to T, i.e., $D(t,T) = \Sigma_{s=t}^{T} e^{r(T-s)} D_s$ where D_s is the amount of dividends to be paid at time $s \in [t, T]$; and r is the risk-free rate.

Transaction costs and restrictions on short sales create upper and lower bounds about the theoretical price, $[F_t^U, F_t^L]$, within which there do not exist arbitrage opportunities. If the futures price is higher than the upper bound, then there exists a long arbitrage opportunity—for example, go long the underlying shares and short the futures. Similarly, if the futures price falls below the lower bound, then there exists a short arbitrage opportunity. Expressions for these bounds are given in the following proposition.

Proposition 1: In the presence of transaction costs and short sales restrictions, the no-arbitrage futures price (F_t) must lie within the following lower (F_t^L) and upper (F_t^U) bounds:

$$F_t^L \le F_t \le F_t^U \tag{2}$$

where

$$F_t^L = \frac{\{e^{r(T-t)}(m - k_{PS}) + (1 - m - k_{PL} - k_{FS})\}P_t - D(t,T)}{1 + e^{r(T-t)}k_{FL} + \{e^{r(T-t)} - 1\}\phi}$$

and

$$F_t^U = \frac{\{e^{r(T-t)}(1 + k_{PL}) + (k_{PS} + k_{FL})\}P_t - D(t, T)}{1 - e^{r(T-t)}\, k_{FS} - \{e^{r(T-t)} - 1\}\phi}$$

In the above, P_t is the index value at time t; $D(t, T)$ is the future value of dividends to be paid on the underlying asset from time t to T; k_{PL} and k_{PS} represent the transaction costs of buying and selling the index, respectively; k_{FL} and k_{FS} are the transaction costs of buying and selling the index futures, respectively; $m \in [0,1]$ is the rate of available short sales proceeds; and ϕ is the futures margin rate. (See Appendix 1 for derivation.)

Several interesting facts emerge from Proposition 1. When $k_{PS} = k_{PL} = k_{FS} = k_{FL} = \phi = 0$, and $m = 1$, the upper bound and the lower bound become equal, and the futures price reduces to the theoretical price given in eq. (1). The greater the transaction costs (k_{PS}, k_{PL}, k_{FS}, k_{FL}), the farther apart will be the no-arbitrage bounds. Further, the greater the futures margin rate, ϕ, the wider the bounds. This effect is attributable to the opportunity cost associated with any non–interest-bearing deposits used to satisfy margin requirements. Similarly, restrictions on the use of short sale proceeds (for example, $m < 1$) do not affect the upper bound but do push down the lower bound. Therefore, because of these various factors, the futures can clearly trade at a discount or at a premium to the theoretical futures price without inducing arbitrage trading.

When computing the upper and lower price bounds, it is important to note that various classes of traders face different transaction costs. Individual investors typically face higher transaction costs than institutional investors who in turn pay more than exchange members do. Similarly, different investor groups have varying degrees of access to short sale proceeds. Differing sets of transaction costs and restrictions on short sales will produce different sets of no-arbitrage bands from the perspective of the different groups. An apparent mispricing from the perspective of one investor group may not represent an arbitrage opportunity for a second group facing higher transaction costs. In practice, the futures price should trade within the no-arbitrage band related to the marginal or lowest transaction cost trader.

CONTRACT DESCRIPTION

The KOPSI 200 futures contract is a cash-settled futures that is based on the KOPSI 200 stock index. (The main features of the contract are presented in Appendix 2.) The KOPSI 200 index is a market-value weighted index comprised of 200 stocks and reflects the general performance of the Korean stock market. The index is computed according to the following: 100 times the current total market value of the 200 component stocks divided by a base aggregate market value set as of 3 January 1990. The contract size for each futures is 500,000 units. On 3 May 1996, for example, this represented a notional amount for the nearby contract equal to 54.25 million won or approximately $70,000.

The futures contract matures on the quarterly cycle of March, June, September, and December; and the last trading day of each contract is the second Thursday of the delivery month or, in the case of a holiday, the preceding day. Each weekday there are two trading sessions: a morning session running from 9:00 am to 11:30 am, and an afternoon session running from 1:00PM to 3:15PM (2:50PM on the last day of trading). On Saturdays there is only a morning session. Trading is conducted electronically with only limit orders permitted.

The futures contract has shown steady growth since its introduction. Average daily volume during the first month of trading, May 1996, was 3,472 contracts with a month-ending open interest of 2,054 contracts. In May 1998, average daily volume in the futures had grown to 45,282 contracts with month-ending open interest of 64,586 contracts. Share volume on the KSE during this period has also grown from a daily average of 38.3 million shares in May 1996 to 54.4 million shares in May 1998. However, on a won basis, volume did not grow due to a large decline in share prices during this period. For example, on 3 May 1996, the first day of futures trading, the KOPSI 200 stock index was at a level of 107.34, whereas on 12 May 1998, the last day in our investigation, the index had declined to 41.75.

Though the trading volume in the futures has been active, only a very minor percentage of this volume has been related to index arbitrage activity. To illustrate, based on information provided by the KSE, the total volume of shares bought and sold during the first five months of 1998 that were related to index arbitrage was 24 million and 39 million shares, respectively. These numbers represent 0.18% and 0.30% of the futures volume on a share equivalent basis.

DATA DESCRIPTION

The sample period for our investigation spans an approximate two-year period beginning with the initial opening of the market on 3 May 1996 and continuing through 12 May 1998. On each date in the sample period, the analysis focuses on the two nearest maturing futures. Our price data consist of daily index values of the KOSPI 200, and prices for both the nearest and second nearest futures. Because the futures market closes 15 minutes later than the stock market, we reduce potential noise from using daily closing and settlement prices by matching the timing of futures prices and index values. We use values recorded closest to 11:30 AM each day. In addition, we obtained daily market value-weighted dividend information and alternative sets of transaction costs.[1] We also obtained daily CD rates to proxy for the applicable financing rate. We have been informed that the KSE and most brokerage houses in Korea consider this rate as a reasonable proxy for determining borrowing costs. All data in the study were provided by the Korea Stock Exchange (KSE).

Trading costs in the Korea securities markets are nontrivial, and hence play an important role in assessing futures mispricing. The following parameters are used in conducting the analysis.

Securities Brokerage Commissions

KSE exchange members pay a nominal fee ("membership fee") of 0.024% to the KSE for buying and selling stocks. For all other traders, actual

[1]Dividend data provided by the KSE reflect interest based on reinvestment at the CD rate. We expect this choice of rate to have little effect on our analysis. In Korea, 97.4% of companies pay dividends at the year's end. Thus, except for the 1997 and 1998 March futures contracts, the effect of dividends in our analysis is minimal. Also, using the 1997 March futures contract for the period from 3 May 1996 to 31 October 1996, Jung and Choi (1996) report no significant differences between prices that do and do not consider interest on dividends.

brokerage commissions for buying and selling are charged. The maximum rate that may be charged by brokerage houses is 0.6%; however, the average commission charged by the top 5 brokerage houses in Korea is 0.5%.

Securities Transfer Tax

Both exchange members and nonmembers alike are assessed a securities transfer tax of 0.3%, which is paid when securities are sold. The Securities Transfer Tax Law sets this rate.

Securities Market Impact Costs

To properly account for the trading costs incurred in the buying and selling of the sizable quantities of securities entailed in an index arbitrage, it is also important to include market impact costs. In conducting the analysis, the market impact costs are assumed to be 0.4% for both buying and selling the stocks in the underlying index. This figure is taken from Lee and Kim (1997), who estimate market impact costs of transacting on the Korea Stock Exchange. They report different costs, depending upon the size of and the number of shares traded. The average market impact cost for a 50-stock portfolio of 10 million dollars is estimated to be approximately 0.4%.

Thus, for purchasing and selling stocks, transaction costs comprised of brokerage commissions, securities transfer tax (for sales), and market impact costs are estimated as follows:

exchange members: $k_{PL} = 0.424\%$, and $k_{PS} = 0.724\%$; and

non–exchange members: $k_{PL} = 0.9\%$ and $k_{PS} = 1.2\%$.

Short Sale Restrictions

When the proceeds from short sales are assumed available for investment, $m = 1$. This situation would apply to exchange members who borrow shares from the KSD. However, non–exchange members who borrow shares from the KSD do not receive use of the proceeds. Thus, for these firms, $m = 0$. Alternatively, firms engaging in quasi-arbitrage by selling existing shares held in inventory could arguably be considered to have full use of the proceeds, and thus, for these firms, $m = 1$. Such firms would include securities companies, banks, and insurance companies. Thus, in conducting the analysis, we consider the following cases:

$$\text{exchange members: } m = 1$$

$$\text{non–exchange members: } m = 0$$

$$\text{non–exchange members: } m = 1 \text{ (quasi-arbitrage).}$$

Futures Trading Costs

KSE exchange members pay a nominal fee of 0.00225% for both buying and selling the futures. Non–exchange members pay a fee of 0.05%. In addition, all traders are subject to an initial futures margin rate of ϕ = 15%. Of the 15% of the initial margin, traders are required to deposit 5% in cash and the remaining 10% in the form of cash or treasury securities. As can be seen in expression (2), the effect of margin funds on the no-arbitrage band is associated with the opportunity cost of non–interest-bearing cash. In the analysis below, traders are assumed to post treasury securities to the maximum extent possible (10%)—and thus the effective margin rate is 5% for purposes of assessing the price impact of margin requirements.[2] In sum, the following futures trading costs are used in the analysis:[3]

$$\text{exchange members: } k_{FL} = k_{FS} = 0.00225\%, \ \phi = 5\%$$

$$\text{non–exchange members: } k_{FL} = k_{FS} = 0.05\%, \ \phi = 5\%.$$

EMPIRICAL ANALYSIS

Measuring Mispricing Rates

In this section we describe our various measures of futures mispricing. As is common in studies of futures market efficiency, we assume that the underlying cash index is priced correctly. In addition, we note that detection of apparent mispricing could also be due to the use of an incorrectly specified model of theoretical prices. In a subsequent section of this article, we further explore this latter issue.

Mispricing rates of futures are measured under four scenarios. First, mispricing is measured as the percentage deviation of market prices from "theoretical" prices. Theoretical prices are computed by assuming in ex-

[2]We have repeated the empirical analysis below using ϕ = 15% and find minor increases in the reported instances of mispricing. These results are available upon request.
[3]Note that market impact costs for the futures are specifically not included, for we are attempting to determine the upper and lower futures price bounds that would preclude arbitrage.

pression (2) that there are no transaction costs or margin requirements and that short sale proceeds are fully available. Thus we define MTHEOR to denote the rate of mispricing of the actual futures price relative to the theoretical price.

Second, for three alternative sets of transaction costs faced by different trader groups, mispricing rates are computed relative to the corresponding upper bound (F_t^U) or the lower bound (F_t^L) of the no-arbitrage band as given in expression (2). Reference to these three additional sets of mispricing rates and corresponding trader groups is denoted by: MEM (for exchange members who pay the lowest set of transactions costs and receive full proceeds on short sales through the KSD); MNEM0 (non–exchange members who pay full transaction costs and receive no use of short sale proceeds from the KSD); and MNEM1 (non–exchange members who pay full transaction costs, but are able to sell shares from inventory to conduct short quasi-arbitrage). To summarize, the following four sets of parameter values are used to establish futures price bounds and to assess mispricing:

MTHEOR: $k_{PL} = k_{PS} = k_{FL} = k_{FS} = 0.0\%$, m $= 1$, $\phi = 0\%$

MEM: $k_{PL} = 0.424\%$, $k_{PS} = 0.724\%$, $k_{FL} = k_{FS} = 0.00225\%$, $m = 1$, $\phi = 5\%$

MNEM1: $k_{PL} = 0.9\%$, $k_{PS} = 1.2\%$, $k_{FL} = k_{FS} = 0.05\%$, $m = 1$, $\phi = 5\%$

MNEM0: $k_{PL} = 0.9\%$, $k_{PS} = 1.2\%$, $k_{FL} = k_{FS} = 0.05\%$, $m = 0$, $\phi = 5\%$.

Each of the four sets of parameters are next applied to calculating mispricing rates for the two nearby KOSPI 200 futures on a daily basis for the period from 3 May 1996 through 12 May 1998. This produced a sample of 593 daily observations for each of the two futures and four sets of mispricing rates. Summary statistics are presented in Table I.

As shown in Table I, the market price of the nearest futures was frequently well below that of the theoretical price (MTHEOR). The daily price deviations ranged from a negative 13.50% to a positive 3.21%, with the futures underpriced on 68.6% of the days. In the three cases where various sets of trading costs are accounted for, mispricing rates dropped substantially. For exchange member firms (MEM), the trader group facing the lowest set of transaction costs, mispricing rates ranged from -12.47% to $+1.96\%$. Still, the actual futures price was beneath that of

TABLE I

Daily Mispricing Rates (in percent) for the KOSPI 200 Futures Contract
In the table MTHEOR is the theoretical mispricing rate, MEM is the mispricing rate based on trading costs faced by exchange members, MNEM1 is the mispricing rate for non-exchange members who have full use of short sale proceeds, and MNEMO is the mispricing rate for non-exchange members who receive no use of short sale proceeds. The time period is May 3, 1996 to May 12, 1998. Number of observation is 593.

	Nearest Futures				*Second Nearest Futures*			
	MTHEOR	*MEM*	*MNEM1*	*MNEMO*	*MTHEOR*	*MEM*	*MNEM1*	*MNEMO*
Minimum	−13.50	−12.47	−11.57	−9.32	−16.77	−15.94	−15.09	−7.85
Maximum	3.21	1.96	0.92	0.92	5.31	3.64	2.58	2.58
Mean	−1.85	−1.38	−1.01	−0.37	−2.91	−2.11	−1.62	−0.14
Frequency								
Under-pricing	68.6	47.0	37.3	18.9	83.0	60.2	48.6	5.7
Fair-pricing	0.0	43.0	61.4	79.8	0.0	35.6	50.8	93.6
Over-pricing	31.4	10.0	1.3	1.3	17.0	4.2	0.6	0.7

the lower price bound (underpriced) on a surprisingly large 47% of the trading days. For non–exchange member firms with access to shares held in inventory (MNEM1), mispricing rates ranged from −11.57% to +0.92 %, with mispricing on 37.3% of the trading days, nearly all of which was underpricing. Mispricing rates for the highest transaction cost trader group (MNEMO) were further reduced to between −9.32% and +0.92%. In this case, the futures were underpriced on only 18.9% of the trading days.

The results in the right-side panel of Table I for the second nearest futures were similar to those of the nearest futures with the degree of mispricing generally slightly greater. For example, the mispricing rates relative to the theoretical futures price (MTHEOR) ranged from −16.77% to +5.31%, and the futures were underpriced on 83% of the trading days. The mispricing rates (MNEMO) for the highest transaction cost trader were an exception: Here the rates ranged between −7.85% to 2.58%, with the futures underpriced on only 5.7% of the trading days.

To summarize, the various transaction costs and restrictions on short sale proceeds account for a substantial portion of the observed mispricing of futures in the Korean stock index futures market. Still, even in the case of the lowest transaction cost trader group and hence marginal trader, the KSE exchange members, there remained frequent mispricing, primarily underpricing. Thus an important question is: Why do we observe persistent underpricing of futures?

What Explains Mispricing of the Futures?

Next, the relationship between mispricing rates and a number of explanatory variables is examined in a regression framework. Variables included relate to maturity, short sale restrictions, market trend and volatility. These factors may shed light on various issues.

First, the ability of an investor or model to value the futures accurately may be related to the time to maturity. Further, a longer term to maturity may create added uncertainty as to how long an arbitrage position will actually need to be maintained—and subsequently unwound—in order to capture the mispricing. Also, recall that shares borrowed from the KSD may be recalled upon five days' notice. Thus, along these lines, observing a negative relationship between maturity and mispricing would indicate that longer-dated contracts are relatively more mispriced.

Second, despite numerous apparent short arbitrage opportunities (that is, futures prices too low), there has been little arbitrage activity—as is mentioned earlier. Further, the KSD's stock loan system, established 2 September 1996, has not been highly utilized by arbitrageurs for executing short arbitrage transactions. As mentioned, cost value accounting requirements provide disincentives for potential short sellers. Traders not only have to realize losses on their inventory holdings, but may also end up increasing their unrealized losses by driving the market down further through their selling activities. Taken together, it is reasonable to expect greater difficulty in executing short sales when the market is falling than at other times. To test the importance of market trend and the stock loan system on futures pricing, we include two additional variables. A moving average variable is included to capture market trend. To examine whether the initiation of stock loan system to facilitate short selling was helpful in reducing mispricing, we include a dummy variable to distinguish between periods before and after the system was introduced.

Third, a volatility measure is also included to examine the effect of market volatility on futures mispricing. Hemler and Longstaff (1991) argue that market volatility can have explanatory power for the pricing of stock index futures. We estimate the time-varying market volatility using the GARCH (1,1) model of Bollerslev (1986). The volatility measure is reestimated daily using prices beginning with 3 January 1990 and ending on the day prior to the day of each mispricing calculation. The volatility estimates are adjusted for the time to the maturity of the futures contract.

The following regression is estimated based on the daily theoretical mispricing rates computed under MTHEOR:

TABLE II

Regression Results for the Nearest Futures Mispricing: KOPSI 200

$$M_t = \beta_0 + \sum_{t=1}^{2} \beta_{1i} M_{t-i} + \beta_2 T_t + \beta_3 D + \beta_4 MA_t + \beta_5 D \cdot MA_t + \beta_6 v_t + \varepsilon_t$$

where M_t is the theoretical mispricing rate; T_t is time in years to the futures maturity date; MA_t is the 6-day moving average of the KOSPI 200; v_t is the maturity-adjusted GARCH (1,1) volatility of the KOSPI 200; and D is a dummy variable set equal to 1 if the date is after the introduction of the stock loan system, and zero otherwise, t-statistics in parentheses are based on the White (1980) heteroskedasticity consistent estimate of the covariance matrix of the parameters. Time period is May 3, 1996 to May 12, 1998. Number of observations is 593.

	β_0	β_{11}	β_{12}	β_2	β_3	β_4	β_5	β_6	R^2	$\chi^2(1)$
(A)	−0.412	0.718	0.142	−3.518	—	0.008	–	–	0.81	3.67
	(−1.23)	(10.48)[a]	(2.69)[a]	(−3.62)[a]		(1.79)[c]				
(B)	0.147	0.719	0.140	–	–	–	–	−0.041	0.81	1.99
	(1.13)	(10.85)[a]	(2.62)[a]					(−2.45)[b]		
(C)	0.448	0.742	0.145	–	−1.514	−0.006	0.019	–	0.80	1.99
	(0.67)	(11.05)[a]	(2.66)[a]		(−1.79)[c]	(−0.93)	(1.90)[c]			
(D)	1.337	0.708	0.135	−3.851	−2.333	−0.012	0.029	–	0.81	3.59
	(2.04)[b]	(10.35)[a]	(2.56)[b]	(−3.78)[a]	(−2.68)[a]	(−1.83)[c]	(2.81)[a]			
(E)	1.274	0.705	0.136	−2.852	−1.639	−0.011	0.021	−0.021	0.81	3.81
	(1.95)[c]	(10.38)[a]	(2.58)[a]	(−2.12)[b]	(−1.70)[c]	(−1.70)[c]	(1.80)[c]	(−0.84)		

[a–c]Significant at the 1%, 5%, and 10% level, respectively.

$$M_t = \beta_0 + \sum_{i=1}^{n} \beta_{1t} M_{t-i} + \beta_2 T_t + \beta_3 D + \beta_4 MA_t + \beta_5 D \cdot MA_t + \beta_6 v_t + \varepsilon_t \quad (3)$$

where M_t is the theoretical mispricing rate for day t; T_t is time in years to the futures maturity date; MA_t is the 6-day moving average of the KOSPI 200; v_t is the maturity-adjusted GARCH (1,1) volatility of the KOSPI 200; and D is a dummy variable set equal to 1 if the date t is after the introduction of the stock loan system (2 September 1996), and zero otherwise. Also included are lagged values of the dependent variable to control for autocorrelation in the residuals as well as an interaction term between the dummy variable and the market trend.

Tables II and III present results of the regression model given in expression (3) for the nearest and second nearest futures, respectively. In both tables, the positive and significant coefficients on the lagged mispricing rates suggest persistence of mispricing over the sample period.[4]

[4]Godfrey chi-square statistics (see Godfrey, 1978) for autocorrelation are reported in Tables II and III. Each is insignificant at the 5% level (critical value equal to 3.84 with one degree of freedom).

TABLE III

Regression Results for the Second Nearest Futures Mispricing: KOPSi 200

$$M_t = \beta_0 + \sum_{i=1}^{3} \beta_{1i} M_{t-i} + \beta_2 T_t + \beta_3 D + \beta_4 MA_t + \beta_5 D \cdot MA_i + \beta_6 \nu_t + \varepsilon_t$$

where M_t is the theoretical mispricing rate; T_t is time in years to the futures maturity date; MA_t is the 6-day moving average of the KOSPI 200; ν_t is the maturity-adjusted GARCH (1,1) volatility of the KOSPI 200; and D is a dummy variable set equal to 1 if the date is after the introduction of the stock loan sysatem, and zero otherwise, t-statistics in parentheses are based on the White (1980) heteroskedasticity consistent estimate of the covariance matrix of the parameters. Time period is May 3, 1996 to May 12, 1998. Number of observations is 593.

	β_0	β_{11}	β_{12}	β_{13}	β_2	β_3	β_4	β_5	β_6	R^2	$\chi^2(1)$
(A)	−1.578	0.562	0.005	0.249	−1.136	–	0.020	–	–	0.67	1.85
	(−3.10)[a]	(6.72)[a]	(0.05)	(2.71)[a]	(−0.97)		(3.02)[a]				
(B)	0.026	0.566	0.004	0.256	–	–	–	–	−0.029	0.68	3.16
	(0.10)	(6.89)[a]	(0.04)	(2.87)[a]					(−1.78)[c]		
(C)	0.216	0.557	0.002	0.245	–	−2.95	−0.006	0.037	–	0.68	1.46
	(0.24)	(6.70)[a]	(0.02)	(2.70)[a]		(−2.51)[b]	(−0.61)	(2.63)[a]			
(D)	0.979	0.552	−0.001	0.240	−1.480	−3.333	−0.008	0.041	–	0.68	1.57
	(0.94)	(6.71)[a]	(−0.01)	(2.66)[a]	(−1.19)	(−2.59)[b]	(−0.92)	(2.66)[a]			
(E)	0.978	0.552	−0.001	0.241	−1.280	−2.849	−0.008	0.035	−0.008	0.68	1.85
	(0.93)	(6.72)[a]	(−0.01)	(2.72)[a]	(−1.20)	(−2.08)[b]	(−0.89)	(2.19)[b]	(−0.36)		

[a–c]Significant at the 1%, 5%, and 10% level, respectively.

In Table II for the nearby contract, the estimated coefficient (β_2) on the time to maturity is negative and significant, indicating that longer dated contracts are relatively more underpriced.[5] This result is also consistent with the findings of MacKinlay and Ramaswamy (1988), Bailey (1989), Cakici and Chatterjee (1991), and Brailsford and Cusack (1997). It also suggests that there may exist risk premia associated with longer dated contracts that is not captured by the cost-of-carry model, an issue investigated below. In Table III for the second nearest contract, however, though the sign of the coefficient on the time variable is negative, it is insignificant.

The estimated coefficient (β_3) of the dummy variable D is negative and significant for both futures maturities. This suggests that the mispricing was greater in the period following the introduction of the stock loan system.

[5]Note from Table I that 68.6% and 83% of the nearest and second nearest futures, respectively, were underpriced. When the regression is run with an absolute value sign on mispricing rates, the results are qualitatively similar.

If short selling were less attractive during downward market trends, we would expect a positive relationship between the futures mispricing and the moving average variable. The sign of the estimated coefficient of the 6-day moving average (β_4) is positive and significant in row (A) of both Tables II and III. In the other specifications, the coefficient is negative and is significantly negative in specification (D) of Table II. However, a significant positive coefficient for the interaction term between the dummy variable and the market trend (β_5) is observed for both futures maturities. This implies that the market trend became important following the introduction of the stock loan system. This evidence furthers the notion that the introduction of the stock loan system provided little help in mitigating the persistent underpricing of futures.

Finally, for both futures maturities, the estimated coefficient on the market volatility term (β_6) in specification (B) is negative and significant.[6] This result suggests that the apparent mispricing could arise because of inadequacies in the use of the cost-of-carry model in determining theoretical futures prices. However, in specification (E), which contains all variables, the volatility coefficient is insignificant. This issue is considered further in the next section.

Cost-of-Carry versus Equilibrium Pricing Model

The prevalence of mispricing implies that the cost-of-carry model is incorrect and/or that the Korean futures market contains pricing inefficiencies. The cost-of-carry model used in determining the theoretical prices is a partial equilibrium model that assumes the stock market is exogenous. As a consequence, the model could fail to capture the dynamic interactions between the stock and futures market. In this section we examine whether the detection of mispricing in our tests arises from use of the cost-of-carry model.

Hemler and Longstaff (1991) develop a closed-form general equilibrium pricing model of stock index futures in a continuous-time economy with stochastic interest rates and market volatility. Their approach allows for interactions between futures, stock, and credit markets; consequently, the stock index futures price, the stock index, and the risk-free rate are determined endogenously as part of the equilibrium. The simple functional form of the stock index futures price (see eq. (15) in Hemler and

[6]We also conduct the regressions making no maturity adjustments to volatility and similarly find negative coefficients. However, only the coefficient on the second nearest futures is significant.

Longstaff, 1991), implies that the logarithm of the dividend-adjusted futures/spot price ratio can be represented as a linear function of both the risk-free rate and the volatility of the market. That is,

$$L_t = \beta_0 + \beta_1 r_t + \beta_2 v_t + \varepsilon_t \tag{4}$$

where $L_t = \ln(F_t^d/S_t)$, F_t^d is the dividend-adjusted futures price, S_t is the stock index price, r_t is the risk-free rate, and v_t is the market volatility. According to the equilibrium model, the predicted signs of the regression coefficients would be $\beta_0 \neq 0$, $\beta_1 > 0$, and $\beta_2 \neq 0$. In contrast, the cost-of-carry model implies that the logarithm of the dividend-adjusted futures/spot price ratio depends on the risk-free rate only. That is, $\beta_0 = 0$, $\beta_1 > 0$, and $\beta_2 = 0$. Thus, the cost-of-carry model can be viewed as a special case of the equilibrium pricing model. Following Hemler and Longstaff, we examine the restrictions imposed on futures prices by both the cost-of-carry and equilibrium pricing models.

To test these restrictions, the time frame for the analysis is again the period from 3 May 1996 to 12 May 1998. Daily dividend-adjusted futures prices (F_t^d) are constructed using the futures prices and dividend data described earlier. Interest rates on 91-day CDs are again used as a proxy for the risk-free rate. GARCH (1,1) volatility is used as a measure of the time-varying market volatility. Consistent with the equilibrium model in Hemler and Longstaff (1991), both the interest rate and volatility estimate are adjusted for the time remaining until the futures maturity.[7]

Table IV reports the regression results for testing the two alternative futures pricing model specifications. Ordinary least-squares procedures were used with standard errors adjusted based on the White (1980) correction for heteroskedasticity. To control for autocorrelation in the residuals, two lagged values of the dependent variable were added to the specification in eq. (4).[8]

As discussed, the cost-of-carry model implies that the constant term (β_0) should be zero. The estimated constant terms are not statistically different from zero for both the nearest and second nearest futures. This finding supports the cost-of-carry model and is contrary to the equilibrium model in this respect. The coefficient of the interest rate term (β_1) is positive and significant for both futures maturities. This finding is consistent and supportive of both models. As discussed above, if the cost-of-

[7]The analysis reported below has been repeated with no maturity adjustments made to either the interest rate or volatility term. The regression results were qualitatively similar.

[8]The Durbin's h statistic (see Durbin, 1970) in Table IV indicates correction for autocorrelation when using lagged variables. Durbin's h has an asymptotic normal distribution with a mean of zero and a variance of one.

TABLE IV

Tests of Futures Pricing Models: Cost-of-Carry versus Equilibrium Model for the KOPSi 200 Stock Index Futures

$$L_t = \beta_0 + \sum_{i=1}^{2} \beta_{0i}L_{t-i} + \beta_1 r_t + \beta_2 v_t + \varepsilon_t$$

where L_t is the natural logarithm of the ratio of the dividend-adjusted futures price to the KOPSI 200 spot index value; r_t is the maturity adjusted interest rate; and v_t is the maturity-adjusted GARCH (1,1) volatility. t-statistics in parentheses are based on the White (1980) heteroskedasticity consitent estimate of the covariance matrix of the parameters. Time period is May 3, 1996 to May 12, 1998. Number of observations is 593.

	β_0	β_{01}	β_{02}	β_1	β_2	R^2	*Durbin's h*
Nearest Futures	0.001	0.710	0.173	0.133	−0.0003	0.79	−0.46
	(0.65)	(9.80)[a]	(2.81)[a]	(1.75)[c]	(−1.61)		
Second Nearest Futures	0.0002	0.599	0.161	0.226	−0.0004	0.59	−0.87
	(0.05)	(7.61)[a]	(2.04)[b]	(3.04)[a]	(−1.96)[b]		

[a–c]Significant at the 1%, 5%, and 10% level, respectively.

carry model determines prices, market volatility should not have significant explanatory power. The coefficient on the market volatility term (β_2) for the nearest futures is negative, but only marginally significant (p-value of 11%). For the second nearest futures, the coefficient is significantly negative at the 5% level. This finding is supportive of the equilibrium model and contrary to the cost-of-carry model.

To summarize, the evidence in favor of either model is mixed as neither of the alternative models is clearly supported. Futures prices do not follow strictly the cost-of-carry model, but it is difficult to conclude that they instead follow the equilibrium pricing model. In a closely related study, Brailsford and Cusack (1997) compare a standard and modified cost-of-carry model with the equilibrium pricing model developed by Hemler and Longstaff (1991) using the data of individual share futures traded on the Sydney Futures Exchange. As is the case here, they find that the three models provide similar results—as none was clearly supported.

CONCLUSIONS

In this article we identify persistent mispricing—in particular, underpricing—observed in the Korean stock index futures market and examine potential contributing factors including transaction costs and restrictions on short sales. In addition, we examine the appropriateness of using the standard cost-of-carry model and test restrictions imposed on futures prices by it and an alternative equilibrium pricing model. Alternative sets of transaction costs that reflect those faced by different trader groups are used to create sets of no-arbitrage bands. We find that a substantial portion of the underpricing can be explained by transaction costs; however, a high incidence of mispricing did remain after accounting for the level of transaction costs faced the lowest cost trader group—the KSE exchange members. We also note the high frequency of underpricing, particularly during periods of downward market trends. This is attributed in part to restrictions on short sales, along with accounting conventions. Further tests of two alternative futures pricing models provided mixed results. Even though it is difficult to reject the cost-of-carry model, an equilibrium pricing model is found to provide reasonable explanatory power. Still, using the cost-of-carry model does not appear to be driving the findings of the persistent underpricing of Korean stock index futures.

APPENDIX 1

Derivation of Proposition 1

We derive the proposition in two steps, based on no-arbitrage arguments.

(1) Derivation of the lower futures price bound (F_t^L)

Suppose there exists a short arbitrage opportunity. An arbitrageur would then initially go short the underlying shares and long the futures, and subsequently reverse the positions at the futures maturity. The associated cash flows are as follows.[9]

	time t	time T
short stocks	mP_t	$(1 - m)P_t - P_T$
cost of short sale	$-k_{PS}P_t$	
payment of dividends		$-D(t, T)$
cost of buying stocks		$-k_{PL}P_t$
long futures		$P_T - F_t$
cost of buying futures	$-k_{FL}F_t$	

[9]Note that at maturity because of convergence between futures and spot prices, $F_T = P_T$. Also, in determining the no-arbitrage price band, technically speaking, it is required that all future cash flows be known as of time t. However, the transaction costs associated with buying or selling the futures or index at maturity are a function of their prices prevailing at maturity—that is, F_T and P_T. Because these prices are not known as of time t, for purposes of computing expected transaction costs, we use P_t to approximate for P_T.

margin payment	$-\phi F_t$	
margin receipt		ϕF_t
cost of selling futures		$-k_{FS}P_t$
lending (r)	$-\{(m - k_{PS})P_t - (k_{FL} + \phi)F_t\}$	$e^{r(T-t)}\{(m - k_{PS})P_t - (k_{FL} + \phi)F_t\}$
net cash flows	0	$-F_t + e^{r(T-t)}\{(m - k_{PS})P_t - (k_{FL} + \phi)F_t\} + (1 - m)P_t - (k_{PL} + k_{FS})P_t + \phi F_t - D(t, T)$

At time t the net investment is equal to zero. Thus, to preclude arbitrage profits, the payoff at time T cannot be greater than zero. That is,

$$-F_t + e^{r(T-t)}\{(m - k_{PS})P_t - (k_{FL} + \phi)F_t\} + (1 - m)P_t - (k_{PL} + k_{FS})P_t + \phi F_t - D(t, T) \leq 0$$

Rearranging terms gives the following lower bound:

$$F_t^L \equiv \frac{\{e^{r(T-t)}(m - k_{FS}) + (1 - m - k_{PL} - k_{FS})\}P_t - D(t, T)}{1 + e^{r(T-t)}k_{FL} + \{e^{r(T-t)} - 1\}\phi} \leq F_t \qquad \text{(A1)}$$

(2) Derivation of the upper futures price bound (F_t^U)

Suppose there exists a long arbitrage opportunity. An arbitrageur would then initially go long the underlying shares and short the futures and subsequently reverse the positions at the futures maturity date. The associated cash flows are as follows.

	time t	time T
long stocks	$-P_t$	P_T
cost of buying stocks	$-k_{PL}P_t$	
dividends		$D(t, T)$
cost of selling stocks		$-k_{PS}P_t$
short futures		$F_T - P_t$
cost of selling futures	$-k_{FS}F_t$	
margin payment	$-\phi F_t$	
margin receipt		ϕF_t
cost of buying futures		$-k_{FL}P_t$
borrowing (r)	$P_t(1 + k_{PL}) + (k_{FS} + \phi)F_t$	$-e^{r(T-t)}\{P_t(1 + k_{PL}) + (k_{FS} + \phi)F_t\}$

net cash flows 0 $F_t - e^{r(T-t)} \{P_t(1 + k_{PL}) + (k_{FS} + \phi)F_t\} - (k_{PS} + k_{FL}) P_t + \phi F_t + D(t, T)$

To preclude arbitrage profits, the payoff at time T cannot be greater than zero. That is,

$$F_t - e^{r(T-t)} \{P_t(1 + k_{PL}) + (k_{FS} + \phi)F_t\} - (k_{PS} + k_{FL})P_t + \phi F_t + D(t, T) \leq 0$$

Rearranging terms gives the following upper bound:

$$F_t \leq \frac{\{e^{r(T-t)} (1 + k_{PL}) + (k_{PS} + k_{FL})\} P_t - D(t, T)}{1 - e^{r(T-t)} k_{FS} - \{e^{r(T-t)} - 1\}\phi} \equiv F_t^U \quad \text{(A2)}$$

Together, equations (A1) and (A2) provide the upper and lower bounds of the no-arbitrage band.

APPENDIX 2

Main Features of the Korean Stock Index Futures Contract

1. Underlying Index	KOSPI (Korea Stock Price Index) 200
2. Contract Months	March, June, September, December
3. Contract Size	KOSPI 200 multiplied by 500,000 won
4. Last Day of Trading	Second Thursday of delivery month (Previous business day in case the second Thursday is holiday)
5. Trading Hours:	
(a) Ordinary day	09:30–11:30 (Morning Session) 13:00–15:15 (Afternoon Session) on weekdays 09:30–11:45 (Morning Session) on Saturday
(b) Last day	9:30–11:30 (Morning Session) 13:00–14:50 (Afternoon Session) on weekdays 09:30–11:20 (Morning Session) on Saturday
6. Minimum Price Change	0.05 points (25,000 won)
7. Price Limits	5% of the previous day settlement price

8. Method of Trading	Individual auction basis through a computer assisted system
9. Types of Orders	Only limit orders are permitted
10. Settlement Procedure	Cash Settlement based on the day's closing futures price (or the most recent day's settlement price if there is no futures trading)
11. Customers Margin	Initial Margin = (Settlement price) × (500,000 won) × (Initial margin rate of 15%) × (No. of open positions) Maintenance Margin Rate = 10%
12. Minimum Deposit	30 million won
13. Withdrawal of Gains from Marking-to-Market	Gains realized from daily marking-to-market shall not be withdrawn or applied as margin for other trading
14. Brokerage Commission	0.05% (upper limit set by the Korea Stock Exchange)

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