Manipulation Prevention and Hedging Effectiveness: Optimal Settlement Window Design for CSI 300 Stock Index Futures

Song Jun and Luo Rui

ABSTRACT: We empirically evaluate the current 120-minute settlement window for China Securities Index 300 Stock Index Futures. We assume that an exchange chooses the optimal settlement window to maximize its profit by increasing its revenue from trading volume and by curtailing its surveillance expenditure via designing contract specifications. Given that a longer settlement window may reduce the hedging effectiveness but result in cost savings, we find that the optimal settlement window is located between zero and forty minutes under varied unit investigation costs and suggest that it may be more appropriate to set a shorter settlement window.

KEY WORDS: hedging effectiveness, manipulation risk, optimal settlement window.

The launch of China's first stock index futures, the China Securities Index (CSI) 300 futures, is evidence of the dramatic progress in the ongoing reform of the Chinese financial system and thus has drawn much attention from both academic researchers and industry practitioners.[1] As Stoll and Whaley (1997) argue, the selection of a settlement procedure by a futures exchange is one of the defining factors in the success of a given futures contract. In particular, the settlement window, defined as the length of the average period for contract settlement, potentially has a significant effect on futures market equity and efficiency. For instance, a not-long-enough window could increase the likelihood of price manipulation, thus resulting in the perception that markets are not operating fairly. An overly long settlement window could invoke the convenience problem between the settlement price and the underlying cash index, thereby harming the hedging performance of the contract.

As shown in Table 1, there are two types of settlement procedures for the world's major index futures contracts. The first type is a single price, meaning that the futures contracts are based on a settlement index level of a single price at some point in time (either market open or market close). The U.S., Japanese, Singaporean, and Brazilian index futures contracts are examples of this type of contract. The second type is an average price, which implies that the futures contracts settle at the average underlying cash index value over a given period. This type of contract is widely used in European index futures contracts, with the settlement window typically ranging from ten minutes to as long as 240 minutes (the entire trading day). However, apart from the Hang Seng Index (HSI) futures contracts, most average price-settled index futures contracts have settlement windows in the range of ten to thirty minutes.

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Table 1. Settlement specifications of major stock index futures contracts

Index futures contract	Exchange	Settlement window (minutes)
Single price		
MSCI Taiwan	SGX	—
Ibovespa	BM&F	—
KOSPI 200	KRX	—
DJIA, S&P 500	CBOT	—
Value Line	KCBT	—
TOPIX	TSE	—
Nikkei 225	OSE	—
Average price		
CAC 40	Euronext Paris	20
FTSE 100	Euronext Liffe	20
DJ Euro STOXX 50	Eurex	10
HSI	HKEX	240

Notes: Futures on MSCI Taiwan (Morgan Stanley Capital International Taiwan Stock Index) are traded on SGX (the Singapore Stock Exchange, www.sgx.com); futures on Ibovespa (Brasil Sao Paulo Stock Exchange Index) are traded on BM&F (the BM&FBOVESPA Securities, Commodities and Futures Exchange, www.bmfbovespa.com.br); futures on KOSPI 200 (the Korean Stock Price Index 200) are traded on KRX (the Korea Exchange, www.krx.co.kr); futures on DJIA (the Dow Jones Industrial Average) and futures on S&P 500 (the Standard & Poor's 500) are traded on CBOT (the Chicago Board of Trade, www.cmegroup.com/company/cbot.html); futures on the Value Line are traded on KCBT (the Kansas City Board of Trade, www.cmegroup.com/company/kcbt.html); futures on TOPIX (the Tokyo Stock Price Index) are traded on TSE (the Tokyo Stock Exchange, www.tse.or.jp); futures on Nikkei 225 (Japan's Nikkei 225 Stock Average) are traded on OSE (the Osaka Securities Exchange, www.ose.or.jp); futures on CAC 40 (Cotation Assistée en Continu 40) are traded on Euronext Paris (the Euronext Paris exchange) of NYX (the NYSE Euronext, www.nyx.com); futures on FTSE100 (the Financial Times Stock Exchange 100 share index) are traded on the Euronext Liffe futures market of NYX (the NYSE Euronext, www.nyx.com); futures on DJ Euro STOXX 50 (the Dow Jones EURO STOXX 50) are traded on the Eurex Exchange (www.eurexchange.com); futures on HSI (the Hang Seng Index) are traded on HKEX (the Hong Kong Stock Exchange, www.hkex.com.hk).

The CSI 300 is a capitalization-weighted index comprising the 300 largest A-share stocks in the Chinese securities market. Futures on the CSI 300 have been trading on the China Financial Futures Exchange (CFFEX) since April 2010. According to the current settlement specification, the CSI 300 futures contracts are cash settled on the expiration day with the settlement price based on an arithmetic average of quotations taken at five-minute intervals during the last two trading hours of the expiration day. Evidence of any expiration-day effects, such as abnormally higher trading volumes or greater return volatility and price manipulation, has been found in this market rarely since the commencement of trading (Zhang and Shen 2011). This appears to support the belief that the choice of an average index price for settlement can prevent market manipulation (Chou et al. 2006).

However, there is also the argument that an excessively long average settlement price may undermine the incentives for arbitrage and hedging activities in futures markets. From the perspective of hedgers, a single price is more desirable because it guarantees convergence between the cash and futures prices, and hedging effectiveness is thus improved (Stoll and Whaley 1997). For instance, the settlement window for HSI futures of 240 minutes may result in some structural problems, with the Hong Kong Exchange reporting that the proportions of hedging and arbitrage activity for HSI futures ranged from 23 percent to 50 percent from 1994 to 2009. When we compare it with other similarly developed markets, in which the proportion of hedging and arbitrage activity typically ranges from 62.5 percent to 78 percent, we can readily observe a glaring disparity. Although it may not be the only reason, the excess length of the futures settlement window appears to be the main cause (Chow et al. 2003).

In this paper, we first assume that an exchange chooses the optimal settlement window to maximize its profit by increasing its revenue from trading volume and by curtailing its surveillance expenditure via designing contract specifications. Then, we endeavor to identify the optimal settlement window and discuss the likelihood that a change in the settlement window will improve hedging effectiveness.

A Brief Literature Review

The design of futures settlement specifications has attracted considerable attention from the perspective of both expiration-day effects and hedging effectiveness. Stoll and Whaley (1997) think that a single-settlement price is much more profitable for hedgers because it ensures convergence between futures and underlying cash prices. They also argue that although an average price appears more difficult to manipulate than a single price, this is not always the case as long as market manipulators are available to respond to noisy buying or selling pressures.

Chow et al. (2003) examine expiration-day effects in the HSI futures market and find that the use of an average index price for settlement over a longer period rather than at any point in time can help mitigate expiration effects. Kumar and Seppi (1992) also investigate the problem of the price manipulation of cash-settled futures contracts and conclude that the susceptibility of futures markets to price manipulation remains because of the presence of asymmetric information. Zheng and Wu (2007) extend Kumar and Seppi's model and prove theoretically that increasing the length of the settlement window cannot always improve the capacity to guard against market manipulation. Huang and Chan (2010) find that the change of the Taiwan Stock Exchange's settlement mechanism from closing price procedure to five-minute call auction facilitates the prevention of manipulation but has little effect on the elimination of either the expiration-day effect or the quarter-end effect.

In terms of studies concerning the CSI 300, Wang and Yu (2007) advise the CFFEX to set a settlement window longer than sixty minutes to eliminate the effects of potential price manipulation. However, the results are not very persuasive as they ignore hedging effectiveness and include only the prevention of market manipulation as a futures market objective, which may not provide a suitable market design.

Another stream of research addresses hedging effectiveness in futures markets. Lien (1989) employs a representative hedger utility function to obtain the optimal estimator of the final cash settlement price for index futures by assuming that the settlement specifications have no effect on the futures price process. Kimle and Hayenga (1994) provide the alternative view that the choice of the settlement window affects how the futures price behaves in terms of volatility, pricing, and basis convergence. Other studies expend considerable effort determining the characteristics of settlement specifications that are important for successful futures contracts (Cita and Lien 1997) and examine the advantages and drawbacks of alternative settlement procedures (Stoll and Whaley 1997).

However, relatively few studies explore how the specific settlement window design for a particular futures contract influences both its pricing behavior and hedging performance. Indeed, existing work on the comparison between alternative settlement procedures does not appear to be directly applicable to an emerging market such as China after considering that "the settlement price should reflect the true condition of the market" (Stoll and Whaley 1997, p. 158).

Researchers emphasize the importance of hedging effectiveness on maintaining profitable trading volume and explaining the success of futures contracts. Silber (1981) concludes that contracts that closely reflect the needs of hedgers seem more likely to attract enough volume to the exchange and be profitable and successful. Johnston and McConnell (1989) present empirical evidence that deteriorated hedging effectiveness could cause contracts to fail. Bergfjord (2007) discusses the idea that the success of a contract is related to the contract design, for example, its attractiveness to hedgers. These studies imply that the volume of a futures contract is positively related to hedging effectiveness in most cases.

Reiffen and Robe (2011) provide a solution on how to combine the two aims of the financial exchange, namely, preventing manipulation and maintaining hedging effectiveness. In their framework, a profit-maximizing exchange that earns revenue through the trading floor and pays costs when implementing enforcement has an incentive to aggressively enforce regulations that protect investors. The assumption is that the exchange that reduces enforcement expenditures may run the risk of losing customers, which consequently makes cost cutting costly.

Although local researchers have widely discussed contact specifications for CSI 300 index futures, few of these researchers have paid necessary attention to other needs of the exchange except for its sustainable need to eliminate manipulation as well as expiration effects; thus, their studies seem both relatively conservative and not coincident with the growing hedging needs in China. Put differently, reform efforts always aim to improve safety at the expense of hedging performance. Zheng and Wu (2007) study the manipulation problem of stock index futures under average cash settlement. However, they cannot accurately estimate key parameters such as the lead–lag relationship, market imperfections, and the depth of trading in both the futures and cash markets.

In addition, according to conventional wisdom, successful futures contracts should consider multiple factors during their design (Chou and Lee 2002). In fact, effective design for cash settlement, especially when determining the settlement window, should consider both hedging effectiveness and manipulation prevention. As financial markets in China develop, the demands of institutional investors to use stock index futures as hedging instruments also increase, thereby making hedging performance a growing perceived need. The main objective of this paper is to provide an analysis of the choice of the settlement window that properly meets the need for both manipulation safeguards and hedging effectiveness. The results presented in this paper have great significance in offering potential improvements to stock index futures contract design and the overall operating efficiency of futures markets in China.

Methodology

Optimization of the Profit-Maximizing Exchange

Following Reiffen and Robe (2011), we assume that a representative exchange chooses the optimal settlement window w^* to maximize its profit, $\Omega(w)$:

$$\Omega(w) = \alpha V(w) - \text{Prob}(w)\pi c, \tag{1}$$

where $V(w)$ is the trading volume and α is the fee charged by the exchange on unit volume. Thus, $\alpha V(w)$ is the transaction fee the exchange earns through trading volume. $\text{Prob}(w)\pi c$ is the enforcement expenditure paid for a contract, represented by the multiple of the exchange's investigation probability Prob(w), the unit investigation cost c, and the probability of state-of-the-world π. Surveillance activities, such as detecting and preventing manipulative practices, may facilitate the profits of trading activity; however, their implementation cost is inevitable. This objective function thus captures the fact that a for-profit exchange may have incentives to boost its revenue through offering contracts that attract the sufficient interest of hedgers to sustain a profitable trading volume level and to curtail its surveillance expenditure. This is done by designing contract specifications that limit the expected manipulative profits to decrease the probability of investigation.

Following standard notation where the futures market is often described as being predisposed toward creating superior value for hedgers (Narver and Slater 1990), thereby generating a high trading volume, we assume $V(w)$ to be positively associated with the hedging effectiveness of the contract. Although other factors could exist, such as the characteristics of the cash market (Black 1986) and possibilities of cross hedging (Bergfjord 2007), which significantly affect the trading volume, hedging effectiveness seems to be the only factor that is related to the settlement specifications and that can be controlled by the exchange. Therefore, we assume that $V(w)$ is a linear function of the hedging effectiveness as follows:

$$V(w) = \eta A(w), \tag{2}$$

where η is a positive constant and $A(w)$ measures the hedging effectiveness. Following Lafuente and Novales (2003), we identify

$$A(w) = 1 - LS, \tag{3}$$

where LS, the loss of hedging effectiveness, is defined as the percentage increase in the variance of the hedged portfolio when the settlement window moves from 0 to w:

$$LS = \frac{\text{Var}(r_t|w) - \text{Var}(r_t|w=0)}{\text{Var}(r_t|w=0)} \times 100\%, \tag{4}$$

where $\text{Var}(r_t|w=0)$ is the variance of the return of the hedged portfolio when the settlement window is specified to be zero minutes (using a single-price procedure), and $\text{Var}(r_t|w)$ is the hedged portfolio's return variance under a w-minute settlement window. Note that LS quantifies the influence of the settlement window w on hedging effectiveness and $A(w)$ therefore seems to be a good proxy for the preserved effectiveness of hedging. Obviously, $A(w)$ slides as w increases.

Regarding the enforcement cost, $\text{Prob}(w)\pi c$, of a risk-neutral exchange, we denote π, the state-of-the-world probability, to be constant because it will not affect how w is determined. We discuss different unit investigation costs c so as to examine exchanges resulting from implementing surveillance at these unit costs.

Of the factors that affect Prob(w), the probability of manipulation is the most important. As the probability of manipulation rises, the probability of investigation rises. Therefore, we denote Prob(w) to be equal to the probability of manipulation.

Thus, following Kumar and Seppi (1992), where manipulation takes place only if the manipulators' expected gain (Π) exceeds zero, we employ a quadratic equation to represent Prob(w) as follows:

$$\operatorname{Prob}(w) = \begin{cases} \left(1 - \dfrac{w}{\bar{w}}\right)^2 & \text{if } w \le \bar{w} \\ 0 & \text{if } w > \bar{w}, \end{cases} \tag{5}$$

where $\bar{w}$ is the zero-profit window when $\Pi = 0$. When $w = 0$, Prob = 1 because manipulation is most profitable at that point and therefore seems most likely to occur. As w exceeds zero, Prob(w) declines with increases in w that continually reduce Π as long as w is less than $\bar{w}$ (corresponding to $\Pi = 0$). Prob(w) then equals 0 for any w larger or equal to $\bar{w}$ as detection is no longer necessary when manipulators have no incentive to carry out manipulative practices. This, along with Equation (3), which depicts that $A(w)$ is monotonically decreasing with w regardless of whether w exceeds $\bar{w}$, makes $\bar{w}$ the upper critical value of the optimal settlement window (w^*). Hence, w^* is expected to be located somewhere between 0 and $\bar{w}$.

Estimation of $\bar{w}$

Assume that the manipulator goes long on index futures and undertakes buying in the spot market to bid up the settlement price at the expiration period. By pushing the settlement index up via large trading positions, he or she may gain profits in both markets.

Suppose that n is the number of index data points used to calculate the final settlement, and $freq$ is the sampling frequency of the spot index. For a given settlement window w, we have $w = n \times freq$. As discussed, with a given settlement window w (of which the corresponding sample size is n), the potential manipulator makes his or her entry decision depending on whether a positive gain is available.

Kumar and Seppi (1992) point out that the patterns of liquidity and the lead–lag relationship between the futures and the spot markets greatly influence manipulators' entry decisions. Accordingly, we can respectively use the permanent market effect coefficient in the stock market and the lead–lag coefficients to describe these features. Depending on the volume, we can classify the effect of trading on the price as a permanent or instantaneous market effect (Holthausen et al. 1987). The former results from large trading positions and thus could affect the stock price for the entire liquidation period; the latter is the price deviation induced by the unevenness of the instantaneous supply and demand with the effect limited to this particular transaction. Thus, the market manipulator can acquire positive profit only by trading a position sufficiently large enough to achieve a permanent market effect on the index price. Assuming that the permanent market effect on the stock price has a linear relationship with trading volume, we express the stock price P as a function of the permanent effect coefficient θ as follows:

$$\ln P_t = \alpha_1 \ln P_{t-1} + \theta_0 vol_t + \varepsilon_t, \tag{6}$$

where P_t is the price of the CSI 300 at time t and vol_t is the log trading volume over the period $[t-1, t]$.

To distinguish between the market effects of buying and selling, we match two data sets according to stock price rises and falls and estimate the buying (selling) permanent effect coefficient $\bar{\theta}$ ($\underline{\theta}$). Let λ be the lead–lag coefficient that measures the effect of the return of the futures price (denoted r_f) at $t - 1$ on the return of the log stock price (denoted r_p) at t. We specify the following vector autoregressive (VAR)(1) framework to estimate λ:

$$\begin{pmatrix} r_p \\ r_f \end{pmatrix}_t = \begin{pmatrix} c_{01} \\ c_{02} \end{pmatrix} + \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \cdot \begin{pmatrix} r_p \\ r_f \end{pmatrix}_{t-1} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix}_t , \tag{7}$$

where α_{12} is the estimate of λ. We use the following equation to ensure that θ_0 and λ are uniform in dimension by representing θ as

$$\theta = \theta_0 \times \mu_{\ln P} \times Value, \tag{8}$$

where $\mu_{\ln P}$ is the mean return of the CSI 300 over the whole sample period and *Value* is the average Chinese renminbi (RMB) value of a unit futures contract. According to Zheng and Wu (2007), $\bar{n}$ is the solution to $\Pi = 0$ and is defined as

$$\bar{n} = \underset{\{n\}}{\arg} \left\{ \Pi = \Delta^2 \left[\sum_{i=1}^{n} (n - i + 1) K_1^2 + \sum_{i=1}^{n} K_1 K_3 \right] + \sigma_e^2 \sum_{i=1}^{n} K_2^2 = 0 \right\}, \tag{9}$$

where Δ is the limited initial endowment of the manipulator, σ_e is the standard deviation of the noise traders' trading volume, n is the sample size, and K_1, K_2, and K_3 are all functions of n and λ/θ. We obtain $\bar{w}$ by multiplying $\bar{n}$ by *freq*.

Our specified data frequency in the analysis is five minutes, which differs from the six-second sampling frequency for the CSI 300. However, Equation (9) indicates that the sampling size n has a direct effect on the manipulator's expected profit. Thus, given the settlement window, a higher sampling frequency will benefit from protection against manipulation. Compared with a six-second frequency, the five-minute frequency we use to estimate $\bar{w}$ is then robust when guarding against manipulation.

Loss of Hedging Effectiveness

The estimates of the minimum variance-hedging ratio, namely, $h^*(w)$, are

$$h^*(w) = \frac{\sigma_{pf}}{\sigma_{ff}}, \tag{10}$$

where σ_{ff} and σ_{pf} represent the variance of the futures returns and covariance between the futures and spot returns, respectively. The cost-of-carry valuation indicates that the theoretical forward price ($\tilde{P}_{t,T}$) maturing at time T is

$$\tilde{P}_{t,T} = P_t e^{r(T-t)}, \tag{11}$$

where P_t is the index value at time t, and r is the riskless return. Assume that a heteroskedastic, geometric Brownian motion process drives the stock index returns,

$$dP_t = \mu_{p,t} P_t dt + \sigma_{p,t} P_t db_{1,t}, \tag{12}$$

and the price process of index futures, which is independent of the manner in which the settlement price is calculated in the nonexpiration interval, is expressed as in Lafuente and Novales (2003),

$$dF_{t,T} = \mu_{f,t} F_{t,T} dt + \sigma_{p,t} F_{t,T} db_{1,t} + \sigma_{n,t} F_{t,T} db_{2,t}, \tag{13}$$

where P_t is the price of the underlying stock index at time t, $F_{t,T}$ denotes the price of the index futures, $\mu_{p,t}$ and $\mu_{f,t}$ represent the instantaneous expected returns of the stock index and the futures, respectively, $\sigma_{p,t}$ is the instantaneous standard deviation of the stock's return, and

$$db_{i,t} = \varepsilon_{i,t}\sqrt{dt} \quad (i = 1,2),$$

where $\varepsilon_{i,t}$ i.i.d. $\sim N(0,1)$, is a Wiener process. We obtain the theoretical price of a futures contract $\mu_{f,t}F_{t,T}dt + \sigma_{p,t}F_{t,T}db_{1,t}$ by applying Ito's lemma, where $\sigma_{n,t}F_{t,T}db_{2,t}$ is the discrepancy between the real futures price and the theoretical futures price arising from market imperfections.

From Equation (12) to Equation (13), the estimate of the deviation of index futures returns σ_{ff} can be written as

$$\hat{\sigma}_{ff} = \hat{\sigma}_{pp} + \hat{\sigma}_n^2 + 2\sqrt{\hat{\sigma}_{pp}}\hat{\sigma}_n\hat{\rho}_{pf}, \tag{14}$$

where the covariance between returns, σ_{pf}, is estimated using

$$\hat{\sigma}_{pf} = \hat{\sigma}_{pp} + \hat{\rho}_{pf}\hat{\sigma}_n\sqrt{\sigma_{pp}}. \tag{15}$$

Substituting Equation (15) into Equation (14) obtains

$$\hat{\sigma}_{pp}\hat{\rho}_{pf} = \left(\hat{\sigma}_{pf} - \hat{\sigma}_{pp}\right)/\hat{\sigma}_n, \tag{16}$$

where, using Equation (16), the market imperfections can be estimated as

$$\hat{\sigma}_n^2 = \hat{\sigma}_{pp} + \hat{\sigma}_{ff} - 2\hat{\sigma}_{pf}. \tag{17}$$

As for the expiration date, given that stock index futures settle at the average price $F^*_{t,T}$ calculated by the average index value over the period of w minutes, following Manfredo and Sanders (2003), the price process of $F^*_{t,T}$ is expressed as

$$dF^*_{t,T} = e^{\varepsilon_T}\left(\sigma_{f,t}F^*_{t,T}dt + \sigma_{p,t}F^*_{t,T}db_{1,t}\right) + \sigma_n F^*_{t,T}db_{2,t}, \tag{18}$$

where $e_T \sim N(0, \sigma^2)$ and

$$\lim_{\varepsilon\to 0}\sigma^2 = \int_0^w \left(\frac{w-t}{w}\sigma_p(t)\right)^2 dt, \tag{19}$$

where e^{ε_T} is the price discrepancy caused by the way in which the expiration price is calculated.

Solving Equations (14) to (19) leads to the optimal hedging ratio:

$$h^*(w) = \frac{e^{\frac{\sigma^2}{2}}\sigma_{pp} + \rho_{pf}\sqrt{\sigma_{pp}}\sigma_n}{\mu_f^2\left(e^{2\sigma^2} - e^{\sigma^2}\right) + e^{2\sigma^2}\sigma_{pp} + \sigma_n^2 + 2e^{\hat{\sigma}^2}\hat{\rho}_{pf}\sqrt{\hat{\sigma}_{pp}}\hat{\sigma}_n}, \tag{20}$$

and the corresponding variance of the hedged position

$$\mathrm{Var}(r_t|w) = \hat{\sigma}_{pp} - \frac{\left(e^{\frac{\hat{\sigma}^2}{2}}\hat{\sigma}_{pp} + \hat{\rho}_{pf}\sqrt{\hat{\sigma}_{pp}}\hat{\sigma}_n^2\right)^2}{\hat{\mu}_f^2\left(e^{2\hat{\sigma}^2} - e^{\hat{\sigma}^2}\right) + e^{2\hat{\sigma}^2}\hat{\sigma}_{pp} + \hat{\sigma}_n^2 + 2e^{\hat{\sigma}^2}\hat{\rho}_{pf}\sqrt{\hat{\sigma}_{pp}}\hat{\sigma}_n}. \tag{21}$$

Equation (21) shows that compared with a single-price procedure, the average-price procedure introduces e^{ε_T} and results in a monotonically increasing optimal hedging ratio and variance of position returns when w increases. This conclusion is robust with respect to the value of market imperfections σ_n^2.

Data and Data Processes

Data Source

The data used in this study include the CSI 300 and CSI 300 stock index futures collected at five-minute intervals from April 16, 2010, to August 19, 2011, representing 329 trading days and 15,792 observations for each market. As the contract nearest to maturity is systematically the most actively traded, we only use data of the nearest contract. We obtain a continuous data series by switching to the next nearest-to-maturity contract on the third Friday of each month.

All our data are from the Tinysoft System (www.tinysoft.com.cn), a professional domestic financial data provider in China. Table 2 provides summary statistics for the intraday five-minute returns in both markets for all trading days.

Estimation of the Intraday Realized Volatility and Hedging Coefficient

To remove any possible micromarket noise in the multivariate high-frequency data, we use the separating information maximum likelihood (SIML) method developed by Kunitomo and Sato (2011) to estimate the intraday realized volatility and the hedging coefficients. For the futures market, we match two data sets: The first includes the data collected for all trading days and is used to estimate the average volatility for all trading days (σ_{ff}, σ_{pf}, σ_{pp}, σ_n); the second comprises the data for expiration days and is used to calculate the average volatility of the expiration dates (σ).

From the SIML method, we obtain the estimate of the realized covariance matrix for the price process,

$$\Sigma_S = \begin{Bmatrix} \sigma_{pp} & \sigma_{pf} \\ \sigma_{fp} & \sigma_{ff} \end{Bmatrix},$$

and the conditional covariance coefficient between the futures returns and the spot returns,

$$\hat{\rho}_{pf} = \frac{\hat{\sigma}_{pf}}{\sqrt{\hat{\sigma}_{ff}\hat{\sigma}_{pp}}}. \tag{22}$$

We apply a similar method to estimate the average intraday volatility σ'_{pp} for the spot returns of the expiration dates. The estimate of annualized volatility over the settlement window is

$$\sigma^2 = \frac{120}{240}\sigma'_{pp}. \tag{23}$$

Table 3 provides summary statistics for the estimates of realized volatility. The annualized volatility in the CSI 300 index futures market is 11.25 percent, and the estimated conditional correlation coefficient between the returns of the two markets is 0.67, indicat-

Table 2. Summary statistics for intraday five-minute returns

	April 16, 2010–August 19, 2011		November 25, 2010–August 19, 2011	
	Futures	Spot	Futures	Spot
Mean	–2.4E-05	0.7E-05	–1.69E-05	6.55E-06
Standard deviation	1.79E-03	1.80E-03	1.48E-03	1.52E-03
Skewness	0.5290	0.1497	–0.0379	0.0614
Kurtosis	10.4930	3.7650	5.5863	4.5016
Observations	15,792	15,792	8,736	8,736

Notes: Annualized standard deviations are shown. We exclude overnight returns for the accuracy needed for modeling high-frequency data (Martens 2002), which is one of the main reasons for the positive skewness[2]. In the left two columns are the statistics data for the whole sampling period, while in the right two columns are the statistics data for the robust check period. In the robust check, we exclude the data of the first few trading months to control the possible instability.

Table 3. Summary statistics of the estimated intraday realized volatilities

	April 16, 2010–August 19, 2011		November 25, 2010–August 19, 2011	
	Futures	Spot	Futures	Spot
Variance	0.1125	0.1138	0.0772	0.0829
Standard deviation	0.1081	0.0900	0.0586	0.0623
Skewness	2.9312	2.3729	1.9538	3.3189
Kurtosis	12.1881	7.2463	4.5870	15.4310
Covariance	0.0759	0.0759	0.0962	0.0962
Correlation coefficient	0.6707	0.6707	0.7162	0.7162
σ^2	0.1306	0.1306	0.1217	0.1217
σ_n^2	0.0745	0.0745	0.0454	0.0454
Observations	329	329	182	182

Note: σ^2 is annualized volatility for data without overnight returns.

ing a rather close link between the two markets. The estimate of the annualized volatility of futures returns over the settlement window, σ^2, is 13.06 percent.

Empirical Results

Estimated Zero-Profit Settlement Window $\bar{w}$

Table 4 reports the estimates for the parameters λ and θ. The coefficient of price effect, θ, is positively associated with market liquidity. For a manipulator with limited endowments, the price effect of his or her portfolio is restricted when market liquidity increases. In other words, as θ increases, the likelihood of gaining a positive profit through manipulation shrinks; consequently, the required settlement window for manipulation prevention tends to be shorter. As shown in Table 4, compared with $\bar{\theta}$, $\underline{\theta}$ has a larger absolute value. This indicates that it is easier to decrease than increase the spot price because trading has a greater effect on prices in falling markets.

Table 4. Estimated λ and θ

	April 16, 2010–August 19, 2011		November 25, 2010–August 19, 2011	
Parameter	Estimate	*t*-test statistic	Estimate	*t*-test statistic
λ	0.5065	45.76*	0.5289	41.09*
$\bar{\theta}$	0.1490	12.05*	0.2186	9.98*
$\underline{\theta}$	–0.1891	–5.43*	–0.2083	–12.23*

Notes: Overnight returns are excluded. * Significance at the 1 percent level.

The estimates of λ capture the influence of the futures price on the spot price and therefore quantify the lead–lag relationship between the two markets. A larger λ thereby indicates the greater effect of futures price changes on spot price changes. As for a manipulator who loses in the spot market but gains in the futures market, a larger value for a positive λ suggests that manipulation sufficiently changes the settlement price in the direction that benefits the manipulator. However, the larger average window increase in the spot price increases the cost of manipulation at the same time.

The estimated λ/θ is about 2.7 to 3.4. Considering that a "short squeeze" takes place more often, we denote λ/θ to be 3.4. This leads us to suggest, using Equation (9), that the zero-profit settlement window is about forty minutes. This implies that with the current lead–lag relationship between the CSI 300 futures and spot markets and their trading depth, a forty-minute settlement window is sufficient to guard against market manipulation. This is much shorter than the 120-minute settlement window currently in place.

Estimated Loss of Hedging Effectiveness

We estimate $h^*(w)$ corresponding to a w-minute settlement window and the return volatility of the hedged positions, $Var(r_t|w)$, using Equations (20) and (21). We then calculate the loss of hedging effectiveness corresponding to different values of w in the range [0, 120]. Table 5 reports the estimated results. As shown, there is no loss of hedging effectiveness when the settlement window is zero minutes, which corresponds to the situation of a single-price procedure. However, the loss increases as the settlement window increases. For example, the percentage loss is 20.03 percent when the settlement window is sixty minutes and 29.78 percent when the average period is 120 minutes. If we impose the zero-profit settlement window (forty minutes), the loss decreases to 15.23 percent. On this basis, it would be both safe and sensible to shorten the settlement window for CSI 300 futures contracts from 120 minutes to 40 minutes as this would induce no additional manipulation risk and would significantly lower the hedging effectiveness loss from 29.78 percent to 15.23 percent.

Estimated Optimal Settlement Window

Numerical calculations are used to derive w^* accounting for the complexity of directly solving Equation (1). The optimal settlement window w^* in Equation (1) depends on three

Table 5. Loss of hedging effectiveness under different settlement windows

Window length *w* (minute)	σ^2	$h(w)$	$\mathrm{Var}(r_t \mid w)$	*LS* (percent)
0	0.0000	0.5876	0.0121	0
20	0.0424	0.5665	0.0146	12.01
40	0.0620	0.5579	0.0156	15.23
60	0.0759	0.5470	0.0164	20.03
90	0.0930	0.5388	0.0174	25.73
120	0.1074	0.5319	0.0183	29.78

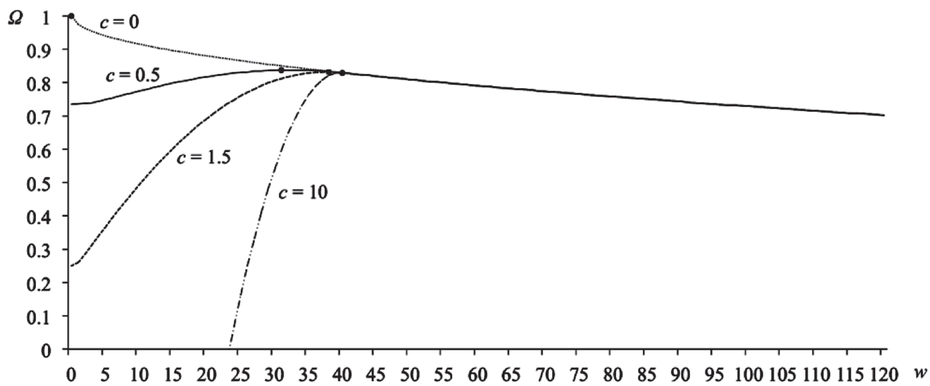

Figure 1. Profit levels under different settlement windows, April 2010–August 2011

parameters: the state probability π, the transaction fee rate α, and the investigation fee rate c. We set $\pi = 1/2$. Note that the optimal solution is unaffected by this assumption because an exchange that emphasizes sustainable business should not rely on bonanzas. The effect on an exchange's profit of implementing enforcement is dependent on the relative values of α and c; therefore, letting α equal 1 makes c the ratio of investigation cost to revenue, which, as Reiffen and Robe (2011) point out, might be different across exchanges. We consider some special cases where c equals 0, 0.5, 1.5, and 10, respectively, in order to simplify implementation and provide future insights. First, we calculate the profit under different settlement windows and obtain four profit curves. Then, we determine the optimal settlement window w^*, which is located at the highest point of each curve. Figure 1 captures how w^* is chosen for the different unit investigation costs.

When implementing enforcement is highly costly (for example, c is set to be 10), the optimal settlement window w^* is forty minutes, which equals the upper critical value of the optimal settlement window. This is consistent with the consensus that a higher unit investigation cost could hamper the exchange's ability to increase its profit via improving hedging effectiveness and induce it to opt for a longer settlement window that facilitates manipulation prevention. If $c = 0$, where surveillance activities are almost costless for exchanges, the optimal settlement window is 0.

For moderate conditions where $c = 0.5$ and $c = 1.5$, the optimal settlement windows are twenty-eight and thirty-eight minutes, respectively. In practice, the futures exchange could choose w^* based on the actual unit investigation cost it bears.

Robust Test

Our initial sample period is from the commencement date of CSI 300 futures contract trading until August 19, 2011. However, upon considering possible instability in the futures market in the first few trading months, we reestimate the model using the data from November 25, 2010, to August 19, 2011.[3] The results show that the values of w^* when c is equal to 0, 0.5, 1.5, and 10 are 0, 22, 23, and 25 minutes, are respectively, smaller than those in Figure 1. Song and Luo (2013) give full specifications of how the w^* for the robust test period is estimated. The robustness test results show a stronger relation of spot and futures markets. However, the growth of liquidity in the spot market appears to be much faster, thus resulting in a smaller λ/θ of 2.5 and a smaller upper critical value of the optimal settlement window, $\bar{w}$, of about twenty-five minutes.

One possible reason for the CFFEX continuing to maintain the 120-minute settlement window might be to protect against the likelihood of increased manipulation. However, the robustness test shows that it is not necessary to be too concerned about these potential adverse changes. As both markets continue to mature, and as liquidity continues to increase along with the strength of the linkage between these markets, the upper limit of λ is set equal to one to ensure the stability of the VAR system. In contrast, there is no upper critical value for θ, indicating that λ/θ is more likely to fall and, as a result, $\bar{w}$ would decrease.

Conclusion

Regulatory reforms are clearly necessary in the dynamic development process of financial markets (Chan et al. 2005). Using data from April 2010 to August 2011, this paper calculates that the optimal settlement window for CSI futures lies in the range of zero to forty minutes. Moreover, if we employ the more recent data, our results indicate that an appropriate length for the settlement window is between zero and twenty-five minutes. Thus, we suggest a shorter settlement window is appropriate for improving hedging effectiveness with little possibility of inducing additional manipulation risk. Moreover, as the constructive development of futures markets should be adapted to updated financial circumstances (Lien and Zhang 2008), we suggest it would be worthwhile to reevaluate the settlement window every two to three years.

In addition, with the increasing maturity of financial markets in China, we expect liquidity in these markets to increase. It is reasonable to predict that the increase in market liquidity will be much faster than the increase in the lead–lag relationship coefficients. Consequently, $\bar{w}$, and therefore the optimal settlement window, will tend to decrease in the long run. In contrast, more hedgers will be attracted to the market for better hedging effectiveness; consequently there is a need for more arbitrageurs for improved convergence of the spot price to the futures price. This will help create greater liquidity in both markets and systematically reduce the manipulation risk (as $\bar{w}$ decreases), thus creating a virtuous and healthy cycle.

Notes

1. As noted in the *Financial Times* on April 16, 2010, “China passes an historic milestone on the path to a market-driven economy on Friday as stock index futures begin trading on the mainland.”

2. Important information is more likely to be announced during nontrading than trading hours; most investors appear to be much more sensitive to negative rather than positive information.

Another reason is the unstable performance of futures return during the first several months following launch.

3. The performance of the CSI 300 stock index futures was unstable during the first several months after its launch. In particular, an extremely positive value on November 24, 2010, biases the returns skewness from negative to positive. To guarantee stability, we undertake the robustness test after excluding the extreme value.

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