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Risk Management Lessons from ‘Knock-in Knock-out’ Option Disaster*

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PDF

Abstract

Currency knock-in knock-out (KIKO) options had been widely used for hedging exchange rate risks in Korean financial markets. However, as the Korean won moved in an unexpected direction during the global financial crisis period of 2007 and 2008, the hedging instruments incurred huge losses to the option holders. In this paper, we analyze the event from the viewpoint of risk assessment and management. We find that, first, if the option holders had assessed the risk levels with and without the KIKO options by using standard risk measures like value-at-risk or conditional value-at-risk, then many KIKO option contracts would not have been justifiable from the beginning. Second, having a proper view on the exchange rate dynamics turned out to be crucial for risk assessment and management. If the companies had a proper view instead of a myopic view on the exchange rate movement, then the KIKO options might not have been chosen. Finally, ‘hedge-and-forget’ behavior proved to be very costly and reckless. If the companies had continuously assessed and managed their risks, then the losses from the KIKO options could have been significantly mitigated. Some relevant pricing issues are also investigated. We find that most KIKO option contracts under

the current account surplus and capital inflows to Korea. Responding to this decade-long gradual appreciation of the domestic currency, many Korean exporting companies tried to hedge the exchange rate risks of their foreign-currency-denominated revenues. The currency knock-in knock-out (KIKO) option was one of the instruments widely used for the purposes of hedging exchange rate risks in Korean financial markets in this period. It is now well known that some commercial banks aggressively persuaded their corporate clients to use the KIKO options for hedging purposes. This KIKO option is designed to offer positive payoffs to the holder when the KRW moderately appreciates up to a certain predetermined rate; in exchange for these positive payoffs, the option holder should take negative payoffs when the KRW significantly depreciates.

However, when the KRW suddenly reversed its direction from the steady appreciation of the past decade and began to depreciate at an accelerating pace amid worsening global financial turmoil from late 2007, KIKO option holders had to face accumulating losses from their holding positions with no hope of reversal. It has been alleged that several hundreds of small and medium enterprises (SME) were on the list of the victims of this KIKO options disaster, and just because of the KIKO failures alone, these apparently healthy SME have fallen into near bankruptcies. As the severe financial damage from the KIKO option transactions became apparent in late 2008, government agencies tried to help the damaged SME. In this period, some victim companies filed lawsuits against the option sellers (banks), citing the unfairness in the option transactions.

The question is, how did this financial disaster happen? First of all, it looks like the KIKO options do not seem to be appropriately designed for hedging purposes. Unlike other usual hedging instruments, for example, forwards or standard options, the KIKO options maintain hedging function only if the KRW moderately appreciates. The KIKO options become risk-enhancing instruments when there is sharp depreciation of the KRW. If the KRW unexpectedly and greatly depreciates, then financial losses are incurred by KIKO option holders. Recognizing this risk, the KIKO option holders should have actively undertaken risk-management; however, most KIKO option-holding SME showed ‘hedge-and-forget’ behavior and were inactive in managing the risks from their KIKO option positions. Furthermore, they did not receive appropriate advice from their counterpart banks with respect to potential exchange rate risks and the resulting financial losses.

In the present paper, we attempt to draw risk management lessons from this KIKO option disaster in the Korean financial market from the perspective of the option holders (i.e. SME.) First of all, if the option holders had assessed the risk levels with or without the KIKO options by using standard value-at-risk (VaR) or conditional VaR (CVaR) risk measures, then many of the KIKO option contracts would not have been justified from the beginning. Second, we find that the option holders seemed to have a myopic view about the KRW exchange rate dynamics. If they had inferred the dynamics from longer time series of the KRW exchange rate including the currency crisis period of 1997, then the typical

In addition to the risk management analysis, we also investigate the KIKO option pricing issues. In particular, we try to answer the following questions. Were the KIKO options fairly priced? If the KIKO options were not fairly priced, then what was the impact of the mispricing? We find that the KIKO options were not significantly mispriced in most cases and that the impacts of the mispricing on the financial losses from the KIKO options were considerable only in a few cases. This finding implies that the pricing issue has only secondary importance when evaluating the KIKO option disaster.

This paper is organized as follows. Section 2 explains the KIKO option disaster. The KIKO option is formally introduced in section 3. Section 4 analyzes the KRW exchange rate dynamics. Risk management using VaR with simulation techniques in the KIKO options is considered in section 5. The KIKO option pricing issues are investigated in section 6. Section 7 concludes.

2. Knock-in Knock-out Option Disaster

According to Korean financial supervisory authorities (Financial Services Commission and Financial Supervisory Services), 519 companies held the outstanding amount of the KIKO options of US$10.1bn as of June 2008, among which 480 companies were SME holding US$7.5bn.[1] The average ratio of the outstanding amount of the KIKO options to the annual export amount of the KIKO option holding firms is 35.2%, and the SME have a similar ratio of 39.5%. However, there were many firms that held large amounts of KIKO options exceeding their export amounts: 71 companies reportedly held KIKO options exceeding their export amounts and the hedge ratio reached 166.7% on average, among which 68 companies were SME with an average hedge ratio of 193.8%.

When the KRW depreciates significantly, companies holding overhedged KIKO option positions relative to their export amounts face big financial losses from their KIKO option positions. At the end of June 2008, the KRW unexpectedly depreciated by 10.5%, and the 68 SME holding overhedged KIKO option positions reported financial losses of KRW402bn (US$384m) from their KIKO option positions, which exceeded financial gains of KRW148bn (US$142m) from their USD-denominated export revenues. The situation might be getting worse as the KRW has been depreciating further. The KRW recorded a depreciation of 32.1% at the end of January 2009 compared with the end of December, 2007.

This KIKO option disaster raises several issues. It has been widely discussed, but it is still controversial whether the KIKO options were fairly sold by FX banks to exporting companies or not. The victim companies have argued that the structure of the KIKO option is very complicated and they were not sufficiently informed about the risks inherent with the options. Many people, including industry experts, have also argued that FX banks should be blamed for selling inappropriately designed financial commodities (KIKO options) to their clients purely for their own interests. It is also a disputed issue whether the KIKO options were fairly priced or not. This paper investigates whether the KIKO options were actually fairly priced or not and it also investigates the impact of the mispricing. Policy

Besides the aforementioned issues, the present paper raises another important but not widely discussed or recognized issue: Did exporting companies make appropriate risk-management efforts? Would the KIKO option disaster still have been unavoidable if exporting companies had made appropriate risk-management efforts? We believe that this issue is at least as fundamental as the aforementioned ones for the purpose of preventing similar disasters occurring again.

3. Currency Knock-in Knock-out Options

The currency KIKO option is written on the KRW exchange rate, expressed as the value of US$1 in the unit of the KRW; therefore, a higher KRW exchange rate implies the depreciation of the KRW. The KIKO is structured as a combination of purchasing one put option and selling multiple (usually two or three) call options. These are European-style put and call options and have a common strike price (exchange rate, here). Two barrier conditions are imposed: The low barrier (*L*) defines the knock-out event for the KIKO option (both call and put options) contract, and the high barrier (*H*) defines the knock-in event for the call option. The option maturity is usually set as 1 year or 2 years; however, the option contract has in most cases predetermined monthly valuation dates. The option payoff is evaluated during each 1-month-long observation period and exchanged at each valuation date. The window KIKO (wKIKO) option payoff for a notional amount of $US1 at each valuation date is formally expressed as:

$$V\left(S_{T_i}, K, H, L, \theta\right) = \left\{ \begin{array}{ll} 0, & \underline{S}_{(T_{i-1},T_i]} \leq L \\ -\theta \cdot \max\left(S_{T_i} - K, 0\right), & \underline{S}_{(T_{i-1},T_i]} > L, \quad \bar{S}_{(T_{i-1},T_i]} \geq H \\ \max\left(K - S_{T_i}, 0\right), & else \end{array} \right\}, \tag{1}$$

where S_{T_i} denotes the KRW exchange rate at the *i*th valuation date T_i, $\underline{S}_{(T_{i-1},T_i]} \equiv \min\{S_t | t \in (T_{i-1}, T_i]\}$, $\bar{S}_{(T_{i-1},T_i]} \equiv \max\{S_t | t \in (T_{i-1}, T_i]\}$, *K* the strike price, and θ the number of call options. Aggregating the option payoffs for all valuation dates, we obtain the whole option payoff.

Figure 1 illustrates the payoff of the wKIKO when $L = 885$, $K = 950$, $H = 965$, and $\theta = 2$, along with the payoff of the FX forward contract with the forward exchange rate (*F*) of 925. The wKIKO has a relative advantage over the FX forward contract when the KRW exchange rate moves within a limited range between 885 and 975. However, if the exchange rate touches the low knock-out barrier level, then the wKIKO provides a payoff of zero. Furthermore, as the exchange rate depreciates and triggers the high knock-in barrier, the payoff of the wKIKO deteriorates faster than that of the forward.

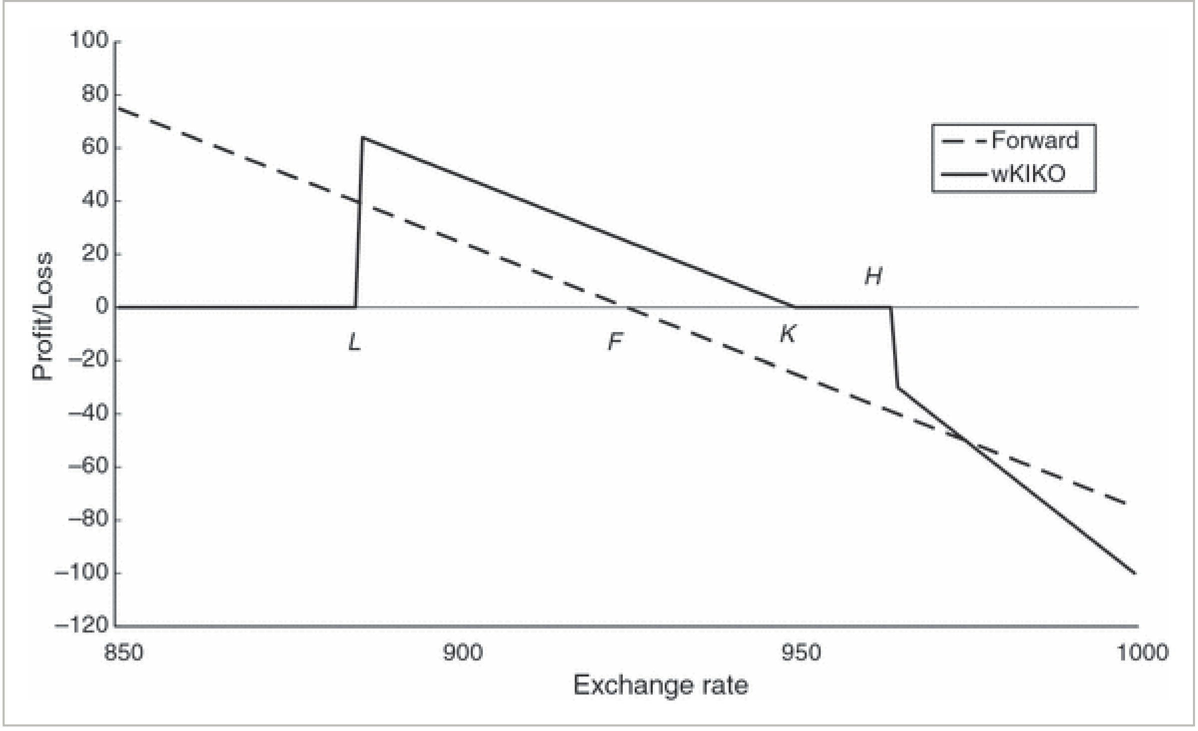

Figure 1

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Payoffs of window knock-in knock-out (wKIKO) option and FX forward: $L = 885$, $K = 950$, $H = 965$, $\theta = 2$, and F (forward exchange rate) $= 925$.

As explained above, the wKIKO options cease to be hedging instruments when either the knock-in or knock-out barrier is triggered, and in this sense the wKIKO options should only be considered as partial or semi-hedging instruments. Because of this feature, the option holders need to continuously assess and manage the risks that depend upon the exchange rate prospect. Section 5 discusses how the risks can be assessed and managed. The next section provides information about the exchange rate prospect.

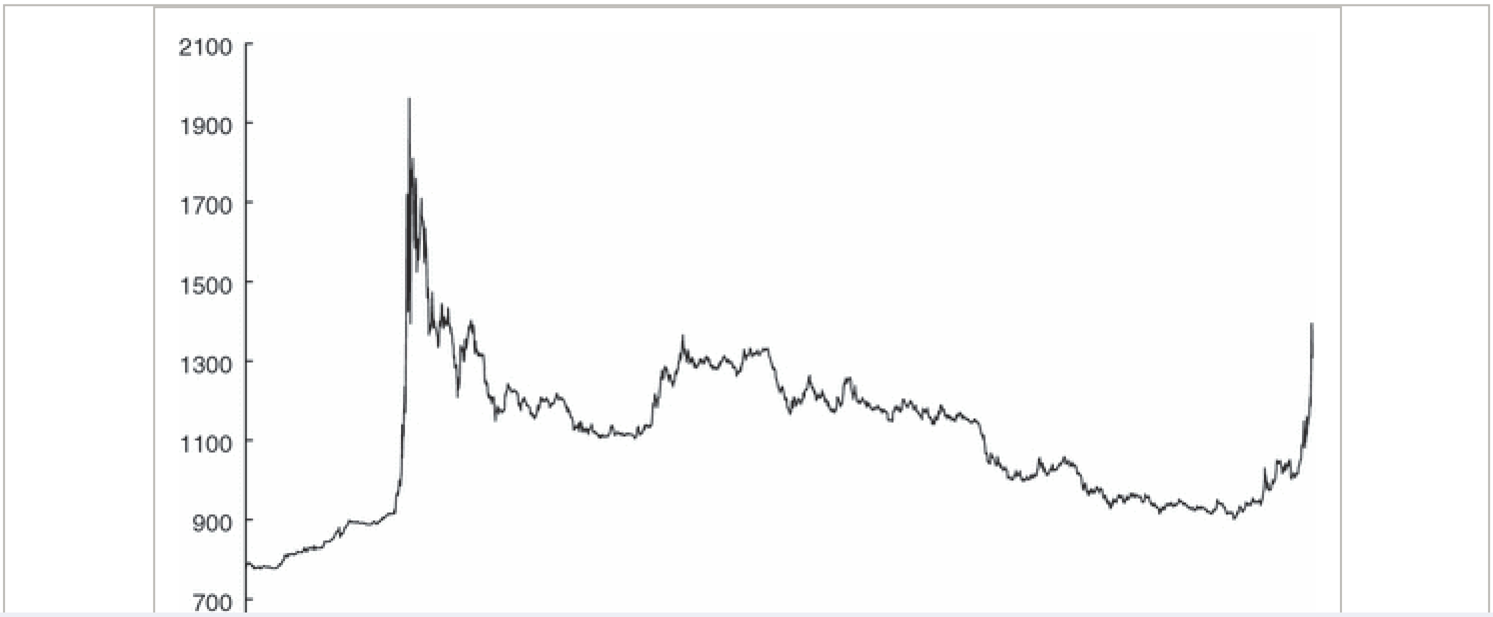
4. Korean Won Exchange Rate Dynamics

It is very important to appropriately specify exchange rate dynamics for pricing the wKIKO options as well as for managing the risks from the wKIKO option positions. In the present study we use the generalized autoregressive conditional heteroskedasticity (GARCH) models for specifying the KRW exchange rate dynamics. Since Bollerslev (1986) proposed the GARCH model, which can capture the time-varying volatility feature, many variants have emerged, and these GARCH-type models have become a standard model class with many applications for financial time series. For example, some

$$S_t = c + \sum_{i=1}^{R} a_i s_{t-i} + \sum_{j=0}^{M} b_j \varepsilon_{t-j}, \quad \varepsilon_t \sim N(0, h_t)$$
$$h_t = k + \sum_{m=1}^{P} g_m h_{t-m} + \sum_{n=1}^{Q} d_n \varepsilon_{t-n}^2, \qquad (2)$$

where $s_t \equiv \log(St/S_{t-1})$. Even if model risk may be an important issue in this study, we restrict our model as described in equation (2) for the sake of simplicity and also based upon the fact that the above model is quite general.

Figure 2 illustrates the time series of the daily KRW exchange rates from 1996 to 2008. The KRW had gradually appreciated since 2001 up to late 2007 and then showed sharp depreciation. Before applying the GARCH model, we do pre-estimation analyses to test the presence of the autoregressive conditional heteroskedasticity (ARCH) effect in the time series of the daily return of the KRW exchange rates from 4 January 2000 to 29 June 2007. As demonstrated in Figure 3, the volatilities of the daily returns of the KRW exchange rates appear time-varying. This feature is formally tested. Table 1 provides the results for the Ljung-Box-Pierce Q-test and Engle's (1982) ARCH test. According to the Q-test, we can reject the null hypothesis that no significant correlation is present in the daily return when tested for up to 10, 15, and 20 lags of the autocorrelation function at the 5% level of significance. The ARCH test also indicates that we can reject the null hypothesis that the time series of the daily return is a random sequence of Gaussian disturbances (i.e. no ARCH effects exist) at the 5% level of significance. Therefore, we can assume the presence of the ARCH effect in the time series and legitimate GARCH models in this application.



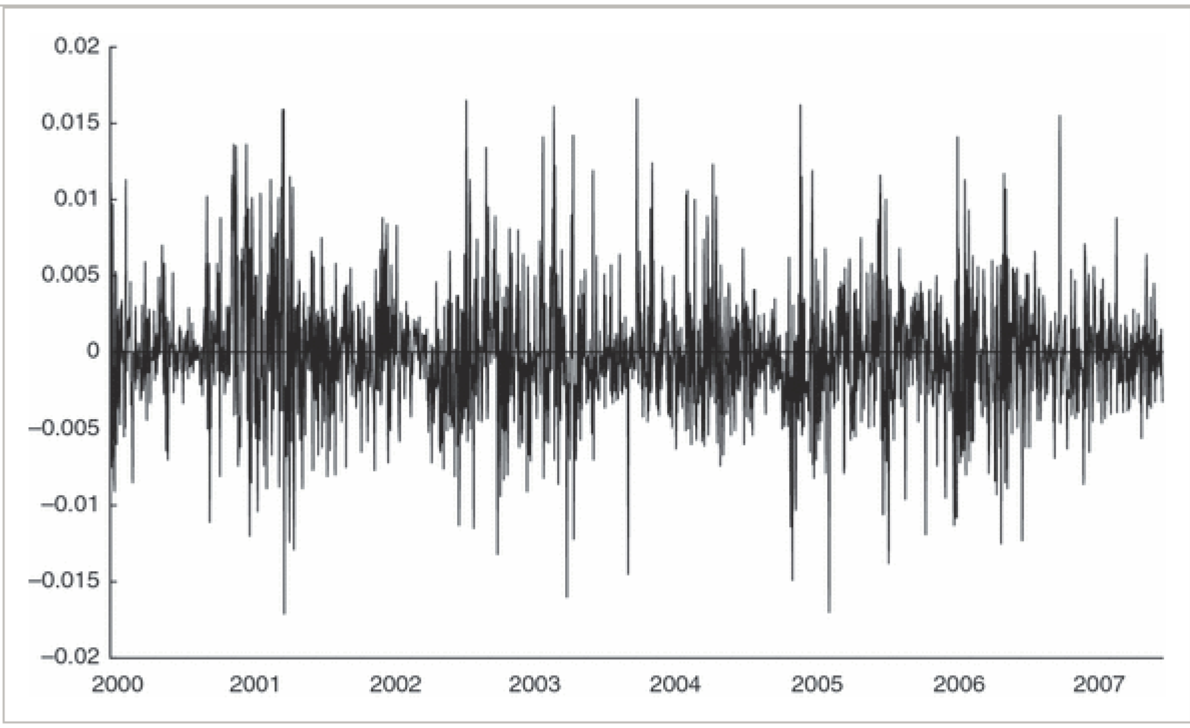


Figure 3

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Time series of the daily returns of Korean won exchange rates from 4 January 2000 to 29 June 2007.

Table 1. Q-test and autoregressive conditional heteroskedasticity (ARCH) test for the daily return of the Korean won exchange rates (from 4 January 2000 to 29 June 2007)

Lags	Q-test			ARCH test		
	Statistic	Critical value	p-value	Statistic	Critical value	p-value
10	263.8	18.3	0.000	129.1	18.3	0.000
15	312.4	25.0	0.000	138.3	25.0	0.000
20	370.8	31.4	0.000	150.2	31.4	0.000

Next, we choose the model specification parameters (R,M)/(P,Q) in a manner to preserve parsimony. We set (0,0)/(1,1) as a benchmark model and add one more parameter into the model. Table 2 reports finally choose the ARMA(0,0)/GARCH(2,1) model as the KRW exchange rate dynamics from 4 January 2000 to 29 June 2007.

Table 2. Parameter estimates of the generalized autoregressive conditional heteroskedasticity (GARCH) model for the daily return of the Korean won exchange rates (from 4 January 2000 to 29 June 2007)

The regression equation is specified in equation (2). The numbers in parentheses indicate t-values. AIC indicates Akaike information criterion, and BIC Bayesian information criterion. LR1 denotes the p-value of the log-likelihood ratio test when the restricted model is (0,0)/(1,1), and the unrestricted model is the model in the corresponding column. Similarly, LR2 is for the case where the restricted model is (0,0)/(2,1).

Parameters	ARMA(R,M)/GARCH(P,Q)						
	(0,0)/(1,1)	(1,0)/(1,1)	(0,1)/(1,1)	(0,0)/(2,1)	(1,0)/(2,1)	(0,1)/(2,1)	(1,1)/(2,1)
c (10^{-3})	−0.1389 (−1.689)	−0.1247 (−1.518)	−0.1332 (−1.613)	−0.1379 (1.678)	−0.1384 (−1.680)	−0.1368 (−1.648)	−0.0056 (−0.565)
k (10^{-7})	4.3347 (5.934)	4.2244 (5.876)	3.8501 (5.791)	5.9093 (5.075)	5.9797 (4.991)	5.5843 (4.839)	5.8240 (4.877)
A		0.0159 (0.651)			0.0108 (0.417)		0.6130 (0.942)
B			0.0144 (0.590)			0.0126 (0.485)	−0.5950 (−0.894)
g_1	0.8940 (91.662)	0.8954 (92.761)	0.8985 (97.598)	0.4257 (2.440)	0.4400 (2.442)	0.4634 (2.439)	0.4553 (2.404)
g_2				0.4264 (2.674)	0.4117 (2.505)	0.3930 (2.346)	0.3998 (2.309)
D	0.0820 (9.394)	0.0811 (9.373)	0.0805 (9.496)	0.1150 (6.886)	0.1148 (6.728)	0.1129 (6.520)	0.1123 (6.524)
AIC (10^4)	−1.5302	−1.5300	−1.5300	−1.5305	−1.5303	−1.5303	−1.5302
BIC (10^4)	−1.5279	−1.5272	−1.5272	−1.5277	−1.5270	−1.5270	−1.5263
LR1 (p-		0.5319	0.6554	0.0026			

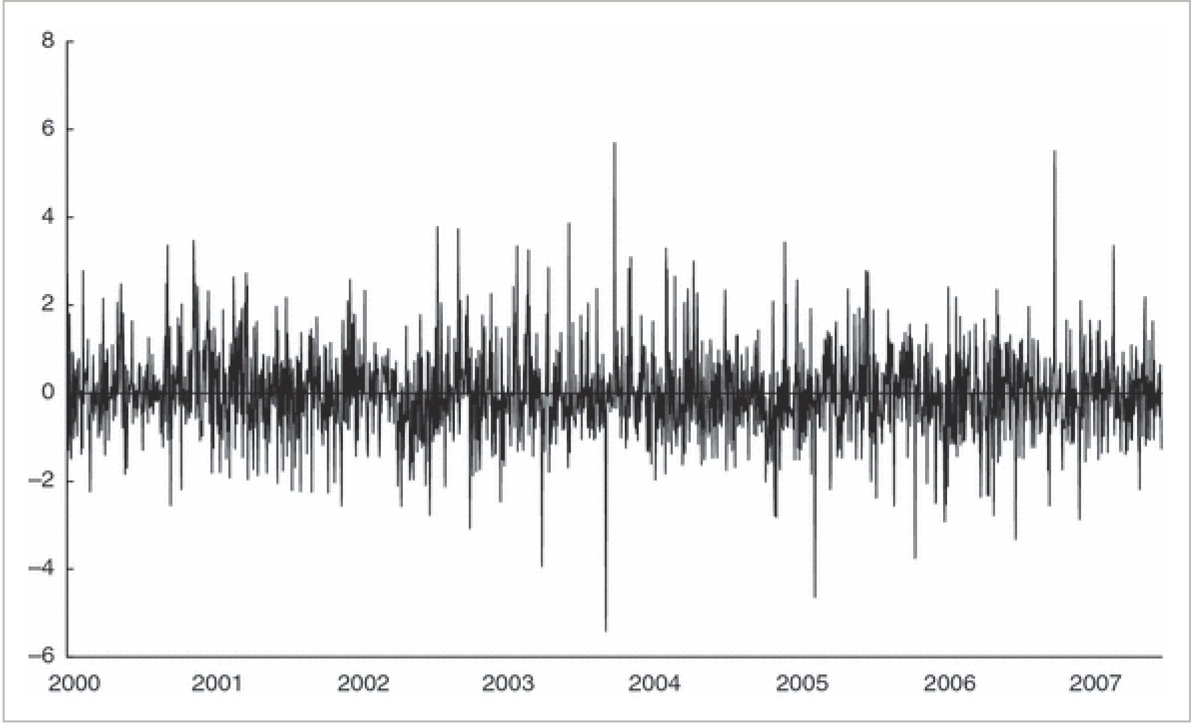

Figure 4

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Time series of the standardized innovations of the Korean won exchange rates from 4 January 2000 to 29 June 2007.

The currency crisis during late 1997 up to early 1998 had a big impact on the Korean economy and also on the KRW exchange rate dynamics. Therefore, including the currency crisis period in the sample period is crucial for determining the KRW exchange rate dynamics. Now we include the currency crisis period into the sample period and follow the similar procedure to determine the model specification parameters (R,M)/(P,Q). Unlike the former case of excluding the currency crisis period, the model with (0,1)/(2,1) is chosen for the case of inclusion of the currency crisis period.[4] The results are omitted for simplicity.

5. Risk Assessment and Management of Knock-in Knock-out Options

In this section we will investigate whether the KIKO option disaster would have been avoidable if standard risk management techniques had been properly employed by the option holders. We will begin with a discussion on the actual KIKO option transaction data.

Table 3 shows detailed information about the company's wKIKO option transactions. The company made eight wKIKO option contracts from December 2006 to January 2008. Maturities range from 11 to 35 months. The contracts have different monthly settled notional amounts from US$1m to US$4m. Summing up notional amounts for all eight contracts and for all valuation dates, the whole amount reaches US$340m. Five (contracts nos. 1, 2, 3, 4, and 8) out of eight contracts have higher strike prices than the spot exchange rates or futures prices, which may look appealing to the company. The remaining three contracts (nos. 5, 6, and 7) have lower strike prices than the spot exchange rates or futures prices; however, while a futures contract delivers negative payoffs when the future spot exchange rate exceeds the futures price at a valuation date, the wKIKO option can yield a payoff of zero if the knock-in barrier is not triggered.

Table 3. Sample window knock-in knock-out option contracts

'Notional amount' indicates the notional amount (US$) settled each month when two barriers are not triggered, and 'Total amount' denotes 'Notional amount' times maturities (months). KI, knock-in barrier; KO, knock-out barrier; K, strike price; S_0, spot Korean won exchange rate; F, Korean won/US$ futures price with the shortest maturity among maturities longer than 1 month.

Contract no.	Date	Maturities (month)	Notional amount (monthly, US$)	Total amount (US$)	KI	KO	K	S_0	F
1	11 December 2006	24	2000000	48000000	965.0	885.0	950.0	926.0	925.3
2	7 March 2007	28	1000000	28000000	985.0	885.0	956.0	948.8	947.2
3	25 May 2007	30	2000000	60000000	963.0	900.0	950.0	928.3	926.9
4	10 September 2007	12	2000000	24000000	965.0	905.0	952.0	939.1	936.6
5	9 January 2008	11	4000000	44000000	963.0	900.0	930.0	937.4	937.0
6	16 January	11	4000000	44000000	960.0	900.0	930.0	940.1	940.8

are various. Based upon these characteristics, we assume that our dataset is somewhat representative of typical KIKO option contracts and will use it for the risk analysis.

5.2 Risk Assessment of Knock-in Knock-out Options

In this subsection, we will assess the risk level of the KIKO options at purchase time to investigate whether the wKIKO options were justifiable as a hedging instrument or not. We use VaR and CVaR to measure risks inherent with hedged and unhedged positions. Unhedged positions are assumed to generate monthly cash flows of $US1 until the maturity date, whereas hedged positions indicate monthly cash flows of $US1 plus monthly payoffs from the wKIKO with a notional amount of $US1 until the maturity date. [6] The hedge performance of wKIKO options will be judged as risk-reducing if the CVaR for the hedged position is less than that for the unhedged position.

Initially, VaR was developed as a practical gauge of financial risk, particularly for the purpose of communicating risks to stakeholders. It has been widely used for financial risk management and has become a common benchmark to compare and control risks. More recently, VaR has been used to decide on the amount of equity capital necessary to buffer possible losses. See Duffie and Pan (1997) and Jorion (2001) for a comprehensive overview of VaR. VaR is defined as the worst loss that can occur over a specified horizon at a specified confidence level. Letting P_t be the price of a financial asset at time t, a k-period ahead VaR at time t is defined as

$$\Pr[P_{t-k} - P_t \leq VaR(t,k,\alpha)] = 1 - \alpha, \quad (3)$$

where (1 − α) denotes the confidence level.

CVaR, which is also known as mean excess loss, mean shortfall, or tail VaR, is defined as the conditional expectation of the loss above VaR (i.e. $E\left[P_{t-k} - P \mid P_{t-k} - P_t \geq VaR(t,k,\alpha)\right]$). Pflug (2000) shows that CVaR is a coherent risk measure that has nice properties, including convexity. See Ogryczak and Ruszczynski (2002) for an overview of CVaR.

Here, VaR and CVaR will be used for reporting or comparing risks. The horizon is set as the same as the maturity of the wKIKO option. We assume that the notional amount settled at each valuation date of a wKIKO is matched with the future cash flow of the unhedged position. Therefore, multiple monthly cash flows are generated from hedged or unhedged positions. We use the interest rate swap (IRS) yield curve to discount multiple monthly cash flows for calculating CVaR. [7] Because it is difficult to derive analytical formulas for CVaR of unhedged or hedged positions under GARCH processes, we use a simulation method for CVaR calculation. We simulate 10000 exchange rate paths based upon the estimated GARCH process and calculate the profit/loss for each simulated path. Then these 10000 implies that even under normal currency movement scenarios, the standard risk management process could detect the inappropriateness of these contracts.

Table 4. Value-at-risk (VaR) and conditional VaR (CVaR) for unhedged and hedged position with window knock-in knock-out (wKIKO) options

'Unhedged' means unhedged position generating monthly cash flows of US$1 until the maturity date. 'Hedged' indicates monthly cash flows of US$1 plus wKIKO notional amount of US$1 until the maturity date. 99, 95, and 90% indicate the respective confidence level. (C)VaR are measured in terms of Korean won.

Contract no.		VaR			CVaR		
		99%	95%	90%	99%	95%	90%
Panel A. Korean won exchange rate dynamics based upon short sample period (4 January 2000–29 June 2007)							
1	Unhedged	3174.2	2454.8	2045.1	3578.6	2907.4	2566.3
	Hedged	3103.7	2369.4	1944.1	3521.2	2838.0	2485.8
2	Unhedged	3723.8	2959.6	2503.3	4139.8	3436.8	3078.6
	Hedged	3661.8	2854.7	2386.4	4155.6	3365.4	2984.4
3	Unhedged	4419.8	3435.7	2922.3	4866.3	4040.6	3600.7
	Hedged	4392.7	3395.4	2867.3	4832.0	3995.1	3553.4
4	Unhedged	1152.8	834.3	682.4	1303.1	1023.5	887.6
	Hedged	1492.8	953.6	750.3	1878.8	1297.8	1071.0
5	Unhedged	965.3	732.4	591.0	1110.2	884.7	770.2
	Hedged	1038.4	787.1	650.2	1200.2	940.1	826.2
6	Unhedged	961.3	730.2	587.6	1108.8	882.0	767.0
	Hedged	1064.1	803.7	672.1	1234.0	965.7	849.0
7	Unhedged	5677.4	4395.8	3729.0	6337.7	5176.9	4600.7

If we expand the sample period to the longer one to take into account the effect of the currency crisis option disaster might have been avoidable. These results show how important it is to apply the proper risk assessment process.

5.3 Risk Management of Knock-in Knock-out Options

As argued in the Introduction to this paper, the companies holding the wKIKO options showed 'hedge-and-forget' behavior. In this subsection, we will investigate how different the outcome would have been if they had been active in managing their risks instead of applying 'hedge-and-forget' behavior.

To overcome the 'hedge-and-forget' attitude, it is necessary to recognize the fact that risk level may change over time. Therefore, even if a hedging instrument is justifiable at purchase time, its risk level should be continuously assessed. Table 5 illustrates the time trend of VaR with 95% confidence level for all hedged positions with wKIKO option contracts.[8] VaR is calculated at each valuation date. As time goes on (maturity diminishes), the total notional amount decreases; therefore, VaR also becomes lower. To adjust this maturity effect, we normalize VaR by dividing it by the maturity (measured in months). Here, the GARCH model is estimated using the short sample period of the KRW exchange rates. In all cases, the risk levels measured by VaR were significantly heightened from February or March 2008. In particular, the risk levels accelerate from September 2008. This risk enhancement was caused by sharp depreciation of the KRW during the period.

Table 5. Time trend of VaR with 95% confidence
Value-at-risk (VaR) is calculated at each valuation date. Considering that total notional amount decreases as time goes on (maturity diminishes), VaR is normalized by divided by the maturity (measured in months).

Date	Contract number							
	1	2	3	4	5	6	7	8
December 2006	2.9							
January 2007	2.2							
February 2007	1.8							
March 2007	2.6	1.7						
April 2007	1.8	1.0						
May 2007	1.8	1.5	2.0					
June 2007	1.9	1.0	1.7					

Date	Contract number							

Now we suppose that the companies are alert to their risk. More formally, we assume that they assess the risks associated with the hedged positions at every valuation date (i.e. once in a month), and that if the assessed risk exceeds the initial risk level, then they try to manage their risks by simply using KRW/USD futures contracts. Taking contract no. 1 as an example, the company would start to manage risk from November 2007, which is the first time when the assessed VaR (4.3) exceeds the initial VaR (2.9).

The KRW/USD futures are actively traded on the Korea Exchange.[9] The six futures with maturities up to 1 year are listed at the same time. One contract indicates the notional amount of $US50 000. For the sake of simplicity, we restrict ourselves to using futures contracts with maturity between 1 and 2 month(s) for managing risks. Therefore, we use the ‘roll-over of short-term futures’ strategy to manage long-term risk. We also restrict the maximum notional amount of the futures position to be less than or equal to the notional amount of the wKIKO option not to be overhedged because of the futures position.

Figure 5 illustrates VaR and CVaR of the hedged position with both wKIKO and KRW/USD futures for contract no.1 on 12 March 2007. On that date, six kinds of KRW/USD futures are traded with maturities: 19 March 2007, 16 April 2007, 14 May 2007, 18 June 2007, 17 September 2007, and 17 December 2007 (listed but not traded), among which the futures with maturity on 16 April 2007 is chosen. Because the notional amount of the wKIKO option is US$2m, 40 futures contracts is the limit to be held. We change the number of futures contracts by one contract from −40 to 40 (negative number of contracts indicates short position), calculate VaR and CVaR for each futures position, and choose the number of futures contracts yielding the minimum risk level. The optimal number of futures contracts turns out to be different depending upon the chosen risk criterion. Because we assume the ‘roll-over of short-term futures’ strategy to manage the risk associated with long-term risky future cash flows, the company should hold the optimal number of futures contracts times the maturity (measured in months), where each set of futures contracts grouped with the optimal contract number will correspond to each notional amount to be settled at each valuation date until the maturity.

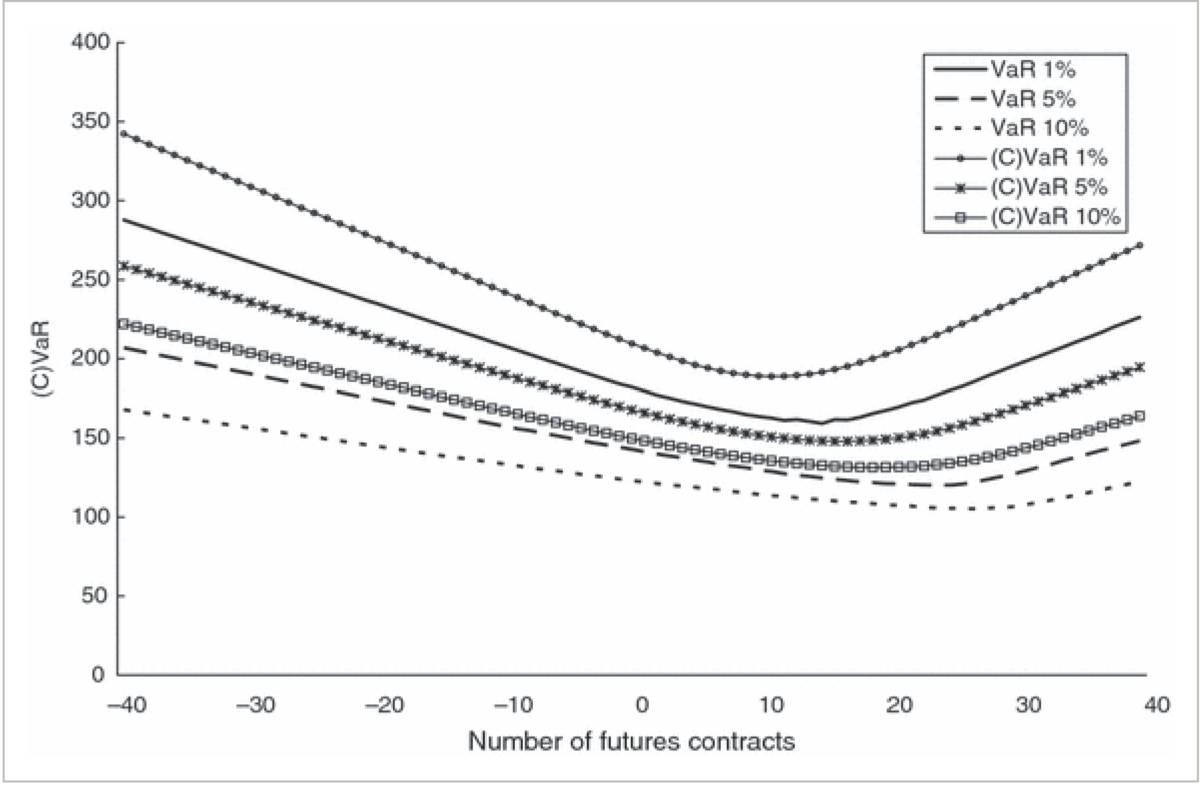

Figure 5

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An illustration of value-at-risk (VaR) and conditional VaR (CVaR) of the hedged position with window knock-in knock-out and Korean won/US$ futures for the contract no. 1 on 12 March 2007.

Table 6 illustrates the payoffs from the futures and wKIKO option positions for contract no. 1 initiated on 11 December 2006. The risk is managed from 12 November 2007 judged by VaR with 95% confidence. The number of futures contracts is decided as explained above. The futures position is rebalanced at each valuation date. The payoff from this futures position is calculated simply by multiplying the changes in futures prices during the holding period by the notional amount of the futures contracts held. For simplicity, we ignore the effects of margin deposits on the payoff. In this particular case, the company lost KRW6.1bn from the wKIKO option. However, if the company had assessed the risk and managed it using futures only once in a month, then the company might have earned KRW1.6bn, which could have partly compensated the loss from the wKIKO option.

Table 6. An illustration of the payoffs from futures and window knock-in knock-out (wKIKO) option positions

Date	Maturity (month)	No. futures contracts	Position built	Position unwound	Payoff from futures (million KRW)	Payoff from wKIKO (million KRW)
			Position built	Position unwound		
12 November 2007	13	−40	909.1	923.8	−382.2	27.8
11 December 2007	12	−23	920.5	937.2	−230.5	9.4
11 February 2008	10	−1	946.3	970.2	−12.0	−80.0
11 March 2008	9	23	971.0	975.7	48.6	−102.8
11 April 2008	8	25	974.5	1043.1	686.0	−378.8
13 May 2008	7	39	1045.2	1030.8	−196.6	−320.0

We do similar experiments for the other contracts and report the results in Table 7. In sum, the futures position could yield positive payoffs and compensate 47.5% of the loss from the wKIKO options. However, the compensation ratios vary across contracts. All but one contract produce positive ratios. Contract no. 4 yields a ratio of −20.7%. This might be because contract no. 4 was terminated on 10 September 2008, earlier than the period of sharp depreciation of the KRW.

Table 7. Payoffs from futures and window knock-in knock-out (wKIKO) option positions
KRW, Korean won.

Contract no.	Payoff from futures (million KRW)	Payoff from wKIKO (million KRW)
1	1576.2	−6101.0
2	2536.9	−3125.6

Contract no.	Payoff from futures (million KRW)	Payoff from wKIKO (million KRW)
Total	32290.6	−67929.0

These experimental results imply that if the companies had continuously assessed risk and tried to manage it, then the losses from the wKIKO options could have been considerably lessened. We might underestimate the benefits from appropriate risk assessment and management for the following reasons: We assessed and managed risk only once a month at the predetermined valuation date. If we relax this restriction into continuous risk assessment and management, the results might be better. We also used only one instrument for hedging. We can expand the class of instruments to be used for hedging purposes. Risk management might deliver better outcomes by using more sophisticated methods.

6. Pricing Issues of Knock-in Knock-out Options

Whether the KIKO options were fairly priced or not has been a controversial issue. In addition, this pricing issue may be related to the previous risk management analysis. By investigating whether the KIKO options were fairly priced or not and by measuring the impact of KIKO option mispricing, we may assess which factor is more responsible for the KIKO option debacle: the mispricing or the risk management failure. These pricing issues are investigated in this section.

6.1 Knock-in Knock-out Option Pricing

To investigate whether the KIKO options were fairly priced or not, we apply simulation methods, which are expected to work relatively well because of the complex structure of the option.[10] As a benchmark KRW exchange rate process, we consider the version of the Black and Scholes (1973) process developed by Garman and Kohlhagen (1983), where the exchange rate satisfies the following dynamics:

$$\frac{dS_t}{S_t} = (r - r_f)dt + \sigma d\hat{W}_t. \quad (4)$$

In their model, r and r_f are the constant domestic and foreign interest rate, respectively. σ denotes the volatility and $d\hat{W}_t$ the increment of a standard Wiener process under the risk-neutral measure $\hat{P}$. We use a cross-currency swap interest rate as the domestic interest rate, r, and the US dollar IRS rate as the foreign interest rate, r_f.[11] We utilize as the volatility, σ, the implied volatility (the average of bid and where time is discretized into equal intervals of Δt, and $\Delta \widehat{W}_t$ denotes a random variable following $N[0, \Delta t] \rightarrow N(0, \Delta t)$. The wKIKO option is priced as the mean of the discounted payoffs of the wKIKO option for each simulated KRW exchange rate path.

As an alternative exchange rate process, we adopt the GARCH process, which has been also used for the previous risk management analysis. Options should be priced under a risk-neutral measure. However, the GARCH process in section 4 was estimated under a physical measure, *P*; therefore, it cannot be directly used for option pricing purposes. Duan (1995) develops the relationship between GARCH processes under a physical measure and under a risk-neutral measure, which can be used for pricing options under GARCH processes. Under a physical measure, the one-period return rate of foreign currency (US dollar) is assumed to follow a GARCH-type process:

$$\begin{aligned} s_t &= (r - r_f) + \lambda\sqrt{h_t} - \frac{1}{2}h_t + \varepsilon_t,\ \varepsilon_t \sim N(0, h_t), \\ h_t &= k + \sum_{m=1}^{P} g_m h_{t-m} + \sum_{n=1}^{Q} d_n \varepsilon_{t-n}^2. \end{aligned} \qquad (6)$$

Then, under the pricing measure $\hat{p}$, the return rate follows the below GARCH-type process:

$$\begin{aligned} s_t &= (r - r_f) - \frac{1}{2}h_t + \xi_t,\ \xi_t \sim N(0, h_t), \\ h_t &= k + \sum_{m=1}^{P} g_m h_{t-m} + \sum_{n=1}^{Q} d_n \left(\varepsilon_{t-n} - \lambda\sqrt{h_{t-n}}\right)^2. \end{aligned} \qquad (7)$$

Here the pricing measure $\hat{p}$ is said to satisfy the locally-risk-neutral valuation relationship; that is: (i) $\hat{p}$ is mutually absolutely continuous with respect to *P*; and (ii) under $\hat{p}$, the conditional gross return rate follows lognormal distribution with mean of $r–r_f$ and variance of h_t. As in section 4, we take (2, 1) for (*P, Q*) and take both the short sample periods from 4 January 2000 and the long sample periods from 3 January 1997 until each KIKO option contract date for estimation. Once the GARCH process of equation (6) is estimated under physical measure *P*, we simulate exchange rate paths by utilizing equation (7) for pricing wKIKO options.

Table 8 reports the pricing results under both the Black and Scholes and the GARCH exchange rate processes. The option prices are expressed as the ratio of the expected discounted payoff from the wKIKO option to the notional amount. If there is no transaction or other hedging cost, then the fair option prices are zero. (The wKIKO options are constructed to be 'zero cost' so that customers do not overpriced than the Black and Scholes model. We may infer from this fact that market expectations at the wKIKO option transaction times might be too myopic and too confident given the low level of volatility at that time. Estimation using the long sample data also results in the wKIKO option prices being more overpriced than with the short sample data under the GARCH model. In sum, the wKIKO options were not significantly overpriced in most cases.

Table 8. Window knock-in knock-out (wKIKO) option prices

'Notional amount' indicates the notional amount (US$) settled each month when two barriers are not triggered. 'wKIKO option prices' means the ratio of the expected discounted payoff from the wKIKO option to the notional amount. 'Short period' starts from 4 January 2000, and 'long period' from 3 January 1997.

Contract no.	Date	Maturities (month)	Notional amount (monthly, USD)	wKIKO option prices (%)		
				Black and Scholes	GARCH (short period)	GARCH (long period)
1	11 December 2006	24	2000000	−0.9	−1.4	−3.0
2	7 March 2007	28	1000000	−0.5	−2.6	−4.3
3	25 May 2007	30	2000000	−0.8	−2.2	−3.8
4	10 September 2007	12	2000000	0.4	−1.0	−1.3
5	9 January 2008	11	4000000	−2.0	−2.9	−3.1
6	16 January 2008	11	4000000	−2.9	−3.6	−3.8
7	22 January 2008	35	2000000	−5.5	−6.6	−8.3
8	28 January	11	2000000	−1.0	−1.8	−2.1

parameters. Positive adjustment would make the overpriced contract fairly priced. Then, we investigate how much these adjustments affect the losses from the wKIKO option transactions.

Table 9 demonstrates the required adjustment of *K* and *H*. For the Black and Scholes model, only three contracts need to be adjusted, while most contracts need to be adjusted under the GARCH models. The amount of adjustment is positively related with the degree of overpricing; therefore, the GARCH models require greater adjustment than the Black and Scholes model, and the estimation with the long sample data requires greater adjustment than with the short sample data. These positive adjustments improve the payoffs from the wKIKO options, and this improvement tends to be greater as the adjustment becomes greater. As indicated in Table 9, these adjustments might save 5.1% of the losses from the wKIKO options under the Black and Scholes model. This improvement increases under the GARCH models: by 10.4% (for the short sample) and 16.7% (for the long sample). Small adjustment in option contracts might yield considerable change in option payoffs. For example, adjustment of 2% from −3 to −1% in the option price (contract no. 1) results in the reduction of losses by 24.3% under the GARCH model with the long sample data. There are 1, 4, and 5 cases under the Black and Scholes and the GARCH models (for the short and long samples), respectively, where the reduction of the losses exceeds 10%.

Table 9. Impact of window knock-in knock-out (wKIKO) option mispricing
‘Notional amount’ indicates the notional amount (US$) settled each month when two barriers are not triggered. ‘Payoffs of wKIKO’ denotes actual payoffs for each contract. ‘Adjustment of wKIKO options’ indicates the amount to be added into K and KI for each contract to ensure the wKIKO price of −1%. ‘Short period’ starts from 4 January 2000, and ‘long period’ from 3 January 1997. ‘Payoff changes of wKIKO’ denotes the changes in payoffs of wKIKO options resulting from the adjustment of wKIKO option contracts. Numbers in the parenthesis are the ratios (%) of the payoff changes to the payoffs of wKIKO options. GARCH, generalized autoregressive conditional heteroskedasticity; KRW, Korean won.

Contract no.	Date	Maturities (month)	Notional amount (monthly, USD)	Payoffs of wKIKO (million KRW)	Adjustment of wKIKO option contracts			Payoff changes of w (million KRW)	
					Black and Scholes	GARCH (short period)	GARCH (long period)	Black and Scholes	GARCH (short period)
1	11 December 2006	24	2000000	−6101.0	0.0	3.9	21.9	0.0 (0.0)	265.6 (4.4)

Contract no.	Date	Maturities (month)	Notional amount (monthly, USD)	Payoffs of wKIKO (million KRW)	Adjustment of wKIKO option contracts			Payoff changes of w (million KRW)	
					Black and	GARCH (short	GARCH (long	Black and	GARCH (short

From the risk management analysis in section 5, we found that proper risk assessment and management could prevent or significantly reduce the financial losses from the wKIKO options. However, potential impacts of the possible wKIKO option mispricing are considerable only in few cases. The risk management failure proves to be more responsible for the KIKO option disaster than the possible mispricing problem.

7. Conclusion

In this paper we analyzed the 'KIKO option losses' from the view point of risk assessment and management. We found the following: (i) If the companies had assessed the risk levels with and without the KIKO options by using standard risk measures like VaR or CVaR, then many wKIKO option contracts would not have been justifiable as hedging instruments at purchase time. (ii) Having a proper view on the exchange rate dynamics turned out to be crucial for risk assessment and management. If the companies had a proper view instead of a myopic view on the exchange rate movement, then the wKIKO options might not have been chosen for hedging. (iii) 'Hedge-and-forget' behavior proved to be very reckless. If the companies had continuously assessed and managed their risks, then the losses from the wKIKO options could have been significantly mitigated.

We also investigated some pricing issues relevant with the KIKO option losses. We found that: (i) most KIKO option contracts under study might not be significantly overpriced; (ii) the potential impacts of the possible mispricing could be considerable in some cases; and (iii) the risk management failure proves to be more important for the KIKO option losses than the possible mispricing problem.

These results basically emphasize the importance of implementing appropriate risk assessment and management. These lessons could be valuable in preventing the recurrence of similar events. Because KIKO-option-like events in the derivatives industry can occur in other countries, this event analysis and the lessons thereof are also applicable to other countries. In addition, we believe this KIKO option disaster of 2008 should be listed as one of the risk management failure examples in the derivatives-related major catastrophes.

However, our results should be interpreted with caution. It is not only the companies (clients) who are responsible for this KIKO option disaster. The FX banks (option sellers) should carry out their business

3 The Q-test and the ARCH-test for the standardized innovations indicate non-existence of ARCH effects for 10 lags of the autocorrelation function but existence of the effects for 15 or 20 lags; however, we stop expanding the model for the sake of model parsimony.
4 The model with (1,0)/(2,1) can also be chosen.
5 Being afraid of unexpected adverse effects on the company, we do not provide the company name. The information is obtained at http://dart.fss.or.kr/ or http://englishdart.fss.or.kr.
6 This assumption implies the case where the company might be overhedged when the knock-in event is triggered. We employ this assumption because the disastrous 'KIKO' option events are related to these overhedged cases, which we want to focus on. Of course, if these overhedged cases are not supposed in the analysis, then the effects of the KIKO options on both overall profits and risk measures will be reduced.
7 The IRS yield curve is used because it provides rich information, particularly for short-term maturities. What the appropriate discount factor is may be controversial. However, the choice of discount factor might not be an important issue in this analysis.
8 By assuming that it is more appropriate to be concerned about the overall risky position rather than just the KIKO position, risk measures are calculated for the hedged (i.e. combined position of foreign currency and the KIKO) positions.
9 The futures prices are available at http://www.krx.co.kr.
10 A closed-form pricing formula for the wKIKO option has not been developed yet. Efficient methods other than simulation are possibly developed but are not reported yet.
11 A CRS contract requires an exchange between a fixed KRW interest rate and a US dollar Libor. An IRS contract indicates an exchange between a fixed (US dollar) interest rate and a floating (US dollar) interest rate. A combination of CRS and IRS denotes an exchange between a fixed KRW interest rate and a fixed US dollar interest rate, which are appropriate market interest rates for equation (4).
12 Implied volatility data are kindly provided by Reuters Korea. We use implied volatility of 1 year, which is the longest available horizon among market quotes.

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