

# A prudent margin setting methodology that controls the frequency of margin changes

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*The purpose of a margin requirement is to protect a clearinghouse from members' defaults resulting from big losses due to adverse movement of futures prices. This paper proposes a margin methodology that can both protect the clearinghouse and control the expected number of margin changes per year. Under this approach, margin level will depend on a volatility forecast. This paper shows that among a large number of volatility forecasts implied volatility gives the best results. This confirms a conjecture that implied volatility may have more information content than other forecasts of future volatility based on historical data.*

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## 1. Introduction

In all financial markets, the institutions responsible for clearing and settlement are the exchange and the clearinghouse, particularly the latter. Bernanke (1990) points out that in some markets, the clearinghouse is a part of the exchange; otherwise, it is a separate nonprofit corporation. Also, all clearinghouses function as an association of the clearing members. Being members of the clearinghouse, private firms acquire the right to clear trades (of futures or options) of their own customers and for non-member firms. Furthermore, members can also do proprietary trading and clear trades on their own. Consequently, a clearing member may end up with a net position. The clearinghouse stands in the centre of the settlement process, disbursing payments and receiving payments to and from clearing members. Thus a clearinghouse acts as

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a centralized counter-party and assumes the default risk of its clearing members. This setup greatly reduces the members' counter-party risk since the clearinghouse is well known to be very prudent in risk management and is backed up by a substantial amount of reserve funds.

Being a centralized counter-party, a clearinghouse normally bears no market risk since at all times, the market values of the long and the short positions cancel each other. However, a clearinghouse is exposed to its members' default risk. When a clearing member defaults, the clearinghouse needs to liquidate the member's position. A clearing member defaults because its clients do so, or because the loss in its own proprietary account forces it to do so. In view of the members' default risk, a clearinghouse may adopt various measures. It may require a member to have a minimum capital level, pay up a guarantee fund, or report regularly its firm capital, to name just a few. Among all the risk management measures, the most substantial one is to put up an initial/maintenance margin, and to require members to do likewise for their clients.

The purpose of a margin requirement is to protect a clearinghouse from members' defaults resulting from big losses due to adverse movements of futures prices. Hence, a clearinghouse should impose a margin level such that margin money collected can cover the future price swing with a large probability. To achieve this goal, Duffie (1989) suggested statistical methods to determine a margin level to guard against a default. In the earlier literatures, normality assumption was usually adopted for calculating an appropriate margin. Later, Warshawsky (1989) showed that the usual normality assumption is inappropriate. In lieu of the normal assumption, Kofman (1993), Longin (2000) and Cotter (2001) used extreme value theory to determine an appropriate margin level. Booth, Broussard, Martikainen and Puttonen (1997) and Booth and Broussard (1998) documented that the use of extreme-value statistical techniques to various futures contracts may be beneficial to the margin-setting committee which holds the final authority in margin determination.

While a margin committee of a clearinghouse would not follow a mechanical formula in setting the margin, they do use some benchmark formula as a reference in their margin decision process. Since statistical theory suggests that the default probability depends on market volatility, such benchmark formula invariably includes a volatility forecast as one of the key determinants in a margin formula. The benchmark margin is often set to be equal to a constant multiple of a volatility forecast. See for instance Lam, Lee, Cox, Leung and Zhou (1999), a report of the Hong Kong Futures Exchange and Clearing Corporation of which the third author K. Lam was a Board director. For

instance, if a clearinghouse adopts a multiplier equal to 3 and if the daily volatility is forecasted to be 2%, the maintenance margin level per contract is suggested to be  $3 \times 2\% = 6\%$  of the contract value. Different clearinghouses would adopt different constant multipliers, depending on how much coverage probability they want to achieve. Needless to say, the larger the multiplier is, the larger the coverage probability will be. The following table is taken from Lam, Sin and Leung (2004), in which they tabulated the multipliers adopted by clearinghouses in various markets in the world. In the table below,  $T$  refers to the number of data points used to compute a historical volatility.

**Table 1: Choices of  $T$  and  $k$  in Various Clearinghouses**

Exchange/clearinghouse	Choice of $T$	Choice of $k$
Chicago Mercantile Exchange	$T = 1, 3, 6$ months	$k = 1.96$
Board of Trade Clearing Corporation	$T = 30, 90, 125$ days	$k = 1.96$
The Options Clearing Corporation	$T = 3$ months, 1 year	$k = 1.96$
London Clearing House	$T = 60$ days, 2 years (concentrate on 60 days)	$k = 3$
Singapore International Monetary Exchange	$T = 30, 90, 180$ days	$k = 2$ to 3
Sydney Futures Exchange Clearing House	$T$ large (long-term)	$k = 2.58$

To sum up, there are two critical inputs in calculating a benchmark margin. The first is the volatility forecast to be used and the second is the magnitude of the constant multiplier  $k$ . In view of the fact that the normality assumption is not valid, it is difficult to determine  $k$  *a priori*. Thus, the most sensible way to determine a constant multiplier is to make it compatible with a small default probability deemed appropriate by the margin committee. In other words, the constant multiplier should be determined empirically using historical data.

In this regard, Lam et al. (2004) reported that in the Hong Kong market, if volatility of returns in the past 60 days is used as a volatility forecast, in order to maintain a 95% chance of coverage,  $k$  is estimated as equal to 2.087. However if a GARCH (generalized auto-regressive conditional heteroskedasticity) model is adopted, to achieve the same coverage probability, the estimate for  $k$  becomes 2.580. From the above discussion, it seems that it does not matter whichever volatility forecast is to be

used because the constant multiplier can always be adjusted so that the margin collected can attain the same goal, that is, maintaining a coverage probability deemed appropriate by a margin setting committee. To compare various volatility forecasts, Lam et al. (2004) introduced another dimension of margin effectiveness. They argued that while margin determination should be prudential, a high margin level drives up the investors' cost. The opportunity cost imposed on investors who pay up the margin should also be taken into consideration. It is this extra dimension that can differentiate between the effectiveness of various volatility forecasts.

## **2. How not to overcharge the investors**

While the primary concern for a clearinghouse is to have a prudential margin system to guard against members' default, the clearinghouse also has to play a role in protecting the interests of the public as specified by the Exchanges and Clearinghouses (Merger) Ordinance (Caption 555). The ordinance requires the HKEx to maintain an orderly and fair market, and to manage risks prudentially. Thus a clearinghouse should take measures not to overcharge the investors and also should maintain a stable margin requirement and not to change the margin requirement too frequently. To take care of the former, Lam et al. (2004) formulated measures of opportunity cost and compare volatility forecasts in terms of such opportunity costs. These measures include (1) the average margin level in the long run, and (2) the amount of overcharge which is defined as  $E[(M - L)^+]$  where  $M$  is the required margin and  $L$  is the actual loss suffered by the investor. Specifically, they compared three variants of volatility forecasts, namely (1) simple moving averages of historical volatility (SMA of HV), (2) exponentially weighted moving averages of historical volatility (EWMA of HV), and (3) a volatility forecast based on the GARCH model. They concluded that as far as Hong Kong market is concerned, (3) is better than (2) which in turn is better than (1), in the sense that (3) saves the most amount of money for investors in the futures market while the same default risk level of the clearinghouse is maintained. In Figure 2 in Lam et al. (2004), it can be seen that the GARCH model achieves the minimum overcharge across all prudential levels measured by the coverage probability.

Although it is found that the GARCH approach out-performs other approaches based on average opportunity cost, their results show that the GARCH approach may sometimes suggest rather extreme margin levels as compared to the other approaches. If we mechanically adopt a GARCH approach, we also run the risk of

changing the margin levels rather frequently. This is of course an undesirable outcome. According to Fenn and Kupiec (1993), it is costly to change margin requirement too frequently. For example, they point out that in a sample period of 7 years, margins were changed 10 times on the S&P500, 7 times on the NXSE Composites. Also within a span of five years, MMI changes its margin 11 times. It seems that most of the clearinghouses change their margin not more than 3 times a year in a longer run. Thus a practical concern in margin policy is the frequency of margin changes. This paper will compare margin setting methodologies taking these practical considerations into account. As pointed out by Brenner (1981), the designated margin committee in a clearinghouse should have the discretion to set the margin taking all factors into consideration. In particular, practical factors like the frequency of margin changes should play a part in their decision process.

### 3. Methodology to maintain margin at a stable level

To maintain market stability, a margin committee may not like to have the margins changed so frequently. As suggested by Fenn & Kupiec (1993), it may be costly to alter margin requirements. They propose that “The margin committee might set initial margin higher on average and not reset margin until it has a higher degree of confidence that volatility has substantially changed.” If we adopt this approach by Fenn & Kupiec (1993), then although a GARCH model may suggest an increase of volatility, the margin committee may still hold the margin at its current level, unless the increase is substantial. To implement this idea, we introduce two parameters  $k(k \geq 0)$  and  $b(0 \leq b \leq 1)$  where  $k$  is sensitive to volatility changes and  $b$  is intended to control the frequency of margin changes. An operational scheme can be introduced as follows. At day one when the futures closes at  $f_1$  and volatility forecast  $\hat{\sigma}_1$  is , we consider margin band  $f_1 k \hat{\sigma}_1 (1 \pm b)$  and charge margin at the upper band level i.e.  $f_1 k \hat{\sigma}_1 (1+b)$ . The margin charged as well as the margin band will remain unchanged until at one day, say day  $t$ , the volatility forecast  $\hat{\sigma}_t$  gives a value which  $f_t k \hat{\sigma}_t$  falls outside the existing margin band. If  $f_t k \hat{\sigma}_t$  exceeds the upper level of the margin band, or if  $f_t k \hat{\sigma}_t$  is smaller than the lower level of the margin band, reset margin at  $f_t k \hat{\sigma}_t (1+b)$  and reset the margin band as  $f_t k \hat{\sigma}_t (1 \pm b)$ . The updated margin level and the margin band will remain unchanged until the next breakout.

In this paper, we recognize that in a practical approach to margin setting, we need to maintain a high coverage probability as well as having a stable margining system. The

nice things about the previous scheme is that we have two parameters  $k$  and  $b$  and we can find a suitable combination of  $k$  and  $b$  to achieve both goals. For example, when historical volatility is used as a volatility forecast, to achieve a coverage probability of 99% and to maintain a frequency of change equal to six times a year in the HSIF market in Hong Kong, empirical data show that this can be achieved by setting  $k = 2.518$  and  $b = 0.352$ . The only question that remains is which volatility forecasts should be used as an input to the practical margin setting scheme. To compare two volatility forecasts, we can first set  $k$  and  $b$  so that both forecasts give rise to the same coverage probability and the same frequency for margin changes. The two volatility forecasts can then be compared by the theoretical framework proposed by Lam, Sin and Leung (2004).

#### **4. Volatility forecasts to be compared**

The usual volatility forecasts to be compared are (1) historical volatility based on equal weighting of past data (abbreviated as HV), (2) historical volatility based on exponential weighting of past data (abbreviated as EWMA), (3) A GARCH model on historical returns (abbreviated as GARCH), or (4) A GARCH model on historical returns with built in asymmetry (abbreviated as GARCH-GJR). In this paper, we broaden the scope to include other volatility forecasts deemed as important by recent literature. As a forecast of the subsequent market volatility, implied volatility is widely believed to be informationally superior to other alternatives because it is the 'markets' forecast of future volatility. Thus in the list of volatility forecasts to be compared, we also include (5) Implied volatility (abbreviated as IV) and (6) Implied volatility with exponential smoothing (abbreviated as IV-EWMA). The reason why we perform exponential smoothing on IV is that it is not uncommon for exponential smoothing to improve on forecasting results. Thus, despite the fact that there is no *a priori* reason for exponential smoothing, we include it to have a more comprehensive comparison. Other than implied volatility, realized volatility based on intraday returns such as the five minute returns also received much attention by recent researchers. In Anderson et al. (2003), a framework to integrate high-frequency intraday data into the measurement, modelling and forecasting of daily return volatilities. Hence the list of volatility forecasts is not complete if we omit RV from the list. In this paper, we also consider volatility forecasts based on RV and include in our study (7) Realized volatility (abbreviated as RV) and (8) Realized volatility with exponential smoothing (abbreviates as RV-EWMA).

After listing the various volatility forecasts to be used as possible inputs in a margin setting system, we now tackle the question as to which forecast is the most effective as a margin determinant. As we have pointed out in previous sections, coverage probability and frequency of margin changes are not important in the comparison because these prescribed levels can all be met by properly designed parameters  $k$  and  $b$ . The only dimension that can now be compared is: which forecast can give us a margin that saves investors from being overcharged. For this purpose, we adopt the AOV (average overcharge) criterion introduced by Lam, Sin and Leung (2003). Data that will be used for the comparison will be described in Section 5 and empirical results will be reported in Section 6.

## 5. Data

The Hang Seng Index Futures (HSIF) market is chosen for comparing the effectiveness of the various volatility forecasts, listed in Section 4. The HSIF market is a relatively volatile market. Immediately after the world stock market crash in 1987, the Hong Kong Futures Exchange has gone through a crisis of near bankruptcy and was saved by a government loan in 1987. Since then, it has gone through some major restructuring and has paid back its loan from the government. The Futures Exchange has since been very prudent in setting its margin level and its prudence pays off in safely weathering the Asian financial crisis when the Hong Kong dollar was under attack by hedge fund managers in 1998. Before Year 2000, the Hong Kong Stock Exchange, the Futures Exchange and the Clearing Corporation are three different entities. They are merged into the Hong Kong Exchanges and Clearing under a demutualization act put forth by the Hong Kong Government in Year 2000. The data sample covers the period from August 1, 1996 to May 30, 2006, which amounts to a total of 2,424 observations. In Table 2 below, summary statistics for the index futures are given for the whole period and several sub-periods. Here the sub-periods are



**Table 2: Summary Statistics for HSI future return (in %) with different sub-periods**

	Full Period	Sub-period 1	Sub-period 2	Sub-period 3
Mean	0.0165	0.0310	-0.0484	0.0669
Median	0.0347	0.0347	-0.0866	0.0958
Standard Deviation	1.94	2.61	1.81	1.08
Skewness	0.37	0.51	-0.08	-0.25
Kurtosis	12.58	9.88	2.00	1.60
Minimum	-16.09	-16.09	-8.90	-4.65
Lower Quartile	-0.88	-1.13	-1.13	-0.49
Upper Quartile	0.92	1.31	0.98	0.64
Maximum	22.15	22.15	6.44	4.05

For *HV* computations, daily closing prices for futures contracts will be collected to compute the daily returns. In order to mitigate the expiration effects, we follow the suggestion of Puttonen (1993) and shift over to the next nearest futures contract one day before the expiration of the nearest futures. For *HV* without exponential smoothing, a 90-day *HV* is computed. For exponential smoothing, a smoothing factor of 0.96 is used. For *IV* computations, we need to compile the prices of near-the-money options at the market close. Apart from the daily data, we also use the intradaily tick-by-tick data to construct the realized volatility (*RV*) for each trading day. Following Taylor and Xu (1997) and Fleming, Kirby and Ostdiek (2003) (see also Müller et al., 1990 and Dacorogna et al., 1993), we compute the five-minute *RV* from the tick-by-tick data provided by the HKEx. More precisely, for each trading day, the raw *RV* is simply the average of the square of five-minute returns of HSIF. In Table 3 below, summary statistics concerning the various forecasts are provided.

## 6. Empirical results

In this Section, we consider various prescription of coverage probability and the yearly expected change frequency for margins. Coverage probabilities considered in this paper include: 98%, 99%, 99.4% and 99.8% and yearly expected change frequency of 3 and 6 times are considered. For each pair of prescribed values, and for each type of volatility forecast, we find a combination of  $k$  and  $b$  value to achieve the prescribed goal. The  $k$  and  $b$  values achieving the prescribed goal are reported in Table 3 below.

**Table 3:  $k$  and  $b$  for different volatility forecast methods**

CP	Yearly expected change frequency	HV				IV		RV	
		HV	HV-EWM A	GARCH	GARCH-GJR	IV	IV-EWM A	RV	RV-EWM A
99.8%	3	3.387, 45.2%	3.276, 53.8%	2.708, 52.9%	2.345, 54.0%	2.143, 68.6%	3.516, 36.3%	1.862, 88.3%	2.977, 39.8%
	6	3.43, 33.4%	3.525, 47.1%	2.568, 42.4%	2.527, 44.5%	2.279, 56.0%	3.47, 29.4%	1.924, 83.3%	3.149, 32.7%
	Unrestricted	4.538, 0%	4.127, 0%	3.282, 0%	3.05, 0%	3.233, 0%	4.262, 0%	4.181, 0%	3.924, 0%
99.4%	3	2.496, 44.5%	2.245, 57.0%	1.992, 52.8%	1.964, 53.7%	1.898, 68.6%	2.720, 36.1%	1.558, 90.5%	2.639, 39.9%
	6	2.766, 34.9%	2.358, 49.7%	2.201, 42.7%	1.946, 44.6%	2.08, 55.9%	2.761, 29.4%	1.65, 84.1%	2.686, 32.6%
	Unrestricted	3.523, 0%	3.549, 0%	2.718, 0%	2.665, 0%	2.981, 0%	3.249, 0%	3.545, 0%	3.301, 0%
99%	3	2.259, 45.1%	2.026, 57.4%	1.807, 53.0%	1.778, 53.6%	1.642, 68.7%	2.403, 36%	1.289, 90.1%	2.29, 40.1%
	6	2.518, 35.2%	2.187, 50.0%	1.944, 42.9%	1.827, 44.6%	1.943, 55.8%	2.521, 29.4%	1.401, 83.8%	2.347, 32.9%
	Unrestricted	3.304, 0%	3.139, 0%	2.489, 0%	2.353, 0%	2.835, 0%	2.977, 0%	3.251, 0%	2.99, 0%
98%	3	2.003, 46.0%	1.719, 63.7%	1.623, 53.2%	1.54, 53.5%	1.484, 68.8%	2.013, 36.4%	1.061, 90.0%	1.896, 40.8%
	6	2.09, 35.0%	1.814, 49.7%	1.738, 43.0%	1.647, 44.6%	1.705, 55.9%	2.141, 29.2%	1.182, 83.9%	2.084, 31.3%
	Unrestricted	2.736, 0%	2.726, 0%	2.133, 0%	2.068, 0%	2.558, 0%	2.641, 0%	2.798, 0%	2.617, 0%

In Table 3 above, the unrestricted row refer to the simple case that we do not put any control on the number of margin changes. It can be noted that the  $k$  values for the

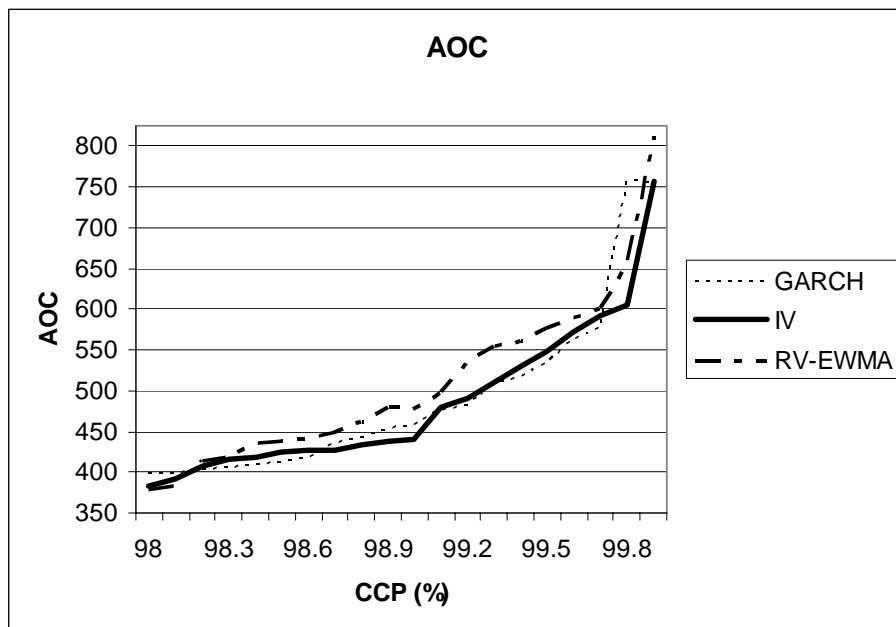
unrestricted case are generally bigger than the k values in the restricted cases. This is not surprising because in the unrestricted case, margins are driven by two parameters k and b. The b values range from 30% to 80 % for all the volatility forecasts and it is interesting to note that the k values for IV and RV are relatively small and the b values for IV are relatively large.

As is mentioned in Section 2, we will use two measures to compare the effectiveness of the volatility forecasts. One measure is simply the margin charged and the other is the amount of overcharge imposed on an investor. The average amount of overcharge is presented in Table 4 below. The numbers in brackets are the corresponding standard errors of the reported average values. The results on the average margin charge will be reported in Section 7 where both margin levels and margin adjustments will be studied in details.

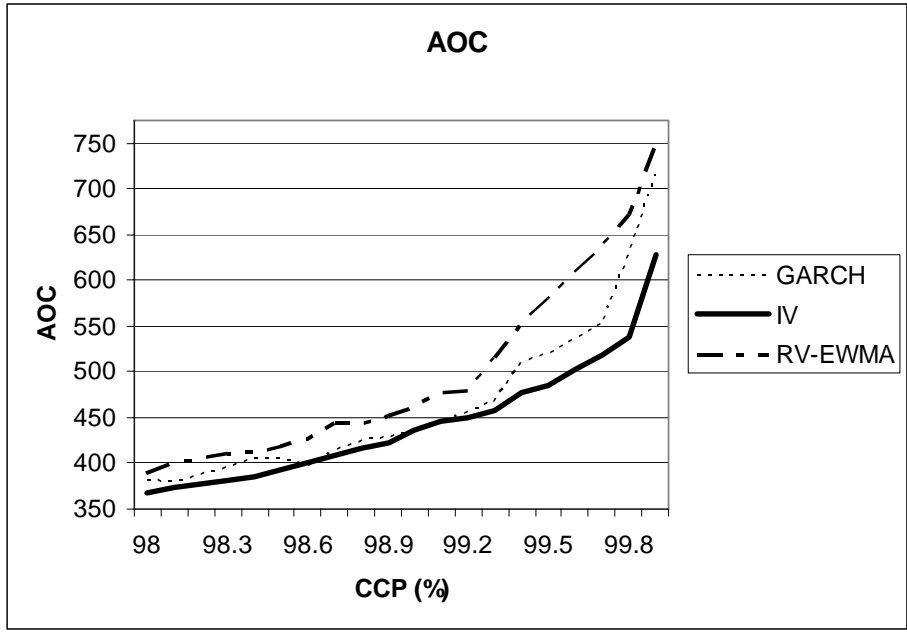
**Table 4: Average overcharge for different volatility forecast methods**

CP	Yearly expected change frequency	HV				IV		RV	
		HV	HV-EWMA	GARCH	GARCH -GJR	IV	IV-EWMA	RV	RV-EWMA
99.8%	3	832.6	913.9	757.3	665.3	<b>605.6</b>	765.1	918.0	656.5
		(9.20)	(10.98)	(8.33)	(6.96)	<b>(6.34)</b>	(7.03)	(12.73)	(6.68)
	6	756.3	929.7	629.2	673.2	<b>537.6</b>	703.5	795.4	672.1
		(8.40)	(11.16)	(7.09)	(6.87)	<b>(5.25)</b>	(6.55)	(9.24)	(6.79)
	Unrestricted	801.3	720.1	550.5	542.7	<b>485.7</b>	699.2	661.1	648.5
		(8.70)	(8.27)	(5.88)	(5.72)	<b>(4.88)</b>	(6.32)	(8.03)	(6.37)
99.4%	3	558.3	595.7	<b>517.7</b>	532.5	529.4	558.6	901.7	561.4
		(6.66)	(8.20)	<b>(6.16)</b>	(5.83)	(5.89)	(5.40)	(10.41)	(6.08)
	6	601.2	598.0	510.5	486.0	<b>477.6</b>	533.8	690.2	551.4
		(7.15)	(7.85)	(5.73)	(5.34)	<b>(4.79)</b>	(5.30)	(7.65)	(5.82)
	Unrestricted	588.8	598.5	<b>430.5</b>	455.5	436.4	498.2	538.1	522.2
		(6.77)	(7.12)	<b>(4.89)</b>	(5.01)	(4.53)	(4.92)	(6.76)	(5.40)
99%	3	494.4	519.9	457.4	468.1	<b>439.8</b>	475.5	738.6	477.7
		(6.05)	(6.99)	(5.63)	(5.30)	<b>(5.15)</b>	(4.84)	(10.75)	(5.44)
	6	533.3	549.4	<b>434.4</b>	447.7	436.4	475.8	563.6	461.4
		(6.46)	(7.24)	<b>(5.10)</b>	(5.03)	(4.50)	(4.87)	(6.48)	(5.01)
	Unrestricted	543.1	512.5	<b>381.9</b>	385.2	407.9	444.5	481.3	459.4
		(6.35)	(6.32)	<b>(4.50)</b>	(4.45)	(4.33)	(4.55)	(6.18)	(4.92)
98%	3	428.0	465.7	397.5	386.7	383.6	<b>377.6</b>	583.3	378.9
		(5.33)	(6.85)	(5.10)	(4.63)	(4.72)	<b>(4.13)</b>	(7.96)	(4.34)
	6	414.5	418.0	381.9	392.3	<b>366.7</b>	383.5	456.5	388.6
		(5.27)	(5.82)	(4.80)	(4.60)	<b>(4.02)</b>	(4.23)	(5.43)	(4.39)
	Unrestricted	425.4	426.5	<b>307.1</b>	321.6	354.3	378.6	394.3	384.5
		(5.29)	(5.52)	<b>(3.02)</b>	(3.96)	(3.95)	(4.10)	(5.30)	(4.36)

In Table 4, the volatility forecasts that give rise to the smallest AOC (average overcharge) or the smallest average margin level is bolded for each prescribed level of coverage probability and frequency changes. It can be seen that IV has the best performance among all volatility forecasts, especially for high coverage probability like 99.8%. GARCH as a volatility forecast also performs well. It seems that these two forecasts are the main competitors as far as AOC is concerned. In the situation where GARCH beats IV, the difference is only minimal but in the situation when IV beats GARCH, the differences are more substantial. This can be well depicted by the graphs presented in Figures 1 and 2 below:



**Figure 1: AOC against CCP (change = 3 per year)**



**Figure 2: AOC against CCP (change = 6 per year)**

To decide which difference is significant and which is not, we compute the pair-wise differences and the results are presented in Tables 5 and 6 below when coverage probability is 99.8% and when the expected number of margin changes is equal to three or six per year.

**Table 5: Pairwise difference of AOC for different volatility forecast methods**

	EWMA	RV	HV	IV -EWMA	GARCH -GJR	RV -EWMA	GARCH	IV
<b>EWMA</b>	0							
<b>RV</b>	4.1	0						
<b>HV</b>	85.3	81.3	0					
<b>IV-EWMA</b>	152.9	148.8	67.6	0				
<b>GARCH-GJR</b>	160.6	156.5	75.3	7.7	0			
<b>RV-EWMA</b>	252.7	248.6	167.3	99.7	92.0	0		
<b>GARCH</b>	261.5	257.4	176.1	108.5	100.9	8.8	0	
<b>IV</b>	312.4	308.3	227.0	159.4	151.7	59.7	50.9	0

**(CCP = 99.8%, number of change per year = 3)**

**Table 6: Pairwise difference of AOC for different volatility forecast methods**

	EWMA	RV	HV	IV -EWMA	GARCH -GJR	RV -EWMA	GARCH	IV
<b>EWMA</b>	0							
<b>RV</b>	134.3	0						
<b>HV</b>	173.5	39.2	0					
<b>IV-EWMA</b>	226.2	92.0	52.8	0				
<b>GARCH-GJR</b>	256.5	122.2	83.0	30.2	0			
<b>RV-EWMA</b>	257.6	123.3	84.1	31.4	1.1	0		
<b>GARCH</b>	300.4	166.2	127.0	74.2	44.0	42.8	0	
<b>IV</b>	392.1	257.8	218.6	165.8	135.6	134.5	91.6	0

**(CCP = 99.8%, number of change per year = 6)**

In Tables 3 and 4, the differences in AOC for a method in the row and a method in the column are shown. A positive result shows that the method in the row fares better than the method in the column. The corresponding z-scores for testing whether the difference is significantly greater than zero are given in Tables 7 and 8 below.

**Table 7: z-score of difference in AOC for different volatility forecast methods**

	EWMA	RV	HV	IV -EWMA	GARCH -GJR	RV -EWMA	GARCH	IV
<b>EWMA</b>	0							
<b>RV</b>	0.2	0						
<b>HV</b>	5.4	5.7	0					
<b>IV-EWMA</b>	10.5	11.4	5.8	0				
<b>GARCH-GJR</b>	10.6	11.4	6.1	0.7	0			
<b>RV-EWMA</b>	17.4	19.1	14.5	10.1	8.5	0		
<b>GARCH</b>	18.2	20.0	15.5	11.2	9.4	0.9	0	
<b>IV</b>	22.0	24.3	20.3	16.8	14.5	6.3	5.5	0

**(CCP = 99.8%, number of change per year = 3)**



**Table 8: z-score of difference in AOC for different volatility forecast methods**

	EWMA	RV	HV	IV -EWMA	GARCH -GJR	RV -EWMA	GARCH	IV
<b>EWMA</b>	0							
<b>RV</b>	9.3	0						
<b>HV</b>	12.4	3.1	0					
<b>IV-EWMA</b>	17.5	8.1	5.0	0				
<b>GARCH-GJR</b>	19.6	10.6	7.6	3.2	0			
<b>RV-EWMA</b>	19.7	10.7	7.8	3.3	0.1	0		
<b>GARCH</b>	22.7	14.3	11.6	7.7	4.5	4.4	0	
<b>IV</b>	31.8	24.3	22.1	19.8	15.7	15.7	10.4	0

**(CCP = 99.8%, number of change per year = 6)**

It can be seen from Tables 7 and 8 that over a wide range of prescribed values, IV is significantly better than many of the other volatility forecasts, but no other forecast can be significantly better than IV. We can hence draw a conclusion that in the context of margin charges, IV is the best volatility forecast to be used by a clearinghouse. Sub-period analysis also shows that this result is consistent over the time periods under our study.

## 7. Margin level and margin adjustment

### 7.1 Average margin level

For a prescribed coverage probability and a prescribed margin change frequency, the resulting average margin levels are reported in Table 9 below. Numbers in brackets represent the standard deviation of the average level. In each row, the smallest average level is bolded. It can be seen that IV has the best performance among all volatility forecasts. GARCH as a volatility forecast also performs well. In the situation where GARCH beats IV, the differences are only minimal but in the situation when IV beats GARCH, the differences are more substantial. The conclusion is that using either the average overcharge or the average margin level as a criteria, IV forecast outperform all other forecasts.

**Table 9: Average margin level for different volatility forecast methods**

CP	Yearly expected change frequency	HV				IV		RV	
		HV	HV-EWMA	GARCH	GARCH -GJR	IV	IV-EW MA	RV	RV-E WMA
99.8%	3	991.2 (9.91)	1072.6 (11.72)	916.2 (9.18)	824.3 (7.74)	<b>764.4</b> <b>(7.02)</b>	923.5 (7.62)	1076.8 (13.69)	815.1 (7.34)
	6	914.6 (9.05)	1088.3 (11.88)	787.9 (7.87)	832.1 (7.68)	<b>696.1</b> <b>(5.86)</b>	862.0 (7.10)	954.2 (10.30)	830.8 (7.48)
	Unrestricted	959.7 (9.34)	878.6 (8.91)	709.3 (6.82)	701.5 (6.65)	<b>644.2</b> <b>(5.58)</b>	857.7 (6.90)	820.0 (9.09)	807.2 (7.06)
99.4%	3	716.0 (7.21)	753.5 (8.79)	<b>676.0</b> <b>(6.81)</b>	691.2 (6.48)	687.9 (6.52)	716.1 (5.79)	1059.9 (11.18)	719.6 (6.69)
	6	758.9 (7.68)	755.5 (8.36)	669.1 (6.39)	644.5 (5.93)	<b>635.7</b> <b>(5.32)</b>	691.2 (5.68)	848.6 (8.59)	709.6 (6.40)
	Unrestricted	746.5 (7.25)	756.4 (7.67)	<b>588.8</b> <b>(5.66)</b>	614.1 (5.81)	594.6 (5.15)	655.8 (5.29)	696.5 (7.72)	680.4 (5.96)
99%	3	651.6 (6.54)	677.2 (7.52)	615.2 (6.21)	626.4 (5.87)	<b>597.5</b> <b>(5.68)</b>	632.4 (5.15)	896.5 (11.66)	635.3 (5.95)
	6	690.6 (6.95)	706.4 (7.70)	<b>592.4</b> <b>(5.66)</b>	605.9 (5.57)	594.2 (4.98)	632.6 (5.19)	721.5 (7.32)	619.0 (5.50)
	Unrestricted	700.4 (6.80)	669.8 (6.79)	<b>539.9</b> <b>(5.19)</b>	543.3 (5.13)	565.9 (4.91)	601.5 (4.86)	639.4 (7.09)	617.0 (5.41)
98%	3	584.4 (5.76)	621.6 (7.29)	554.6 (5.61)	544.0 (5.09)	540.4 (5.18)	<b>533.0</b> <b>(4.31)</b>	740.1 (8.69)	535.2 (4.69)
	6	570.0 (5.61)	573.3 (6.24)	539.0 (5.31)	549.6 (5.05)	<b>523.5</b> <b>(4.39)</b>	539.0 (4.45)	613.6 (6.16)	545.0 (4.78)
	Unrestricted	581.1 (5.63)	582.5 (5.91)	<b>463.9</b> <b>(4.46)</b>	478.6 (4.52)	511.4 (4.44)	534.6 (4.32)	551.5 (6.12)	541.1 (4.75)

## 7.2 Average margin adjustment

In this paper, we propose a methodology to control the frequency of margin changes. However, we have not yet considered the amount of margin adjustment per time of change. Obviously, the market is less disturbed if the exchange is going to increase the margin by 10% instead of increasing it by 100%. In order to have a feel for this impact, we provide in Table 10 below the average adjustment over the period under study. It is interesting to observe that IV performs very well in this aspect. Take the case of CP=99.8% and number of changes=3 for example. The amount of adjustment is 437.3 index points for IV, 447.0 index points for HV, 747.7 index points for GARCH, and 644.1 index points for RV. The large adjustment needed under the GARCH approach is not unexpected because it has been reported (see Lam et. el.) that GARCH forecasts generate quite erratic fluctuation in required margin. This again reinforces our conclusion that IV is the best forecast even if we take this additional dimension into consideration.

**Table 9: Average absolute margin changes for different volatility forecasts**

		HV				IV		RV	
CP	Number of change	HV	HV- EWM	GARCH	GARCH- GJR	IV	IV- EWMA	RV	RV- EWM
		99.8%	3	447.0	827.8	747.7	649.0	437.2	333.3
6	339.3		677.9	531.1	464.9	394.2	294.7	667.9	290.2
Unrestricted	26.1		60.3	36.9	38.3	65.1	14.7	219.4	18.9
99.4%	3	326.4	544.2	547.6	538.5	387.8	256.8	589.3	309.0
	6	290.2	510.9	424.4	358.3	364.0	232.3	612.5	251.0
	Unrestricted	20.9	52.4	30.8	33.6	47.4	11.4	186.0	15.9
99%	3	297.5	507.4	497.6	487.2	336.6	226.8	665.7	270.9
	6	250.1	476.8	378.8	336.4	339.9	212.6	519.7	214.7
	Unrestricted	19.7	47.1	28.2	29.7	45.1	10.4	170.6	14.5
98%	3	260.9	470.7	447.7	421.7	308.5	184.9	548.1	239.0
	6	217.0	350.5	355.6	302.7	299.9	174.2	440.1	182.7
	Unrestricted	16.9	42.0	24.1	26.1	40.8	9.2	147.1	12.8

## 8. The cost in maintaining market stability

We remarked in Section 3 that the act to control the number of changes in a year is to maintain market stability. The clearinghouse is happy to do it providing that it can be accomplished without sacrificing its own protection, which is shown by this paper to be feasible. However, while investors enjoy a relatively stable environment with limited

number of changes in margin levels, they may be paying more margins along the way for such stability goal to be realized. The next interesting question to ask is: what is the cost to the investors in order to maintain a stable market? In below, we investigate how much more margin an investor has to put up before they can enjoy a relatively more stable margin environment. For this purpose, we compare the average margin level under a controlled environment verses the uncontrolled environment. Table 10 below show the results of such computations.

**Table 10: Additional margin to be charged for different volatility forecasts**

		HV				IV		RV	
CP	Number of change	HV	HV- EWMA	GARCH	GARCH- GJR	IV	IV- EWMA	RV	RV- EWMA
		99.8%	3	31.5	194.0	206.9	122.8	120.2	65.8
6	-45.1		209.7	78.6	130.6	51.9	4.3	134.2	23.6
99.4%	3	-30.5	-2.9	87.2	77.1	93.3	60.3	363.4	39.2
	6	12.4	-0.9	80.3	30.4	41.1	35.4	152.1	29.2
99%	3	-48.8	7.4	75.3	83.1	31.6	30.9	256.8	18.3
	6	-9.8	36.6	52.5	62.6	28.3	31.1	82.1	2.0
98%	3	3.3	39.1	90.7	65.4	29.0	-1.6	188.6	-5.9
	6	-11.1	-9.2	75.1	71.0	12.1	4.4	62.1	3.9

Note that some values in the table are negative, which is not surprising because these are only sample values. Although theoretically, the difference is positive, individual sample value can be negative. The overwhelmingly positive values support the

intuition that a price needs to be paid to maintain a stable market. Since IV is the recommended forecast to use, we will look at the cost under the IV column. Take the case of CP=99.8% and number of changes=6 for example. Investors have to pay  $(696.1-644.2)=51.9$  more index points in margins in order to have a change of around 6 times a year, an increase of around 8%. However, if they want the number of margin changes to be held to about three times a year, the extra margin to be put up is averaged to be  $(764.4-644.2)=120.2$  index points, an increase of 19%. Since the clearinghouse is able to maintain the same prudential level under both the controlled and the uncontrolled cases, it is the investors who have to decide whether they want to have margin change less frequently by paying slightly more margin. Maybe the clearinghouse can consult the investors on whether they are willing to pay such a price or not.

## **9. Conclusion**

This paper makes contributions to the practices and the theory of setting margins. On the practical side, this paper is the first to propose a margin methodology that can both protect the clearinghouse and control the expected number of margin changes per year. On the theoretical side, this paper confirms that implied volatility has more information content than other volatility forecast as far as margin setting is concerned. Note that in comparing information content, it is difficult to draw a conclusion without an actual context. For example, method A can do better than method B as far as the sum of squared error is concerned, however method B can do better than method A as far as the sum of absolute error is concerned. This paper shows that from an end-user's view point, IV is a better input to the margin setting formula than other volatility forecasts.

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