

Trading 1Min Bar Crude Light Futures Using The Fading Memory Polynomial Velocity Strategy

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This is a mathematical technique that fits a n^{th} order polynomial to the last N price bars but calculates the coefficients of the polynomial such that the error between the current n^{th} order polynomial and the current bar is weighted much higher than the error between the price N bars ago and the value of the n^{th} order polynomial N bars ago. As an example, if the latest price is at time t and the price made a turn at time bar $t-10$, then we do not want prices prior to $t-10$ affecting the current polynomial fit as much. As will be shown the most familiar case of this fading memory technique is the exponential moving average. The fading memory technique is in contrast to the Least Squares Polynomial fit, which weights all past errors between the polynomial and the price bar equally.

In previous working papers at <http://www.meyersanalytics.com/papers.html> we showed how the application of a price curve generated by Nth Order Fixed Memory Polynomial Velocity could be used to develop a strategy to buy and sell futures intraday. The reasoning behind this type of strategy was to only trade when the price trend velocity was above a certain threshold. Many times, prices meander around without any notable trend and this is considered noise. During these times, we do not wish to trade because of the cost of whipsaw losses that would occur from this type of price action. When a price trend finally starts, the velocity of that price trend moves above a minimum threshold noise value. Thus, the velocity strategy would only issue a trade when certain velocity thresholds above “noise” levels are crossed.

The velocity strategy that we will use here to trade the Crude Light futures contract is called the Nth Order **Fading** Memory Adaptive Polynomial Velocity Strategy. The word “Adaptive” is used because the polynomial inputs change over time, adapting to the changing trading patterns of the Crude Light futures contract. The Nth Order Fading Memory Adaptive Polynomial Velocity Strategy has a number of unknown inputs that we must determine before we can use this strategy to trade. These unknown inputs to the Fading Memory Polynomial are the polynomial order (degree), the optimum number of prices we need to determine the coefficients of the polynomial and finally the velocity thresholds. Here we will use Walk Forward Optimization and out-of-sample performance to determine the “best” polynomial inputs as well as how these inputs should change over time. We will use the n^{th} Order Fading Memory Adaptive Polynomial Velocity Strategy to trade the Crude Light futures contract on an intraday basis using one-minute bar price data. To test this strategy, we will use one-minute bar prices of the Crude Light futures contract (CL) traded on NYMEX WTI and Globex for the five+ years from January 5, 2011 to August 11, 2017.

The n^{th} Order Fading Memory Adaptive Polynomial Velocity Defined

The adaptive n^{th} order Fading Memory Polynomial Velocity is constructed and plotted at each bar by solving for the coefficients $b_1, b_2, b_3, \dots, b_n$ for the discrete orthogonal Meixner polynomials at each bar using the exponential decay factor $\alpha=(1-\beta)$ and the equation for b_j shown in the “Math” appendix of this paper. Then next day estimated **Velocity(t+1)** is constructed from the equation shown in the “Math” appendix and plotted under the price chart.

The velocity of a 2nd, 3rd and 4th order polynomial should change faster than the straight line (1st order velocity). As observed from the 2nd order velocity equation in the “Math” section, there is an acceleration component in the calculation of the velocity. This means that the 2nd order velocity will reflect a change in the price trend much faster than the straight-line velocity which does not have an acceleration component. The same is true for 3rd and 4th order velocities. Whether higher order polynomial velocities are an advantage or not we will let the computer decide when we let the computer search for the “best” polynomial degree as described below.

At each bar, we calculate the nth order (1st through 4th) fading memory polynomial velocity from the formulas in the “Math” appendix. As we will show below, optimization will determine the order or degree for nth order polynomial velocity that will be used. When the velocity is greater than the threshold amount *vup* we will go long. When the velocity is less than the threshold amount *-vdn* we will go short.

Buy Rule:

IF Velocity is greater than the threshold amount *vup* then buy at the market.

Sell Rule:

IF Velocity is less than the threshold amount *-vdn* then sell at the market.

The strategy follows the velocity curve. When the velocity is greater than the threshold amount *vup* a buy signal is issued. The threshold *vup* serves as a noise filter. That is, price noise creates a lot of small back and forth velocity movement. Unless the velocity can break some threshold to the upside, no trade is issued and the move is considered price noise. The same logic holds for the sell threshold *vdn*.

Intraday Bars Exit Rule:

Close the position at 1420 EST when the open outcry pit session ends. (no trades will be carried overnight).

First Trade of Day Entry Rule:

All trade signals before the 9am EST open outcry pit session are ignored. We’ve included this rule because we observed that overnight Globex trading mostly consists of price movements with few sustainable trends. 60-70% of sustainable trends usually occur during the open outcry pit session hours.

To test this strategy, we will use one-minute bar prices of the mini Crude Light futures contract traded on the NYMEX WTI and Globex and known by the symbol CL for the 293 trading weeks from January 5, 2012 to August 11, 2017.

We will test the Fading Memory strategy with the above CL 1 min bars on a *walk forward basis*, where the in-sample(IS) will be 30 calendar days and the out-of-sample(OOS) will be the next 7 calendar days following as will be described below. The 7-calendar day OOS periods will end on a Friday as will the 30-calendar day IS periods.

Testing the Polynomial Velocity Strategy Using Walk Forward Optimization

There will be four strategy parameters to determine:

1. **degree**, degree=1 for straight line velocity, degree=2 for 2nd order velocity, etc.
2. **alpha** = $(1-\beta)$ The exponential decay weight for the Nth Order Fading Memory Polynomial calculation.
3. **vup**, the threshold amount that velocity must be greater than to issue a buy signal
4. **vdn**, the threshold amount that velocity must be less than to issue a sell signal

We will test this strategy with the above CL 1 min bars on a walk forward basis, as will be described below. To create our walk forward files we will use the *add-in* software product called the Power Walk Forward Optimizer (PWFO). In TradeStation (TS) or MultiCharts(MC), we will run the PWFO strategy *add-in* along with the nth Order Fading Memory Polynomial Velocity Strategy on the CL 1min data from January 5, 2012 to August 11, 2017. The PWFO will breakup and create 30-day calendar in-sample sections along with their corresponding one calendar week out-of-sample sections from the 293 weeks of CL (see Walk Forward Testing below) creating 288 out-of-sample weeks.

What Is an In-Sample Section and Out-Of-Sample Section?

Whenever we do a TS optimization on many different strategy inputs, TS/MC generates a report of performance metrics (total net profits, number of losing trades, etc.) vs these different strategy inputs. If the report is sorted on

say the total net profits(*tnp*) performance metric column then the highest *tnp* would correspond to a certain set of inputs. This is called an *in-sample* or *test section*. If we choose a set of strategy inputs from this report based upon some performance metric we have no idea whether these strategy inputs will produce the same results on future price data or data they have not been tested on. Price data that is not in the in-sample section is defined as *out-of-sample data*. Since the performance metrics generated in the in-sample section are mostly due to “curve fitting” (see Walk Forward Out-of-Sample Testing section below) it is important to see how the strategy inputs chosen from the in-sample section perform on out-of-sample data.

What Does the Power Walk Forward Optimizer (PWFO) Do?

The PWFO is a TS/MC *add-in* that breaks up the TS/MC optimization run into many user selectable in-sample and out-of-sample sections. The PWFO prints out the in-sample sample performance metrics **and the out-of-sample performance results**, on one line, for each case or strategy input variable combination that is run by the TradeStation(TS) optimization module to a user selected spreadsheet comma delimited file. The PWFO can generate up to 500 different in-sample and out-of-sample date optimization files in one TS run, saving the user from having to generate optimization runs one at a time. The PWFO output allows you to quickly determine whether your procedure for selecting input parameters for your strategy just curve fits the price and noise, or produces statistically valid out-of-sample results. In addition to the out-of-sample performance results presented for each case, 30+ superior and robust performance metrics (many are new and never presented before) are added to each case line in the in-sample section and printed out to the comma delimited file. These 30+ performance metrics allow for a superior and robust selection of input variables from the in-sample section that have a higher probability of performing well on out-of-sample data (Please see <http://meyersanalytics.com/Walk-Forward-Optimization.html> for a listing of these performance metrics).

For our computer run we will have the PWFO breakup the 293 weeks of CL one-minute bar price data into 288 in-sample and out of sample files. The in-sample sections will be 30 calendar days and the out-of-sample(oos) section will be the one week following the in-sample section. The oos week will always end on a Friday as will the 30-day calendar in-sample section. As an example, the first in-sample section would be from 1/5/2012 to 2/3/2012 and the out-of-sample section would be the week following from 2/6/2012 to 2/10/2012. (all in-sample and out-of-sample sections always end on a Friday). We would then move everything ahead a week and the 2nd in-sample section would be from 1/12/2012 to 2/10/2012 and the week following out-of-sample section would be from 2/13/2012 to 2/7/2012 Etc.

The PWFO 288 in-sample/out-of-sample section dates are shown in **Table 1** below. We will then use another software product called the Walk Forward Performance Metric Explorer (WFME) on each of the 288 in-sample and out-of-sample(oos) sections generated by the PWFO to find the best in-sample section performance *filter* that determines the strategy input parameters (*degree, N, vup, vdn*) that will be used on the out-of-sample data. Detailed information about the PWFO and the WFME can be found at www.meyersanalytics.com

For the in-sample data we will run the TradeStation optimization engine on the 288 weeks of CL 1 min bars with the following ranges for the nth order fading memory polynomial velocity strategy input variables.

1. **pw=degree from 1 to 4**
2. **N from 20 to 70 in steps of 10.**
3. **vup from 0.25 to 3 in steps of 0.25**
4. **vdn from 0.25 to 3 in steps of 0.25**
5. **Mult = 36, (See Appendix 2, the Normalization Multiplier)**

Note: I use N because it gives a better understanding of how many bars of past data are approximately being used. N and α ($\alpha=1-\beta$) are approximately related by the formula $\alpha=2/(1+N)$. N is converted to α by this formula in the Nth Order Fading Memory Polynomial calculation

This will produce 3456 different cases or combinations of the input parameters for each of the 288 PWFO output files.

Walk Forward Out-of-Sample Testing

Walk forward analysis attempts to minimize the curve fitting of price noise by using the law of averages from the Central Limit Theorem on the out-of-sample performance. In walk forward analysis the data is broken up into many in-sample and out-of-sample sections. Usually for any strategy, one has some performance metric selection procedure, which we will call a filter, used to select the input parameters from the in-sample optimization run. For instance, a *filter* might be all cases that have a profit factor (PF) greater than 1 and less than 3. For the number of cases left, we might select the cases that had the best percent profit. This procedure would leave you with one case in the in-sample section output and its associated strategy input parameters. Now suppose we ran our optimization on each of our many in-sample sections and applied our filter to each in-sample section output. We would then use the strategy input parameters found by the *filter* in each in-sample section on the out-of-sample section immediately following that in-sample section. The input parameters found in each in-sample section and applied to each out-of-sample section would produce independent net profits and losses for each of the out-of-sample sections. Using this method, we now have "x" number of independent out-of-sample section profit and losses from our filter. If we take the average of these out-of-sample section net profits and losses, then we will have an estimate of how our strategy will perform on average. Due to the Central Limit Theorem, as our sample size increases, the spurious noise results in the out-of-sample section performance tend to average out to zero in the limit leaving us with what to expect from our strategy and filter. **Mathematical note:** *This assumption assumes that the out-of-sample returns are from probability distributions that have a finite variance.*

Why use the walk forward technique? Why not just perform an optimization on the whole price series and choose the input parameters that give the best total net profits or profit factor? Surely the price noise cancels itself out with such a large number of in-sample prices and trades. Unfortunately, nothing could be farther from the truth! Optimization is a misnomer and should really be called combinatorial search. As stated above, whenever we run a combinatorial search over many different combinations of input parameters on noisy data on a fixed number of prices, *no matter how many*, the best performance parameters found are guaranteed to be due to *“curve fitting”* the noise and signal. What do we mean by *“curve fitting”*? The price series that we trade consists of random spurious price movements, which we call noise, and repeatable price patterns (*if they exist*). When we run, for example, 5000 different input parameter combinations, the best performance parameters will be from those strategy input variables that are able to produce profits from the price pattern *and* the random spurious movements. While the price patterns will repeat, the same spurious price movements will not. If the spurious movements that were captured by a certain set of input parameters were a large part of the total net profits, as they usually are in real price movements, then choosing these input parameters will produce losses when traded on future data. These losses occur because the spurious movements will not be repeated in the same way. This is why strategy optimization, neural net optimizations or combinatorial searches with no out-of-sample testing cause losses when traded in real time by mistaking chance fluctuations for genuine effects. Unfortunately, it is human nature to extrapolate past performance to project future trading results and thus results from the chance fluctuations of curve fitting give the illusion, a modern “siren call” so to speak, of future trading profits.

To gain confidence that our input parameter selection method using the optimization output of the in-sample data will produce profits, we must test the input parameters we found in the in-sample section on out-of-sample data. In addition, we must perform the in-sample/out-of-sample analysis many times. Why not just do the out-of-sample analysis once or just three times? Well just as in Poker or any card game, where there is considerable variation in luck from hand to hand, walk forward out-of-sample analysis give considerable variation in week to week out-of-sample profit “luck”. That is, by pure chance we may have chosen some input parameter set that did well in the in-sample section data *and* the out-of-sample section data. To minimize this type of “luck”, statistically, we must repeat the walk forward out-of-sample (oos) analysis over many in-sample/oos sections and take an average of our weekly results over all out-of-sample sections. This average gives us an expected weekly return and a standard deviation of weekly returns which allows us to statistically estimate the expected equity and its path ranges for N weeks in the future.

Finding the Strategy Input Parameters in The Walk Forward Test Sections

The PWFO generates a number of performance metrics in the in-sample section. (Please see <http://meversanalytics.com/Walk-Forward-Optimization.html> for a listing of these performance metrics). The question we are attempting to answer statistically, is which performance metric or combination of performance metrics (which we

will call a *filter*) in the in-sample section will produce strategy inputs that produce statistically valid profits in the out-of-sample section. In other words, we wish to find a metric *filter* that we can apply to the in-sample section that can give us strategy inputs that will produce, on average, good trading results in the out-of-sample sections. The PWFO produces a total of 32 different performance metrics in the in-sample section. If we have 3456 different input variations or cases then the in-sample section consists of 32 columns of performance metrics for each of the 3456 different strategy inputs or rows.

An example of a simple filter would be to choose the row in the in-sample section that had the highest net profit or perhaps a row that had one the best performance metric from one of the other 32 PWFO metrics. Unfortunately, it was found that this type of simple filter very rarely produces good out-of-sample results. More complicated metric filters can produce good out-of-sample results minimizing spurious price movement biases in the selection of strategy inputs.

A note first: In all previous working papers, I assumed that high profit factors (**PF**) in the in-sample section usually meant poor performance in the out-of-sample-section. In addition, I assumed that high equity correlation coefficients (r^2) in the in-sample section also meant usually meant poor performance in the out-of-sample-section. I assumed this because I felt the curve fitted performance in the in-sample section would have high **PF**s and high r^2 s and would not continue to perform well in the out-of-sample section... A kind of reversion to the mean and a measure of how well the price noise is being fitted in the in-sample section assumption. In this paper, I tested those assumptions by scanning for filters that have high **PF**s and r^2 s in the in-sample section and examined how these filters performed in the out-of-sample section. I was surprised, at least for the CL 1-min data examined here, high **PF** and r^2 filters in the in-sample section performed much better than my previous assumptions.

Here is a combination filter, discovered by the Walk Forward Metric Explorer that is used in this paper with good out-of-sample results. In the in-sample section we eliminate all strategy input rows that have a $PF < 1.25$. **R2** is defined as the in-sample trade equity regression trend line coefficient of correlation r^2 . r^2 is a measure of how well a straight line fits the equity curve generated by a set of in-sample strategy inputs. So, in the in-sample section we eliminate all strategy input rows that have a $R2 < 50$. After using the **PF-R2** filter, as described, there can still be 100's of rows left in the in-sample section. The PWFO generates the metric **mKr**. This metric is the **Modified k-ratio = eqTrn/mDev**, where **eqTrn** is the **Slope of In-Sample Trade Equity Trend Line** and **mDev** is the **Median of the absolute deviations of equity from straight line fit to equity curve**. Let us choose the 10 rows in the in-sample section that contain the highest(top) value of **mKr** from the rows that are left after the **PF-R2** row elimination. This filter will now leave 10 rows in the in-sample section that satisfy the above filter conditions. Suppose for this filter, within the 10 in-sample rows that are left, we want the row that has the maximum metric **tnp** in the in-sample section. **tnp is the Total Net profits for a given set of inputs in the In-Sample section**. This would produce a filter named **t10mKr|pf>1.25| r2>50-tnp**. This in-sample filter leaves only one row in the PWFO in-sample section with its associated strategy inputs and out-of-sample net profit in the out-of-sample section. This particular filter **t10mKr|pf>1.25| r2>50-tnp** finds the strategy inputs parameters in each of the 288 in-sample sections and applies these inputs to each of the 288 out-of-sample sections. Using the filter in-sample strategy inputs on the 288 out-of-sample sections, the average out-of-sample performance is calculated. In addition, many other important out-of-sample performance statistics for this filter are calculated and summarized. **Figure 3** shows such a filter computer run along with a small sample of other filter combinations that are constructed in a similar manner. **Row 3** of the sample output in **Figure 3** shows the results of the filter discussed above. A total of 67500 different metric filters were examined. We chose **Row 3** because it had a lower **BE**, **BLW** and **Dev^2** and a higher **KTau** and **eqR2** along with better statistics than the rows below it. More on this below and on how that number of filters combinations effect the probability that the filter chosen was or was not due to chance.

Bootstrap Probability of Filter Results: Using modern "Bootstrap" techniques, we can calculate the probability of obtaining each filter's total out-of-sample *net* profits by chance. By *net* we mean subtracting the cost and slippage of all round-trip trades from the total out-of-sample profits. Here is how the bootstrap technique is applied. Suppose as an example, we calculate the total out-of-sample net profits(toNP) over all out-of-sample weeks for a given filter like above. A mirror filter is created. However, instead of picking an out-of-sample net profit(OSNP) from a row that the filter picks, the mirror filter picks a *random* row's OSNP in each of the 288 PWFO files. Suppose we repeat this random row section 5000 times. Each of the 5000 mirror filters will choose a random row's OSNP of their own in

each of the 288 PWFO files. At the end, each of the 5000 mirror filters will have 288 *random* OSNP's picked from the rows of the 288 PWFO files. The sum of the 288 random OSNP picks for each of the 5000 mirror filters will generate a random total out-of-sample net profit(toNP). The average and standard deviation of the 5000-mirror different random toNPs will allow us to calculate the chance probability for each of *our* filter's toNP. Thus, given the mirror filter's bootstrap random toNP average and standard deviation, we can calculate the probability of obtaining our filter's toNP by pure chance alone. Figure 3 lists the 5000-mirror filter's bootstrap random average for our 288 out-of-sample files of (**\$135.3**) with a bootstrap standard deviation of **\$65.9**. (Side Note. The average is the average per out-of-sample period(weekly). So, the average for the random selection would be the random (Average Random toNP/288. The average net weekly for **our filter, t10mKr|pf>1.25| r2>50-tnp**, would be the filter toNP/ (# of OOS) periods traded or **69430/249=278.8**. The probability of obtaining our filters average weekly net profit of **278.8** is 2.88×10^{-7} which is **5.00** standard deviations from the bootstrap average. For our filter, in row 3 in Figure 3, the expected number of cases that we could obtain by pure chance that would match or exceed **\$278.8** is $[1 - (2.88 \times 10^{-7})^{67500}] \sim 67500 \times 2.88 \times 10^{-7} = 0.019$ where **67500** is the total number of different filters we looked at in this run. This number is much less than one so it is improbable that our result was due to pure chance.

Results

Table 1 on page 8 below presents a table of the 288 in-sample and out-of-sample windows, the selected optimum strategy inputs and the weekly out-of-sample results using the filter described above.

Figure 1 presents a graph of the equity and net equity curves generated by using the filter on the 288 weeks ending 2/10/12 to 8/11/17. The equity curves are plotted from the Equity and Net Equity columns in Table 1. Plotted on the equity curves are 2nd Order Polynomial fits. The blue line is the equity curve without commissions and the red dots on the blue line are new highs in equity. The brown line is the net equity curve with commissions and the green dots are the new highs in net equity. The grey line is the weekly CL prices superimposed on the equity chart.

Figure 2 Walk Forward Out-Of-Sample Performance for CL Fading Memory Polynomial Velocity Strategy
1-minute bar chart of CL from 8/10/17-8/11/2017

Figure 3 Partial output of the Walk Forward Metric Performance Explorer (WFME)
Run on the 288 PWFO files of the CL 1min bars Nth Order Fading Memory Velocity Strategy

Discussion of Strategy Performance

In Figure 3 Row 4 of the spreadsheet filter output are some statistics that are of interest for our filter. **BE** is the break-even weeks. Assuming the trade average and standard deviation for this filter are from a normal distribution, this is how many weeks we need to trade this strategy so that we have a 98% probability that all equity paths after that number of weeks will be greater than zero. BE is 56 weeks for this filter. This means we would have to trade this strategy for at least 56 weeks to have a 98% probability that our equity would be positive. Another interesting statistic is **Blw**. Blw is the maximum number of weeks the OSNP equity curve failed to make a new high. Blw is 31 weeks for this filter. This means that 31 weeks was the longest time that the equity for this strategy failed to make a new equity high.

To see the effect of walk forward analysis, look at **Table 1**. Notice how the input parameters *pw*, *N*, *vup* and *vdn* take sudden jumps from high to low and back. This is the walk forward process quickly adapting to changing volatility conditions in the in-sample sample. In addition, notice how often *degree* changes from a straight-line velocity with *degree=1* to a 2nd, 3rd and 4th order velocity with *degree= 2, 3 and 4*. The 3rd and 4th order velocities, due to the higher order components, change much faster than the straight-line velocity. When the data gets very noisy with a lot of spurious price movements, it's better to have the velocity change slower filtering out the noisy data. During other times when the noise level is not as much it is better to have the velocity break its *vup* and *vdn* barriers faster to get onboard a trend faster. This is what the filter is doing. When there is a lot of noise in the in-sample section it switches to the 1st or 2nd order curve velocity. When the noise level is lower in the in-sample section, it switches to the faster changing 3rd or 4th order curve velocity.

Using this filter, the strategy was able to generate \$69,430 net equity after commissions and slippage trading one CL contract for 288 weeks. Note \$20 roundtrip commission and slippage was subtracted from each trade and no positions were carried overnight. The average net profit after commissions and slippage in the weeks that were traded was \$279/week. The largest losing week was -\$3780, the largest losing trade was -\$2680 and the largest drawdown was -\$8120. The longest time between new equity highs was 31 weeks.

In observing Table 1 we can see that this strategy and filter made trades from a low of no trades/week to a high of 26 trades/week with an average of 3.8 trades/week on the weeks it did trade. The strategy seemed to wait for strong trends and then initiate a buy or sell. There were many weeks that had no trades. Out of the 288 out-of-sample weeks the filter only traded 249 of those weeks or 86% of the time with 53% of all trades profitable and 61% of all oos weeks profitable. In observing the Equity Curve plot in Figure 1 we can see that the equity did quite well in both big down moves and range based moves of the CL.

References

1. Efron, B., Tibshirani, R.J., (1993), "An Introduction to the Bootstrap", New York, Chapman & Hall/CRC.
2. Morrison, Norman "Introduction to Sequential Smoothing and Prediction", McGraw-Hill Book Company, New York, 1969.

**Figure 1 Graph of Equity Curves Applying the Walk Forward Filter Each Week
On CL 1min Bar Prices 02/05/12 – 8/11/17**

Note: The blue line is the equity curve without commissions and the red dots on the blue line are new highs in equity. The brown line is the equity curve with commissions and the green dots are the new highs in net equity. The grey line is the CL Weekly Closing prices superimposed on the Equity Chart.

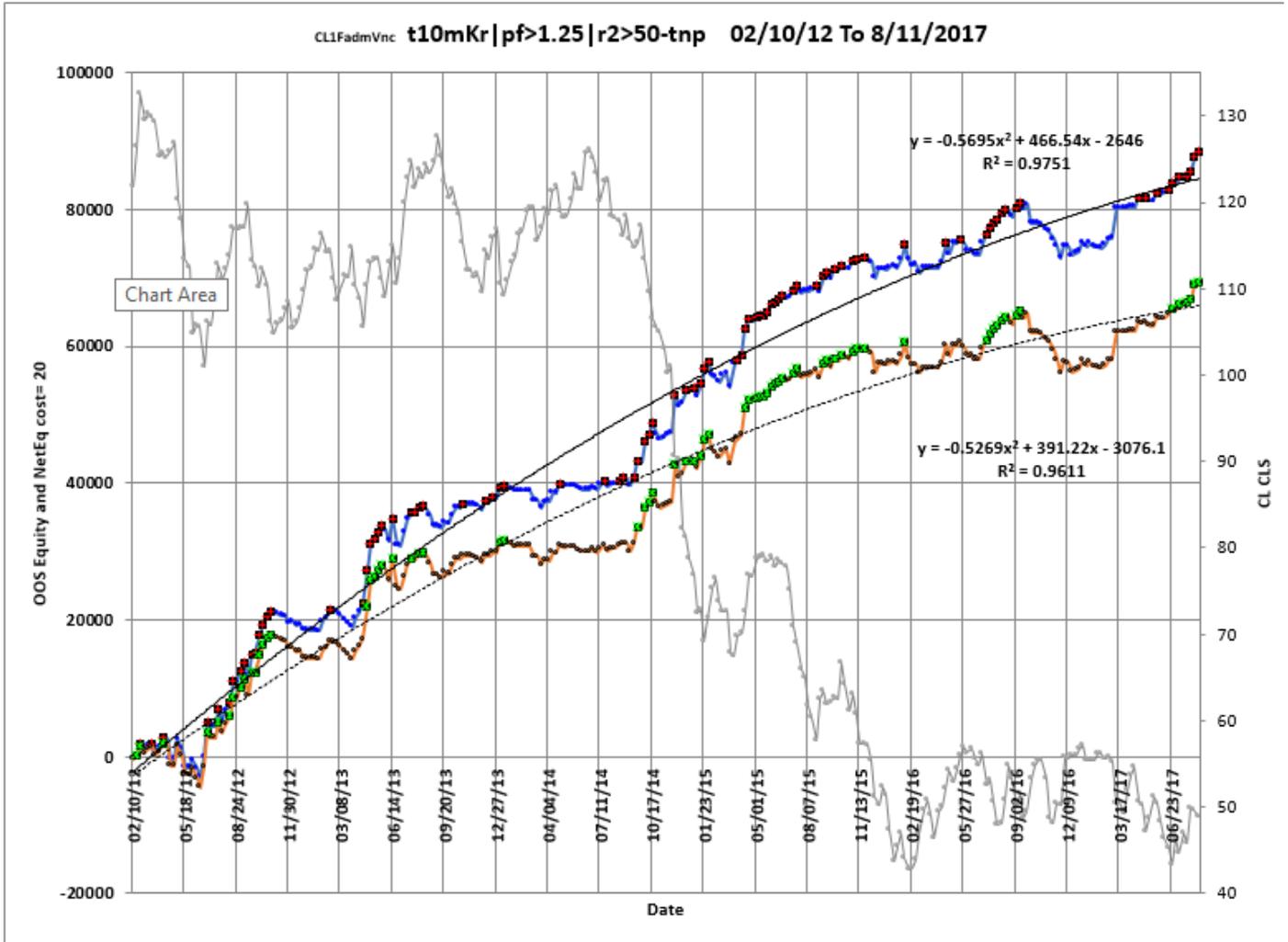
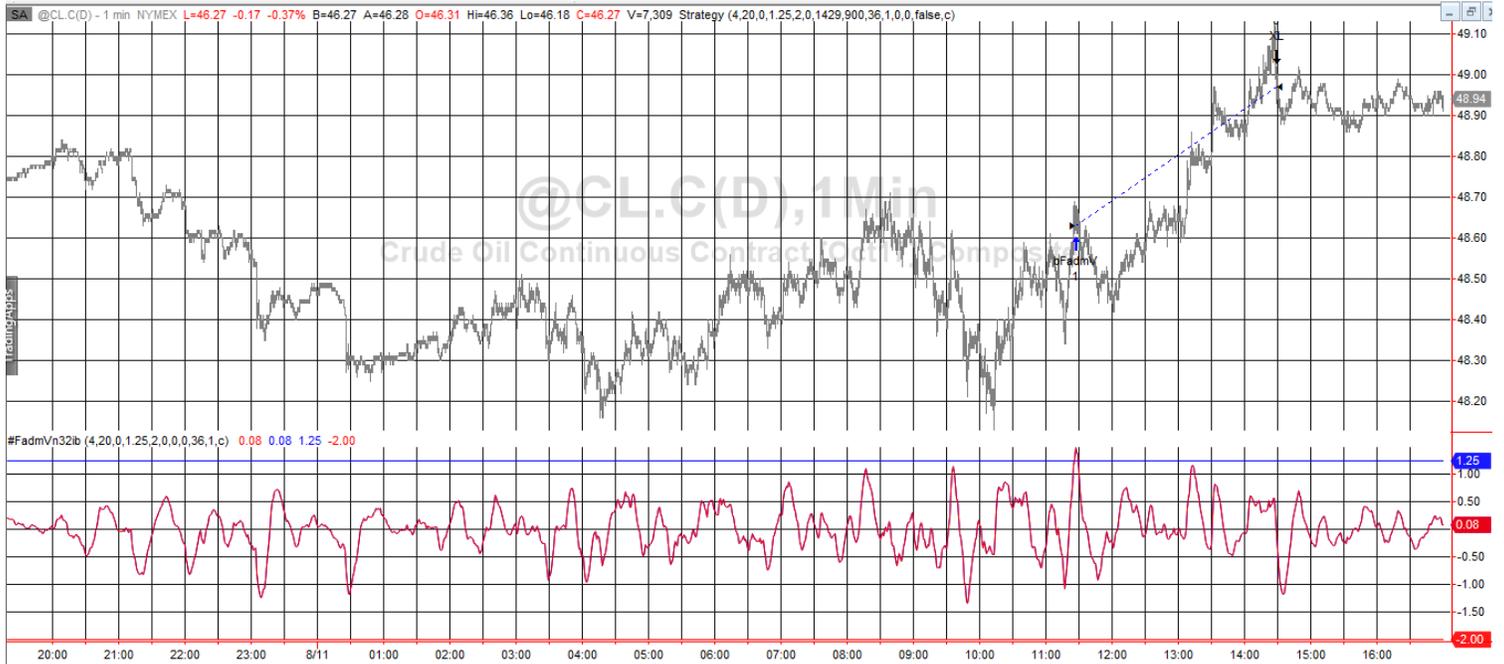


Figure 2 Walk Forward Out-Of-Sample Performance for CL Fading Memory Polynomial Velocity Strategy
1-minute bar chart of CL from 8/10/17-8/11/17



**Figure 3_ Partial output of the Walk Forward Metric Performance Explorer (WFME)
CL1 min bars Nth Order Fading Memory Velocity Strategy**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1	CL1FadmVnc	s02/10/12	e08/11/17	#288	AnyTnp							a(135.3)	s82.8	f67500							c=\$20				
2	Filter-Metric	toGP	toNP	aoGP	aoTr	ao#T	std	t	oW oL	%Wtr	%P	LLtr	LLp	eqDD	wpr	lpr	#	eqTrn	eqV^2	Dev^2	KTau	eqR2	Blw	BE	Prob
3	t10mKr pf>1.25 r2>50-tnp	88310	69430	355	93.5	3.8	1331	4.21	1.26	53	61	-2680	-3780	-8120	8	7	249	302	139	5370	86	96	31	56	2.88E-07
4	t10mKr pf>1.5 r2>50-tnp	86440	67560	350	91.6	3.8	1339	4.11	1.26	53	60	-2680	-3780	-10720	8	6	247	297	111	5946	81	95	44	59	4.00E-07
5	t10mKr pf>1.5 r2>60-tnp	86630	66630	352	86.6	4.1	1363	4.05	1.26	53	61	-2680	-3780	-12480	8	7	246	301	73	6666	78	93	46	60	4.72E-07
6	t10mKr -tnp	82350	66230	342	102.2	3.3	1332	3.98	1.23	54	61	-2680	-3780	-7010	8	6	241	285	96	5887	81	94	45	61	3.70E-07
7	t10mKr pf>1.75 r2>50-tnp	84230	65810	351	91.5	3.8	1391	3.91	1.22	53	60	-2510	-3780	-9850	8	8	240	285	122	6397	75	93	40	63	3.84E-07
8	t10mKr pf>1.25 -tnp	83460	65260	339	91.7	3.7	1338	3.98	1.26	53	59	-2680	-3780	-7150	8	7	246	283	157	5388	78	95	37	62	6.63E-07
9	t10mKr pf>2 -tnp	82420	63940	341	89.2	3.8	1366	3.88	1.24	53	60	-2110	-3780	-6190	8	7	242	272	102	5570	79	94	37	64	7.08E-07
10	b20mDev pf>1.5 r2>70-eq2A	76980	63060	377	110.6	3.4	1348	4	1.36	53	59	-2460	-3330	-7880	9	7	204	289	140	5973	80	94	45	51	4.05E-08

The WFME Filter Output Columns are defined as follows:

Row 1 CL1FadmVnc is the strategy abbreviation, First OOS Week End Date (2/05/11), Last OOS Week End Date (8/11/17), **Number of weeks** (#288) a=weekly average of bootstrap random picks. s= weekly standard deviation of bootstrap random picks. f=number of different filters examined. c= slippage and round-trip trade cost(c=\$20).

Filter = The filter that was run. Row 3 filter **t10mKr|pf>1.25| r2>50-tnp**

The **t10mKr|pf>1.25| r2>50-tnp** filter produced the following average 288 week statistics on Row 3.

toGP = Total out-of-sample(oos) gross profit for these 304 weeks.

toNP = Total out-of-sample gross profit(toGP) minus the total trade cost.
toNP=toGP – (Number of trade weeks)*ao#T*Cost.

aoGP = Average oos gross profit for the 304 weeks

aoTr = Average oos profit per trade

ao#T = Average number of oos trades per week

std = standard deviation of weekly oos gross profit

t = The student t statistic for the 304 weekly oos profits. The higher the t statistic the higher the probability that this result was not due to pure chance

oW|oL = The average oos winning trade divided by the average oos losing trade

%Wtr = percent of all oos trades that were winning trades

%P = percent of all oos periods that were profitable.

LLtr = The largest losing oos trade in all oos periods,

LLp = The largest losing oos period(week)

eqDD = The oos equity drawdown

wpr = The largest number of winning oos periods (weeks) in a row.

lpr = The largest number of losing oos periods (weeks) in a row

= The number of weeks this filter produced a weekly result. Note for some weeks there can be no strategy inputs that satisfy a given filter's criteria and thus there are no trades for that oos period.

eqTrn = The straight line trend of the oos gross profit equity curve in \$/week.

eqV² = The ending velocity of 2nd order polynomial that is fit to the oos equity curve

eqR² = The correlation coefficient(r^2) of a straight line fit to the oos equity curve

Dev² = A measure of equity curve smoothness. The square root of the average [(equity curve minus a straight line)²]

Blw = The maximum number of weeks the oos equity curve failed to make a new high.

BE = Break even weeks. Assuming the average and standard deviation are from a normal distribution, this is the number of weeks you would have to trade to have a 98% probability that your oos equity is above zero.

Prob = the probability that the filter's toNP was due to pure chance.

Table 1 Walk Forward Out-Of-Sample Performance Summary for CL Nth Order Fading Memory Polynomial Velocity Strategy

CL-1 min bars 1/5/2012 - 8/11/2017. The input values *degree(pw)*, *N*, *vup*, *vdn* are the values found from applying the filter to the in-sample section optimization runs.

Filter= **t10mKr|pf>1.25| r2>50-tnp** PF>=1.25, r2>=50 then top 10 mKr and then maximum tnp

- osnp** = Weekly Out-of-sample gross profit in \$
- NOnp\$20** = Weekly Out-Of-Sample Net Profit in \$ = **osnp-ont*20**.
- ont** = The number of trades in the out-of-sample week
- ollt** = The largest losing trade in the out-of-sample section in \$.
- odd** = The drawdown in the out-of-sample section in \$.
- EQ=Equity** = Running Sum of weekly out-of-sample gross profits \$
- NetEq=Net Equity** = running sum of the weekly out-of-sample net profits in \$
- pw= degree**, degree=1 for straight line velocity, degree=2 for 2nd order velocity, etc.
- N** = N the lookback period
- vup**, the threshold amount that velocity must be greater or equal to for a buy signal
- vdn**, the threshold amount that velocity has to be less than or equal to for a sell signal
- Note:** Blank rows indicate that no out-of-sample trades were made that week

In-Sample Dates			Out-Of-Sample Dates			osnp	NOnp\$20	ont	ollt	odd	EQ	NetEq	pw	N	vup	vdn
01/05/12	to	02/03/12	02/06/12	to	02/10/12	(290)	(370)	4	-1100	-1100	(290)	(370)	1	20	3	2
01/12/12	to	02/10/12	02/13/12	to	02/17/12	550	530	1	0	0	260	160	4	40	2.75	2.75
01/19/12	to	02/17/12	02/20/12	to	02/24/12	1650	1570	4	-360	-360	1910	1730	3	30	2.25	3
01/26/12	to	02/24/12	02/27/12	to	03/02/12	(1040)	(1240)	10	-1480	-3120	870	490	3	30	2.5	3
02/02/12	to	03/02/12	03/05/12	to	03/09/12	690	630	3	-220	-220	1560	1120	4	50	2.75	3
02/09/12	to	03/09/12	03/12/12	to	03/16/12	380	280	5	-720	-720	1940	1400	4	50	2.75	3
02/16/12	to	03/16/12	03/19/12	to	03/23/12	(1080)	(1160)	4	-1060	-1080	860	240	4	50	2.75	3
02/23/12	to	03/23/12	03/26/12	to	03/30/12	560	500	3	-740	-740	1420	740	3	60	2.75	3
03/01/12	to	03/30/12	04/02/12	to	04/06/12	1300	1160	7	-640	-1080	2720	1900	4	20	3	2
03/08/12	to	04/06/12	04/09/12	to	04/13/12						1900	1900	1	50	3	2.5
03/15/12	to	04/13/12	04/16/12	to	04/20/12	(3060)	(3180)	6	-1000	-3060	(340)	(1280)	1	70	2.5	1.75
03/22/12	to	04/20/12	04/23/12	to	04/27/12						(1280)	(1280)	1	70	2.75	2
03/29/12	to	04/27/12	04/30/12	to	05/04/12	2960	2900	3	-40	-40	2620	1620	1	70	2.75	2
04/05/12	to	05/04/12	05/07/12	to	05/11/12	(1510)	(1530)	1	-1510	-1510	1110	90	1	50	3	3
04/12/12	to	05/11/12	05/14/12	to	05/18/12	(2650)	(2750)	5	-1190	-3020	(1540)	(2660)	1	70	0.25	2
04/19/12	to	05/18/12	05/21/12	to	05/25/12						(2660)	(2660)	4	50	3	3
04/26/12	to	05/25/12	05/28/12	to	06/01/12	1050	910	7	-530	-530	(490)	(1750)	4	70	2.75	1.75
05/03/12	to	06/01/12	06/04/12	to	06/08/12	(1220)	(1340)	6	-1070	-2630	(1710)	(3090)	4	70	2.75	1.75
05/10/12	to	06/08/12	06/11/12	to	06/15/12	(1290)	(1350)	3	-1610	-2810	(3000)	(4440)	1	70	2.75	2
05/17/12	to	06/15/12	06/18/12	to	06/22/12	2890	2850	2	0	0	(110)	(1590)	2	70	3	2
05/24/12	to	06/22/12	06/25/12	to	06/29/12	5150	5110	2	0	0	5040	3520	1	50	2.5	2.25
05/31/12	to	06/29/12	07/02/12	to	07/06/12	(650)	(730)	4	-1540	-1540	4390	2790	1	40	2.75	2.5
06/07/12	to	07/06/12	07/09/12	to	07/13/12	60	0	3	-310	-320	4450	2790	1	40	2.75	2.5
06/14/12	to	07/13/12	07/16/12	to	07/20/12	2400	2320	4	0	0	6850	5110	1	70	1.25	3
06/21/12	to	07/20/12	07/23/12	to	07/27/12	(1500)	(1640)	7	-940	-1510	5350	3470	1	60	1.25	1.75
06/28/12	to	07/27/12	07/30/12	to	08/03/12	1360	1220	7	-680	-2190	6710	4690	4	20	2	3
07/05/12	to	08/03/12	08/06/12	to	08/10/12	1310	1190	6	-40	-40	8020	5880	4	60	2	1.75
07/12/12	to	08/10/12	08/13/12	to	08/17/12	2920	2780	7	-150	-150	10940	8660	4	60	2	1.75
07/19/12	to	08/17/12	08/20/12	to	08/24/12	(30)	(50)	1	-30	-30	10910	8610	1	60	3	2.75
07/26/12	to	08/24/12	08/27/12	to	08/31/12	1680	1600	4	-70	-70	12590	10210	3	30	3	2.5
08/02/12	to	08/31/12	09/03/12	to	09/07/12	1200	1100	5	-1220	-2120	13790	11310	4	40	3	3
08/09/12	to	09/07/12	09/10/12	to	09/14/12	(2110)	(2370)	13	-810	-3050	11680	8940	4	40	1.25	2
08/16/12	to	09/14/12	09/17/12	to	09/21/12	3360	3280	4	-470	-470	15040	12220	4	30	2.25	3

In-Sample Dates			Out-Of-Sample Dates			osnp	NOnp\$20	ont	ollt	odd	EQ	NetEq	pw	N	vup	vdn
08/23/12	to	09/21/12	09/24/12	to	09/28/12	190	90	5	-710	-1030	15230	12310	3	30	2.75	0.5
08/30/12	to	09/28/12	10/01/12	to	10/05/12	2710	2570	7	-2050	-2050	17940	14880	3	30	2.75	0.25
09/06/12	to	10/05/12	10/08/12	to	10/12/12	1450	1390	3	-550	-550	19390	16270	4	30	3	3
09/13/12	to	10/12/12	10/15/12	to	10/19/12	1200	1080	6	-790	-1390	20590	17350	4	40	3	2.5
09/20/12	to	10/19/12	10/22/12	to	10/26/12	580	500	4	-440	-940	21170	17850	2	50	2.5	2
09/27/12	to	10/26/12	10/29/12	to	11/02/12	(60)	(140)	4	-810	-1300	21110	17710	2	50	2.5	2
10/04/12	to	11/02/12	11/05/12	to	11/09/12	(170)	(330)	8	-1370	-2610	20940	17380	2	70	2.25	0.75
10/11/12	to	11/09/12	11/12/12	to	11/16/12	(240)	(300)	3	-510	-510	20700	17080	1	60	2	3
10/18/12	to	11/16/12	11/19/12	to	11/23/12	(130)	(190)	3	-970	-1140	20570	16890	1	70	2.25	1.5
10/25/12	to	11/23/12	11/26/12	to	11/30/12	(930)	(990)	3	-610	-930	19640	15900	1	70	3	1.25
11/01/12	to	11/30/12	12/03/12	to	12/07/12	150	110	2	0	0	19790	16010	3	70	3	2.75
11/08/12	to	12/07/12	12/10/12	to	12/14/12	(600)	(720)	6	-450	-940	19190	15290	4	20	2	2.25
11/15/12	to	12/14/12	12/17/12	to	12/21/12	180	160	1	0	0	19370	15450	1	70	2.5	2.5
11/22/12	to	12/21/12	12/24/12	to	12/28/12	(930)	(1070)	7	-590	-1190	18440	14380	4	20	2	1.25
11/29/12	to	12/28/12	12/31/12	to	01/04/13							14380	1	60	2.5	2.75
12/06/12	to	01/04/13	01/07/13	to	01/11/13							14380	1	60	2.5	2.75
12/13/12	to	01/11/13	01/14/13	to	01/18/13	50	30	1	0	0	18490	14410	1	50	2	3
12/20/12	to	01/18/13	01/21/13	to	01/25/13	(110)	(130)	1	-110	-110	18380	14280	1	30	2.25	3
12/27/12	to	01/25/13	01/28/13	to	02/01/13	1450	1350	5	-250	-250	19830	15630	4	40	1.75	3
01/03/13	to	02/01/13	02/04/13	to	02/08/13	450	270	9	-460	-460	20280	15900	4	30	1.75	1.25
01/10/13	to	02/08/13	02/11/13	to	02/15/13	1110	990	6	-420	-620	21390	16890	4	40	1.75	1.5
01/17/13	to	02/15/13	02/18/13	to	02/22/13	(50)	(70)	1	-50	-50	21340	16820	1	40	2	3
01/24/13	to	02/22/13	02/25/13	to	03/01/13	(230)	(250)	1	-230	-230	21110	16570	1	40	1.75	3
01/31/13	to	03/01/13	03/04/13	to	03/08/13	(440)	(460)	1	-440	-440	20670	16110	3	40	3	2.5
02/07/13	to	03/08/13	03/11/13	to	03/15/13	(610)	(650)	2	-570	-610	20060	15460	2	30	2.25	2.25
02/14/13	to	03/15/13	03/18/13	to	03/22/13	(440)	(520)	4	-1010	-1010	19620	14940	4	70	2.25	2.25
02/21/13	to	03/22/13	03/25/13	to	03/29/13	(650)	(670)	1	-650	-650	18970	14270	4	30	2.5	3
02/28/13	to	03/29/13	04/01/13	to	04/05/13	1370	1250	6	-370	-370	20340	15520	3	50	1	2.75
03/07/13	to	04/05/13	04/08/13	to	04/12/13	860	720	7	-520	-1110	21200	16240	4	50	1.25	2.25
03/14/13	to	04/12/13	04/15/13	to	04/19/13	1200	980	11	-530	-640	22400	17220	3	50	1	2
03/21/13	to	04/19/13	04/22/13	to	04/26/13	4770	4610	8	-490	-490	27170	21830	3	60	1	2
03/28/13	to	04/26/13	04/29/13	to	05/03/13	4000	3860	7	-440	-440	31170	25690	3	60	1	2
04/04/13	to	05/03/13	05/06/13	to	05/10/13	730	610	6	-1190	-1850	31900	26300	3	60	1	2
04/11/13	to	05/10/13	05/13/13	to	05/17/13	1000	960	2	0	0	32900	27260	1	70	2	3
04/18/13	to	05/17/13	05/20/13	to	05/24/13	780	740	2	0	0	33680	28000	1	60	2	3
04/25/13	to	05/24/13	05/27/13	to	05/31/13	(510)	(570)	3	-840	-840	33170	27430	1	70	1.75	2.5
05/02/13	to	05/31/13	06/03/13	to	06/07/13	(1670)	(1730)	3	-1680	-2050	31500	25700	1	50	2.25	3
05/09/13	to	06/07/13	06/10/13	to	06/14/13	3260	3140	6	0	0	34760	28840	4	20	0.25	2.5
05/16/13	to	06/14/13	06/17/13	to	06/21/13	(3780)	(4040)	13	-870	-3780	30980	24800	4	20	0.75	2.5
05/23/13	to	06/21/13	06/24/13	to	06/28/13	(180)	(360)	9	-940	-1730	30800	24440	3	40	1.25	2.25
05/30/13	to	06/28/13	07/01/13	to	07/05/13	1980	1800	9	-520	-620	32780	26240	4	60	1	2
06/06/13	to	07/05/13	07/08/13	to	07/12/13	1880	1780	5	-980	-980	34660	28020	4	60	0.75	2.25
06/13/13	to	07/12/13	07/15/13	to	07/19/13	950	890	3	-830	-830	35610	28910	1	70	1	3
06/20/13	to	07/19/13	07/22/13	to	07/26/13	70	(10)	4	-460	-460	35680	28900	1	70	1	3
06/27/13	to	07/26/13	07/29/13	to	08/02/13	860	820	2	0	0	36540	29720	1	40	1.75	3
07/04/13	to	08/02/13	08/05/13	to	08/09/13	210	130	4	-870	-1010	36750	29850	1	70	1.75	2.5
07/11/13	to	08/09/13	08/12/13	to	08/16/13	(550)	(610)	3	-520	-550	36200	29240	1	60	1.75	2
07/18/13	to	08/16/13	08/19/13	to	08/23/13	(910)	(970)	3	-1370	-1370	35290	28270	1	60	1.75	3
07/25/13	to	08/23/13	08/26/13	to	08/30/13	(1550)	(1630)	4	-960	-1870	33740	26640	3	30	2.75	2.75
08/01/13	to	08/30/13	09/02/13	to	09/06/13	10	(70)	4	-930	-930	33750	26570	3	30	2.75	3
08/08/13	to	09/06/13	09/09/13	to	09/13/13	(280)	(440)	8	-670	-1380	33470	26130	2	20	0.25	2.75
08/15/13	to	09/13/13	09/16/13	to	09/20/13	870	830	2	-570	-570	34340	26960	1	70	1.5	2.5
08/22/13	to	09/20/13	09/23/13	to	09/27/13	(210)	(250)	2	-240	-240	34130	26710	1	70	2	2
08/29/13	to	09/27/13	09/30/13	to	10/04/13	1200	1180	1	0	0	35330	27890	1	50	2.25	3

In-Sample Dates			Out-Of-Sample Dates			osnp	NOnp\$20	ont	ollt	odd	EQ	NetEq	pw	N	vup	vdn
09/05/13	to	10/04/13	10/07/13	to	10/11/13	1170	1110	3	-160	-160	36500	29000	2	70	2.5	3
09/12/13	to	10/11/13	10/14/13	to	10/18/13	(150)	(170)	1	-150	-150	36350	28830	2	60	2.5	3
09/19/13	to	10/18/13	10/21/13	to	10/25/13	520	500	1	0	0	36870	29330	2	70	2.5	3
09/26/13	to	10/25/13	10/28/13	to	11/01/13							29330	2	60	2.75	3
10/03/13	to	11/01/13	11/04/13	to	11/08/13							29330	2	60	2.75	3
10/10/13	to	11/08/13	11/11/13	to	11/15/13	(30)	(70)	2	-50	-50	36840	29260	2	70	2.25	3
10/17/13	to	11/15/13	11/18/13	to	11/22/13	(130)	(210)	4	-390	-560	36710	29050	3	40	2.75	2.75
10/24/13	to	11/22/13	11/25/13	to	11/29/13	(530)	(610)	4	-580	-1010	36180	28440	4	20	1.75	2
10/31/13	to	11/29/13	12/02/13	to	12/06/13	1190	970	11	-500	-1070	37370	29410	4	20	1.5	1.75
11/07/13	to	12/06/13	12/09/13	to	12/13/13							29410	4	50	2.5	3
11/14/13	to	12/13/13	12/16/13	to	12/20/13	420	400	1	0	0	37790	29810	4	50	2.5	3
11/21/13	to	12/20/13	12/23/13	to	12/27/13							29810	4	40	2.75	3
11/28/13	to	12/27/13	12/30/13	to	01/03/14	1590	1570	1	0	0	39380	31380	4	40	2.5	3
12/05/13	to	01/03/14	01/06/14	to	01/10/14	320	280	2	-190	-190	39700	31660	2	60	1.75	1.75
12/12/13	to	01/10/14	01/13/14	to	01/17/14	(40)	(60)	1	-40	-40	39660	31600	1	30	2.25	2
12/19/13	to	01/17/14	01/20/14	to	01/24/14	(500)	(520)	1	-500	-500	39160	31080	1	30	2.5	2
12/26/13	to	01/24/14	01/27/14	to	01/31/14	(280)	(340)	3	-760	-760	38880	30740	1	70	2.75	1.5
01/02/14	to	01/31/14	02/03/14	to	02/07/14	90	70	1	0	0	38970	30810	1	70	2	2.25
01/09/14	to	02/07/14	02/10/14	to	02/14/14							30810	1	50	2.75	2
01/16/14	to	02/14/14	02/17/14	to	02/21/14							30810	1	50	2.75	2.25
01/23/14	to	02/21/14	02/24/14	to	02/28/14							30810	1	50	2.75	2.25
01/30/14	to	02/28/14	03/03/14	to	03/07/14	(1510)	(1590)	4	-1250	-2370	37460	29220	1	50	1.75	2
02/06/14	to	03/07/14	03/10/14	to	03/14/14							29220	4	70	2.5	2.5
02/13/14	to	03/14/14	03/17/14	to	03/21/14	(1100)	(1160)	3	-700	-1100	36360	28060	4	70	2.25	2.5
02/20/14	to	03/21/14	03/24/14	to	03/28/14	870	730	7	-590	-590	37230	28790	4	70	2.5	0.75
02/27/14	to	03/28/14	03/31/14	to	04/04/14	90	(110)	10	-960	-1570	37320	28680	4	50	1.75	0.75
03/06/14	to	04/04/14	04/07/14	to	04/11/14	1290	1150	7	-520	-680	38610	29830	4	50	1.75	1
03/13/14	to	04/11/14	04/14/14	to	04/18/14	0	(100)	5	-670	-670	38610	29730	4	40	1.5	1.25
03/20/14	to	04/18/14	04/21/14	to	04/25/14	1260	1200	3	-30	-30	39870	30930	1	50	2.5	1
03/27/14	to	04/25/14	04/28/14	to	05/02/14	(270)	(310)	2	-260	-270	39600	30620	1	70	2.25	1.5
04/03/14	to	05/02/14	05/05/14	to	05/09/14	90	70	1	0	0	39690	30690	1	70	2.5	1.75
04/10/14	to	05/09/14	05/12/14	to	05/16/14							30690	1	30	2.75	1.5
04/17/14	to	05/16/14	05/19/14	to	05/23/14							30690	1	30	2.75	1.5
04/24/14	to	05/23/14	05/26/14	to	05/30/14	(430)	(470)	2	-460	-460	39260	30220	2	70	2.5	1.5
05/01/14	to	05/30/14	06/02/14	to	06/06/14	(220)	(280)	3	-510	-510	39040	29940	4	20	3	2
05/08/14	to	06/06/14	06/09/14	to	06/13/14							29940	1	20	2.5	2.5
05/15/14	to	06/13/14	06/16/14	to	06/20/14							29940	1	20	1.75	2.5
05/22/14	to	06/20/14	06/23/14	to	06/27/14	400	360	2	0	0	39440	30300	2	70	1.25	2.75
05/29/14	to	06/27/14	06/30/14	to	07/04/14	(340)	(400)	3	-570	-570	39100	29900	3	60	2	2.25
06/05/14	to	07/04/14	07/07/14	to	07/11/14	710	510	10	-820	-1170	39810	30410	3	30	1.5	0.25
06/12/14	to	07/11/14	07/14/14	to	07/18/14	480	460	1	0	0	40290	30870	1	20	2.75	2.25
06/19/14	to	07/18/14	07/21/14	to	07/25/14	(750)	(790)	2	-420	-750	39540	30080	3	30	3	2.5
06/26/14	to	07/25/14	07/28/14	to	08/01/14	370	350	1	0	0	39910	30430	2	50	2.5	2.25
07/03/14	to	08/01/14	08/04/14	to	08/08/14							30430	3	30	2.75	2.75
07/10/14	to	08/08/14	08/11/14	to	08/15/14	520	500	1	0	0	40430	30930	3	30	2.75	2.75
07/17/14	to	08/15/14	08/18/14	to	08/22/14	330	310	1	0	0	40760	31240	1	40	2.25	2
07/24/14	to	08/22/14	08/25/14	to	08/29/14							31240	2	20	3	3
07/31/14	to	08/29/14	09/01/14	to	09/05/14	(1120)	(1220)	5	-640	-1330	39640	30020	1	20	2	2.5
08/07/14	to	09/05/14	09/08/14	to	09/12/14	1210	1190	1	0	0	40850	31210	1	70	1.75	3
08/14/14	to	09/12/14	09/15/14	to	09/19/14	2330	2290	2	0	0	43180	33500	1	50	1.75	2.25
08/21/14	to	09/19/14	09/22/14	to	09/26/14							33500	2	60	2.5	2.75
08/28/14	to	09/26/14	09/29/14	to	10/03/14	3020	2920	5	-1090	-1090	46200	36420	2	60	2.5	2.75
09/04/14	to	10/03/14	10/06/14	to	10/10/14	820	780	2	0	0	47020	37200	1	30	2.25	2.75
09/11/14	to	10/10/14	10/13/14	to	10/17/14	1650	1530	6	-930	-1410	48670	38730	1	20	2.5	3

In-Sample Dates			Out-Of-Sample Dates			osnp	NOnp\$20	ont	ollt	odd	EQ	NetEq	pw	N	vup	vdn
09/18/14	to	10/17/14	10/20/14	to	10/24/14	(1560)	(1600)	2	-1240	-1560	47110	37130	1	50	2.5	2.75
09/25/14	to	10/24/14	10/27/14	to	10/31/14	(740)	(800)	3	-560	-1100	46370	36330	1	70	1	3
10/02/14	to	10/31/14	11/03/14	to	11/07/14	350	290	3	-500	-500	46720	36620	1	70	1.25	3
10/09/14	to	11/07/14	11/10/14	to	11/14/14	370	290	4	-540	-540	47090	36910	1	70	1.25	2.75
10/16/14	to	11/14/14	11/17/14	to	11/21/14	350	310	2	-50	-50	47440	37220	1	60	1.5	2.25
10/23/14	to	11/21/14	11/24/14	to	11/28/14	5490	5430	3	0	0	52930	42650	1	40	2.75	2.75
10/30/14	to	11/28/14	12/01/14	to	12/05/14	(1730)	(1790)	3	-1590	-3160	51200	40860	1	50	2.5	3
11/06/14	to	12/05/14	12/08/14	to	12/12/14	580	540	2	0	0	51780	41400	1	70	2	2.5
11/13/14	to	12/12/14	12/15/14	to	12/19/14	1780	1720	3	0	0	53560	43120	1	50	3	3
11/20/14	to	12/19/14	12/22/14	to	12/26/14							43120	1	70	2	2.75
11/27/14	to	12/26/14	12/29/14	to	01/02/15	180	160	1	0	0	53740	43280	1	50	2.75	2.75
12/04/14	to	01/02/15	01/05/15	to	01/09/15	(1060)	(1080)	1	-1060	-1060	52680	42200	1	50	2.5	2.75
12/11/14	to	01/09/15	01/12/15	to	01/16/15	1850	1770	4	-2110	-2110	54530	43970	1	60	2.25	2.5
12/18/14	to	01/16/15	01/19/15	to	01/23/15	2340	2280	3	0	0	56870	46250	1	50	2.5	1.25
12/25/14	to	01/23/15	01/26/15	to	01/30/15	930	890	2	-730	-730	57800	47140	2	70	2.75	2.5
01/01/15	to	01/30/15	02/02/15	to	02/06/15	(2020)	(2180)	8	-1460	-2860	55780	44960	1	40	2.75	2.75
01/08/15	to	02/06/15	02/09/15	to	02/13/15	(320)	(440)	6	-1090	-1650	55460	44520	1	70	1	2.5
01/15/15	to	02/13/15	02/16/15	to	02/20/15	(660)	(740)	4	-1190	-1190	54800	43780	1	70	3	2
01/22/15	to	02/20/15	02/23/15	to	02/27/15	870	770	5	-960	-960	55670	44550	1	40	0.75	3
01/29/15	to	02/27/15	03/02/15	to	03/06/15	330	250	4	-820	-820	56000	44800	2	70	1	3
02/05/15	to	03/06/15	03/09/15	to	03/13/15	(1920)	(1980)	3	-1360	-1920	54080	42820	2	70	0.75	2.75
02/12/15	to	03/13/15	03/16/15	to	03/20/15	3350	3250	5	-130	-130	57430	46070	2	70	1	3
02/19/15	to	03/20/15	03/23/15	to	03/27/15	620	460	8	-1520	-2400	58050	46530	1	40	1.75	1.25
02/26/15	to	03/27/15	03/30/15	to	04/03/15	530	450	4	-800	-1290	58580	46980	2	70	1	2.75
03/05/15	to	04/03/15	04/06/15	to	04/10/15	3990	3910	4	0	0	62570	50890	1	50	2.25	3
03/12/15	to	04/10/15	04/13/15	to	04/17/15	1390	1370	1	0	0	63960	52260	2	50	2.75	3
03/19/15	to	04/17/15	04/20/15	to	04/24/15	(200)	(220)	1	-200	-200	63760	52040	2	70	2.75	3
03/26/15	to	04/24/15	04/27/15	to	05/01/15	470	450	1	0	0	64230	52490	1	30	2.75	3
04/02/15	to	05/01/15	05/04/15	to	05/08/15	150	90	3	-310	-310	64380	52580	4	70	2.75	2.75
04/09/15	to	05/08/15	05/11/15	to	05/15/15	80	60	1	0	0	64460	52640	1	70	1.5	2.75
04/16/15	to	05/15/15	05/18/15	to	05/22/15	440	420	1	0	0	64900	53060	1	70	1.5	2.75
04/23/15	to	05/22/15	05/25/15	to	05/29/15	1170	1150	1	0	0	66070	54210	3	70	2.5	2.5
04/30/15	to	05/29/15	06/01/15	to	06/05/15	360	280	4	-1050	-1160	66430	54490	2	30	2	2.5
05/07/15	to	06/05/15	06/08/15	to	06/12/15	380	360	1	0	0	66810	54850	3	50	2	2.75
05/14/15	to	06/12/15	06/15/15	to	06/19/15	530	490	2	0	0	67340	55340	2	20	3	3
05/21/15	to	06/19/15	06/22/15	to	06/26/15	(380)	(440)	3	-1010	-1010	66960	54900	3	50	3	2.25
05/28/15	to	06/26/15	06/29/15	to	07/03/15	270	250	1	0	0	67230	55150	3	20	2.5	3
06/04/15	to	07/03/15	07/06/15	to	07/10/15	920	800	6	-590	-1140	68150	55950	4	30	2.25	2.75
06/11/15	to	07/10/15	07/13/15	to	07/17/15	740	700	2	-110	-110	68890	56650	3	20	3	3
06/18/15	to	07/17/15	07/20/15	to	07/24/15	(1130)	(1150)	1	-1130	-1130	67760	55500	3	20	2.75	3
06/25/15	to	07/24/15	07/27/15	to	07/31/15	270	250	1	0	0	68030	55750	3	60	2.75	3
07/02/15	to	07/31/15	08/03/15	to	08/07/15	0	(20)	1	0	0	68030	55730	2	50	2.5	2.5
07/09/15	to	08/07/15	08/10/15	to	08/14/15	330	310	1	0	0	68360	56040	3	70	2.75	2
07/16/15	to	08/14/15	08/17/15	to	08/21/15	540	500	2	-30	-30	68900	56540	4	70	2.75	2.25
07/23/15	to	08/21/15	08/24/15	to	08/28/15	(970)	(1130)	8	-840	-1210	67930	55410	4	30	2.75	2.75
07/30/15	to	08/28/15	08/31/15	to	09/04/15	2340	2180	8	-1240	-3250	70270	57590	2	70	2.25	2.75
08/06/15	to	09/04/15	09/07/15	to	09/11/15	580	440	7	-500	-1130	70850	58030	2	50	2.25	1.5
08/13/15	to	09/11/15	09/14/15	to	09/18/15	(970)	(1050)	4	-1110	-1390	69880	56980	3	70	1.5	3
08/20/15	to	09/18/15	09/21/15	to	09/25/15	1430	1330	5	-840	-840	71310	58310	3	40	2	3
08/27/15	to	09/25/15	09/28/15	to	10/02/15	(280)	(360)	4	-1100	-1180	71030	57950	3	40	2.25	3
09/03/15	to	10/02/15	10/05/15	to	10/09/15	740	720	1	0	0	71770	58670	3	70	2.75	3
09/10/15	to	10/09/15	10/12/15	to	10/16/15	(160)	(200)	2	-1620	-1620	71610	58470	1	70	2.5	2.25
09/17/15	to	10/16/15	10/19/15	to	10/23/15	(300)	(320)	1	-300	-300	71310	58150	1	70	3	2.25
09/24/15	to	10/23/15	10/26/15	to	10/30/15	1100	1080	1	0	0	72410	59230	1	70	2.75	2.25

In-Sample Dates			Out-Of-Sample Dates			osnp	NOnp\$20	ont	ollt	odd	EQ	NetEq	pw	N	vup	vdn
10/01/15	to	10/30/15	11/02/15	to	11/06/15	360	340	1	0	0	72770	59570	1	70	3	2.25
10/08/15	to	11/06/15	11/09/15	to	11/13/15							59570	2	70	3	2.75
10/15/15	to	11/13/15	11/16/15	to	11/20/15	190	170	1	0	0	72960	59740	1	50	2.75	2.5
10/22/15	to	11/20/15	11/23/15	to	11/27/15							59740	1	40	3	2.5
10/29/15	to	11/27/15	11/30/15	to	12/04/15	(730)	(790)	3	-390	-730	72230	58950	4	30	3	3
11/05/15	to	12/04/15	12/07/15	to	12/11/15	(2280)	(2800)	26	-540	-2300	69950	56150	3	30	0.5	1.25
11/12/15	to	12/11/15	12/14/15	to	12/18/15	1360	1260	5	-740	-760	71310	57410	3	20	1.5	2.75
11/19/15	to	12/18/15	12/21/15	to	12/25/15							57410	1	70	3	1.25
11/26/15	to	12/25/15	12/28/15	to	01/01/16	(150)	(170)	1	-150	-150	71160	57240	2	50	3	1.5
12/03/15	to	01/01/16	01/04/16	to	01/08/16	440	400	2	-300	-300	71600	57640	4	70	2	2.5
12/10/15	to	01/08/16	01/11/16	to	01/15/16	200	160	2	-20	-20	71800	57800	4	50	2.75	2.5
12/17/15	to	01/15/16	01/18/16	to	01/22/16	(350)	(430)	4	-1140	-1140	71450	57370	1	70	2.75	1
12/24/15	to	01/22/16	01/25/16	to	01/29/16	1310	1230	4	-40	-40	72760	58600	2	20	2.75	2.75
12/31/15	to	01/29/16	02/01/16	to	02/05/16	2100	2020	4	-180	-180	74860	60620	2	20	2.75	2.75
01/07/16	to	02/05/16	02/08/16	to	02/12/16	(2240)	(2360)	6	-970	-2240	72620	58260	3	40	2.75	2.25
01/14/16	to	02/12/16	02/15/16	to	02/19/16	(860)	(940)	4	-1280	-1390	71760	57320	4	30	3	2.25
01/21/16	to	02/19/16	02/22/16	to	02/26/16	170	(10)	9	-1230	-2360	71930	57310	4	40	2.5	1.75
01/28/16	to	02/26/16	02/29/16	to	03/04/16	(1220)	(1260)	2	-860	-1220	70710	56050	1	50	2.5	1.75
02/04/16	to	03/04/16	03/07/16	to	03/11/16	760	740	1	0	0	71470	56790	1	70	2.5	2
02/11/16	to	03/11/16	03/14/16	to	03/18/16							56790	1	50	2.75	3
02/18/16	to	03/18/16	03/21/16	to	03/25/16							56790	2	70	2.75	2.75
02/25/16	to	03/25/16	03/28/16	to	04/01/16							56790	1	60	0.25	1.25
03/03/16	to	04/01/16	04/04/16	to	04/08/16							56790	1	60	1.5	2.25
03/10/16	to	04/08/16	04/11/16	to	04/15/16	840	760	4	-540	-590	72310	57550	4	30	1.5	2.75
03/17/16	to	04/15/16	04/18/16	to	04/22/16	2810	2710	5	-530	-950	75120	60260	4	30	2	3
03/24/16	to	04/22/16	04/25/16	to	04/29/16	(1630)	(1670)	2	-1200	-1630	73490	58590	1	70	2.5	1.25
03/31/16	to	04/29/16	05/02/16	to	05/06/16	1570	1510	3	0	0	75060	60100	3	40	1.75	2.25
04/07/16	to	05/06/16	05/09/16	to	05/13/16	60	(20)	4	-670	-880	75120	60080	4	30	2.25	2.25
04/14/16	to	05/13/16	05/16/16	to	05/20/16	590	490	5	-420	-420	75710	60570	2	20	1.75	2
04/21/16	to	05/20/16	05/23/16	to	05/27/16	(630)	(690)	3	-840	-840	75080	59880	3	20	2.25	2.5
04/28/16	to	05/27/16	05/30/16	to	06/03/16	(1110)	(1150)	2	-1040	-1110	73970	58730	3	70	2.75	2.25
05/05/16	to	06/03/16	06/06/16	to	06/10/16							58730	1	20	2.5	2.75
05/12/16	to	06/10/16	06/13/16	to	06/17/16	(650)	(670)	1	-650	-650	73320	58060	1	40	2	3
05/19/16	to	06/17/16	06/20/16	to	06/24/16							58060	3	70	2.25	3
05/26/16	to	06/24/16	06/27/16	to	07/01/16	1770	1670	5	-570	-570	75090	59730	4	50	0.75	2.75
06/02/16	to	07/01/16	07/04/16	to	07/08/16	1310	1230	4	-280	-350	76400	60960	4	20	3	2.75
06/09/16	to	07/08/16	07/11/16	to	07/15/16	920	880	2	0	0	77320	61840	2	50	2	3
06/16/16	to	07/15/16	07/18/16	to	07/22/16	670	650	1	0	0	77990	62490	3	60	1.75	2.75
06/23/16	to	07/22/16	07/25/16	to	07/29/16	510	470	2	0	0	78500	62960	3	60	1.75	2.75
06/30/16	to	07/29/16	08/01/16	to	08/05/16	880	840	2	-20	-20	79380	63800	3	40	1.75	2.5
07/07/16	to	08/05/16	08/08/16	to	08/12/16	540	500	2	0	0	79920	64300	3	60	1.75	3
07/14/16	to	08/12/16	08/15/16	to	08/19/16							64300	4	70	3	2.5
07/21/16	to	08/19/16	08/22/16	to	08/26/16	(980)	(1060)	4	-1000	-1380	78940	63240	2	60	2.75	1.75
07/28/16	to	08/26/16	08/29/16	to	09/02/16	1200	1140	3	0	0	80140	64380	1	70	2.25	1.5
08/04/16	to	09/02/16	09/05/16	to	09/09/16	900	840	3	-110	-110	81040	65220	2	20	1.75	3
08/11/16	to	09/09/16	09/12/16	to	09/16/16	(1010)	(1110)	5	-1200	-1540	80030	64110	1	30	1.5	2.25
08/18/16	to	09/16/16	09/19/16	to	09/23/16	740	720	1	0	0	80770	64830	2	70	2.75	2
08/25/16	to	09/23/16	09/26/16	to	09/30/16	(2830)	(2870)	2	-2680	-2830	77940	61960	1	50	3	2.25
09/01/16	to	09/30/16	10/03/16	to	10/07/16							61960	2	40	2.75	3
09/08/16	to	10/07/16	10/10/16	to	10/14/16							61960	2	40	2.75	3
09/15/16	to	10/14/16	10/17/16	to	10/21/16	(180)	(200)	1	-180	-180	77760	61760	1	60	1.5	2.75
09/22/16	to	10/21/16	10/24/16	to	10/28/16	(640)	(680)	2	-640	-640	77120	61080	4	20	2.75	3
09/29/16	to	10/28/16	10/31/16	to	11/04/16	(320)	(420)	5	-300	-320	76800	60660	4	30	1.25	2.25
10/06/16	to	11/04/16	11/07/16	to	11/11/16	(1100)	(1240)	7	-1010	-1770	75700	59420	2	30	3	0.5

In-Sample Dates			Out-Of-Sample Dates			osnp	NOnp\$20	ont	ollt	odd	EQ	NetEq	pw	N	vup	vdn
10/13/16	to	11/11/16	11/14/16	to	11/18/16	(1170)	(1350)	9	-1320	-2190	74530	58070	4	20	2.5	0.25
10/20/16	to	11/18/16	11/21/16	to	11/25/16	(1610)	(1990)	19	-570	-2870	72920	56080	4	40	1	0.5
10/27/16	to	11/25/16	11/28/16	to	12/02/16	1730	1650	4	0	0	74650	57730	3	60	1	3
11/03/16	to	12/02/16	12/05/16	to	12/09/16	(80)	(180)	5	-720	-820	74570	57550	2	60	0.25	2.25
11/10/16	to	12/09/16	12/12/16	to	12/16/16	(1280)	(1320)	2	-1060	-1280	73290	56230	1	70	1.75	1.75
11/17/16	to	12/16/16	12/19/16	to	12/23/16	290	270	1	0	0	73580	56500	1	40	1	2.75
11/24/16	to	12/23/16	12/26/16	to	12/30/16	270	210	3	-300	-320	73850	56710	1	70	0.25	1
12/01/16	to	12/30/16	01/02/17	to	01/06/17	1400	1240	8	-630	-810	75250	57950	1	60	0.25	1
12/08/16	to	01/06/17	01/09/17	to	01/13/17	(650)	(730)	4	-1300	-1460	74600	57220	4	50	2.75	1.75
12/15/16	to	01/13/17	01/16/17	to	01/20/17	520	480	2	0	0	75120	57700	1	50	2.5	1.5
12/22/16	to	01/20/17	01/23/17	to	01/27/17	(580)	(620)	2	-430	-580	74540	57080	1	60	2.25	1.25
12/29/16	to	01/27/17	01/30/17	to	02/03/17	(130)	(170)	2	-70	-130	74410	56910	1	70	1.75	1.25
01/05/17	to	02/03/17	02/06/17	to	02/10/17	(70)	(90)	1	-70	-70	74340	56820	2	60	2.75	1.75
01/12/17	to	02/10/17	02/13/17	to	02/17/17	440	300	7	-410	-540	74780	57120	4	20	2.25	0.25
01/19/17	to	02/17/17	02/20/17	to	02/24/17	880	780	5	-180	-180	75660	57900	4	20	2.75	0.25
01/26/17	to	02/24/17	02/27/17	to	03/03/17	110	90	1	0	0	75770	57990	1	30	2	2.5
02/02/17	to	03/03/17	03/06/17	to	03/10/17	4490	4190	15	-370	-440	80260	62180	4	20	1.75	0.25
02/09/17	to	03/10/17	03/13/17	to	03/17/17							62180	4	60	2	1.75
02/16/17	to	03/17/17	03/20/17	to	03/24/17							62180	4	60	2	1.75
02/23/17	to	03/24/17	03/27/17	to	03/31/17							62180	3	60	2.25	1.5
03/02/17	to	03/31/17	04/03/17	to	04/07/17	110	90	1	0	0	80370	62270	3	60	2	1.5
03/09/17	to	04/07/17	04/10/17	to	04/14/17							62270	2	30	2.5	1.5
03/16/17	to	04/14/17	04/17/17	to	04/21/17	1400	1340	3	-200	-200	81770	63610	1	30	1.75	1.5
03/23/17	to	04/21/17	04/24/17	to	04/28/17	(260)	(280)	1	-260	-260	81510	63330	2	30	2.25	2
03/30/17	to	04/28/17	05/01/17	to	05/05/17	270	230	2	0	0	81780	63560	2	70	3	1.75
04/06/17	to	05/05/17	05/08/17	to	05/12/17	(500)	(520)	1	-500	-500	81280	63040	1	60	2.75	1.25
04/13/17	to	05/12/17	05/15/17	to	05/19/17							63040	1	50	2.75	1.75
04/20/17	to	05/19/17	05/22/17	to	05/26/17	1190	1170	1	0	0	82470	64210	1	70	2.75	1.5
04/27/17	to	05/26/17	05/29/17	to	06/02/17	(110)	(130)	1	-110	-110	82360	64080	4	70	2	2.75
05/04/17	to	06/02/17	06/05/17	to	06/09/17	50	10	2	-370	-370	82410	64090	2	70	2	2
05/11/17	to	06/09/17	06/12/17	to	06/16/17	550	530	1	0	0	82960	64620	4	50	2.75	2.75
05/18/17	to	06/16/17	06/19/17	to	06/23/17	850	830	1	0	0	83810	65450	3	50	2.75	1.75
05/25/17	to	06/23/17	06/26/17	to	06/30/17							65450	3	50	2.75	1.75
06/01/17	to	06/30/17	07/03/17	to	07/07/17	900	840	3	-160	-160	84710	66290	3	50	2.75	1.75
06/08/17	to	07/07/17	07/10/17	to	07/14/17	(290)	(330)	2	-440	-440	84420	65960	3	70	2.25	1.5
06/15/17	to	07/14/17	07/17/17	to	07/21/17	430	410	1	0	0	84850	66370	4	70	2.25	1.25
06/22/17	to	07/21/17	07/24/17	to	07/28/17	630	530	5	-360	-610	85480	66900	4	20	1.25	2.5
06/29/17	to	07/28/17	07/31/17	to	08/04/17	2200	2100	5	0	0	87680	69000	4	20	1.25	2.5
07/06/17	to	08/04/17	08/07/17	to	08/11/17	630	430	10	-650	-1010	88310	69430	4	20	1.25	2

Appendix 1: n^{th} Order Fading Memory Polynomial Next Bar's Forecast Math

What is The N^{th} Order Fading Memory Polynomial ?

This is a mathematical technique that fits a n^{th} order polynomial to the last T price bars but calculates the coefficients of the polynomial such that the error between the current n^{th} order polynomial and the current bar is weighted much higher than the error between the price T bars ago and the value of the n^{th} order polynomial T bars ago. As an example, if the latest price is at time t and the price made a turn at time bar $t-10$, then we do not want prices prior to $t-10$ affecting the current polynomial fit as much. As will be shown the most familiar case of this fading memory technique is the exponential moving average. The fading memory technique is in contrast to the Least Squares Polynomial fit, which weights all past errors between the polynomial and the price bar equally.

Consider a time series $x(t)$ where t is an integer value (a price bar number) like the number of days or minutes, etc from some starting time. Suppose we want to find at some given time some n^{th} -degree polynomial that fits the data well at current and recent prices but ignores the fit as we move into the distant past. One way to construct this type of fit would be to weight the past data with a number that got smaller and smaller the further back in time we went. If we let the polynomial function be represented by the symbol $\mathbf{p}(\mathbf{t}-\boldsymbol{\tau})$ where $\mathbf{p}(\mathbf{t}-\mathbf{0})$ is the current value of the polynomial, $\mathbf{p}(\mathbf{t}-\mathbf{1})$ is the previous value of the polynomial, etc., then an error function can be formed that consists of the weighted sum of the squared difference between the price series $\mathbf{x}(\mathbf{t}-\boldsymbol{\tau})$ and the polynomial $\mathbf{p}(\mathbf{t}-\boldsymbol{\tau})$ given by

$$\text{error} = \sum \beta^{\tau} (\mathbf{x}(\mathbf{t}-\boldsymbol{\tau}) - \mathbf{p}(\mathbf{t}-\boldsymbol{\tau}))^2 \quad \tau=0 \text{ to } \infty \quad (1)$$

where $0 < \beta < 1$ and β^{τ} is much much less than 1 for large τ .

It turns out that if we let the n^{th} degree polynomial $\mathbf{p}(\mathbf{t}-\boldsymbol{\tau})$ be constructed as a linear combination of orthogonal polynomials called Meixner polynomials then minimizing the error with respect to the coefficients of the orthogonal polynomials yields the best estimate of $\mathbf{x}(\mathbf{t}-\boldsymbol{\tau})$ as $\mathbf{x}_{\text{est}}(\mathbf{t}-\boldsymbol{\tau})$ and given by the equation

$$x_{\text{est}}(t - \tau) = (1 - \beta) \sum_{k=0}^n \beta^k b_{k,t} \Phi_k(t) |_{\tau} \quad (2)$$

Where

$$\Phi_n(t) = \sum_{k=0}^n \binom{n}{k} \binom{t}{k} z^k$$

$$\binom{n}{k} = \frac{n!}{k!(n-k)!}$$

$$b_{j,t} = \sum_{k=0}^{\infty} \beta^k \Phi_j(k) x(t-k)$$

$$z = 1 - 1/\beta$$

where n is the polynomial degree, $\Phi_k(\boldsymbol{\tau})$ are the Meixner polynomials of degree k ($k=0$ to n), and $\mathbf{b}_k(\mathbf{t})$ are the coefficients that minimize the error of equation (1). Generally the summation for $\mathbf{b}_j(\mathbf{t})$ can be terminated when $\beta^k \ll 1$.

Appendix 1: n^{th} Order Fading Memory Polynomial Next Bar's Forecast Math

For the exact mathematical solutions that produce equation (2) and the mathematical descriptions of the Meixner polynomials refer to Reference 1.

To yield the 1 day ahead prediction the above equation becomes;

$$\mathbf{x}_{\text{est}}(\mathbf{t}+1) = (1-\beta) \sum_{\mathbf{k}=0}^{\mathbf{n}} \beta^{\mathbf{k}} \mathbf{b}_{\mathbf{k},\mathbf{t}} \Phi_{\mathbf{k}}(-1) \quad \mathbf{k}=0 \text{ to } \mathbf{n} \quad (3)$$

After some algebraic manipulation with the Meixner polynomials the $\mathbf{b}_{\mathbf{k},\mathbf{t}}$ coefficients satisfy the following recursive relationship. (see Reference 1)

$$\mathbf{b}_{\mathbf{k},\mathbf{t}} = \beta \mathbf{b}_{\mathbf{k},\mathbf{t}-1} + \mathbf{b}_{\mathbf{k}-1,\mathbf{t}} - \mathbf{b}_{\mathbf{k}-1,\mathbf{t}-1}$$

One case is of immediate interest where the polynomial is a constant, that is $n=0$.

For this case the solution to equation (3) can be found after some algebraic manipulation to be:

$$\mathbf{X0}_{\text{est}} = \beta * \mathbf{X0}_{\text{est}}[1] + (1-\beta) * \mathbf{x}(\mathbf{t}) \quad (4)$$

Where $\mathbf{X0}_{\text{est}}[1]$ is the previous estimated value, $\mathbf{x}(\mathbf{t})$ is the current bar's price and where the 0 in $\mathbf{X0}_{\text{est}}$ indicates that we are estimating a polynomial of degree 0 or simply a constant. If a change of variables is made letting $\alpha = (1-\beta)$ then equation (4) becomes:

$$\mathbf{X0}_{\text{est}} = (1-\alpha) * \mathbf{X0}_{\text{est}}[1] + \alpha * \mathbf{x}(\mathbf{t}) \quad (5)$$

This is the familiar formula for the exponential moving average.

Higher orders of n don't yield such compact solutions as the case where $n=0$. equations

$$\mathbf{P}_F(\mathbf{T}+1) = (1-\beta) * [\mathbf{b}_{0,\mathbf{t}} \phi_{0|\mathbf{t}=-1} + \beta \mathbf{b}_{1,\mathbf{t}} * \phi_{1|\mathbf{t}=-1} + \beta^2 \mathbf{b}_{2,\mathbf{t}} * \phi_{2|\mathbf{t}=-1} + \dots + \beta^n \mathbf{b}_{n,\mathbf{t}} * \phi_{n|\mathbf{t}=-1}]$$

$$\mathbf{Velocity} = (d\mathbf{P}_F/d\mathbf{t})_{(\mathbf{T}=-1)} = (1-\beta) [\beta \mathbf{b}_{1,\mathbf{t}} * (d\phi_1/d\mathbf{t})_{|\mathbf{t}=-1} + \beta^2 \mathbf{b}_{2,\mathbf{t}} * (d\phi_2/d\mathbf{t})_{|\mathbf{t}=-1} + \dots + \beta^n \mathbf{b}_{n,\mathbf{t}} * (d\phi_n/d\mathbf{t})_{|\mathbf{t}=-1}]$$

The n^{th} Order Fading Memory Forecast Next Bar's Velocity Strategy Defined

The least squares forecast is constructed by solving for the coefficients $\mathbf{b}_0, \mathbf{b}_1, \mathbf{b}_2, \dots, \mathbf{b}_n$ recursively at each bar using the last \mathbf{T} bars of closing prices and the Discrete Orthogonal Meixner Polynomial equations above. Then **Velocity** = $d\mathbf{P}_F(\mathbf{T}+1)/d\mathbf{t}$ is constructed from the velocity equation above and plotted under the price chart. In general what we will be doing is following the plotted curve of **Velocity** which is calculated at each bar from the previous \mathbf{T} bars. When the velocity is greater than a threshold amount vup we will go long. When the velocity is less than a threshold amount $-vdn$ we will go short.

Buy Rule:

IF **Velocity** is greater than the threshold amount vup then buy at the market.

Sell Rule:

IF **Velocity** is less than the threshold amount $-vdn$ then sell at the market.

Appendix 1: n^{th} Order Fading Memory Polynomial Next Bar's Forecast Math

References

1. Morrison, Norman "Introduction to Sequential Smoothing and Prediction", McGraw-Hill Book Company, New York, 1969.

Appendix 2 -The Normalization Multiplier

What is the Multiplier ?

The n^{th} Order Fading Memory Polynomial, also called here an n^{th} Order Polynomial, is the least square fit of a polynomial of the form $P_F(T+1) = (1-\beta)[b_{0,t} \phi_{0|t=-1} + \beta b_{1,t} \phi_{1|t=-1} + \beta^2 b_{2,t} \phi_{2|t=-1} + \dots + \beta^n b_{n,t} \phi_{n|t=-1}]$ to a *Fading* number of past data points. Where t is discrete time bars. Time could be daily bars or one minute bars. We use the term “Fading Memory” because we weight the past data with a number that gets smaller and smaller the further back in time we go. It is assumed that the time bars occur at fixed intervals of time so tic bars would not be appropriate for this analysis. Suppose we want to find at some given time some n^{th} -degree polynomial that fits the data well at current and recent prices but ignores the fit as we move into the distant past. One way to construct this type of fit would be to weight the past data with a number that got smaller and smaller the further back in time we went. This type of error minimization is mathematically solvable and is widely used in science and mathematics. Once the b_n coefficients are found then the next bar’s estimate ($T+1$) of the n^{th} order polynomial Acceleration and acceleration can be easily found by the equations below.

$$\text{Velocity} = (dP_F/dt)_{(T=1)} = (1-\beta)[\beta b_{1,t} *(d\phi_1/dt)_{|t=-1} + \beta^2 b_{2,t} *(d\phi_2/dt)_{|t=-1} + \dots + \beta^n b_{n,t} *(d\phi_n/dt)_{|t=-1}]$$

$$0 < \beta < 1$$

Please see the *n^{th} Order Fading Memory Polynomial Next Bar’s Forecast Math* section for a more detailed explanation.

For any tradable, the inputs to the polynomial are the **polynomial degree(aka Order)** and exponential decay constant β . When we plot the velocity, we notice that the amplitude, and the maximum and minimum values of and standard deviation of the velocity vary quite significantly with different polynomial degree and β inputs.

Below is a table of the standard deviation of the 288156 calculated Velocity values for different **degree** and β inputs. The lookback period **N (number of bars of past data)** is approximately related to α ($\alpha=1-\beta$) by the formula $\alpha=2/(1+N)$. I use N because it gives a better understanding of how many bars of past data are approximately being used. We used 1 min bars of the Crude Light future from 1/5/2012 to 8/11/2017 to generate this table.

@CL.C 1 min bars Date Range 1120102 to 1170811
Total Number of Bars=1917847 Norm=0
Trading Times Constraint Start Time=900 EndTime=1430
FadmVn Multiplier to Scale Velocity pw and N Range to One Std

pw	N	Std	1/Std	Std*Mult
1	20	0.00757329	132.043	0.865148
1	30	0.00615409	162.494	0.703023
1	40	0.00531118	188.282	0.606733
1	50	0.00473725	211.093	0.541168
1	60	0.00431417	231.794	0.492837
1	70	0.00398518	250.93	0.455254
		pw=1 Ave	196.106	
2	20	0.0131743	75.9054	1.50499
2	30	0.0106961	93.4923	1.22188
2	40	0.00922913	108.353	1.05431
2	50	0.00822868	121.526	0.940018
2	60	0.00748949	133.52	0.855575
2	70	0.00691445	144.625	0.789885
		pw=2 Ave	112.904	
3	20	0.0181217	55.1823	2.07017
3	30	0.0146857	68.0934	1.67765
3	40	0.0126693	78.9307	1.4473

Appendix 2 -The Normalization Multiplier

3	50	0.0112991	88.5025	1.29077
3	60	0.0102876	97.2042	1.17523
3	70	0.0095003	105.26	1.08528
		pw=3 Ave	82.1955	
4	20	0.0227218	44.0107	2.59566
4	30	0.0183648	54.4519	2.09794
4	40	0.0158306	63.1686	1.80844
4	50	0.0141183	70.8303	1.61282
4	60	0.0128565	77.7816	1.46869
4	70	0.0118752	84.2093	1.35658
		pw=4 Ave	65.742	

The standard deviation varies from 0.003 to 0.022. The problem may get worse when we want to find good inputs for other tradables. Other tradables, because of their scales and tick size have much different Velocity ranges than the CL for the same degree and N. Thus the search ranges have to be different for each different tradable, N and degree.

To solve this problem and to have a standard search space for each tradable, I created a **Mult** input for each FadmVn Velocity strategy and indicator .. If each tradable's Velocity is multiplied by a number such that the standard deviation of that tradable's Velocity is close to one standard deviation then the search space for vup and vdn for each tradable would be 0 to 3 standard deviations and we wouldn't have to change the optimization search space every time we wanted to examine a new stock or future. The complicated equations that I use to normalize the ranges to one standard deviation for degree and N were derived using the software TableCurve 3D, automated surface and equation discovery. These equations are independent of the tradable and only depend on the polynomial degree and N. If you do not wish to use these equations then set iNorm=0 as above and use the average multiplier and larger ranges and search increments .

How to Find The Mult.

Here is how to use the #FadmVMultStd. First load your chart with as much data as you are going to use. *Click on Insert-> Indicator.* Select the #FadmVMultStd. Modify the inputs to the indicator or just leave them at their default values. A table will be produced as shown below. Notice that since the strategy is only trading from 900 EST to 1430EST the #FadmVMultStd only calculates the velocity STDs during that time window.

```
@CL.C 1 min bars Date Range 1120102 to 1170811
Total Number of Bars=1917847 Norm=1
Trading Times Constraint Start Time=900 EndTime=1430
FadmVn Multiplier to Scale Velocity pw and N Range to One Std
```

pw	N	Std	1/Std	Std*Mult
1	20	0.0277973	35.9748	0.992863
1	30	0.0280167	35.693	1.0007
1	40	0.0282222	35.4331	1.00804
1	50	0.0284016	35.2093	1.01445
1	60	0.0285572	35.0175	1.02
1	70	0.0286896	34.8559	1.02473
		pw=1 Ave	35.3639	
2	20	0.027696	36.1063	0.989246
2	30	0.0278901	35.8551	0.996177
2	40	0.0280888	35.6014	1.00327
2	50	0.0282565	35.3901	1.00927
2	60	0.028395	35.2175	1.01421
2	70	0.0285106	35.0747	1.01834

Appendix 2 -The Normalization Multiplier

		pw=2 Ave	35.5408	
3	20	0.0274987	36.3654	0.982198
3	30	0.0276403	36.1791	0.987256
3	40	0.0278323	35.9295	0.994113
3	50	0.0280063	35.7063	1.00033
3	60	0.0281532	35.52	1.00558
3	70	0.0282754	35.3665	1.00994
		pw=3 Ave	35.8444	
4	20	0.0273592	36.5508	0.977216
4	30	0.0274274	36.4599	0.979651
4	40	0.0275958	36.2374	0.985665
4	50	0.0277678	36.0129	0.99181
4	60	0.027918	35.8191	0.997176
4	70	0.0280453	35.6566	1.00172
		pw=4 Ave	36.1228	
		Mult=	35.718	

For each tradable chart:

1. Apply the **FadmVMultStd** indicator to your chart.
2. Find the Multiplier as shown above.
3. Record the multiplier value and delete the indicator from your chart.
4. **Apply that multiplier to the Mult input** with **iNorm=1** in the strategy.
5. Do the parameter search for vup & vdn in the default range 0.25 to 3 by 0.25 .