Adapting Moving Averages To Market Volatility

by Tushar S. Chande, Ph.D.

If a market is active, it has volatility: that cannot be avoided. And because the market is continuously changing, an indicator that attempts to predict market activity must itself adapt and change. How? Tushar Chande presents a dynamic—not static—indicators: a variable-length moving average, which adapts to the volatility in question by exponentially smoothing data based on standard deviation.

Technicians can be trend followers or contrarians. Trend followers use price-based indicators, such as moving averages, while contrarians prefer oscillators such as overbought-oversold indicators. But the market never does quite the same thing twice, and so no indicator works all the time. The market is dynamic, adjusting rapidly to information: a continuous tug of war between greed and fear, fact and fiction. Technical indicators, on the other hand, are static, mechanically applying the same formula to the relevant data. What is needed is a combination, dynamic indicators that will automatically adapt to the changing nature of markets, a new class of dynamic indicators that combine exponential moving averages with other technical indicators to adapt automatically to changing price behavior. What is needed is an exponential moving average with a continuously variable smoothing index that adjusts rapidly to changes in price behavior. The smoothing index can be tied to any market variable. It is the continuous, not discrete, changes in the smoothing index that increases the sensitivity of these moving averages to changes in price behavior. These new dynamic exponential averages can be referred to a variable index dynamic average (VIDYA).

Let us first examine exponential moving averages and how they can be modified to obtain VIDYA, and in turn compare VIDYA with conventional indicators to illustrate its dynamism. Then we will combine dynamic averages to derive other indicators and then illustrate their effectiveness.

BUT FIRST, THE BACKGROUND

Exponential moving averages give greater weight to more recent data. An exponential moving average may be defined as:

(1) $E_d = t \times C_d + (1-t) \times E_{d-1}$

where

E_d is the new value of the moving average

E_{d-1} is the previous value

C_d is the new data value

t is the smoothing constant of the average

The smoothing constant *t* of the average may be referred to as the smoothing index of the moving average, so it no longer has to be visualized as a numerical constant. Implicitly, *t* must be less than 1 for the term (1-*t*) to be positive. As the smoothing index *t* increases, the new value has a greater proportion of the most recent data and the exponential average moves more rapidly. Conversely, as *t* decreases, more weight is given to the previous value, giving a heavily smoothed average that changes quite slowly. Thus, a larger value of *t* makes the exponential moving average more sensitive to new data; a smaller index *t* makes it less sensitive.

George Arrington in the June 1991 STOCKS & COMMODITIES discussed a variable-length simple moving average in which the number of days changed by discrete integers. The length is increased or decreased by an integral number of days based on the magnitude of price changes. He argued that this approach does not work well with exponential moving averages. A closer look at the smoothing constant *t* suggests that it could be a continuous variable (index), thus allowing the use of fractional time periods. For example, we can write *t* as

(2) $t = k \times V$

where *k* is a numerical constant such as 0.15 and *V* is a dimensionless market-related variable, such as a ratio of the standard deviation of the market's closing prices over two different periods.

The smoothing constant is simply a mechanism for incrementing the old value of the moving average to a new value, and a fractional value of *t* less than 1 prevents instability. Varying the smoothing index corresponds to taking larger or smaller portions of the latest data to update the moving average.

Any indicator may be used to connect the index *t* to the nature of the market's price changes. For example, the midpoint oscillator, %M, may be used as a measure of the market and inserted as *V* in equation 2. By design, the moving average will move faster as prices approach an overbought or oversold condition. Alternately, market momentum indicators (say, the 26-week price rate of change) may be used so that changes occur more quickly as prices change rapidly, slowing down as prices stabilize. This ability to quicken or slow down gives these variable-index exponential averages their dynamism.

DEFINING VIDYA AND RAVI

Specifically, I constructed a variable-index dynamic moving average (VIDYA) connecting the smoothing index to the market's volatility as follows:

$$VIDYA_d = \left(k\frac{\sigma_n}{\sigma_{ref}}C_d\right) + \left(1-\left(k\frac{\sigma_n}{\sigma_{ref}}\right)\right)VIDYA_{d\text{-}1}$$

Here, the subscripts *d* and *d*-1 denote the new and old time period, *C* is the closing price at the end of period *d*, σ (sigma) is the standard deviation of the market's prices over the past *n* periods, σ is a reference standard deviation of the market over some period of time longer than *n*, and *k* is a numerical constant. The reference standard deviation could also be an arbitrary value to obtain the desired degree of smoothing.

From an investor's viewpoint, a "long" VIDYA can be defined with *k*=0.078, corresponding roughly to a 25-week exponential moving average. A 13-week standard deviation is used to adapt to market volatility. A reference standard deviation of 6 is used, which represents a 10-year average for weekly Standard & Poor's 500 data. More precisely, the long VIDYA is given by

(4) $VIDYA^L_d = 0.078 \times \sigma_{13} / 6 \times C_d + (1 - 0.078 \times \sigma_{13}/6) \times VIDYA^L_{d\text{-}1}$

A "short" dynamic average is also defined with *k* = 0.15, roughly equal to a 12-week exponential moving average. The standard deviation of closing prices is calculated over 10 weeks. The value of the reference standard deviation is set at 4.

(5) $VIDYA^S_d = 0.15 \times \sigma_{10}/4 \times C_d + (1\text{-}0.15 \times \sigma_{10}/4) \times VIDYA^S_{d\text{-}1}$

To clarify the dynamism of these averages, I tabulated the 13-week standard deviation of the S&P 500 weekly close during three market periods. Also shown is the effective smoothing index using equation 4. Then I estimated the effective length of the equivalent simple moving average using the well-known formula for the smoothing constant of an exponential moving average (2/(*n*+1)), where *n* is the length of the equivalent simple moving average.

DYNAMISM OF VIDYA

Weekly period	13-wk stand. dev. (σ13)	Effective smoothing index $0.078 \times \sigma_{13}/6$ (*k*)	Effective length of $VIDYA^L$ (weeks) (2-*k*) / *k*
9/11-12/4/87	36.83	0.479	3.18
6/22-9/14/90	18.38	0.239	7.37
4/19-7/12/91	4.83	0.063	30.75

The dynamic range of $VIDYA^L$ is about a factor of 10 (i.e.,30.75 3.18), since it adjusts all the way from a rather long to a very short moving average based on market volatility. As market volatility increases, the effective length decreases. Even greater dynamic range is possible, as long as the factor (1-*t*) is positive. Clearly, $VIDYA^L$ is superbly responsive to the market. $VIDYA^S$ also exhibits a similar dynamism.

Now, we define the rapid adaptive variance indicator (RAVI), defined as

(6) $RAVI_d = VIDYA^S_d - VIDYA^L_d$

where the long and short dynamic averages are as defined in equations 4 and 5.

OTHER TRADING STRATEGIES

All trading strategies based on moving averages can be implemented using VIDYA. For example, RAVI is a two-average crossover indicator. A buy signal is generated when RAVI turns positive from a negative value. Similarly, a sell signal occurs when RAVI turns negative from a positive value.

I used weekly S&P 500 data to illustrate the smoothing characteristics using a VIDYA^{L} and VIDYA^{S}, representing heavy and light smoothing, respectively.

RAVI can be combined with its moving average to simulate a moving average convergence/divergence (Macd) strategy. Due to its sensitivity, this more responsive or TurboMACD can be defined as follows:

$$(7)\ TMACD_d = RAVI_d - (0.2 \times RAVI_d + 0.8 \times RAVI_{d-1})$$

where the second term represents the trigger line, an exponential moving average with a smoothing constant of 0.2. A buy signal is produced when TurboMACD changes from negative to positive values, and a sell signal occurs when it goes from positive to negative values.

BACK TESTING RESULTS

The results of back testing can be divided into two parts: first, the smoothing characteristics of VIDYA, and second, long trades using RAVI and TMACD. Now let us use moving average crossovers and MACD for comparison.

I used weekly S&P 500 data to illustrate the smoothing characteristics using a VIDYA^{L} and VIDYA^{S}, representing heavy and light smoothing, respectively. Figure 1 covers a market period from January 1990 to July 1991 and compares VIDYA^{L} to the equivalent exponential moving average with a smoothing constant of 0.078 . Note how the variable index dynamic average adjusts rapidly to the drop in August 1990. In contrast, an exponential moving average barely responds to the rapid price changes. VIDYA^{L} takes small steps when the market trades in a narrow range and takes large ones when the market makes big moves in any direction. Observe how VIDYA^{L} responded near the market bottom in September-October 1990, while rising rapidly and leveling out in May 1991 when the market entered a trading range.

The lightly smoothed VIDYA^{S} follows the market even more closely, as shown in Figure 2. It also flattens as the market trading range narrows, as in June-July 1990. Clearly, it can be used as a trigger line in market trading systems. Even though the equivalent exponential moving average with a smoothing constant of 0.15 responds quickly to price changes, VIDYA^{S} responds with even greater agility.

An even better picture of VIDYA's responsiveness to price changes can be seen in Figure 3, which compares the smoothing behavior of VIDYA^{L} with a short exponential moving average with a smoothing constant of 0.15. The long dynamic average is more sensitive to rapid changes than even the short exponential average and tracks price changes more powerfully.

The responsiveness of VIDYA and its vulnerability to instabilities was severely tested during the severe

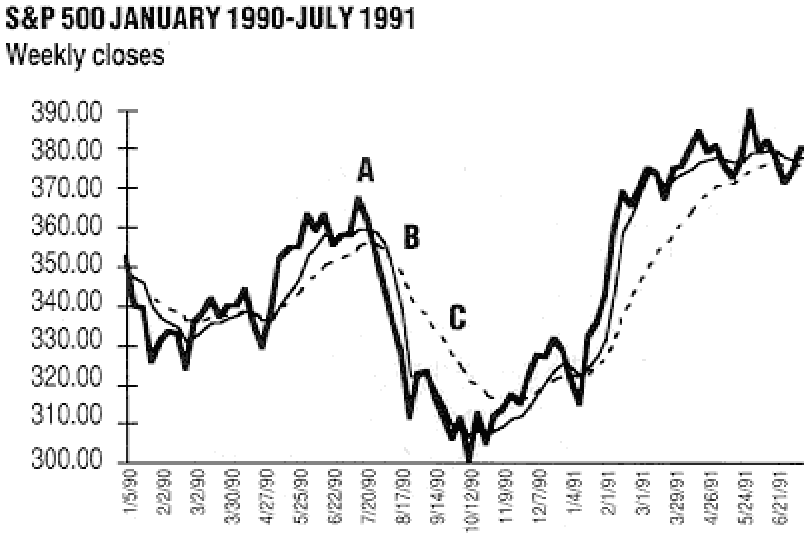

FIGURE 1: *The S&P 500 weekly closes (A) are plotted along with both the long variable index dynamic moving average (B) and with the equivalent exponential moving average (C). Note how quickly the indexed moving average responds to the decline by the S&P 500 in August 1990.*

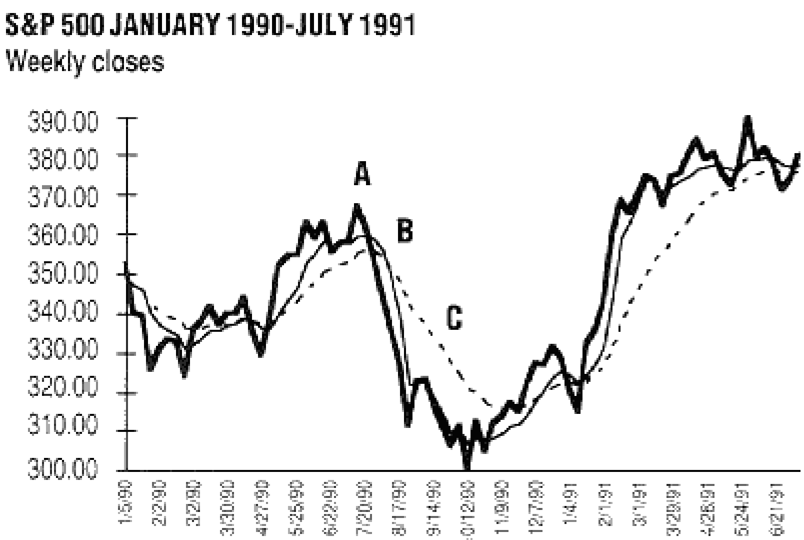

FIGURE 2: *The S&P 500 weekly closes (A) are plotted along with both the short variable index dynamic moving average (B) and with the equivalent exponential moving average (C). The short version of the indexed moving average follows the market closely.*

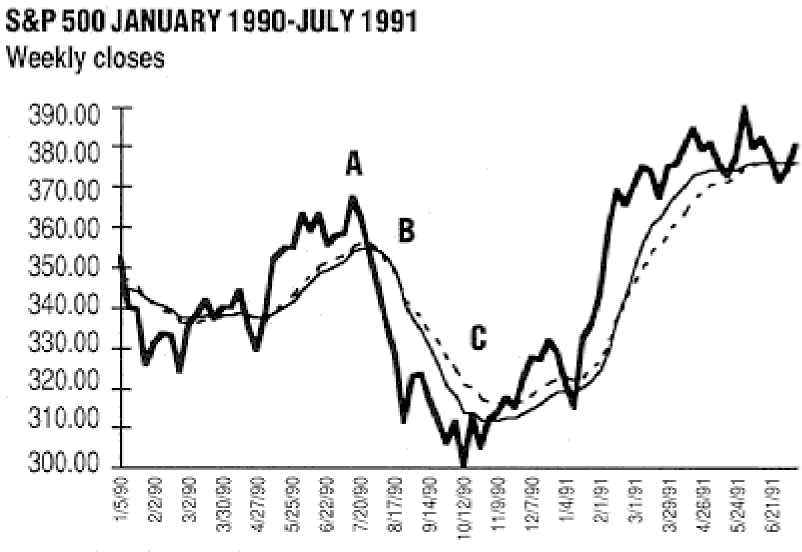

FIGURE 3: *The S&P 500 weekly closes (A) are plotted this time with the long variable index dynamic moving average (B) and with the short exponential moving average (C). The long version of the indexed moving average still follows the market more close/y than a short exponential moving average.*

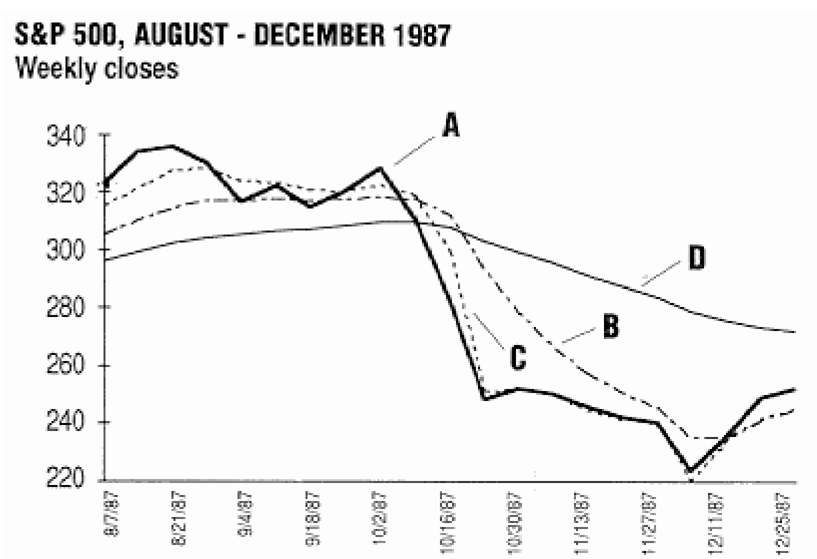

FIGURE 4: *The S&P 500 weekly closes (A) are plotted this time with the long (B) and short (C) variable index dynamic moving average and with the equivalent long exponential moving average (D). The narrowing of the difference between the two indexed moving averages indicates a possible trend reversal*

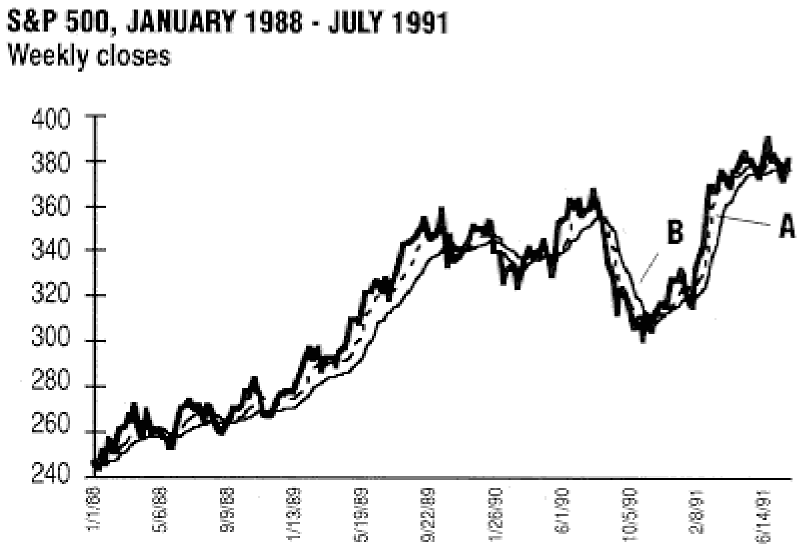

FIGURE 5: *Using the difference between the short (A) and long (B) versions of the varriable index dynamic moving average produces the rapid adaptive variance indicator, creating a crossover method for trading signals.*

market correction of October 1987 (Figure 4). The narrowing of the variance between the two dynamic averages signaled a possible market top in September, confirmed in early November as the two averages crossed over. The lightly smoothed $VIDYA^S$ tracks the market tightly and the heavily smoothed $VIDYA^L$ responds rapidly as well. In comparison, the equivalent long exponential average glances over the extreme price changes. Note the slight instability caused by the market volatility when the short average dipped below the market low in early December.

The quantitative results are now easier to interpret, as we have a good feel for the smoothing behavior of these dynamic averages. Now look at RAVI. A buy is signaled when RAVI turns positive from negative territory and a sell occurs when RAVI goes negative from positive ground, which is the same as the short VIDYA crosses over or under the long VIDYA (Figure 5).

The results of long trades using RAVI over a test period of January 1980 to July 1991 are in Figure 6.The total point gain is approximately 207 points (with one open trade) using this strategy. If trade 9 were closed on July 12, 1991, the gain would be approximately 265 S&P 500 points. For comparison, the same moving average crossover strategy using the equivalent exponential moving averages with smoothing constants of 0.15 and 0.078 (same as the *k* values for $VIDYA^S$ and $VIDYA^L$) produced a gain of just 122 S&P 500 points with five long trades (see Figure 7). If the currently open trade for the exponential averages were closed on July 12, 1991, the gain would be 159 S&P 500 points.

The MACD indicator is composed of the difference between two exponential moving averages with smoothing constants of 0.15 and 0.077. A moving average of the difference with a smoothing constant of 0.2 is used as a trigger line. I tested the profitability of MACD over the same test period using MetaStock software. The MACD indicator produced 20 trades and a gain of 205 S&P 500 points (Figure 8). Currently, there are no open trades with MACD, since it issued a sell signal on May 17, 1991. Trades with TurboMACD over the same period are summarized in Figure 9. In total, there were 25 long trades, with a gain of approximately 218 points in all.

A comparison of each of the four methods discussed is found in Figure 10. Clearly, RAVI beat both the simple crossover of exponential averages and MACD over the past 11 years. RAVI produced more trades than did the simple crossover model but less than half as many as did the MACD. A look at the detailed trades shows that TMACD signaled key turning points two to three weeks before MACD. Its greater sensitivity produced more trades, which is a key limitation of the MACD approach from an investor's perspective. RAVI can also be used as an overbought-oversold indicator, since its values peak at over +10 or -10.

TO SUMMARIZE

Overall, the back testing results show that VIDYA tracks the market (as measured by the S&P 500 index) better than exponential moving averages do using a fixed smoothing constant. Trading strategies based on VIDYA seem to perform better than those based on exponential moving averages, as summarized in Figure 5.

FIGURE 6

R A VI - LONG POSITIONS ON LY
5/30/80 to 7/12/91

DATE	TRADE	S&P500	GAIN/LOSS POINTS	TO TAL POINTS
5/30/80	BUY	111.24		
9/11/81	SELL	121.61	10.37	10.37
9/30/82	BUY	120.97		
3/9/84	SELL	154.35	33.38	43.75
8/17/84	BUY	164.14		
9/26/86	SELL	232.33	68.19	11.94
10/31/86	BUY	243.98		
10/16/87	SELL	282.70	38.72	150.66
12/18/87	BUY	249.16		
12/25/87	SELL	252.02	2.86	153.52
1/1/88	BUY	247.08		
1/8/88	SELL	243.40	-3.68	149.84
1/15/88	BUY	252.06		
1/26/90	SELL	325.80	73.74	223.58
5/11/90	BUY	352.00		
8/10/90	SELL	335.52	-16.48	207.10
11/30/90	BUY	322.22		
7/12/90	SELL **	380.25	58.03	265.13
Total long trades: 9				
Profitable longs: 7 (78%)				
Biggest gain:			73.74	

** Trade closed for completeness; no sell signal from this model on 7/12/90

The results of long positions only are presented. The sell signal on July 12, 1991, is the open profit on that date.

FIGURE 7

PRICE OSCILLATOR (LONG POSITIONS ONLY)
S&P 500, Formula A
6/27/80 to 7/12/91

Total long trades	: 5	Total short trades	: 0
Profitable longs	: 3 (60.0%)	Profitable shorts	: 0 (0.0%)
Total buy stops	: 0	Total sell stops	: 0
Biggest gain	: 84.080	Biggest loss	: -40.490
Successive gains	: 1	Successive losses	: 1
Total gain/loss	: 122.170	Average gain/loss	: 24.434
Total gain/loss ($)	: 1,004.77	Total gain/loss (%)	: 100.48

Using only long positions in a crossover trading strategy based on the equivalent short and long exponential moving averages produced a gain of 122.17 points in the S&P 500. If the current open trade had been closed on July 12, 1991, the total gain would have been 159 points.

FIGURE 8

S&P 500, MACD
(9-unit moving average of indicator)
6/27/80 to 7/12/91

Total long trades	: 20	Total short trades	: 0
Profitable longs	: 11 (55.0%)	Profitable shorts	: 0 (0.0%)
Total buy stops	: 0	Total sell stops	: 0
Biggest gain	: 70.760	Biggest loss	: -15.230
Successive gains	: 1	Successive losses	: 1
Total gain/loss	: 204.560	Average gain/loss	: 10.228
Total gain/loss ($)	: 1,344.96	Total gain/loss (%)	: 134.50

Testing the standard moving average convergence/divergence indicator for long positions resulted in the above. The MACD uses the difference between a 26- and 12-day exponential moving average and a nine-day exponential moving average of the MACD line for the signal line. Crossovers of the MACD line and the signal line generate the buy and sell signals.

FIGURE 9

TURBO MACD - LONG POSITIONS ONLY 5/30/80-7/12/91

DATE	TRADE	S&P500	GAIN/LOSS POINTS	TOTAL POINTS
5/30/80	BUY	111.24		
1/16/81	SELL	134.77	23.53	23.53
11/27/81	BUY	125.09		
1/15/82	SELL	116.33	-8.76	14.77
4/16/82	BUY	116.81		
6/18/82	SELL	107.28	-9.53	5.24
8/20/82	BUY	113.02		
12/10/82	SELL	139.57	26.55	31.79
1/14/83	BUY	146.65		
6/17/83	SELL	169.13	22.48	54.27
3/8/84	BUY	162.35		
11/30/84	SELL	163.58	1.23	55.5
1/18/85	BUY	171.32		
3/22/85	SELL	179.04	7.72	63.22
5/17/85	BUY	187.42		
8/2/85	SELL	191.48	4.06	67.28
11/8/85	BUY	193.72		
1/17/86	SELL	208.43	14.71	81.99
2/21/86	BUY	224.62		
4/11/86	SELL	235.97	11.35	93.34
6/27/86	BUY	249.6		
7/11/86	SELL	242.22	-7.38	85.96
8/29/86	BUY	252.93		
9/12/86	SELL	230.67	-22.26	63.7
10/31/86	BUY	243.98		
3/13/87	SELL	289.89	45.91	109.61
6/19/87	BUY	306.97		
9/4/87	SELL	316.7	9.73	119.34
11/20/87	BUY	242		
12/4/87	SELL	223.92	-18.08	101.26
12/11/87	BUY	235.32		
4/15/88	SELL	259.77	24.45	125.71
6/10/88	BUY	271.26		
7/22/88	SELL	263.5	-7.76	117.95
9/30/88	BUY	271.91		
11/18/88	SELL	266.47	-5.44	112.51
12/23/88	BUY	277.87		
3/3/89	SELL	291.18	13.31	125.82
4/14/89	BUY	301.36		
6/16/89	SELL	321.35	19.99	145.81
7/28/89	BUY	342.15		
9/15/89	SELL	345.06	2.91	148.72
12/8/89	BUY	348.69		
1/12/90	SELL	339.93	-8.76	139.96
3/16/90	BUY	341.91		
4/27/90	SELL	329.11	-12.8	127.16
5/4/90	BUY	338.39		
7/13/90	SELL	367.31	28.92	156.08
10/5/90	BUY	311.5		
3/15/91	SELL	373.59	62.09	218.17

Total long trades:	25
Profitable longs:	16 (64%)
Biggest gain:	62.09

Testing the moving average crossover method produced these results.

FIGURE 10

	EXP MA * CROSSOVER	MACD	RAVI *	TURBO MACD
Total long trades:	6	20	9	25
Profitable longs:	4 (67%)	11 (55%)	7 (78%)	16 (64%)
Biggest gain:	84.08	70.76	73.74	62.09
Biggest loss:	-40.49	-15.23	-16.48	-22.96
Average gain:	26.56	10.23	29.45	8.73
Total gain:	159.37	204.56	265.13	218.17

NOTES:
* Assumes last open trade closed on 7/12/91; no sell signal from these models at 7/12/91

Comparing the four different methods highlights the strengths of using moving averages that respond to changes in the market volatility.

FIGURE 11

APPENDIX: LOTUS SPREADSHEET FORMULAS

APPENDIX: LOTUS SPREADSHEET FORMULAS

			F	G	H	I	J	K	L
CLOSE			S&P500 weekly close	EXP MA LONG	EXP MA SHORT	VIDYA LONG	VIDYA SHORT	RAVI (J-I)	TRADE INDICATOR
YR	MO	DT							
80	1	4	106.52	106.52	106.52	106.52	106.52	0.00	
80	1	11	109.92	106.79	107.03	106.79	107.03	0.27	
80	1	18	111.07	107.12	107.64	107.12	107.64	2.05	
80	1	25	113.61	107.63	108.53	107.63	108.53	3.91	
80	2	1	115.12	108.21	109.52	108.21	109.52	5.06	
80	2	8	117.95	108.97	110.78	108.97	110.78	6.59	
80	2	15	115.41	109.47	111.48	109.47	111.48	6.69	
80	2	22	115.04	109.91	112.01	109.91	112.01	6.23	
80	2	29	113.66	110.20	112.26	112.01	112.26	4.50	
80	3	7	106.51	109.91	111.40	109.04	111.47	5.56	0
80	3	14	105.43	109.56	110.50	107.60	110.60	5.07	0

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G19: 0.078*F19+(1-0.078)*G18
H19: 0.15*F19+0.85*H18
I19: 0.077*@STD(F7..F19)/6*F19+(1-0.077*@STD(F7..F19)/6)*I18
J19: 0.15*@STD(F10..F19)/4*F19+(1-0.15*@STD(F10..F19)/4)*J18
K19: [W7] +J19-I19
L19: (F0) [W4] @IF(K19/K18<0,1,0)
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The basic formulas for each column are presented in a Lotus spreadsheet. Column F is the weekly close for the S&P 500, while column G is the exponential moving average using a 0.078 smoothing constant. Column H is the EMA using a 0.15 smoothing constant, and column I is the Lotus formula for the long VIDYA. STD is the standard deviation formula in Lotus for the cell range stated within the parenthesis. Column J is the short version formula. Column K is the difference between column J and I.

In sum, this new class of variable index dynamic moving averages — VIDYA — adapts moving averages to the changing nature of markets.

A single formulation tracks market changes well despite the increased volatility of recent years. VIDYA serves as a variable-length exponential moving average, taking a greater "bite" out of the most recent data as market volatility increases. Like all moving averages, VIDYA also lags the market, since it is derived from past data — probably its biggest limitation.

In sum, this new class of variable index dynamic moving averages — VIDYA — adapts moving averages to the changing nature of markets. Any dimensionless market variable can be used to link these averages to the market. The figures provided illustrate well the responsiveness of these averages to market changes. Common trading strategies for moving averages can be implemented using VIDYA, demonstrated with RAVI and TurboMACD. VIDYA is also well suited for setting stops, as it closely tracks the market. VIDYA should be a formidable and dynamic addition to the trader's arsenal.

Tushar Chande holds a doctorate in engineering from the University of Illinois and a master's degree in business administration from the University of Pittsburgh.

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