Nikkei Stock Average Volatility Index
Real-time Version
Index Guidebook

Nikkei Inc.

- With the modification of the methodology of the Nikkei Stock Average Volatility Index as Nikkei Inc. (Nikkei) starts calculating and publishing it on the real-time basis since January 30, 2012, which had been calculated on the end-of-day basis since November 2010, Nikkei drew up the Index Guidebook of the Nikkei Stock Average Volatility Index Real-time Version. It would be changed or modified corresponding to the revision of the index calculation rule etc in the future.

- This English document is a translation of the original document dated December 30 2011 in Japanese and may not be an entirely accurate translation of the original Japanese document. In any case where differences arise between the English version and the original Japanese version, the original Japanese document will prevail.

(January 30, 2012 version)

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1: Concept

Prices traded on option markets are usually determined, among others, by the volatility of its underlying asset. From this price formation, in the calculation of the Nikkei Stock Average Volatility index, the volatility expected by investors is inferred from the option prices (premiums) in the markets.

A method widely used to estimate the fair variance rate in trading a variance swap etc on the OTC market is used in the index calculation.

2: Index Calculation

(1)Basic Points

・The index value is expressed as the figures rounded to two decimal places. Unit of the index value is “points”.
・Use the prices of the Nikkei 225 futures and Nikkei 225 options on the Osaka Securities Exchange (OSE), which the OSE publishes as the future and option prices respectively.
・The index is calculated every 15 seconds during the day session of the Nikkei 225 options on the OSE (excluding the pre-closing). The index starts to be calculated from 15 seconds after the end of the opening auction usually 15 seconds past 9 A.M., and it is also calculated at the end of the closing auction.
・Cover the near-term (the first-term) option and the next-term (the second-term) option. The options to calculate the index are rolled to the next delivery month on three business days before the last trading date of the near-term option. Also cover the near-term (the first-term) future, and the future is rolled to the next-term future on three business days before the last trading date of the near-term future.

(2)Selection of the prices

The prices of the futures and options used for the calculation are selected in the following order of the priority.

①Latest traded price in for the past 15 seconds (however, at the end of the closing auction, a traded price obtained when the orders are matched by so called “Itayose” method)
②Middle price of best bid and best ask at the time of the calculation (every 15 seconds) while the orders are matched by the so called “Zaraba” method (however, at the end of the closing auction, the middle price of best bid and best ask after the orders are matched by the “Itayose” method (*1)
③Last traded price of today’s session at the time before the past 15 seconds (including the night session on the previous business day)

*1: Best bid and best ask prices to compute a middle price are invalid in cases that 1)best bid price is lower than or equal to 10yen and the difference between the best bid and best ask is greater than or equal to 4yen, 2)best bid price is greater than 10yen and best ask is greater than best bid by 30% or more, 3) best ask is lower than or equal to best bid.

(3)Formula

The Nikkei Stock Average Volatility Index is calculated in accordance with the following procedure.

①Calculate the volatility $\sigma_{1,t}$ based on the near-term (first-term) option at a time of t, and the volatility $\sigma_{2,t}$ based on the next-term (second-term) option at a time of t.

$$\sigma_{i,t} = \sqrt{\frac{1}{(T_i - t)/Y_{365}} \left(1 + \frac{L_{i,t}(T_i - t)}{Y_{360}}\right) \sum_{j=0}^{n_j} \left(\frac{V(K_{i,j,t}, T_i, t)}{{K_{i,j,t}}^2} + \frac{V(K_{i,j+1,t}, T_i, t)}{{K_{i,j+1,t}}^2}\right) \Delta K_{i,j,t}}$$

T_i : the expiration date of i th-term option (9:00:00am on SQ date) (*2)
Y_{365} : the number of seconds in a year on 365 day-basis (31,536,000 seconds)
Y_{360} : the number of seconds in a year on 360 day-basis (31,104,000 seconds)
$L_{i,t}$: Euroyen LIBOR (360 days basis) on the previous business day (1-month rate for the near-term and 2-month rate for the next-term)(*3)
$K_{i,j,t}$: j th lowest Strike price (i.e. ascending order) of i th-term option at a time of t
$V(K_{i,1,t}, T_i, t) \ldots V(K_{i,p_t-1,t}, T_i, t)$: Closing price of put option with the expiration date of T_i at a time of t
$V(K_{i,p_t,t}, T_i, t) \ldots V(K_{i,n_i,t}, T_i, t)$: Closing price of call option with the expiration date of T_i at a time of t
(however $V(K_{i,0,t}, T_i, t) = 0, V(K_{i,n_i+1,t}, T_i, t) = 0$

$$V(K_{i,q_t,t}, T_i, t) = \frac{Put(K_{i,q_t,t}, T_i, t) + Call(K_{i,q_t,t}, T_i, t)}{2} - \frac{|F_t - K_{i,q_t,t}|}{2(1 + L_{i,t}(T_i - t)/Y_{360})}$$ (*4))

F_t : the price of the near-term future at a time of t
p_t : minimum j satisfying $F_t < K_{i,j,t}$
q_t : j minimizing the absolute difference between F_t and $K_{i,j,t}$ at a time of t (*5)
$n_{i,t}$: the number of strike prices of i th-term options using for the calculation at a time of t (*6,*7)
$\Delta K_{i,j,t} = K_{i,j+1,t} - K_{i,j,t}$ (however, $\Delta K_{i,0,t} = \Delta K_{i,1,t}, \Delta K_{i,n_j,t} = \Delta K_{i,n_{j-1},t}$)

*2: the term to the expiration date is measured on the second time scale.
*3: In case that the previous day for the calculation was not a business day in the London market or that the Euroyen LIBOR was not published for any reason, use the LIBOR rate previously available on the nearest day. Even if the previous day for the calculation was not a business day in Japanese markets and was a business day in the London market, the LIBOR rate on the day is used.
*4: For the option price whose strike price is nearest from the future price at a time of t, use the adjusted value calculated from the put option price and call option price at the strike price. In addition, $Put(K_{i,q_t,t}, T_i, t)$ and $Call(K_{i,q_t,t}, T_i, t)$ are put option price and call option price at strike price of $K_{i,q_t,t}$ and the expiration date of T_i at a time of t.

*5: If $F_t < K_{i,q_t,t}$,then $q_t = p_t$ and if $F_t \geq K_{i,q_t,t}$,then $q_t = p_t$ -1

*6: Use out-of-the-money (OTM) traded options (which have some volume) where the future price at the time of the calculation is defined as at-the-money(ATM). However, the options whose prices are invalid at the time of the calculation are treated as if these strike prices are not set (including cases by the Trading Suspension and the Immediately Executable Price Range Rule).

*7 : In case that the option prices at 3 or more consecutive strike prices are invalid, the prices of put options at lower strike prices than these consecytuve strike prices and the prices of call options at higher strike prices than these consecutive strike prices are not used for the calculation even if these options are traded with some volume..

②Obtain the index value by linear interpolation of $\sigma_{1,t}$ and $\sigma_{2,t}$ to make the time to expiration 30 days (*8,*9,*10)

$$\text{Index Value} = \sqrt{\frac{1}{M}\left(\frac{(M-(T_1-t))(T_2-t)}{T_2-T_1}{\sigma_{2,t}}^2 + \frac{((T_2-t)-M)(T_1-t)}{T_2-T_1}{\sigma_{1,t}}^2\right)} \times 100$$

M : the number of seconds in 30 days (2,592,000 seconds)

*8: If the term to expiration date is longer than 30 days, the index is calculated by liner extrapolation.

*9: As a result of the liner extrapolation, in case that the index value becomes imaginary number (meaning that the result for the square root becomes negative), the index value is calculated at a time of t by using $\sigma_{1,t-1}$ and $\sigma_{2,t-1}$ used for the calculation at a time of t -1 (just before the calculation of this time), instead of $\sigma_{1,t}$ and $\sigma_{2,t}$ (however, at the first calculation of the day, use closing price on the previous day)

*10: In the calculation of i th-term option at a time of t , 1)in case that the number of the strike prices whose option prices are valid is 0 or 1, or 2)in case that the price of near-term future is invalid, $\sigma_{i,t}$ at a time of t is not calculated, and the index value at a time of t is calculated by using $\sigma_{i,t-1}$ which is used just before the calculation of this time, instead of using $\sigma_{i,t}$ (however excluding in case of “3:Miscellaneous (3)In case the Circuit Breaker Rule is applied linked to Nikkei 225 Futures”).

3: Miscellaneous

(1)Previous and Retroactively Calculation in the past

From the commencement date of the calculation (November 19th 2010) to January 27th 2012, the index was calculated on the end-of-day basis. And the index was calculated retroactively dating back from Jun 11th 1989 to November 18th 2010 by the same end-of-day basis method.

(2) Modification of the index value

If any event which affects the index value occurs (e.g. correction of the option or futures prices published by the OSE), as a general rule, retroactive calculation for the modification will not be conducted.

(3) In case the Circuit Breaker Rule is applied linked to Nikkei 225 Futures

In case that all trades of the Nikkei 225 futures and Nikkei 225 options are halted by the Circuit Breaker Rule linked to Nikkei 225 futures, Nikkei shall halt the updating of the Nikkei Stock Average Volatility Index. The complete trading suspensions of the OSE caused by its system failure etc., is treated as the same above.

4: Calculation Example (in case of the closing (3:15:00pm) on November 1st 2011)

(1) Conditions for the calculation are described below:

Closing price of the near-term Nikkei 225 future (expiration month: December 2011) = 8850

Euroyen LIBOR 1-month rate = 0.14313%, 2-month rate = 0.15863%

The term to the expiration date of near-term option (expiration month: November 2011) = 841,500 seconds

The term to the expiration date of next-term option (expiration month: December 2011) = 3,260,700 seconds

The nearest strike price from ATM (future price) = 8750

(2) Decide Options used for the calculation for the near-term; expiration month: Nov 2011 (see grayed cells)

Call Options			Put Options		
Strike Price	Last Traded Price	Middle Price between Bid and Ask	Strike Price	Last Traded Price	Middle Price between Bid and Ask
5000	-	3850	5000	1 (9:00)	-
5500	-	3350	5500	1 (15:09)	-
6000	-	2850	6000	1 (13:26)	-
6250	-	2600	6250	1 (9:23)	-
6500	2400 (13:00)	2350	6500	1 (15:15)	-
6750	-	2100	6750	1 (9:11)	-
7000	-	1850	7000	1 (15:15)	1.5
7250	-	1600	7250	1 (15:15)	1.5
7500	-	1350	7500	2 (15:15)	2.5
7750	1190 (9:49)	1105	7750	4 (15:15)	4.5
8000	855 (14:53)	857.5	8000	8 (15:15)	7.5
8250	650 (13:54)	617.5	8250	16 (15:15)	15.5
8500	380 (14:57)	390	8500	36 (15:15)	36.5
8750	195 (15:09)	192.5	8750	95 (15:15)	92.5
9000	70 (15:15)	67.5	9000	215 (15:15)	217.5
9250	17 (15:15)	17.5	9250	415 (15:05)	417.5
9500	4 (15:15)	3.5	9500	625 (13:02)	652.5
9750	1 (15:15)	1.5	9750	-	900
10000	1 (9:28)	-	10000	-	1150
10250	-	-	10250	-	1400
10500	-	-	10500	-	1650
10750	-	-	10750	-	1900
11000	-	-	11000	-	2150
11500	-	-	11500	-	2650
12000	-	-	12000	-	3150
12500	-	-	12500	-	3650
13000	-	-	13000	-	4150

Note)Use the OTM options

13500	－	－	13500	－	4650
14000	－	－	14000	－	5150

Note） '-' indicates there was no traded option price or no valid middle price between Bid and Ask at the Strike price

(3) Calculate the adjusted value from option prices at the strike price nearest from the future price for the near-term; expiration month: Nov 2011

$$\text{Adjusted Value} = \frac{192.5+95}{2} - \frac{|8850-8750|}{2(1+0.14313\% \times 841500/31104000)} = 143.75 - 100 \div 2.00007745 \fallingdotseq 93.75193607$$

(4) Calculation of the variance of the underlying asset price derived from the prices of the selected near-term options (expiration month: Nov 2011)

Strike Price	Number(j)	ΔK	Prices	α (*11)
－	0	500	－	0.00002000
5000	1	500	1	0.00003653
5500	2	500	1	0.00003042
6000	3	250	1	0.00001334
6250	4	250	1	0.00001232
6500	5	250	1	0.00001140
6750	6	250	1	0.00001059
7000	7	250	1	0.00000986
7250	8	250	1	0.00001365
7500	9	250	2	0.00002554
7750	10	250	4	0.00004790
8000	11	250	8	0.00009002
8250	12	250	16	0.00018334
8500	13	250	36	0.00043478
8750	14	250	93.75193607(*12)	0.00052626
9000	15	250	70	0.00026572
9250	16	250	17	0.00006075
9500	17	250	4	0.00001371
9750	18	250	1	0.00000513
10000	19	250	1	0.00000250

*11: α indicates the value used with the Σ (i.e. summation) in “2:Index Calculation (3)Formula-①”

*12: Use the adjusted value for the nearest stripe price from the future price

$$\sigma_1^2 = \frac{1}{841500/31536000} \times \left(1 + \frac{0.14313\% \times 841500}{31104000}\right) \times \sum \alpha \fallingdotseq 37.47738701 \times 0.00180559 \fallingdotseq 0.06766863$$

(5) Decide Options used for the calculation for the next-term; expiration month: Dec 2011 (see grayed cells)

Call Options			Put Options			
Strike Price	Last Traded Price	Middle Price between Bid and Ask	Strike Price	Last Traded Price	Middle Price between Bid and Ask	
3000	－	5850	3000	－	－	
3500	－	5350	3500	－	－	
4000	－	4850	4000	1 (9:00)	－	
4500	－	4350	4500	2 (15:06)	1.5	(*13)
5000	－	3855	5000	2 (9:00)	1.5	(*13)

5500	-	3355	5500	3 (14:57)	2.5	(*13)
6000	-	2855	6000	4 (15:15)	4.5	
6250	-	2610	6250	6 (15:15)	6	
6500	2430 (10:54)	2360	6500	8 (14:47)	7.5	(*13)
6750	-	2110	6750	11 (15:15)	10.5	
7000	-	1865	7000	13 (15:15)	13.5	
7250	-	1620	7250	18 (15:15)	18.5	
7500	-	1380	7500	26 (15:15)	26	
7750	1200 (10:01)	1140	7750	38 (15:15)	37.5	
8000	910 (15:05)	912.5	8000	55 (15:15)	57.5	
8250	750 (9:23)	692.5	8250	90 (15:15)	87.5	
8500	485 (14:47)	490	8500	135 (15:15)	137.5	
8750	310 (15:15)	315	8750	215 (15:15)	212.5	
9000	185 (15:15)	180	9000	325 (15:15)	327.5	Note)Use the OTM options
9250	95 (15:15)	92.5	9250	480 (14:38)	487.5	
9500	41 (15:15)	41.5	9500	-	-	
9750	17 (15:15)	16.5	9750	830 (9:22)	912.5	
10000	7 (15:15)	7.5	10000	1150 (15:15)	1150	
10250	3 (14:32)	2.5	10250	-	1400	(*13)
10500	1 (14:06)	-	10500	-	1645	
10750	1 (8:00)	-	10750	-	1895	
11000	-	-	11000	-	2145	
11500	-	-	11500	-	2645	
12000	-	-	12000	-	3145	
12500	-	-	12500	-	3645	
13000	-	-	13000	-	4145	
13500	-	-	13500	-	4645	
14000	-	-	14000	-	5145	
14500	-	-	14500	-	5645	
15000	-	-	15000	-	6145	
15500	-	-	15500	-	6645	
16000	-	-	16000	-	7145	

Note） '-' indicates there was no traded option price or no valid middle price between Bid and Ask at the Strike price
*13: Use the middle price between best bid and best ask at the end of the closing auction.

(6) Calculate the adjusted value from option prices at the strike price nearest from the future price for the next-term; expiration month: Dec 2011

$$\text{Adjusted Value} = \frac{310+215}{2} - \frac{|8850-8750|}{2(1+0.15863\% \times 3260700/31104000)} = 265 - 100 \div 2.00033259 \fallingdotseq 212.5083134$$

(7) Calculation of the variance of the underlying asset price derived from the prices of the selected next-term options (expiration month: Dec 2011)

Strike Price	Number(j)	ΔK	Prices	α (*14)
-	0	500	-	0.00003125
4000	1	500	1	0.00006829
4500	2	500	1.5	0.00006704
5000	3	500	1.5	0.00007132
5500	4	500	2.5	0.00009688
6000	5	250	4	0.00006618
6250	6	250	6	0.00008278

6500	7	250	7.5	0.00010474
6750	8	250	11	0.00012668
7000	9	250	13	0.00015194
7250	10	250	18	0.00020117
7500	11	250	26	0.00027372
7750	12	250	38	0.00037301
8000	13	250	55	0.00054542
8250	14	250	90	0.00079771
8500	15	250	135	0.00116103
8750	16	250	212.5083134(*15)	0.00126489
9000	17	250	185	0.00084856
9250	18	250	95	0.00039115
9500	19	250	41	0.00015828
9750	20	250	17	0.00006221
10000	21	250	7	0.00002345
10250	22	250	2.5	0.00000822
10500	23	250	1	0.00000443
10750	24	250	1	0.00000216

*14: α indicates the value used with the Σ (i.e. summation) in "2:Index Calculation (3)Formula-①"
*15: Use the adjusted value calculated from options prices at the stripe price nearest from the future price

$$\sigma_2^{\ 2} = \frac{1}{3260700 \ / 31536000} \times \left(1 + \frac{0.15863\% \times 3260700}{31104000}\right) \times \sum \alpha \fallingdotseq 9.67315125 \times 0.00698250 \fallingdotseq 0.06754283$$

(8) Obtain the index value by linear interpolation of $\sigma_1^{\ 2}$ and $\sigma_2^{\ 2}$ to make the time to expiration 30 days (2,592,000 seconds)

$$\sqrt{\frac{1}{2592000}\left(\frac{(2592000 - 841500) \times 3260700}{3260700 - 841500} \times 0.06754283 + \frac{(3260700 - 2592000) \times 841500}{3260700 - 841500} \times 0.06766863\right)}$$

$$\times 100 \fallingdotseq \underline{25.99} \ \text{...Index Value}$$

5: Others

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(3)Corporation for the development of the index

In developing the Nikkei Stock Average Volatility Index, Nikkei has gained the cooperation of Quantitative Research Center of Nomura Securities CO., LTD. The disclaimers in the above (2) are also applied to Quantitative Research Center of Nomura Securities.

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