

# THE PRICING OF STOCK INDEX FUTURES DURING THE ASIAN FINANCIAL CRISIS: EVIDENCE FROM FOUR ASIAN INDEX FUTURES MARKETS

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## Abstract

Market imperfections are traditionally measured individually. Hsu and Wang (2004) and Wang and Hsu (2006) recently proposed the concept of the degree of market imperfections, which reflects the total effects of all market imperfections between the stock index futures market and its underlying index market when implementing arbitrage activities. This study discusses some useful applications of this concept. Furthermore, Hsu and Wang (2004) developed an imperfect market model for pricing stock index futures. This study further compares the relative pricing performance of the cost of carry and the imperfect market models for four Asian index futures markets (particularly for the Asian crisis period). The evidence indicates that market imperfections are important in determining the stock index futures prices for immature markets and turbulent periods with high market imperfections. Nevertheless, market imperfections are excluded from the cost of carry model. Therefore, when selecting a pricing model to estimate the theoretical values of stock index futures, practitioners should identify the degree of market imperfections for the markets in which they are participating.

**Key words:** Asian financial crisis, Pricing of stock index futures, Cost of carry model, Market imperfections, Implied method.

**JEL Classifications:** C00, G13.

## 1. Introduction

Until now, the cost of carry model has been the most widely used one for pricing stock index futures. This model was developed under the assumptions of perfect markets and no-arbitrage argument. In theory, when the markets are perfect and the arbitrage mechanism works completely, the riskless arbitrage ensures that the difference between the index futures price and the index price equals the carrying cost. However, sufficient reasons exist to believe that real capital markets are not perfect and index arbitrage cannot be complete. Several researchers (e.g., Figlewski (1984) and Gay and Jung (1999)) have found significant differences between actual futures prices and theoretical values estimated by the cost of carry model.

In fact, capital markets are not perfect. Market imperfections are traditionally measured individually. For example, transaction costs are measured alone and seldom combined with other market imperfections such as short selling, indivisibility of securities, and so on. In dealing with the impacts of market imperfections on financial and economic theories, researchers often modified the financial theory by incorporating individual market imperfections into the theory to derive a new modified formula. For example, the standard capital asset pricing model (CAPM) is modified by taking account of differential lending and borrowing interest rates, personal taxes, and heterogeneous expectations, respectively. The cost of carry model is modified by accounting for differential transaction costs to obtain the upper and lower bounds of futures prices. The key problem of this approach is that when considering a market imperfection, the new modified formula does not consider the effects of other market imperfections.

Motivated by these considerations, Hsu and Wang (2004) and Wang and Hsu (2006) recently proposed the concept of the degree of market imperfections, which reflects the total effects of all market imperfections between the stock index futures market and its underlying spot index market when implementing arbitrage activities. This study further discusses some useful applica-

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tions of this concept. One such application is to develop a theoretical model in imperfect markets and compare the pricing performance of this model in imperfect markets to that of the model in perfect markets. According to this application, Hsu and Wang (2004) developed a pricing model of stock index futures in imperfect markets (hereafter an imperfect market model). This study extends the evidence regarding an imperfect market model in two ways. First, market imperfections differ among markets. Mature markets have higher information efficiency than immature markets. Moreover, financial market frictions, such as transaction costs, regulatory barriers, and capital constraints, are less likely in mature markets. A number of studies (e.g., Sofianos (1993)) have found that the arbitrage mechanism works well in mature markets with low market imperfections, such as the S&P 500 index futures market. Interestingly however, some researches have observed that market imperfections could affect the implementation of arbitrage mechanism in immature markets with high market imperfections. For example, Gay and Jung (1999) argue that transaction costs and restrictions on short sales are important factors affecting the underpricing of Korean stock index futures. Thus, there is certainly room for market imperfections to affect arbitrage mechanism in immature markets. Thus, by using the Nikkei 225, the Hang Seng, the KOSPI 200 (South Korean composite stock index 200), and the SGX (Singapore Exchange Limited) MSCI Taiwan index futures contracts, this study compares the predictive power of the cost of carry and imperfect market models for mature and immature markets<sup>1</sup>. Second, by closely examining the price behavior of four Asian index futures markets during the Asian crisis, the result shows that 76% of trading days displayed a negative basis for the SGX futures market<sup>2</sup>. Meanwhile, for the Nikkei 225, Hang Seng, and KOSPI 200 markets, 58%, 60%, and 51% of trading days, respectively, had a negative basis. If arbitrage opportunities exist, then in most instances the arbitrage trading rule should be long-hedge arbitrage opportunities (that is, going long in the futures and shorting the underlying shares). However, constraints on short selling of stocks impede long-hedge arbitrage due to the transaction costs and barriers involved in shorting the underlying shares. For example, Butterworth and Holmes (2002) argue that execution risk and short sales restrictions impede index arbitrage in the UK. Hence, compared to the other periods, the Asian crisis period displays high market imperfections. This study represents the first attempt to apply the imperfect market model to the case of the Asian crisis, and investigate the question of whether this model can effectively predict stock index futures prices during the Asian crisis.

## 2. Degree of Market Imperfections and the Pricing Models of Stock Index Futures

Until now, the cost of carry model has been the standard model for pricing stock index futures. If interest rates and continuous dividend yields are non-stochastic, the cost of carry model can be written as

$$F_t = S_t e^{(r-q)(T-t)}, \quad (1)$$

where  $F_t$  is the theoretical futures price at time  $t$ ;  $S_t$  denotes the current stock index;  $r$  represents the risk-free interest rate;  $q$  is the dividend yield; and  $T-t$  denotes the time to expiration.

If the underlying stock index pays irregular and lumpy dividends, the cost of carry model becomes

$$F_t = (S_t - D_t) e^{r(T-t)}, \quad (2)$$

<sup>1</sup> The stock and index futures markets of Japan, Hong Kong, Korea, and Taiwan represent some of the larger markets in the Asian region. Thus, an understanding of price and arbitrage behavior in these four major Asian markets is essential for international investors. Additionally, under the MSCI (Morgan Stanley Capital International) taxonomy, Japan and Hong Kong are categorized as “developed” markets. Korea and Taiwan are classified as “emerging” markets. Thus, the Nikkei 225 and the Hang Seng index futures markets represent mature markets with low market imperfections, and the KOSPI 200 and the SGX MSCI Taiwan stock index futures markets represent immature markets with high market imperfections.

<sup>2</sup> This study defines the negative basis as  $AF_t < S_t$ . The basis is defined as the difference between the actual price of index futures and the spot index price,  $AF_t - S_t$ .

where  $D_t$  is the sum of the present values of all cash dividends distributed by the underlying component stocks at time  $t$  during the life of the futures contract.

The cost of carry model was developed under the assumptions of perfect markets. Under the assumptions of perfect markets, since the arbitrage mechanism can work completely, a hedged position consisting of stocks and futures can be “continuously” rebalanced to remain riskless. However, sufficient reasons exist to believe that real capital markets are not perfect and index arbitrage can not be complete. Figlewski (1989) found that continuously rebalancing hedged positions is impossible in real capital markets. Thus, Hsu and Wang (2004) accounted for the factor of price expectation, which reflects the effects of all market imperfections, to develop an imperfect market model.

The model assumes that the stock index ( $S$ ) follows a geometric Wiener process. Consider a hedged portfolio  $P$  that consists of one unit of the underlying index and  $x$  units of the futures contracts. It is assumed that no initial cash outflow is required for the futures contracts. The rate of return of the hedged portfolio is then given by

$$\frac{dP}{P} = (w_f \mu_f + u)dt + (w_f \sigma_f + \sigma)dZ, \quad (3)$$

where  $w_f = \frac{xF}{S}$ ,  $F$  represents the futures price;  $u$  and  $\sigma$  denote the constant expected growth rate in  $S$  and the constant volatility of  $S$ , respectively;  $\mu_f$  and  $\sigma_f$  denote the instantaneous expected return on futures, and the instantaneous standard deviation of return on futures, respectively; and  $dZ$  is a Wiener process.

If  $w_f = -\frac{\sigma}{\sigma_f}$ , then  $w_f \sigma_f + \sigma = 0$ . In this case, the return of  $P$  is certain and the portfolio

is riskless. However, to keep the portfolio riskless, it therefore is necessary to “continuously” rebalance  $w_f$  until the expiration of the futures contract. Figlewski (1989) found that forming a riskless hedge and rebalancing continuously until expiration are only possible in a perfect market. In imperfect markets, because arbitrage mechanism can not be complete and index arbitrage is exposed to large risk, the portfolio cannot be riskless at any instant. This means that the portfolio must earn some expected rate of return (which can be greater than, smaller than, or equal to the risk-free rate), rather than the risk-free rate at any instant.

Let  $u_p$  and  $\sigma_p$  denote the instantaneous expected rate of return of the hedged portfolio, and the coefficient of  $dZ$  in equation (3), respectively. Thus, they obtain

$$w_f \mu_f + u = u_p, \quad (4)$$

$$w_f \sigma_f + \sigma = \sigma_p. \quad (5)$$

From (4) and (5), they obtain the following partial differential equation (PDE)

$$\frac{1}{2} \sigma^2 S^2 F_{ss} + u_\alpha S F_s + F_t = 0, \quad (6)$$

where the price expectation parameter,  $u_\alpha = [(u_p - q) - (u - q) \frac{\sigma_p}{\sigma}] / (1 - \frac{\sigma_p}{\sigma})$ .

Since  $\frac{\sigma_p}{\sigma}$  reflects the total effects of all market imperfections between the stock index futures market and its underlying spot index market when implementing arbitrage activities, Hsu and Wang (2004) and Wang and Hsu (2006) defined  $\frac{\sigma_p}{\sigma}$  in equation (6) as the degree of market imperfections<sup>1</sup>.

Moreover, the solution to PDE (6) is given by

<sup>1</sup> To value the degree of market imperfections, Hsu and Wang (2004) also derived a theoretical valuation model as follows.

$$F_t = S_t e^{\mu_\alpha(T-t)} \quad (7)$$

Equation (7) is an imperfect market model, and satisfies PDE (6)<sup>1</sup>.

If the underlying stock index pays irregular and lumpy dividends, an imperfect market model can be modified as follows

$$F_t = (S_t - D_t) e^{u'_\alpha(T-t)}, \quad (8)$$

where  $u'_\alpha = [u_p - u \frac{\sigma_p}{\sigma}] / (1 - \frac{\sigma_p}{\sigma})$ .

### 3. Applications of the Degree of Market Imperfections

The degree of market imperfections is a useful concept owing to its ability to be combined with the total effects of all market imperfections without separating individual effects when researchers develop financial and economic theories in imperfect markets, or when practitioners consider practical problems such as arbitrage. The degree of market imperfections can be applied to one or more of the following areas:

$$\frac{\sigma_p}{\sigma} = (1 - \rho),$$

where  $\rho$  is the instantaneous correlation coefficient between the futures and the index returns. For a detailed discussion of the concept of the degree of market imperfections and its valuation model, see Hsu and Wang (2004).

For the detailed derivation of this solution, see Hsu and Wang (2004), Appendix, pp. 179-182. When the market is perfect,  $\sigma_p = 0$  and  $u_p = r$ . An imperfect market model thus is identical to the cost of carry model.

First, capital markets are not perfect, and arbitrage mechanisms cannot be complete, particularly for index arbitrage. Furthermore, arbitrage mechanisms differ among markets. Using the concept of the degree of market imperfections, practitioners can measure the extent of arbitrage activities between a derivative market and its underlying spot market, such as the extent of index arbitrage between the index futures market and its spot market.

Second, this concept enables practitioners to predict deviations of actual derivative prices from theoretical prices based on the model of perfect market assumptions, such as in the following situations: (1) the actual stock index futures prices deviate from the theoretical prices based on the cost of carry model; and (2) the actual stock index option prices deviate from the theoretical prices based on the Black and Scholes (1973) model. Wang and Hsu (2006) observed that the absolute discrepancy between the actual futures price and the theoretical futures price estimated by the cost of carry model using the S&P 500 index futures, the SGX, and the TAIEX (Taiwan Futures Exchange) Taiwan stock index futures increases with the degree of market imperfections.

Finally, the best-known model for pricing stock index futures is undoubtedly the cost of carry model. A number of studies found that arbitrageurs quickly eliminate mispricings, and the cost of carry model is supported in highly competitive financial markets with low market imperfections, for example, as Brooks, Garrett, and Hinich (1999) demonstrated for the FTSE 100 index futures and the S&P 500 index futures markets. Notably, some researches have observed that market imperfections could affect the implementation of arbitrage mechanisms in immature markets with high degrees of imperfections. For example, Gay and Jung (1999) argued that transaction costs and restrictions on short sales are important influences on the underpricing of Korean stock index futures. Moreover, Huang, Kuo, and Shyu (1998), using SGX Taiwan stock index futures data, found that ex-ante arbitrage profits were attractive after considering transaction costs and execution delays. Indeed, room certainly exists for market imperfections to affect arbitrage

<sup>1</sup> For the detailed derivation of this solution, see Hsu and Wang (2004), Appendix, pp. 179-182. When the market is perfect,  $\sigma_p = 0$  and  $u_p = r$ . An imperfect market model thus is identical to the cost of carry model.

mechanisms in actual markets with high degrees of imperfections. Thus, researchers can apply this concept to develop accurate theoretical models in imperfect markets for pricing derivatives (e.g., futures, options, and exotic options) and to compare the pricing performance of these models in imperfect markets with that of models in perfect markets.

## 4. Comparison of the Cost of Carry and Imperfect Market Models

### 4.1. Methodology

According to the third application in Section 3, Hsu and Wang (2004) accounted for the total combined effects of all market imperfections, and developed an imperfect market model. By using four major Asian index futures contracts (particularly for the Asian crisis period), this study further compares the relative pricing performance of the cost of carry and imperfect market models in two ways. First, to examine how well the cost of carry model explains the price behavior of stock index futures for four Asian index futures markets and the Asian crisis period, this study tests the fitness of the cost of carry model. For the Hang Seng index futures, following Fung and Draper (1999), this study uses the cost of carry model with continuous dividend (i.e., equation (1)) to test the model fitness. Taking a natural logarithm on both sides of equation (1) and rearranging it yields the following equation

$$\ln F_t = \ln S_t + (r-q)(T-t). \quad (9)$$

For regression purposes, equation (9) can be written as

$$\ln AF_t = \beta_0 + \beta_1 \ln S_t + \beta_2 (T-t) + \varepsilon_t, \quad (10)$$

where  $AF_t$  is the actual futures price on day  $t$ , and  $\varepsilon_t$  is an error term. If the model fitness tested is correct, then  $\beta_0 = 0$ ,  $\beta_1 = 1$ , and  $\beta_2 = r-q$  in equation (10).

In Japan, Taiwan, and Korea, the cash dividend payouts are relatively lumpy<sup>1</sup>. Thus, equation (2) can be used to test the model fitness for the Nikkei 225, the SGX and the KOSPI 200 futures contracts. Taking the natural logarithm on both sides of equation (2) and rearranging it produce the following equation

$$\ln F_t = \ln(S_t - D_t) + r(T-t). \quad (11)$$

Equation (11) can be used for regression purposes

$$\ln AF_t = \beta_0 + \beta_1 \ln(S_t - D_t) + \beta_2 (T-t) + \varepsilon_t. \quad (12)$$

If the model fitness tested is adequate, then  $\beta_0 = 0$ ,  $\beta_1 = 1$ , and  $\beta_2 = r$  in equation (12).

To control for autocorrelation, the regression coefficients of both equations (10) and (12) are estimated with an iterative Cochrane-Orcutt procedure.

Second, an alternative approach to evaluating model pricing performance is via the most popular accuracy measures, mean percentage errors (MPE) and mean absolute percentage errors (MAPE). MPE and MAPE are defined as follows:

$$\text{MPE} = \frac{1}{n} \sum_{t=1}^n \left( \frac{AF_t - F_t}{AF_t} \right), \quad (13)$$

$$\text{MAPE} = \frac{1}{n} \sum_{t=1}^n \left| \frac{AF_t - F_t}{AF_t} \right|, \quad (14)$$

<sup>1</sup> In Japan, cash dividends are clustered at the end of March and September. In Korea, most of the companies pay dividends at the end of the year. As for the Taiwanese shares, cash dividends for the underlying component stocks are mostly paid only once per year, and are concentrated in July.

where  $n$  represents the number of observations.

Additionally, the imperfect market model tested requires estimating one unobservable parameter ( $u_\alpha$  or  $\mu'_\alpha$ ). This study uses the implied method to estimate this parameter. This method is the same as the implied volatility in the Black-Scholes model. That is,  $u_\alpha$  (or  $\mu'_\alpha$ ) can be backed out implicitly using the observed-traded-futures prices. For the Hang Seng index futures, the implied  $u_\alpha$  at time  $t-1$  can be obtained from equation (7)<sup>1</sup>.

$$u_{\alpha,t-1} = \frac{1}{T - (t - 1)} \ln\left(\frac{F_{t-1}}{S_{t-1}}\right). \quad (15)$$

As for the Nikkei 225, the SGX and the KOSPI 200 futures, the implied  $u'_\alpha$  at time  $t-1$  can be calculated from equation (8).

$$u'_{\alpha,t-1} = \frac{1}{T - (t - 1)} \ln\left(\frac{F_{t-1}}{S_{t-1} - D_{t-1}}\right). \quad (16)$$

This implied  $u_\alpha$  (or  $\mu'_\alpha$ ) at time  $t-1$  is used as the estimator of  $u_\alpha$  (or  $\mu'_\alpha$ ) at time  $t$ .

#### 4.2. Data

The Nikkei 225 index futures based on the Nikkei 225 stock index began trading on the Osaka Securities Exchange (OSE) on September 3, 1988. The futures contract is a major stock index futures contract in Japan. The Hang Seng index futures contract is based on the Hang Seng index, which comprises 33 representative stocks listed on the Stock Exchange of Hong Kong. The KOSPI 200 index futures contract is based on the KOSPI 200 stock index. The KOSPI 200 index is a value-weighted index comprising 200 leading stocks which represent over 70% of the total market capitalization of the Korean Stock Exchange. The SGX Taiwan index futures contract uses the MSCI Taiwan index, which is composed of 103 representative stocks listed on the Taiwan Stock Exchange. The MSCI Taiwan index closely correlates with the Taiwan capitalization weighed index. Table 1 describes the main features of the four futures contracts and their underlying indexes.

Table 1

Main Features of the Nikkei 225, the Hang Seng, the KOSPI 200, and the SGX Taiwan Index Futures Contracts

	Nikkei 225 futures	Hang Seng futures	KOSPI 200 futures	SGX futures
1. Opening date	September 3, 1988	May 6, 1986	May 3, 1996	January 9, 1997
2. Underlying index	Nikkei Stock Average (Nikkei 225)	Hang Seng index	KOSPI 200 index	MSCI Taiwan index
3. Contract size	Futures price times ¥ 1,000	Futures price times HK\$50	Futures price times KRW\$500,000	Futures price times US\$100
4. Contract months	March, June, September, December cycle (five contract months open at a time)	The spot month, the next calendar month, and the next two calendar quarterly months	March, June, September and December	2 nearest serial months and 4 quarterly months on a March, June, September, and December cycle

<sup>1</sup> The cost of carry model was developed under the assumption of perfect markets. In perfect markets, riskless and profitable arbitrage would ensure that the difference between the futures price and the spot price converges the carrying cost. Thus, the implied carrying cost must be equal to  $r-q$ .  $r-q$  should be positive (unless the dividend yield is higher than the risk-free interest, which seldom occurs). The imperfect market model proposes that the value of  $u_\alpha$  depends on market expectation of future spot prices and market imperfections. Thus, an implied  $u_\alpha$  derived with the implied method can be greater than, smaller than, or equal to  $r-q$ . This  $u_\alpha$  can be positive or negative.

<sup>2</sup> Equations (15) and (16) are not applicable at  $t = T+1$  (that is, one day after the maturity date), since their values do not exist.

Table 1 (continued)

	Nikkei 225 futures	Hang Seng futures	KOSPI 200 futures	SGX futures
5. Minimum price change	¥ 10,000 per contract	1 index point = HK\$50 per contract	0.05 index point = KRW\$25,000 per contract	0.10 index points = US\$ 10 per contract
6. Last trading day	The business day prior to the second Friday of each contract month	The business day immediately preceding the last business day of the contract month	The second Thursday of the contract month	Second last business day of the contract month
7. Settlement	cash	cash	cash	cash

Source: Osaka Securities Exchange (OSE), Hong Kong Exchanges and Clearing Limited (HKEx), Korea Exchange (KRX), and Singapore Exchange Limited (SGX).

For the four stock index futures, the nearest maturity contracts all have significant trading volume. To reduce thin trading problems, this study only considers the near-month contracts. The daily data cover the period from July 2, 1997 through December 31, 2005. To capture different market conditions during the sample period, two approximately equal length sub-samples were considered. The first and second sub-periods are from July 2, 1997 to December 31, 2001 and from January 1, 2002 to December 31, 2005, respectively. Additionally, the Asian financial crisis period is defined as being from July 2, 1997 to September 30, 1998<sup>1</sup>.

For the Nikkei 225 futures, the three-month Gensaki rates are used as the risk-free interest rates. The dividend data of the underlying component stocks in the index were obtained from the QUICK Research Institute and the Tokyo Stock Exchange. For the Hang Seng stock index futures, the middle quotes of one-month Hong Kong inter-bank rates are used as the substitute of risk-free interest rates. The annualized month-end dividend yields of Hang Seng index for the same period were obtained from the Hang Seng Index Services Ltd. In the case of the KOSPI 200 futures, the three-month inter-bank rates are used as the substitute of risk-free interest rates. The dividend data of the underlying component stocks in the index come from the Korea Stock Exchange. As for the SGX MSCI Taiwan index futures, 30-day commercial paper rates in secondary market are used as the proxy of risk-free interest rates. The dividend data come from the Taiwan Economic Journal and the Taiwan Security Exchange.

## 5. Empirical Results

Table 2 summarizes the results of testing the fitness of the cost of carry model. If the model fitness tested is correct, then  $\beta_0 = 0$ ,  $\beta_1 = 1$ , and  $\beta_2 = r - q$  (or  $\beta_2 = r$ ) in equation (10) (or equation (12)). From Table 2, the cost of carry model fits the Nikkei 225 futures contract better than three other futures contracts. Particularly for the second sub-period for the Nikkei 225 futures contract, none of the null hypotheses  $H_0: \beta_0 = 0$ ,  $H_0: \beta_1 = 1$ , and  $H_0: \beta_2 = r$  are rejected, indicating that the cost of carry model perfectly fits the actual data of the Nikkei 225. Overall, as demonstrated by Brooks, Garrett, and Hinich (1999), the cost of carry model is more suitable for application to mature markets, such as the Nikkei 225 futures market. Thus, the cost of carry model can be expected to give substantially better pricing performance for mature markets, compared to immature markets.

Next, this study also tests the fitness of the cost of carry model for the Asian crisis period. The results are also presented in Table 2. Table 2 indicates that all of the null hypotheses  $H_0: \beta_0 = 0$ ,  $H_0: \beta_1 = 1$ , and  $H_0: \beta_2 = r - q$  (or  $\beta_2 = r$ ) are strongly rejected at the 5% or the 1% level for all four

<sup>1</sup> Although pinpointing the start of the Asian financial crisis is difficult, analysts often point to the 17% devaluation of the Thai baht on July 2, 1997 as the triggering event. From July of 1997 to September of 1998, stock markets in the Asia-Pacific region displayed dramatic declines. For example, the Nikkei 225 index dropped from 20575 on July 28, 1997 to 13406 on September 30, 1998. Meanwhile, the KOSPI 200 index dropped from 82.38 on July 4, 1997 to 33.17 on September 22, 1998. It was not until October 1998 that most Asian governments made effort to restore the confidence of investors. This led to a strong improvement in the stock markets. Thus, following the wide definition of the Asian crisis of Baig and Goldfajn (1998), this study defines the Asian crisis period as the period from July 2, 1997 to September 30, 1998.

futures contracts. This implies that when the cost of carry model is applied to the Asian crisis period with high market imperfections, one would expect that there would be much larger differences between actual futures prices and theoretical values estimated by the cost of carry model.

Table 2

## Fitness Test of the Cost of Carry Model

	$H_0: \beta_0 = 0$	$H_0: \beta_1 = 1$	$H_0: \beta_2 = r - q$ (or $H_0: \beta_2 = r$ )	Sample size
<b>Nikkei 225</b>				
Full sample	-0.0078** (-2.081)	0.0008 (1.386)	-0.0052*** (-4.010)	2074
Period 1	-0.0088 (-1.283)	0.0010 (1.352)	-0.0086*** (-5.121)	1101
Period 2	-0.0086 (-1.136)	0.0009 (1.070)	-0.0011 (-0.727)	973
Crisis period	-0.0447** (-2.293)	0.0046** (2.061)	-0.0072*** (-2.410)	309
<b>Hang Seng</b>				
Full sample	-0.0696*** (-6.223)	0.0073*** (6.166)	-0.0161*** (-2.506)	2091
Period 1	-0.0818*** (-5.117)	0.0086*** (5.070)	-0.0290*** (-2.646)	1107
Period 2	-0.0272*** (-4.021)	0.0029*** (3.968)	-0.0066 (-1.354)	984
Crisis period	-0.0935*** (-4.192)	0.0100*** (4.147)	-0.0962*** (-4.005)	310
<b>SGX</b>				
Full sample	-0.0378*** (-2.672)	0.0067*** (2.654)	-0.0524*** (-5.967)	2190
Period 1	0.0180* (1.941)	-0.0034** (-2.088)	-0.0559*** (-3.795)	1196
Period 2	-0.1008*** (-5.670)	0.0184*** (5.679)	-0.0318*** (-3.690)	994
Crisis period	-1.0979*** (-6.388)	0.1896*** (6.361)	-0.2623*** (-8.634)	347
<b>KOSPI 200</b>				
Full sample	-0.0536*** (-11.949)	0.0117*** (11.716)	-0.0201*** (-4.250)	2091
Period 1	-0.1021*** (-13.339)	0.0234*** (13.186)	-0.0338*** (-4.104)	1104
Period 2	-0.0182*** (-4.041)	0.0037*** (3.884)	-0.0052* (-1.875)	987
Crisis period	-0.2930*** (-13.436)	0.0720*** (13.156)	-0.0940*** (-4.475)	307

Notes: Figures in parentheses are t-values. \*, \*\*, and \*\*\* denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 3 summarizes the pricing errors of the two models. First, the “percentage error” column shows that the cost of carry model tends to overprice all four futures contracts. This finding is consistent with the findings of previous studies, for example Bailey (1989) for the Nikkei



225 contract. Next, Table 3 shows that for all of the markets and periods the magnitude of MPE of the cost of carry model clearly exceeds that of the imperfect market model. Particularly in the Asian crisis period, the MPE measures of the cost of carry model are extremely high, ranging from -0.0675% (Nikkei 225) to as high as -2.2014% (KOSPI 200). These MPE measures indicate that the cost of carry model seriously overprices all four futures contracts (particularly for the KOSPI 200 contract) during the Asian crisis.

Table 3

## Summary Statistics for the Pricing Errors of the Cost of Carry and Imperfect Market Models

	Cost of carry model				Imperfect market model			
	Percentage error		Absolute percentage error		Percentage error		Absolute percentage error	
	Mean (%)	Std (%)	Mean (%)	Std (%)	Mean (%)	Std (%)	Mean (%)	Std (%)
<b>Nikkei 225</b>								
Full sample	-0.0421	0.3552	0.2579	0.2477	-0.0033	0.4087	0.3058	0.2711
Period 1	-0.0390	0.4013	0.2920	0.2779	0.0021	0.4321	0.3276	0.2816
Period 2	-0.0456	0.2945	0.2193	0.2016	-0.0095	0.3808	0.2812	0.2567
Crisis period	-0.0675	0.4767	0.3304	0.3497	0.0058	0.3650	0.2768	0.2374
<b>Hang Seng</b>								
Full sample	-0.1310	0.6309	0.4056	0.5006	-0.0173	0.5955	0.3916	0.4489
Period 1	-0.1912	0.7894	0.5169	0.6263	-0.0251	0.7601	0.5200	0.5547
Period 2	-0.0633	0.3695	0.2805	0.2485	-0.0085	0.3235	0.2475	0.2082
Crisis period	-0.4690	1.0972	0.8053	0.8797	-0.0372	0.9234	0.6628	0.6429
<b>SGX</b>								
Full sample	-0.2762	1.0420	0.6540	0.8568	-0.0035	0.7914	0.4833	0.6266
Period 1	-0.3605	1.2910	0.8530	1.0337	-0.0101	0.9603	0.6076	0.7435
Period 2	-0.1747	0.6073	0.4146	0.4767	0.0044	0.5198	0.3335	0.3985
Crisis period	-1.2775	1.5660	1.4942	1.3601	-0.0318	0.9557	0.6402	0.7094
<b>KOSPI 200</b>								
Full sample	-0.3877	1.7763	1.0014	1.5173	-0.0054	1.2164	0.7092	0.9881
Period 1	-0.6535	2.3546	1.5448	1.8929	-0.0074	1.5951	1.0206	1.2254
Period 2	-0.0904	0.5642	0.3937	0.4139	-0.0031	0.5406	0.3615	0.4019
Crisis period	-2.2014	3.4802	3.0221	2.7949	-0.0630	2.5160	1.6764	1.8747

Table 4 further classifies the percentage errors as either premiums or discounts<sup>1</sup>. The imperfect market model displays no clear difference between the number and size of premiums and discounts for all of the markets and periods. However, as for the cost of carry model, the full sample shows that the magnitude of the discounts obviously exceeds that of the premiums for the SGX and the KOSPI 200 markets with high market imperfections. Particularly for the Asian crisis period, in terms of magnitude, discounts are about 288.92% and 384.25% of premiums for the SGX and the KOSPI 200 markets, respectively.

<sup>1</sup> If actual futures prices are higher than theoretical futures prices, the percentage errors are classified as premiums. Conversely, percentage errors are classified as discounts.

Table 4

## Summary Statistics for the Premiums and Discounts

	Cost of carry model				Imperfect market model			
	Number of premiums	Number of discounts	Mean premium (%)	Mean discount (%)	Number of premiums	Number of discounts	Mean premium (%)	Mean discount (%)
<b>Nikkei 225</b>								
Full sample	941	1132	0.2378	-0.2744	976	1062	0.3158	-0.2966
Period 1	498	602	0.2796	-0.3019	518	563	0.3440	-0.3124
Period 2	443	530	0.1908	-0.2432	458	499	0.2839	-0.2787
Crisis period	123	185	0.3301	-0.3298	137	165	0.3115	-0.2480
<b>Hang Seng</b>								
Full sample	926	1164	0.3100	-0.4820	1002	986	0.3714	-0.4122
Period 1	474	632	0.3801	-0.6201	535	516	0.4862	-0.5551
Period 2	452	532	0.2364	-0.3180	467	470	0.2398	-0.2552
Crisis period	105	204	0.4955	-0.9682	153	140	0.5990	-0.7325
<b>SGX</b>								
Full sample	953	1226	0.4342	-0.8290	1056	1020	0.4739	-0.4977
Period 1	527	663	0.5588	-1.0911	569	566	0.5986	-0.6220
Period 2	426	563	0.2800	-0.5202	487	454	0.3282	-0.3428
Crisis period	64	282	0.5874	-1.6971	153	177	0.6561	-0.6264
<b>KOSPI 200</b>								
Full sample	953	1137	0.6712	-1.2773	1013	1042	0.7139	-0.7046
Period 1	485	618	1.0102	-1.9635	527	557	1.0421	-1.0004
Period 2	468	519	0.3198	-0.4602	486	485	0.3580	-0.3649
Crisis period	114	192	1.0868	-4.1761	133	167	1.8196	-1.5623

Figures 1 to 4 further plot the premiums and discounts for two alternative models during the Asian crisis. Clearly, the cost of carry model tends to persistently and seriously overprice the SGX and the KOSPI 200 futures contracts during the Asian crisis relative to the imperfect market model. As indicated earlier, during the Asian crisis these two futures markets have more than 50% of trading days displaying a negative basis. If arbitrage opportunities exist, then in most instances the arbitrage trading rule should be long-hedge arbitrage (that is, short stock, long futures). However, even if arbitrage opportunities are apparent, market imperfections (e.g., short sales restrictions, execution risk, and transaction costs) may impede long-hedge arbitrage so that both the negative bases and the discounts persist. To summarize, as can be seen from Tables 3 to 4 and Figures 1 to 4, in highly imperfect financial markets and periods, such as the KOSPI 200 market and the Asian crisis period, the extent of persistence in the discounts is larger for the cost of carry model than for the imperfect market model.

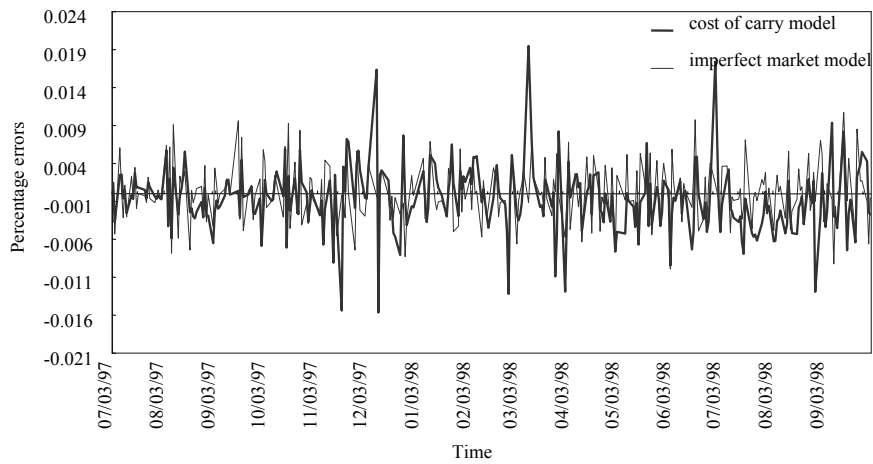


Fig. 1. Percentage Errors of Two Alternative Pricing Models during the Asian Crisis for the Nikkei 225 Futures

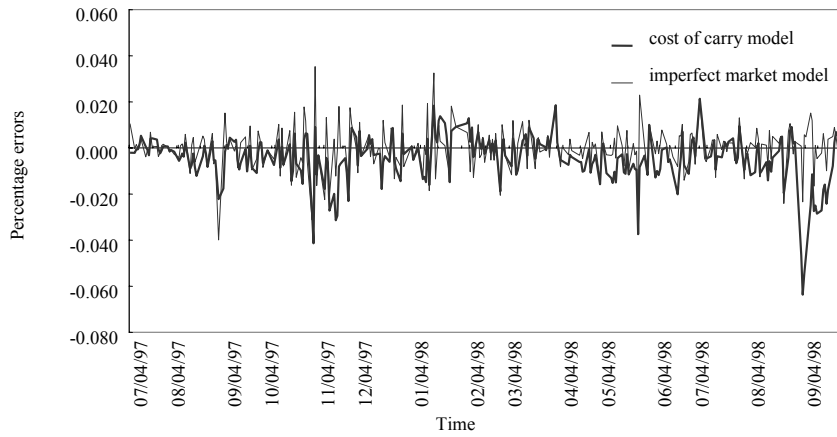


Fig. 2. Percentage Errors of Two Alternative Pricing Models during the Asian Crisis for the Hang Seng Futures

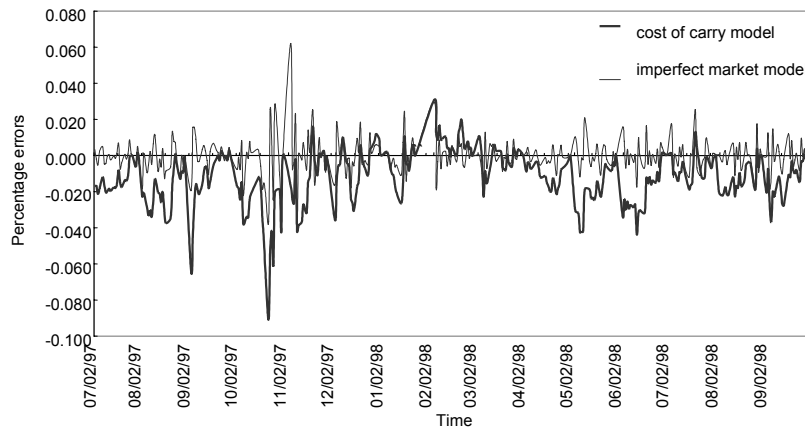


Fig. 3. Percentage Errors of Two Alternative Pricing Models during the Asian Crisis for the SGX Futures

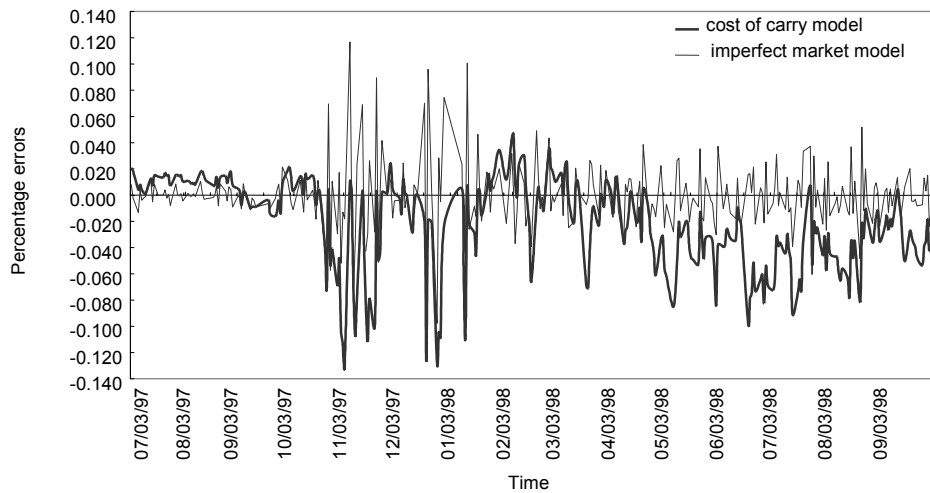


Fig. 4. Percentage Errors of Two Alternative Pricing Models during the Asian Crisis for the KOSPI 200 Futures

To robustly test the relative pricing performance of the cost of carry and imperfect market models, this study also calculates the MAPE measures of these two models. Table 3 lists the empirical results. Table 5 summarizes the results of statistical tests for differences in MAPE between the two pricing models. First, in the case of the Nikkei 225 futures, the full sample (see Tables 3 and 5) indicates that the MAPE value of the cost of carry model is 0.2378%, and is significantly smaller than that of the imperfect market model. As for the Hang Seng futures, for the full sample, the MAPE values of the cost of carry and imperfect market models are 0.4056% and 0.3916%, respectively. As illustrated in Table 5, the MAPE values of these two models do not differ significantly. Thus, overall, for mature markets with low market imperfections, such as the Nikkei 225 market, the cost of carry model outperforms the imperfect market model. The imperfect market model provides no improvement over the cost of carry model, perhaps because as analyzed earlier in this section, the cost of carry model is more suitable for application to the Nikkei 225 futures market with low market imperfections. Alternatively, this comparison involves just one particular method (that is, the implied method) for estimating the price expectation parameter  $u_\alpha$  (or  $\mu'_\alpha$ ) in the imperfect market model. Hence, the imperfect market model does not outperform the cost of carry model for mature markets.

Table 5

Statistical Tests for Differences in MAPE between the Two Pricing Models

	Cost of carry model (MAPE) vs. Imperfect market model (MAPE)			
	Full sample	Period 1	Period 2	Crisis period
Nikkei 225	-5.912***	-2.972**	-5.882***	2.220**
Hang Seng	0.945	-0.124	3.159***	2.279**
SGX	7.464***	6.611***	4.075***	10.314***
KOSPI 200	7.361***	7.702***	1.746*	6.981***

Notes: If the MAPE of the cost of carry model is greater than that of the imperfect market model, t-value is positive. Conversely, t-value is negative. \*\* and \*\*\* denote statistical significance at the 5% and 1% levels, respectively.

Next, for the SGX and the KOSPI 200 markets with high market imperfections, from Tables 3 and 5, the imperfect market model yields significantly better pricing performance than the

cost of carry model. For instance, for the full sample for the SGX futures contract, the MAPE when the imperfect market model is used is 0.4833%. The reduction in MAPE (relative to the cost of carry model), shown in Table 5, is statistically significant at the 1% level, based on a *t*-test of the mean difference.

Finally, this study also compares the MAPE measures of these two models for the Asian crisis period with high market imperfections. Overall, no matter whether the market is mature or immature, the MAPE value of the cost of carry model is significantly larger than that of the imperfect market model during the Asian crisis. For example, for the KOSPI 200 futures market, during the Asian crisis the MAPE value of the cost of carry model reached as high as 3.0221%, with a standard deviation of 2.7949%, whereas the MAPE value when the imperfect market model is used is substantially reduced to 1.6764%, with a standard deviation of 1.8747%.

To summarize, as one would expect, in highly imperfect financial markets and turbulent periods, such as the KOSPI 200 futures market and the Asian crisis period, the force of index arbitrage cannot drive an actual futures price to a theoretical value estimated by the cost of carry model due to some market imperfections. Consequently, the cost of carry model does not perform better than the imperfect market model. The empirical results from the SGX futures market, the KOSPI 200 futures market, and the Asian crisis period imply that market imperfections play an important role in determining the stock index futures prices for immature markets and turbulent periods with high degrees of market imperfections. Nevertheless, market imperfections are excluded from the cost of carry model.

## 6. Conclusions

Market imperfections are traditionally measured individually. Hsu and Wang (2004) and Wang and Hsu (2006) recently proposed the concept of the degree of market imperfections, which reflects the total effects of all market imperfections between the stock index futures market and its underlying index market when implementing arbitrage activities. This study further discusses some useful applications of the concept of the degree of market imperfections. The degree of market imperfections can be applied, at a minimum, to the following areas: (1) to show the extent of arbitrage activities between a derivative market and its underlying spot market; (2) to predict deviations of actual derivative prices from theoretical prices based on the model of perfect market assumptions; and, (3) to develop theoretical models for pricing derivatives in imperfect markets. According to the third application, Hsu and Wang (2004) developed an imperfect market model. By using the Nikkei 225, the Hang Seng, the SGX, and the KOSPI 200 futures contracts, this study further compares the relative pricing performance of the cost of carry and the imperfect market models for mature, immature markets, and turbulent periods.

The results of model fitness show that the cost of carry model is more suitable for application to mature markets, such as the Nikkei 225 futures market, than to immature markets, such as the SGX and the KOSPI 200 futures markets. Moreover, the results of the MPE indicate that in highly imperfect financial markets and periods, such as the SGX, the KOSPI 200 futures markets, and the Asian crisis period, the extent of persistence in the discounts is larger for the cost of carry model than for the imperfect market model. Based on MAPE, the results from the SGX, the KOSPI 200 futures markets, and the Asian crisis period also indicate that the imperfect market model provides more accurate pricing performance than the cost of carry model. This finding implies that incorporating market imperfections into pricing models is beneficial for predicting stock index futures prices for immature markets and turbulent periods with high degrees of market imperfections. Nevertheless, the cost of carry model excludes market imperfections. Therefore, when selecting a pricing model to estimate the theoretical values of stock index futures, practitioners should identify the degree of market imperfections for the markets they participated.

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