

*When investment advisers do not control for backtest overfitting,
good backtest performance is an indicator of negative future results. [1]*

Abstract:

Understanding the behavior of the VIX and developing trading strategies for VIX related products is the leitmotif of the Sibyl-Working papers (see [2] to [8]). In the previous papers a signal based approach was used. These strategies are the cash cows of the Sibyl-Fund.

This working paper develops first a mean-reverting logarithmic model for the VIX. In the next step the relation between the VIX and VIX Futures is modeled. VIX Options are evaluated by Monte-Carlo Simulation of Option-Trading Strategies. The model is also applied to the VIX based ETN VXX and VXX Options and extended to the VSTOXX and VSTOXX Futures.

The performance of several model-based trading strategies is backtested. The paper presents not only good but also bad or dubious trading ideas. The signal based strategies exploit the term-structure of VIX Futures. The model exploits additionally the mean-reversion of volatility. This improves – at least in the backtest – the performance. The paper discusses in appendix B the critique on the backtest methodology formulated in [1]. The (well known) critique has to be taken serious, but the suggested solution is of no practical use.

Version 1 adds a completely different VXX trading strategy which was suggested by a reviewer.

1) Volatility-Index-Modeling:

1.1) The VIX:

There are several published VIX models. In [9] Katja Ahoniemi presents ARIMA (1,1,1), ARIMA-GARCH, ARIMAX and ARIMAX-GARCH models. The ARIMA-GARCH model augments the ARIMA(1,1,1) with GARCH errors. In the ARIMAX model other explanatory variables like seasonality indicators (Monday, Friday effect) and the lagged S&P-500 returns are added.

Adding GARCH errors improves the model significantly, the added external ARIMAX variables have only a very low additional explanatory power.

In [10] Qunfang Bao presents two simple approaches which model explicitly the mean-reverting behavior of volatility. The first is a Heston model developed by Grünbichler and Longstaff [11].

$$dVIX_t = \lambda * (\mu - VIX_t) * dt + \sigma * \sqrt{VIX_t} * dW_t \quad (1)$$

The second was introduced by Detemple and Osakwe in [12]. It is a simple Ornstein-Uhlenbeck (OU)-process on the logarithmic time series.

$$d \ln VIX_t = \lambda * (\mu - \ln VIX_t) * dt + \sigma * dW_t \quad (2)$$

According to [10] the fit of (2) is considerably better. From the Grünbichler and Longstaff model follows also a very unrealistic behavior of the VIX Futures beta (see paragraph 2). Additionally the parameters of (2) can be very easily estimated. One calculates the linear regression

$$\ln VIX_t = \alpha + \beta \ln VIX_{t-1} + \varepsilon_t \quad (3)$$

From the exact update-equation follows (see [13])

$$\lambda = -\ln(\beta) \quad (4)$$

$$\mu = \alpha / (1 - \beta) \quad (5)$$

$$\sigma = \text{sd}(\varepsilon) * \text{sqrt}(2 * \lambda / (1 - \exp(-2 * \lambda))) \quad (6)$$

Where $\text{sd}(\varepsilon)$ is the standard deviation of the residuals. The right right term in (6) is a correction factor for the mean-reversion behavior of the process.

Note: if $\beta > 1$, the process is not mean-reverting. Volatility has a strong mean-reverting behavior. β is always considerable smaller than 1.

One can estimate α , β in (3) with plain OLS. But my favorite method is the very robust and efficient Theil-Sen estimator (see [14]). Using a robust estimator is essential for this application. The distribution of the VIX returns is far from normal, asymmetric and fat tailed to the right. OLS reacts very sensitive to the outliers, the Theil-Sen estimator is almost unaffected. There is unfortunately no practicable extension of the Theil-Sen estimator to multiple regression problems. The estimation uses in the current implementation per default a time-window of 2 years. The estimation of the parameters is done for each new calculation. The parameters are not constant and drift over time (see Graphic-1, 2). Using a longer estimation window does not improve the behavior of the model. Reducing it to one year makes the estimation of λ relative unstable. This is a well known problem for the parameter estimation of an OU-process (see [13]).

The Monte-Carlo Path-Generation does not use σ of equation (6). It is well known that the volatility of the VIX shows strong volatility clustering. Following [6] I implemented the GRJ-GARCH model. GRJ is a shortcut of the authors (Glosten, Jagannathan, Runkle). This is one of the more popular GARCH models. It is the simplest model which handles the asymmetric impact of negative and positive returns.

$$\begin{aligned} \sigma_t^2 &= a_0 + a_1 * \sigma_{t-1}^2 + a_2 * R_t^2 + a_3 * I_t * R_t^2 \\ I_t &= (R_t > 0) \end{aligned} \quad (7)$$

Note: In the usual GRJ model the condition is $I_t = (R_t < 0)$. For the VIX the role of negative and positive returns are reversed.

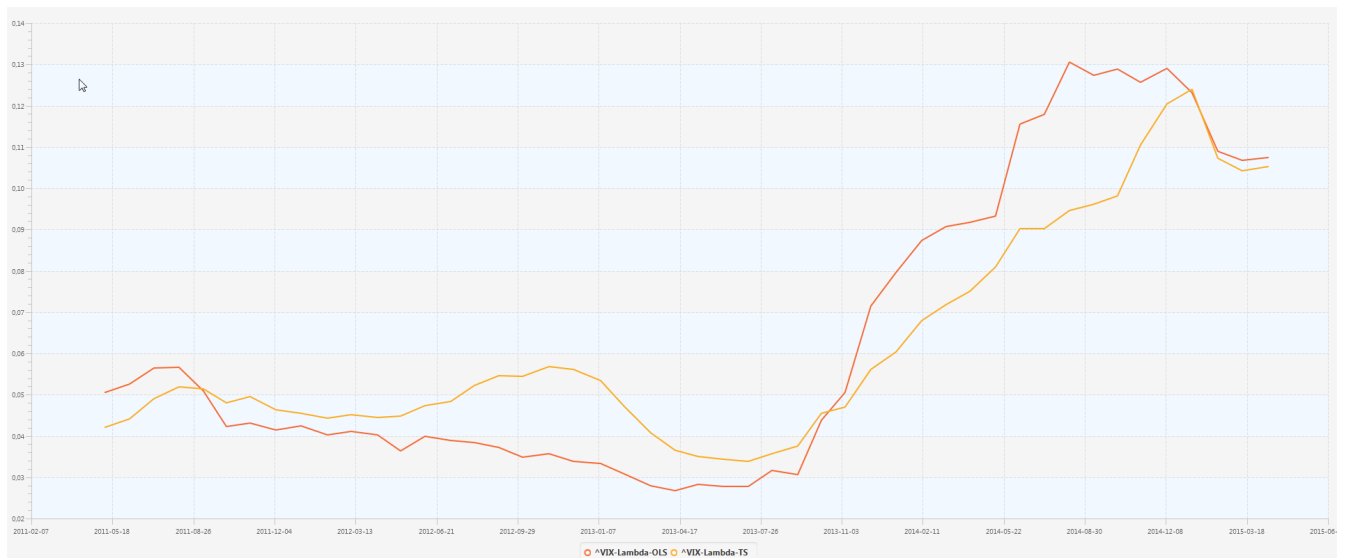
In the estimation step the VIX innovations (returns) within the estimation window are normalized to mean 0 and standard deviation 1. In the path-generation phase one draws at random one of these normalized returns and scales it with the GARCH- σ . The simulated innovation is used to update the GARCH equation. The next normalized return is drawn, it is scaled with the GARCH- σ This is alongside the Filtered Historical Simulation developed by Giovanni Barone-Adesi (see [15]). For the exact update equation of the OU process one has to scale the innovation by the term (see [13])

$$W = \text{sqrt}((1.0 - \exp(-2.0 * \lambda)) / (2.0 * \lambda)) \quad (8)$$

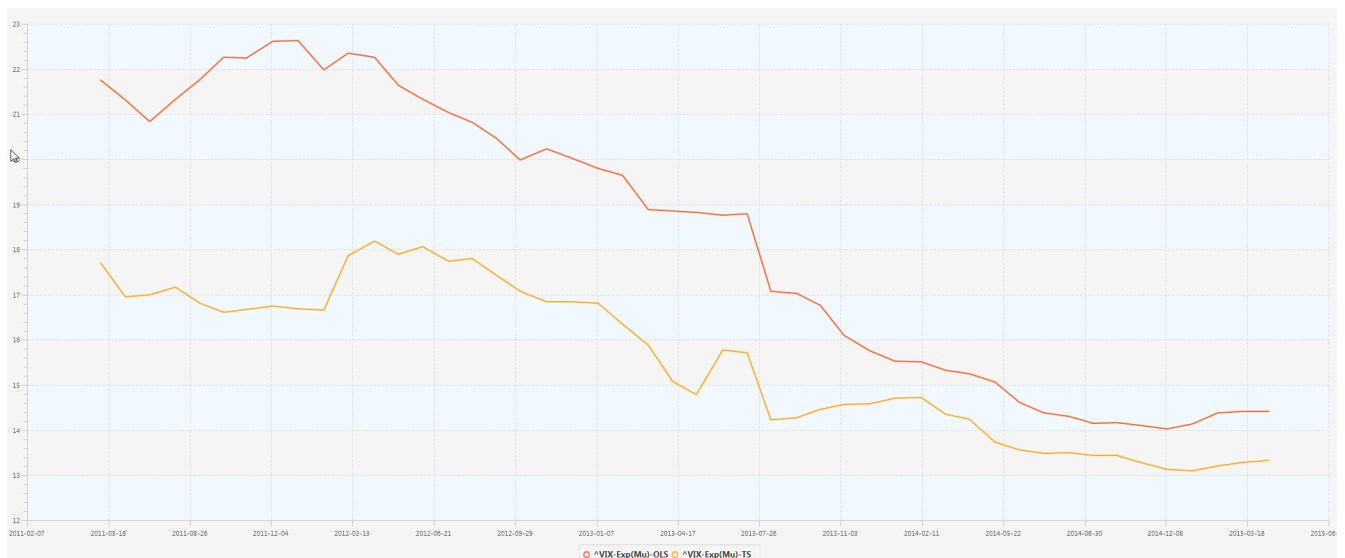
In [10] Qunfang Bao adds an additional jump term. In the current context a return is defined as a jump, if it is positive and $\geq 4 * \text{MAD}$ (Median Absolute Deviation) of all returns in the estimation window. The jumps can be added optionally to the diffusive term of the Monte-Carlo simulation. One simply sets all returns which are smaller than the MAD-threshold to zero and draws at random from these returns (the draw is independent from the diffusive term). The returns are not scaled. In this way one

can generate also in a low volatility regime with small σ a large upwards jump of the VIX.

Graphic-1 and 2 show the estimated values for λ and $\exp(\mu)$ ($\exp(\mu)$ is the original value) over the last 4 years. The red-line is for the OLS estimation, the yellow for Theil-Sen. The calculation uses a sliding window of 504 trading-days. The mean-reversion level of Theil-Sen is considerable lower then for OLS. This is essentially the difference between the mean (OLS) and the median (Theil-Sen) level of the VIX. The mean-reversion level is falling in the considered time-span. The mean-reversion parameter λ is significantly increasing since August 2013. This is an artificial effect of the estimation window. The crash of Aug. 2011 is “disappearing” from the estimation. If the window is extended to 756 trading-days (3 years) the increase of λ happens almost a year later. The decreasing mean-reversion level and the increase of λ are related. The overall VIX level is relative low. But markets react strongly to bad news. Once the news are digested the VIX falls relative fast to it's initial low level.



Graphic-1: VIX λ from 2011-05-06 to 2015-05-06. Red OLS, yellow Theil-Sen.



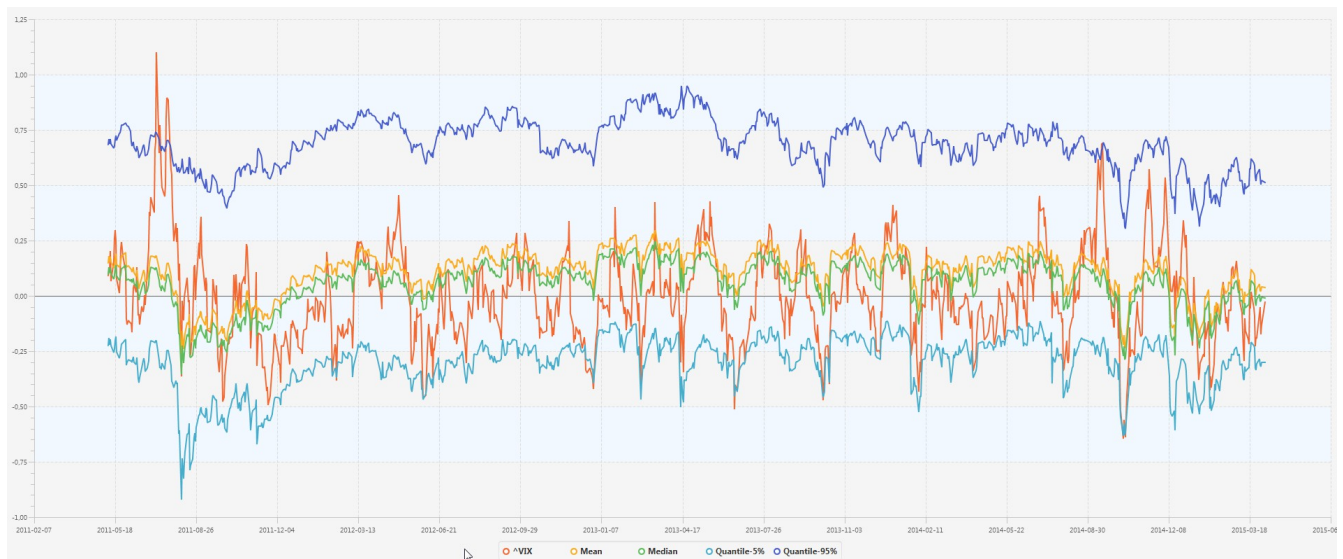
Graphic-2: VIX $\exp(\mu)$ from 2011-05-06 to 2015-05-06. Red OLS, yellow Theil-Sen.

Graphic-3 and 4 show the result of a 21-trading days model forecast over the last 4 years. The red line is the actual VIX movement over the forecast horizon. The yellow line is the mean of 5000 Monte-

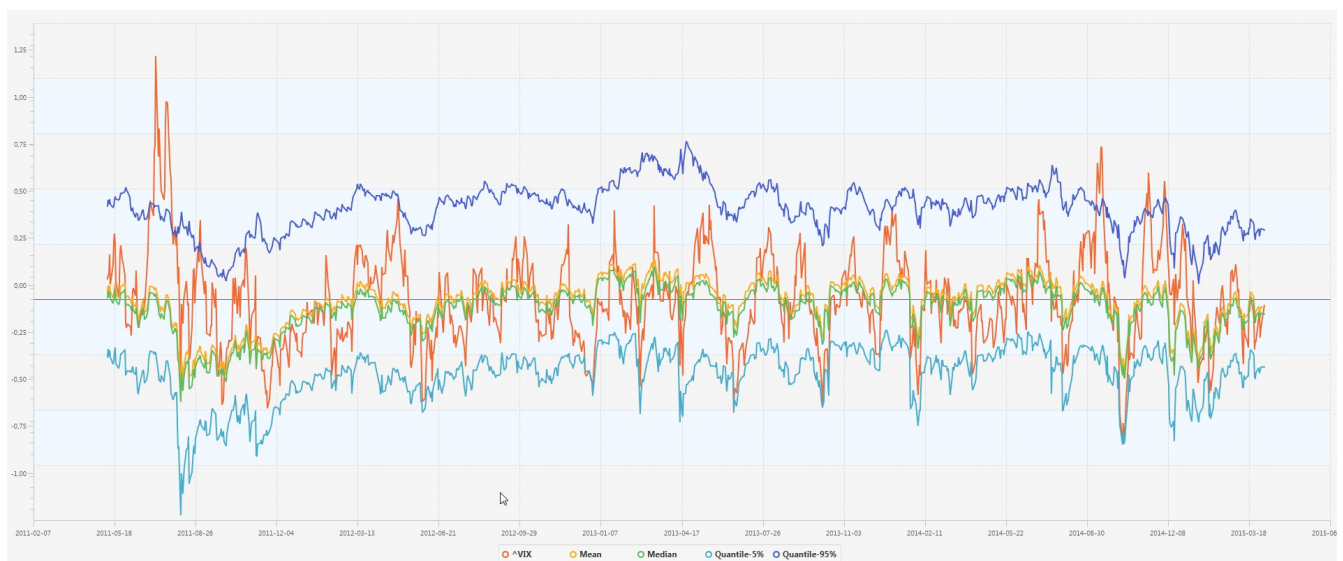
Carlo paths. The green line is the median. The lower light-blue is the 5% quantile, the upper dark blue the 95% quantile. In Graphic-3 jumps are added to the Monte-Carlo paths. In Graphic-4 only the diffusive innovations are used. The difference is most visible in the 95% quantile. The VIX spike of the Aug. 2011 crash is only moderately over the 95% quantile. The other spikes are within the upper quantile. But there is a relative strong positive bias. The VIX has in the mean a 1-month return of -0.5% (the VIX was falling in the last 4 years). The model mean is +10.0%. The sign of the VIX movement is forecasted in 52.6% of the cases right. The VIX is in 1.6% of the cases below the 5% quantile, and in 0.7% above the 95% quantile.

The diffusive only model has a monthly mean of -1.0% and gets the sign in 69.7% of the cases right. The VIX is in 0.6% of the cases below the 5% quantile, and in 3.8% above the 95% quantile.

The jump model is somewhat too conservative/pessimistic (if one considers a VIX spike as bad news), the diffusive-only model slightly too optimistic. Overall the diffusive-model seems to be the superior forecaster. This is also confirmed in the trading-application. Mixing diffusion-only and jump-paths did not improve the performance.



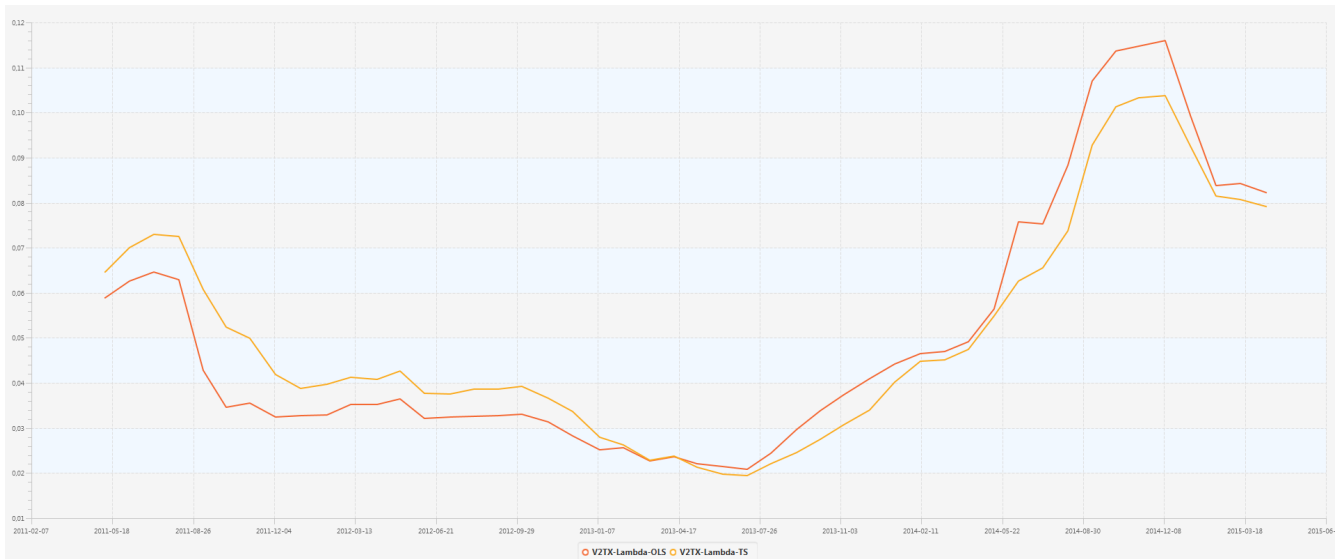
Graphic-3: 21-days VIX Forecast from 2011-05-06 to 2015-05-06 with jump



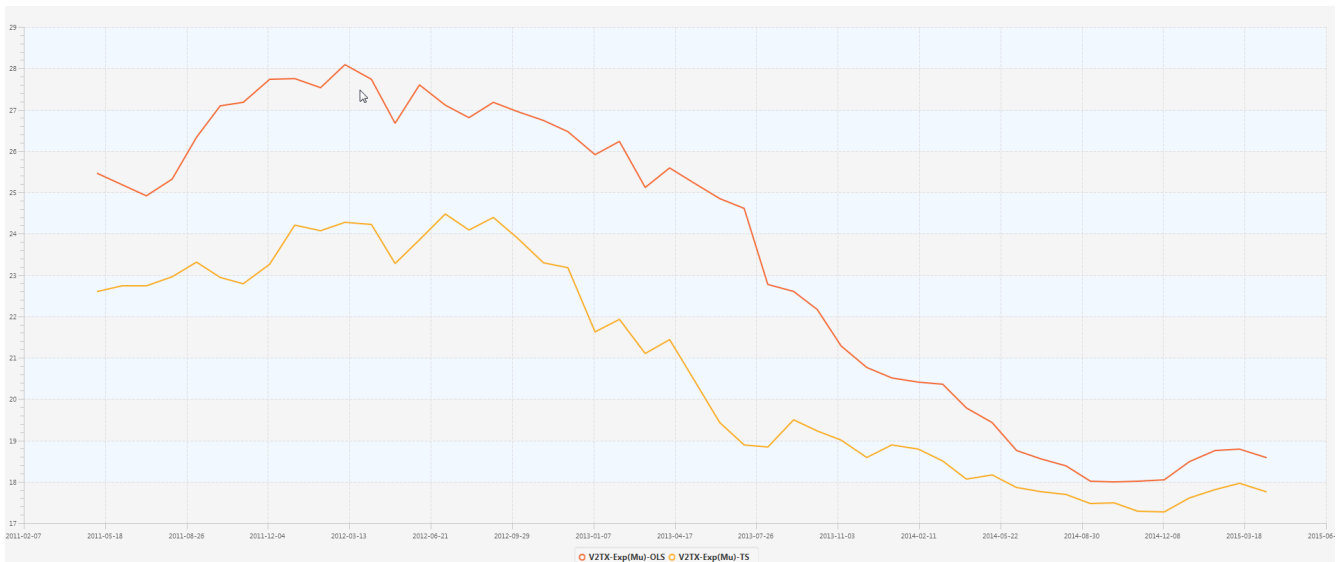
Graphic-4: 21-days VIX Forecast from 2011-05-06 to 2015-05-06 diffusion only.

1.2) The VSTOXX:

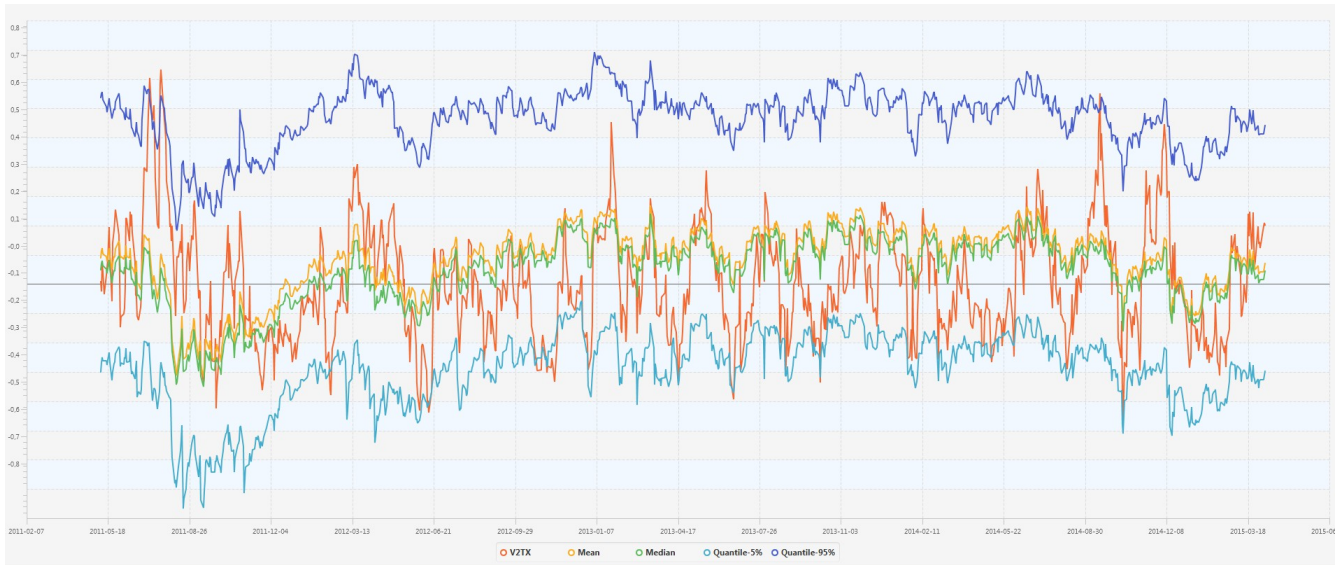
The model can be applied to other volatility-indexes. Graphics-5 to 8 are the VSTOXX equivalent of Graphic-1 to 4. The behavior is qualitative similar. The mean-reversion parameter λ is slightly smaller (Graphic-1 and 5), the mean-reversion level $\exp(\mu)$ is about 5 points higher than for the VIX (Graphic-2 and 6). The jump model has also for the VSTOXX a large positive bias, the diffusion-only model a small negative one. The jump-model predicts the direction in 54% of the cases right, the diffusion-only model in 62.2%.



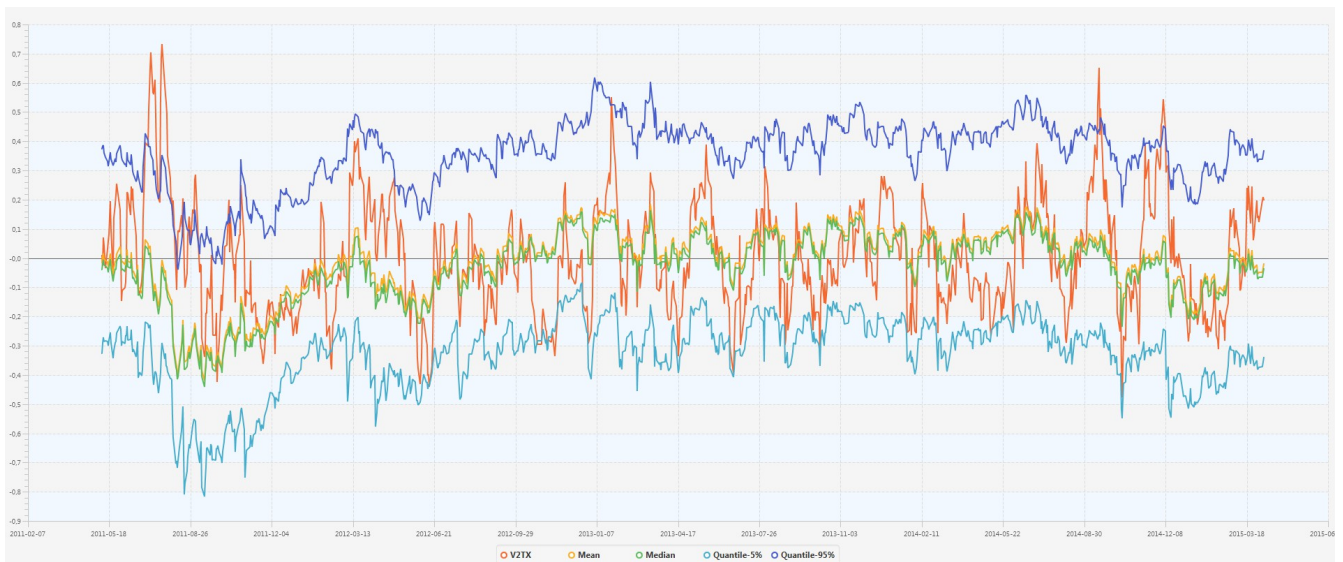
Graphic-5: VSTOXX λ from 2011-05-06 to 2015-05-06. Red OLS, yellow Theil-Sen.



Graphic-6: VSTOXX $\exp(\mu)$ from 2011-05-06 to 2015-05-06. Red OLS, yellow Theil-Sen.



Graphic-7: 21-days VSTOXX Forecast from 2011-05-06 to 2015-05-06 with jump



Graphic-8: 21-days VSTOXX Forecast from 2011-05-06 to 2015-05-06 diffusion only.

2) The Relation between the Index and the Futures:

Zhang, Shu and Brenner model in [16] the relation between the VIX and the VIX Future with

$$F_t^T = \alpha + \beta_1 * VIX_t + \beta_2 * VIX_t^2 + \varepsilon_t \quad (9)$$

F_t^T is the price of a future with maturity T at time t . The estimate the equation for Futures with maturities of 30, 60, 90 and 120 calendar-days. Usually such a future does not directly exist. One creates a synthetic future with a weighted mean of the 2 closest ones. For 30 days this is the 1st and 2nd Future. The VIX calculation uses a similar methodology for the options data. The quadratic term is according the authors essential. This is in agreement with my own calculations for the latest data. But after a logarithmic transformation the significance of the quadratic term disappears. The practical problem of this approach is: Usually one does not trade a synthetic position, but e.g. just the 1st future.

One needs the coefficients of the regression for $T=1, \dots, n$. There is only 1 value per month available. One has to use a kernel regression to increase the number of available data points. For the estimation of T one uses also the weighted values for $T-k, \dots, T+k$. I tried this approach, but the results were clearly worse than equation (12) below. Equation (9) does not consider the fact that the Futures prices is not only a function of the VIX but also of the risk premium. Equation (9) assumes that the premium is constant or is directly related to the VIX level.

Grünbichler and Longstaff model in [11] the Future as

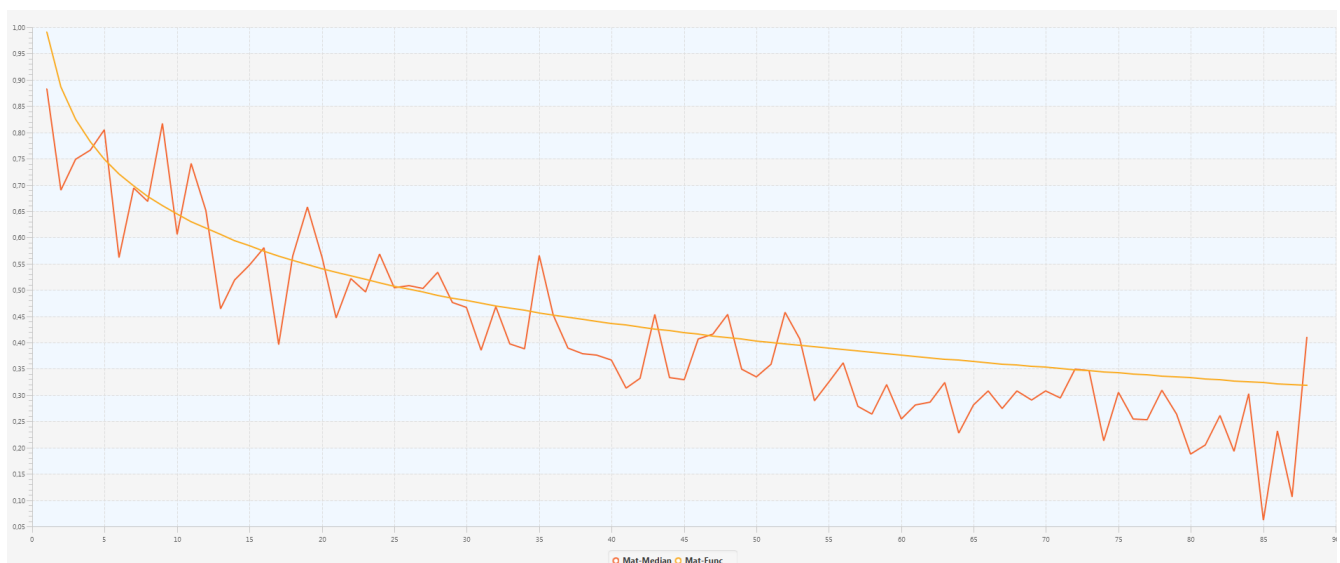
$$F(V, T) = (\alpha/\beta) * (1 - \exp(-\beta * T)) + \exp(-\beta * T) * V \quad (10)$$

Equation (10) is presented in the original formulation in [11]. The volatility Futures prices are exponentially weighted averages of the current value of V and the long-run mean α/β of the risk-adjusted process. The equation follows from the Heston model. The term $\exp(-\beta * T)$ is the beta of the Future to the underlying index. The paper was written in 1995. The VIX Futures were introduced almost 10 years later at 2004-03-26. The exponential decline of the Futures beta is not in agreement with the observed trading data. The model-beta is falling much too fast.

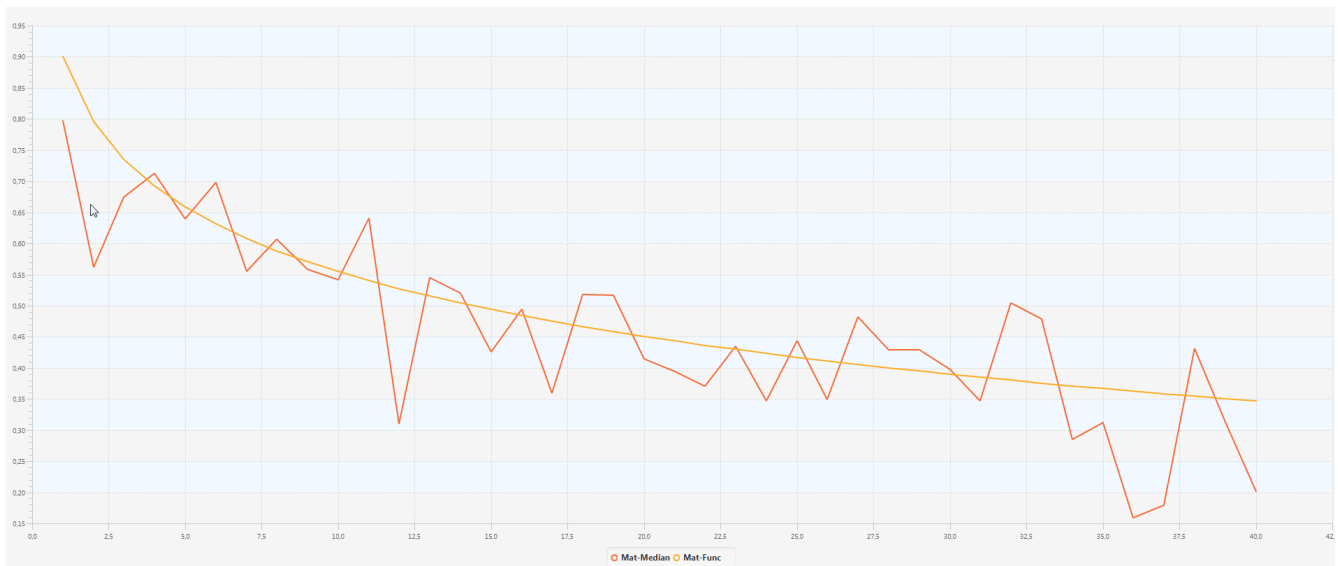
According an article in the Morgan Stanley QDS Vega Times magazine [17] the Futures beta is

$$\beta_T = 0.96 - 0.15 * \ln(T) \quad (11)$$

Beta is falling with the logarithm of maturity. I got better results with the constant 0.99 instead of 0.96. Zhang, Shu and Brenner report in [16] a relative volatility of the Futures to the VIX of 48% (47.9) for $T=30$, 36.6% (37.6) for $T=60$, 32% (31.5) for $T=90$ and 29.0% (27.2) for $T=120$. The numbers in parenthesis are the values which follow from equation (11). They are in almost perfect agreement. Graphic-9 shows the median of the VIX Future betas (red line) and the model equation (yellow) for the data of the last 4 years. There are due to the relative sparsity of the data fluctuations around the line. But overall the fit seems to be reasonable. Graphic-10 is the same for the VSTOXX. For the VSTOXX the intercept was set to 0.9. One should assume, that the beta converges close to 1 for small maturities. But it isn't.



Graphic-9: VIX Future Beta: Red median, yellow eq. (11), from 2011-05-06 to 2015-05-06



Graphic-10: VSTOXX Future Beta: Red median, yellow eq. (11), from 2011-05-06 to 2015-05-06

The Grünbichler and Longstaff formula is hence modified to:

$$F_t^T = F_{\mu} * (1 - \beta_T) + \beta_T * VIX_t \quad (12)$$

Where F_{μ} is the mean reversal level of the risk-adjusted process. Grünbichler and Longstaff call it the long run mean (α/β) in (10). The problem is: There is not such a thing as the long run mean. The risk-premium is not constant. If one inspects the data there is not only a clearly visible volatility clustering, but also a risk-premium clustering. **Assuming a constant risk-premium is as wrong as the assumption of a constant long-term volatility.** For estimating the current volatility one uses a relative small window of past returns or an alpha of 0.94 for the exponential moving average in the RiskMetrics methodology (see [18]). The GARCH models are somewhat more sophisticated versions of these simple filters.

In the same vein the F_{μ} is calculated in a small window of the past 21 trading days. The range of maturities is restricted to the maturities in the trading application. E.g. if one trades only the 1st and 2nd Future, one considers only 1st and 2nd Futures within the estimation window. For each data point F_{μ} is calculated from (11) and (12). The estimated F_{μ} is the median of these values.

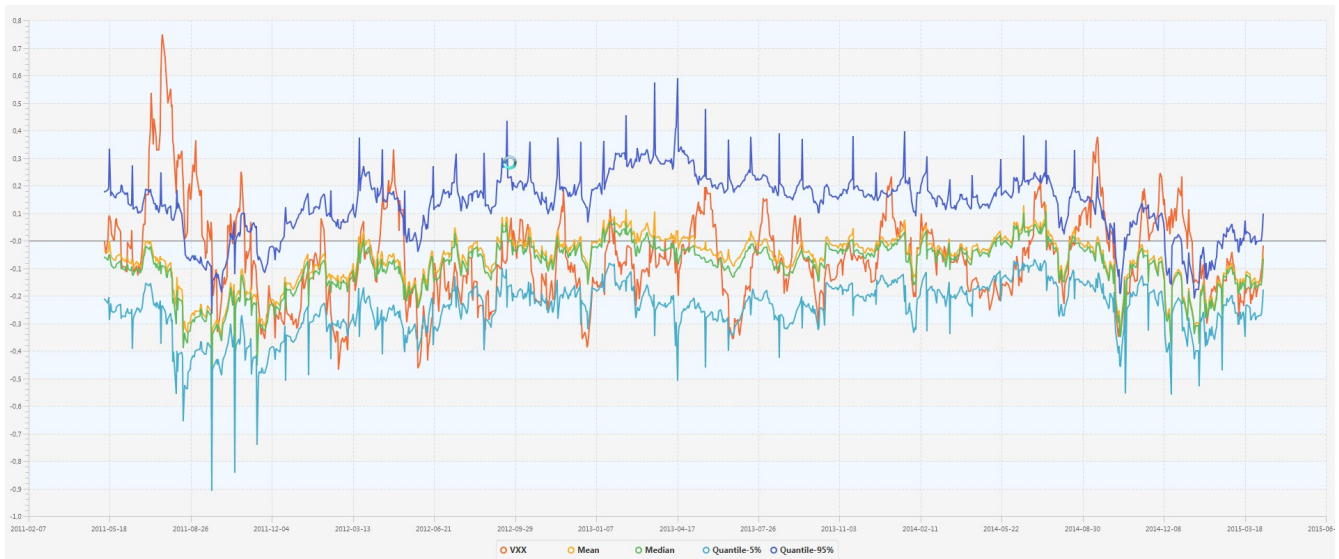
The method does a reasonable job of determining the current F_{μ} . For Monte-Carlo simulations one can update the volatility with a GARCH- or the simpler RiskMetrics-model. **The same should be done for F_{μ} . But I don't know of any reasonable way to model the behavior of F_{μ} along a simulation path.** F_{μ} reflects market sentiment. Probably Newton's famous quote "*I can calculate the motion of heavenly bodies, but not the madness of people*" is also valid for this case.

3) The VIX Short Term Futures Index:

An application of the VIX Futures model is the simulation of the VIX Short Term Futures Index and its ETN VXX. The index rolls on a daily basis from the 1st to the 2nd Future. The exact calculation can be found in [19]. The ETN VXX is the most straightforward way to trade volatility. The VXX gained immediate popularity although its advantages are unclear for a long equity investor. The VXX suffers from the negative roll yield and has a suboptimal hedging performance (see [20]). The Sibyl-Fund exploits this behavior with the short VXX Mojito strategy (see [4]).

Graphic-11 shows the simulation for a 21 trading-days horizon within the last 4 years. The underlying VIX model is diffusive only. The VXX returns within the forecast horizon are in red. Yellow is the model mean, green the median, the lower light-blue line is the 5% quantile, the upper dark-blue the 95% quantile. The empirical monthly return is -6.0%, the model mean is -7.2%. The model underestimates somewhat the VXX spikes. If one uses instead the VIX model with jumps, the blue line moves up considerable and most of the spikes are within the 95% quantile band. But the model mean is close to zero. The model does not capture any more the negative roll yield. The model gets the sign of the VXX return in 63.5% of the cases right. But the dummy rule “the sign is always negative” is with 70% superior.

If one uses the VIX jump model, the correct sign prediction drops to 48.7%. Although the diffusive model underestimates the risk of a short VXX strategy, it is clearly superior to the jump model. The jump model avoids to enter a position because there is no roll yield to harvest.



Graphic-11: 21-days VXX Forecast from 2011-05-06 to 2015-05-06 diffusion only.

4) VIX v. VSTOXX Trading:

Colin Bennet proposes in [21] to short the 1st VIX Future and to go the 1st VSTOXX Future long. The argument behind this strategy is the imbalance in the VIX futures market due to large ETN's like VXX. There is according to Bennet no similar buying pressure for the VSTOXX.

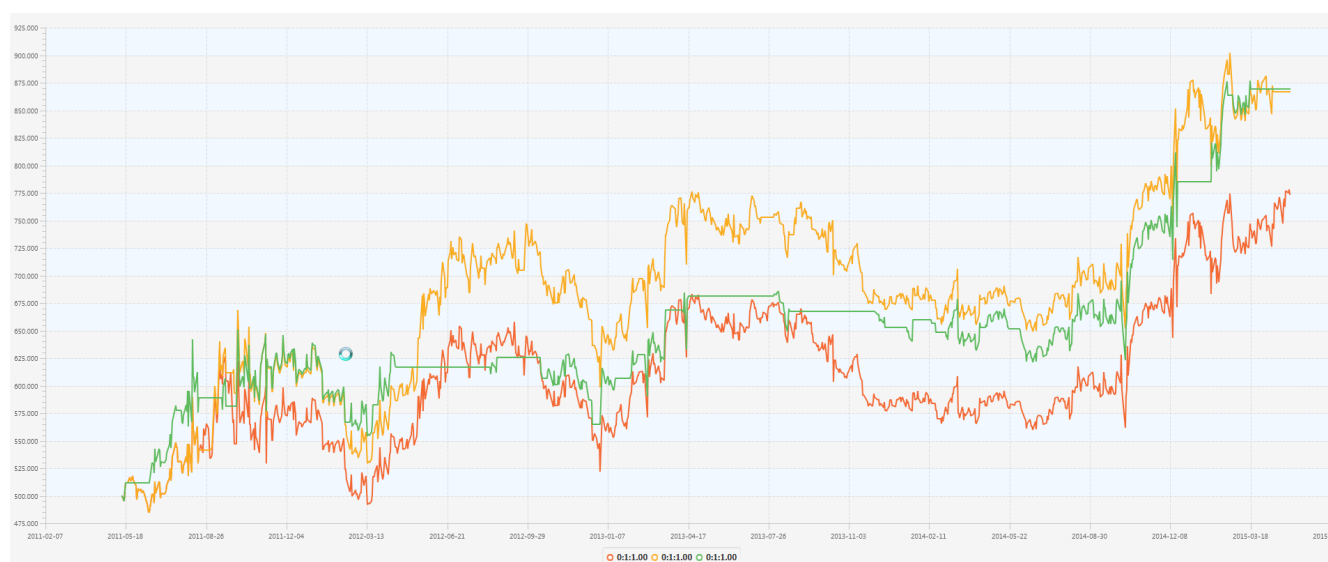
The red-line in Graphic-12 is a naive implementation of this idea. One goes – for the same money-amount – the 1st VSTOXX Future long and the 1st VIX short. At expiry one enters the next position. A more sophisticated strategy uses the VIX and VSTOXX model and the modeling of the Futures in relation to the underlying index. The Futures beta and hence the weight in equation (12) is calculated for both futures as

$$\beta_T = 0.99 - 0.15 \cdot \ln(T) \quad (13)$$

One generates the paths and calculates a sort of Sharpe-Ratio: The mean and the standard-deviation over all paths at the horizon. One enters only a position, if this MC-Sharpe-Ratio is above a given threshold. For the yellow-strategy the minimum Sharpe Ratio is 0.0. Entering a position should be at least an (expected) break even.

For the green-strategy the threshold is 0.2. The strategy stays sometimes for a considerable amount of time on the sideline. The leverage was set to 2%. If the index is at 500,000, one goes -10 VIX futures short and the equivalent amount of 100 VSTOXX Futures long (The multiplier is 1000 and 100). Note: For simplicity the different currencies of the Futures were not taken into account. It was assumed, that VSTOXX Futures trade also in \$. The currency risk makes things worse.

All strategies start with an initial amount of 500,000\$. This is a convention from previous working papers. The naive red strategy has a final value of 773,455\$ (+54.7%), a monthly Sharpe-Ratio of 0.58 and a max. relative drawdown of 22.2%. The yellow-strategy ends at 867,070\$ (+73.4%), with a Sharpe-Ratio of 0.69 and a drawdown of 20.8%. The green-strategy which stays more on the sideline ends at 869,475\$ (+73.9%), a Sharpe-Ratio of 0.87 and a drawdown of 14.8%. The model seems to have an economic value for defining profitable entry-points. But any attempts to define model-based exit conditions failed.



Graphic-12: Long 1st VSTOXX versus short 1st VIX Future from 2011-05-06 to 2015-05-06

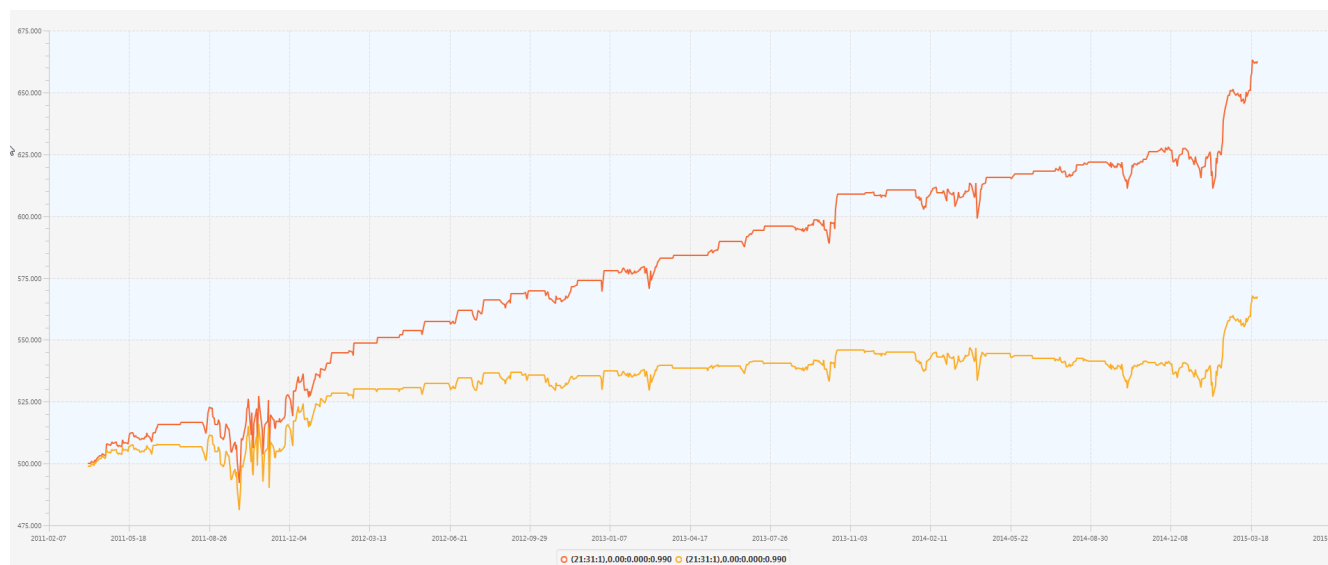
5) VIX Futures Calendar Spread:

Another strategy proposed in [21] is a calendar spread. One goes the 4th Future long and the 3rd Future short. The position is kept till the expiry of the initial 3rd Future. One exploits the fact that the gap between the 4th and 3rd Future is relative small and opens till expiry. The entry point is calculated like above with a model of the spread. The MC-Sharpe Ratio must be greater zero. There is additionally a stop loss if the spread moves in the wrong direction. One closes the position if the loss is greater than the 99% quantile of the model-calculation. This quantile bound is calculated at each step of the MC-paths. One compares the realized loss after 1 trading day with the MC-loss-distribution after 1 day, the realized loss after 2 tradings days with the MC-loss-distribution after 2 days

The starting value is as before 500,000\$, the leverage 2.0%. One goes initially 10 Futures long and short. The performance is without trading costs attractive. The final position is 662,480\$ (+32.5%) with a monthly Sharpe-Ratio of 1.05 and a max. relative drawdown of 5.8% (red-line in Graphic-13). One can increase the leverage because the downside risk is relative low. Unfortunately the situation is less profitable if one takes trading-costs into account. The VIX Futures have a minimal bid-ask-spread of 0.05. This is also most of the time the actual spread. If one assumes that one loses in each trade the

bid-ask and has no other costs – the trading costs are 50\$ per trade and Future - one gets the performance of the yellow line. The final value drops to 567,170\$ (+13.4%) with a monthly Sharpe-Ratio of 0.64 and a drawdown of 6.0%. This is in general the problem of spread strategies. The trading-costs eat up a considerable part of the profit. But trading life would be otherwise too simple and boring. One can't compare these results with that of Colin Bennet because the book does not contain one.

The strategy should perform somewhat better for VSTOXX Futures. I have unfortunately only data for the 1st, 2nd and 4th to 7th Futures. The 3rd is missing in the free data collection of Eurex. The futures are distributed for calculating the Short-Term- and Mid-Term Futures index. This corresponds to the VIX ETNs VXX and VXZ.



Graphic-13: VIX Calendar spread from 2011-05-06 to 2015-05-06

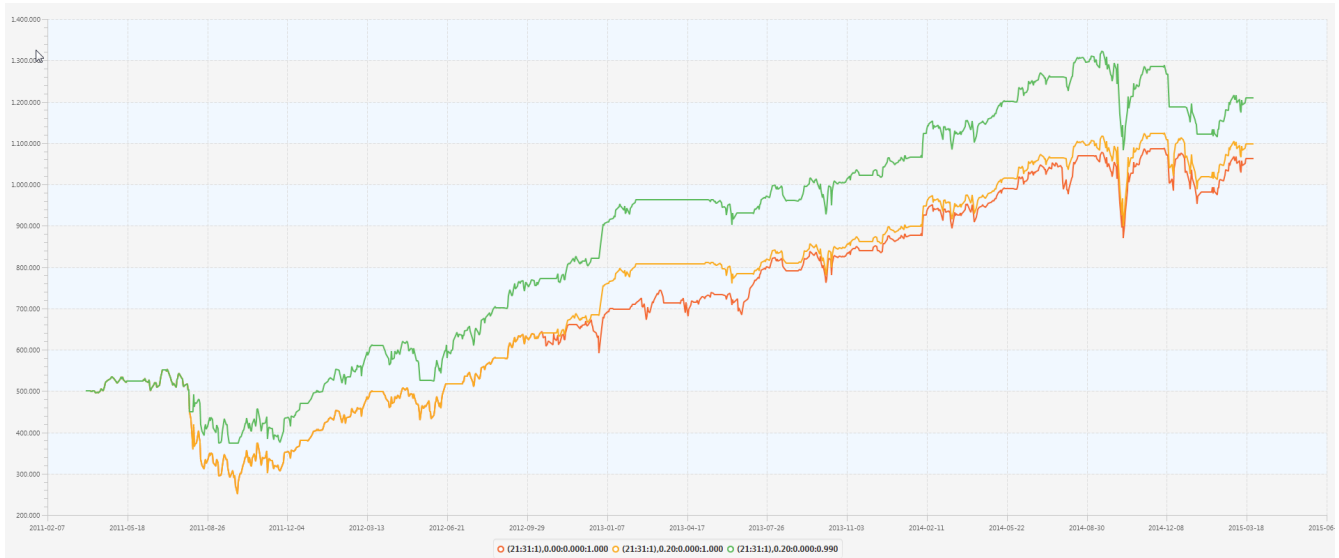
6) Short VIX Futures:

I analyzed in [5] a short VIX Futures strategy. This strategy is based on the roll-value of the VIX Futures. It assumes that the current Futures value does not forecast the VIX at expiry. The current VIX level is a better forecast. The strategy does not take the mean-reverting behavior of the VIX into account. The current strategy uses the model. One selects a Future which has a maturity between 21 and 31 trading days. This is according the results in [5] and also according actual trading the most interesting entry point. One enters the position if the MC-Sharpe-Ratio is above a given threshold. For the red line in Graphic-14 the threshold was set to zero. The leverage is as before 2.0%. The Future is always kept till expiry. Trading costs are as in paragraph 5 the bid-ask spread of 0.05. The final value is 1,061,880\$ (+112.4%) with a Sharpe-Ratio of 0.55 and a maximum relative Drawdown of 54.7%. The strategy loses a lot of money in the August 2011 crash and in October 2014.

The yellow line shows the behavior if one increases the Sharpe-Ratio to 0.2. There is no difference during times of trouble. But the strategy stays in 2013 on the sideline. This was a low VIX regime. The model enters the short-position during a crash, because the mean-reverting behavior should drive down the values. This is in principle right, but the high volatility regime lasts sometimes longer. Staying on the sideline during a very low-volatility regime has a similar logic. The model assumes that the short position is due to mean-reversion not profitable. This is a valid assumption.

The green line shows a strategy with a 99% quantile stop loss. If the Future prices passes the 99% quantile threshold of the MC-distribution, the position is closed. This improves the performance

significantly. The final value is 1,209,980\$ (+142.0%) with a Sharpe-Ratio of 0.79 and a drawdown of 32.4%. But one has still the problem that the strategy enters in times of troubles a short VIX Future position.



Graphic-14: Short VIX Future from 2011-05-06 to 2015-05-06

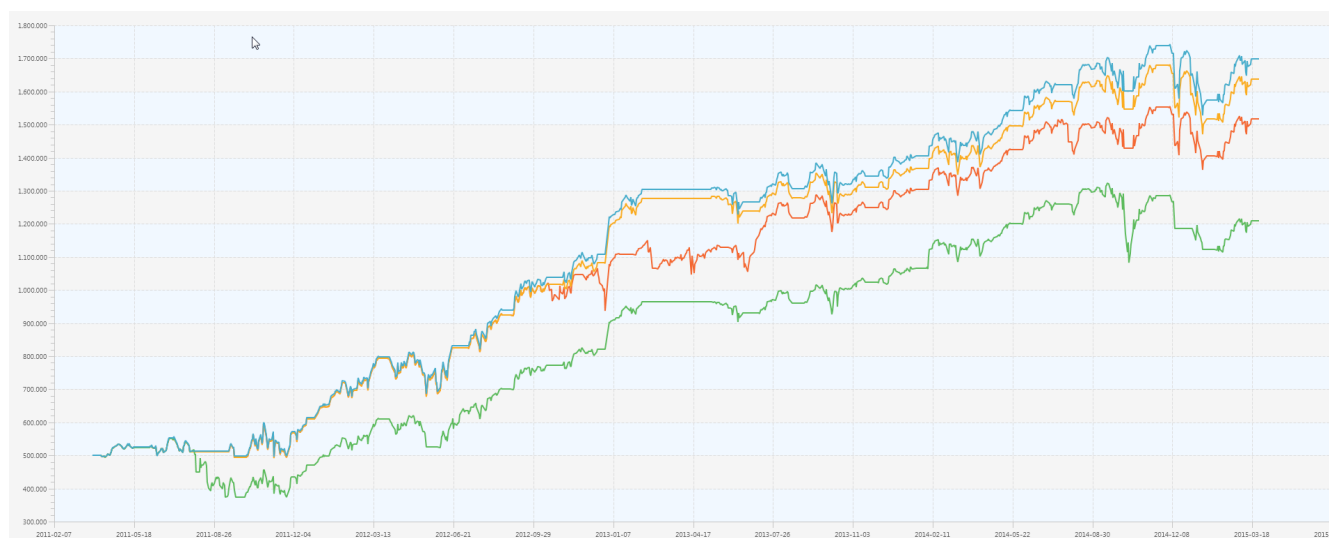
In [4] the concept of the Implied-Volatility-Term-Structure IVTS was introduced.

$$IVTS_t = VIX_t / VXV_t \quad (14)$$

The IVTS is the ratio between the 1-month Volatility index VIX and the 3-months index VXV. This ratio is under normal market conditions below 1. It moves above 1 during a market turmoil. The IVTS is used with good success in the short VXX trading strategy of [4].

Graphic-15 shows the performance if one augments the model with the IVTS. The red line shows a strategy with a minimum MC-Sharpe Ratio of 0.0. Additionally the IVTS must be at the entry below 1.0. The position is closed if the IVTS moves above 1.03. The final value is 1,517,540\$ (+203.5%) with a monthly Sharpe-Ratio of 1.05 and a drawdown of 17.3%. The performance is almost identical if one removes the MC-Sharpe-Ratio condition at all. The threshold of 0.0 is for this trade too weak.

Like in Graphic-14 the performance is improved if one raises the MC-Sharpe-Ratio threshold to 0.2 (yellow in Graphic-15). This avoids the very low VIX regime with little profit potential. The IVTS signal can not cope with this situation. The IVTS is during such a regime around 0.85. But it is also not profitable to add another low-threshold. The mean-reverting model handles this case considerable better. The final value is 1,637,630\$ (227.5%) with a Sharpe-Ratio of 1.10 and a drawdown of 17.3%. The green line is the same strategy than in Graphic-14. It is drawn to show the effect of the IVTS signal. The blue line is the same strategy than the yellow one. Only the trading costs are set to zero. The difference between the blue and yellow line are the trading costs. They are – in contrast to calendar spread in Graphic-13 – relative modest. The strategy is still attractive if one increases the bid-ask spread to 0.10 or adds additional trading fees.



Graphic-15: Short VIX Future with IVTS signal from 2011-05-06 to 2015-05-06

7) VIX Call-Writing:

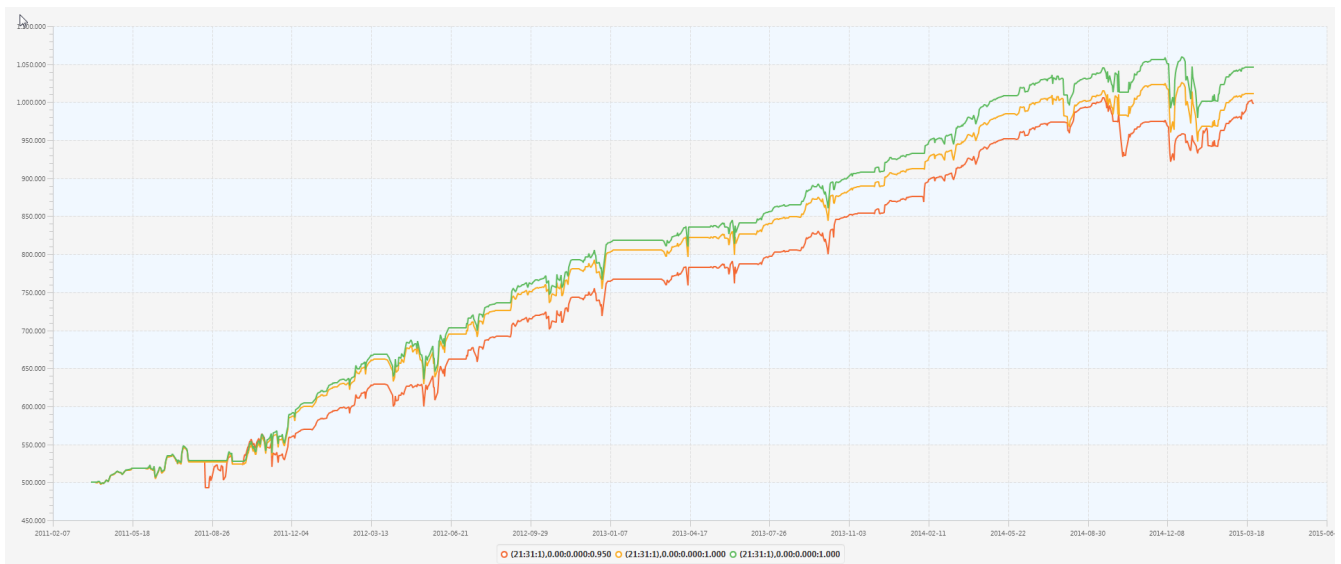
Another interesting idea of selling volatility is Call-Writing. The payoff of VIX options is based on the index. But they are evaluated on the Future with the same maturity. A delta of 0.5 does not mean that the strike is at the index, but at the Futures price. This is normally above the index. Trading Calls exploits hence the same roll-mechanism. For the Monte-Carlo evaluation one needs also an implied volatility. I have not tried to develop an additional IV model. Instead the option has a constant IV over it's path. This assumption is not completely wrong. The IV of VIX options does not move in the same way than SPX options. If the VIX raises, the IV moves only slowly up. At the same time the strike is moving towards the underlying. The smile is inverse to the smile of SPX options. OTM Calls have a higher IV than ATM. So the IV of a given option is relative sticky. It is also not the purpose of the MC-Model to calculate an exact options value. It's purpose is to trigger an entry and/or an exit. As for the Futures the leverage is 2.0%. For an index value of 500,000\$ one writes 100 Calls. The delta was set to 0.5. As noted before, this does not mean that the strike is at the VIX but at the VIX Future with the same maturity. The maturity of an entry must be as for the Futures between 21 to 31 trading days.

The red line in Graphic-16 shows the performance of a MC-model based strategy. The MC-Sharpe Ratio threshold is 0.0. One closes the position if the underlying VIX! (not the future) moves above the 95% quantile of MC-VIX-paths. The final value is 998,682\$ (+99.7%) with a Sharpe-Ratio of 1.24 and a max. relative drawdown of 9.8%.

The strategy for the yellow line uses instead the IVTS. At the entry point the IVTS must be – like for the Futures – below 1.0. Additionally the MC-Sharpe Ratio must be above zero. The position is closed, if the IVTS moves above 1.03. The final value is 1,011,302\$ (+102.2%) with a Sharpe Ratio of 1.23 and a drawdown of 7.6%.

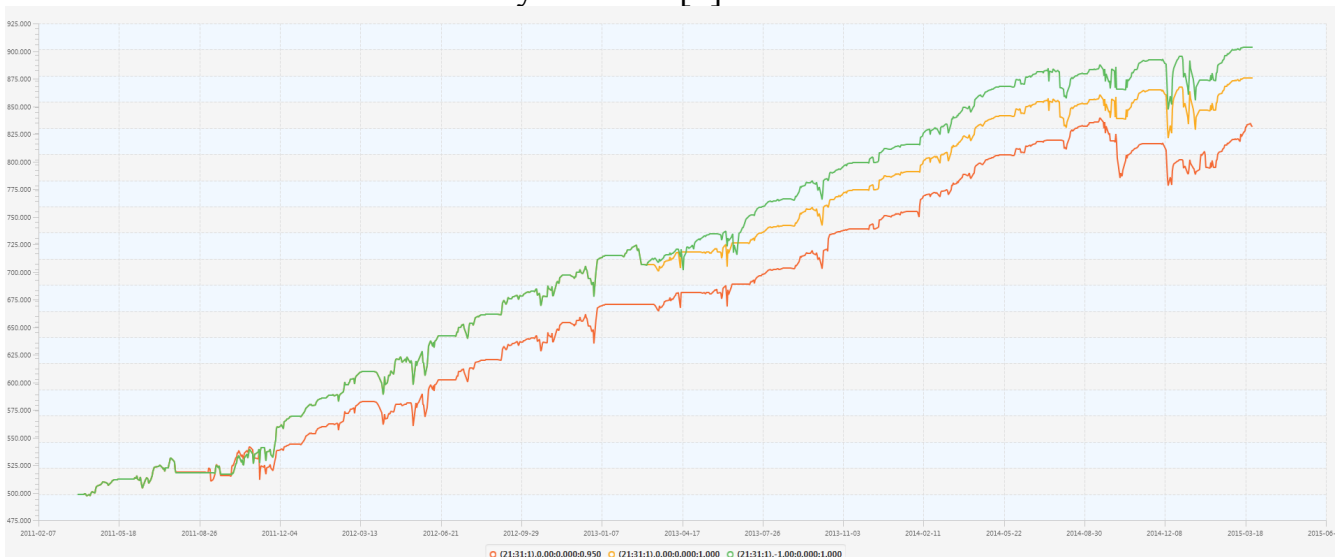
The typical (and minimal) bid-ask spread of VIX options is 0.05. Like for the Futures it is assumed that this spread are the trading costs (5\$ per option and trade). The green line is the same strategy than the yellow one. Only the trading costs are set to zero. The trading costs are moderate and the strategy would be still highly profitable if one doubles the cost to 10\$.

Note: The backtest is only till 2015-03-26, because the available options data end at this date.



Graphic-16: VIX-Call-Writing with delta = 0.5 from 2011-05-06 to 2015-03-26

The red and yellow line in Graphic-17 represent the same strategies than in Graphic-16. Only the Call delta is set to 0.4. The model based red strategy has a final value of 851,830\$ (+70.3%) with a Sharpe-Ratio of 1.25 and a drawdown of 7.5%. The overall profit is lower, but also the risk is reduced. The IVTS based strategy has a final value of 897,640\$ (79.5%) with a Sharpe-Ratio of 1.28 and a drawdown of 5.2%. The strategy for the green line does not use the VIX model at all. It enters a position if the IVTS is below 1.0 and closes the position if the IVTS is above 1.03. The performance is for the first half of the backtest identical to the yellow strategy (therefore one sees only the green line which is drawn above the yellow one). But overall this trivial strategy is somewhat better than the sophisticated MC-Model. The final value is 927,215\$ (85.4%) with a Sharpe-Ratio of 1.29 and a max. relative drawdown of 5.2%. Or with other words, the sophisticated MC-Model is for this trade of no use. A similar result was already found in [6].

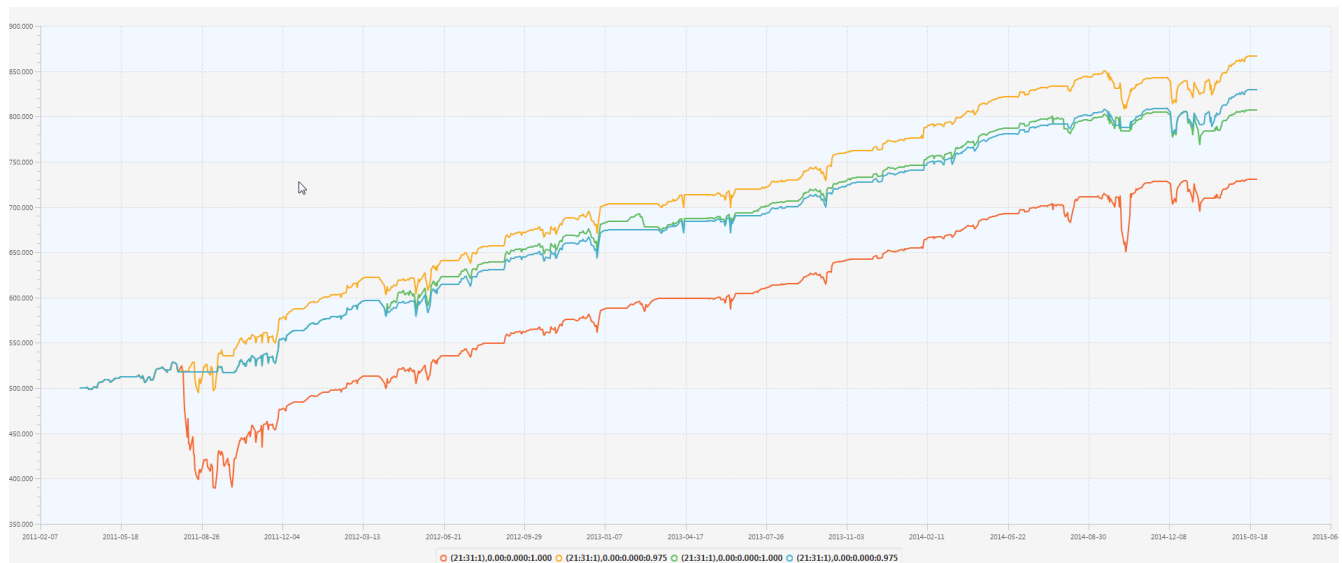


Graphic-17: VIX Call Writing with delta 0.4 from 2011-05-06 to 2015-03-26

8) VIX Call-Spread:

The historic losses of the Call write strategy are not dramatic. But naked written options are generally not for the fainthearted. Some brokers ask for extra margins and even for extra fees. A simple alternative is a spread. One goes the lower strike short and the higher strike long. The maturity is the same. The maximum loss is restricted by the strike-differences. The problem is the positive slope of the smile. The long Call with the higher strike is – measured in IV – more expensive.

Graphic-18 shows the performance of a spread where the short position has a delta of 0.4 (actually the option which delta is closest to 0.4) and the long position has a delta of 0.1. The other settings are the same as for Call-Writing in paragraph 7.



For the red-strategy in Graphic-18 there is only an entry condition. The MC-Sharpe-Ratio must be greater than zero. A position is never closed. It terminates always at the expiry. The final value is 730,522\$ (+46.1%) with a Sharpe-Ratio of 0.64 and a drawdown of 26.4%. There is a protection by the long position, but the losses are in the August 2011 crash and the October 2014 spike considerable. For the yellow strategy the position is closed, once the VIX moves above the 97.5% quantile of the MC-VIX-paths. This stop-loss condition avoids most of the severe losses in August 2011 and works also in October 2014 reasonable. The final value is 866,570\$ (+73.3%) with a Sharpe-Ratio of 1.30 and a drawdown of 6.5%.

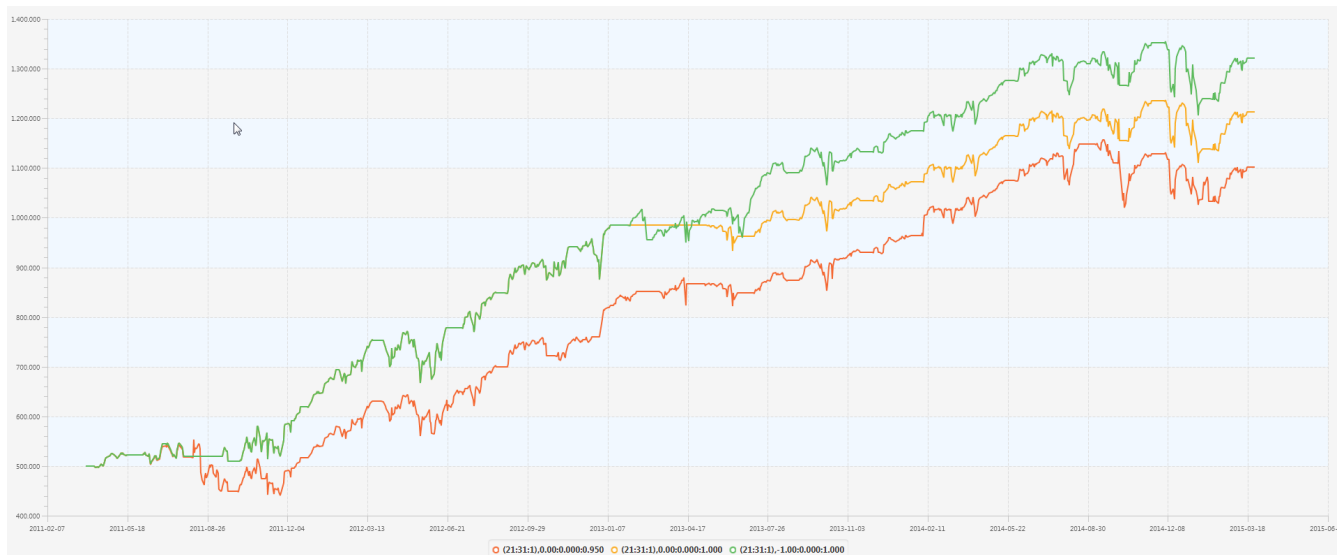
The green line is the IVTS based alternative. At the entry the IVTS must be - additionally to the positive MC-Sharpe ratio - below 1.0. The position is closed once the IVTS moves above 1.03. The final value is 807,370\$ (+61.5%) with a Sharpe-Ratio of 1.27 and a drawdown of 4.7%.

The blue strategy combines both conditions. The position is also closed, if the VIX moves above the 97.5% MC-quantile. The final value is 829,760\$ (+65.9%) with a Sharpe-Ratio of 1.29 and small drawdown of 3.6%.

The strategy is on a risk adjusted basis at least on par with Call-Writing. It is probably the more comfortable one.

9) VIX Covered-Put-Writing:

For the Covered Put one sells a Put and goes the equivalent number of Futures short. The covered Put has a similar payoff then Call-Writing. The lines in Graphic-19 represent exactly the same strategies than in Graphic-17. For the red line one exits the position if the VIX moves above its 95% threshold. The leverage is this time 1% (or 2 x 1%). For an index of 500,000\$ one sells 5 Futures and writes 50 Puts. The delta of the Put is set to -0.4. Like above the trading costs are the bid-ask spread of 0.05 for Futures and Options.



Graphic-19: VIX Covered Put with delta -0.4 from 2011-05-06 to 2015-03-26

The final value of the model based red strategy is 1,101,420\$ (102.8%) with a Sharpe-Ratio of 0.97 and a max. relative drawdown of 20.4%. The final value of the IVTS based yellow strategy is 1,213,530\$ (+142.7%) with a Sharpe-Ratio of 1.09 and a drawdown of 13.5%. If one ignores the model at all and drops also the MC-Sharpe must be greater zero conditions the final value increase to 1,321,180\$ (+164.2%) with a historic Sharpe-Ratio of 1.11 and a drawdown of 13.5%.

10) Plain VXX Trading:

The most popular VIX related product is the ETN VXX (see paragraph 3 above). A simple and also in real trading life successful strategy was developed in [4]. For this paper the leverage was set to 50%. If the index is at 500,000 and the VXX price is 25 one goes $250,000/25 = 10,000$ shares short. The ratio is rebalanced daily. If the VXX is falling, additional shares are shorted, if the VXX is going up, some of the shorted shares are bought back. It was shown in [4] that the result does not differ significantly if the rebalance is only done once the leverage leaves a band of 45 to 55%. The bid ask-spread of the VXX is typical 0.01. But it should be noted that there are additional costs for shorting. These costs are ignored.

The red line in Graphic-20 shows the most basic VXX strategy. One shorts at the beginning the VXX and does – besides the rebalance – no further action. The strategy relies on the long term roll-down effect. The heavy losses in between (August 2011) are simply ignored. The strategy ends with a final value of 1,169,055\$ (+133.8%) a Sharpe-Ratio of 0.59 and a max. relative drawdown of 45.2%. In [4] a position was entered, if the IVTS is below 0.91. It was closed if the term-structure inverted and the IVTS climbed above 1.0. There are sometimes short VIX spikes. It proved to be profitable to remove

the spikes with a median-5 filter. With the filter the closing condition becomes: The IVTS has to be on 3 out of the last 5 trading days above 1.0. The yellow line in Graphic-19 shows the performance of this strategy. The final value is 1,431,109\$ (+186.2%) with a Sharpe-Ratio of 0.85 and a drawdown of 27.6%. For the VIX derivatives strategies considered above the IVTS threshold to enter a position was 1.0 and the close-threshold 1.03. No filter was used. The green line in Graphic-20 shows the performance of this rule. It is up to Oct. 2013 similar to the yellow strategy, but performs since then superior. The final value is 1,749,835\$ (250.0%) with a Sharpe-Ratio of 0.94 and a drawdown of 19.5%.



Graphic-20: VXX with IVTS signal from 2011-05-06 to 2015-05-06

In paragraph 3 a VXX model was developed. The model assumes a fixed path length/forecast horizon. The ETN has a practically unlimited maturity. It is obviously not possible to simulate the VXX till doomsday. As in paragraph 3 the path length was set to 21 trading days. The model looks month for month ahead.

Graphic-21 shows again in red the best IVTS strategy of Graphic-20 (the green line). For the yellow strategy the IVTS was augmented with the model. The entry condition is: The IVTS is below 1.0 and the MC Sharpe Ratio is greater than zero. The model predicts a profitable position for the next 21 trading days. The position is closed, if the IVTS rises above 1.03 or the VXX moves above the 99% quantile of the MC VXX distribution. Additionally the MC simulation is repeated after each 21 trading days. If the MC Sharpe Ratio drops below zero, the position is also closed. The bounds for the next 21 trading days are recalculated. The final value of the red IVTS strategy is 1,749,835\$ (250.0%) with a Sharpe-Ratio of 0.94 and a drawdown of 19.5%. The model augmented yellow strategy has a final value of 1,432,049\$ (+186.4%) with a Sharpe-Ratio of 1.06 and a drawdown of 12.3%. The final profit of the model based strategy is somewhat lower, but the performance is much smoother. The additional model-signal seems to be beneficial.



Graphic-21: VXX with IVTS- and model-signal from 2011-05-06 to 2015-05-06

11) VXX Weekly Call Writing:

There are weekly options traded on the VXX. Especially the 1st and 2nd week are liquid. The bid-ask spread is usually 0.01. Like for the VIX the role of Calls and Puts are reversed. The smile has a positive slope. For VIX options the question of the “real” underlying is relative tricky. In case of the VXX options it is like for plain stock options the VXX itself.

The implemented Monte-Carlo simulation is analogous to the VIX options. I have not tried to develop an additional IV model. Instead the option has a constant IV over its path (see paragraph 7 for further explanations).

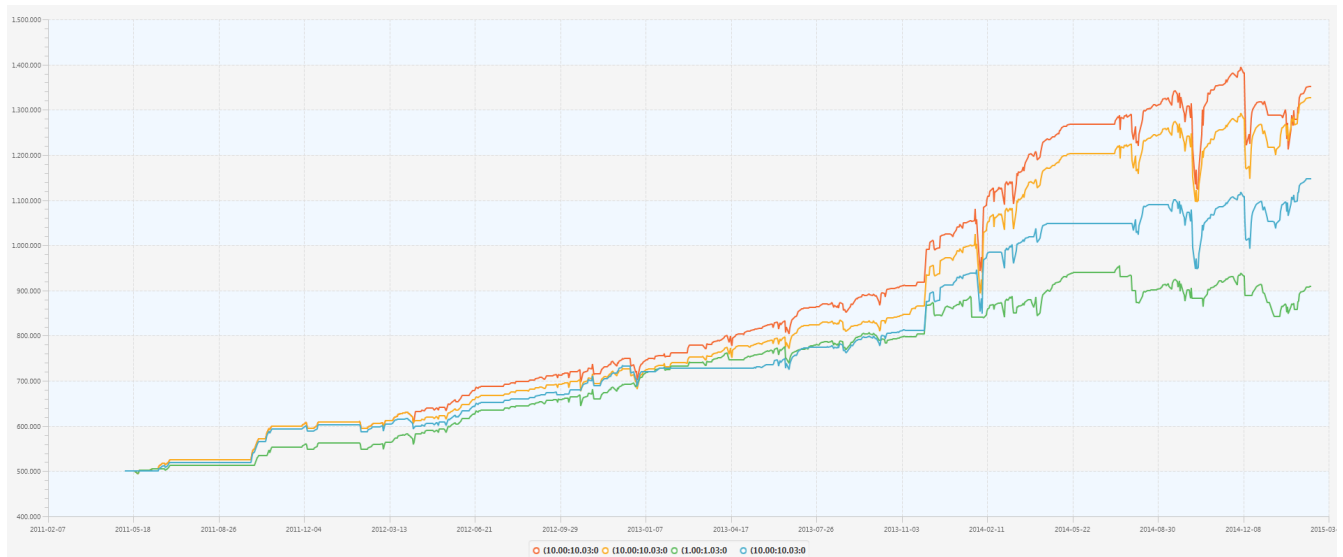
The strategy starts like before with an index of 500,000\$. The leverage is 2%. One writes for this index value 100 options. The maturity at entry is set between 3 and 16 trading days. The Calls in Graphic-22 have a delta between 0.4 and 0.5. There can be several options which meet these criteria. One selects the option with the highest MC-Sharpe-Ratio. The only trading cost is the bid-ask spread of 0.01 or 1\$ per trade and option.

VXX Calls are attractive candidates for a writing strategy. There is a high risk premium and additionally the VXX has a significant negative drift. The drift is for the value theoretically irrelevant, but for a naked options position of course helpful. But volatility and spikes dominate the short-term behavior.

The red-line in Graphic-22 shows a strategy where the only condition is that the best MC-Sharpe ratio at entry is greater than zero. One keeps the position till expiry. No matter what happens in between. The final value is 1,279,687\$ (+155.9%) with a Sharpe-Ratio of 1.22 and a max. relative drawdown of 14.5%.

The yellow line in Graphic-22 adds an exit condition. If the VXX moves above the 97.5% quantile of the MC-paths, the position is closed. The final value is 1,271,850\$ (+154.4%) with a Sharpe-Ratio of 1.24 and a drawdown of 12.1%. The exit condition reduces the risk. But there is such a high risk-premium that this safety measure does not improve the final value.

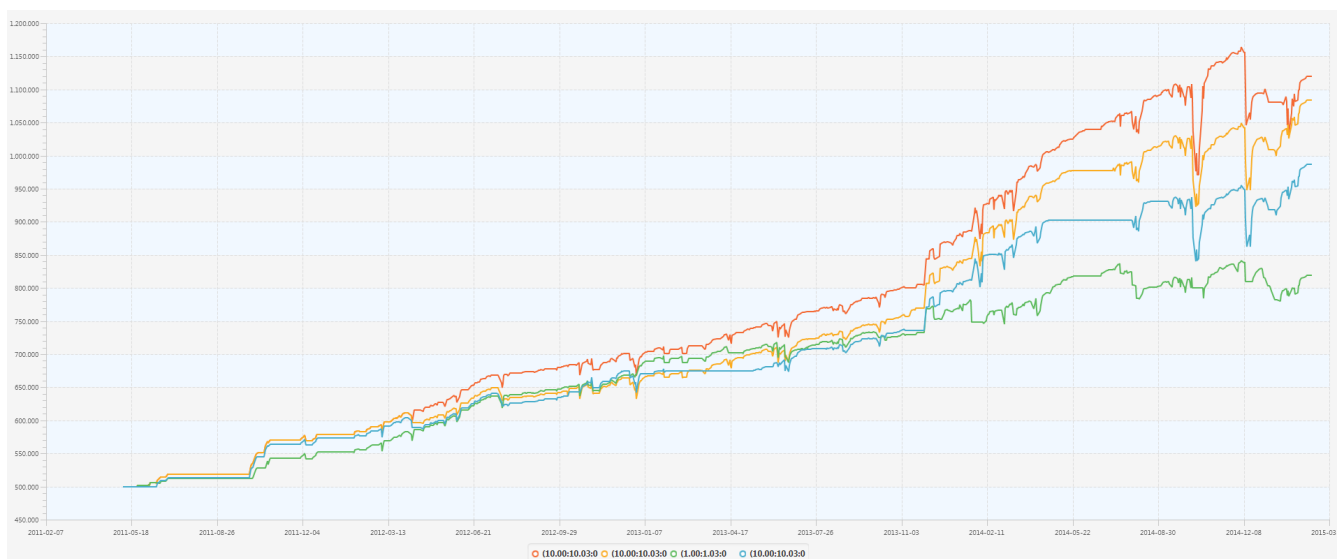
The green strategy uses the IVTS for risk reduction. The entry condition is as before a MC-Sharpe-Ratio greater than zero. Additionally the IVTS must be below 1.0. One closes the position if the IVTS



Graphic-22: VXX Weekly Call with delta in [0.4,0.5] from 2011-05-06 to 2015-03-26

moves above 1.03. The final index value is 892,821\$ (+78.6%) with a Sharpe-Ratio of 1.13 and a drawdown of 7.7%. The major difference to the yellow strategy is: If the IVTS moves above 1.03 the position is closed and one stays on the sideline till the IVTS falls below 1.0. The model based exit strategy performs in this situations usually a roll-up or a roll-over. The old position is closed and a new position either with a higher strike and/or a longer maturity is entered. This is a common strategy in options trading. The close and stay on the sideline strategy is less risky. This can be seen on the considerable smaller drawdown of the green strategy. But it misses also high risk premiums.

The blue strategy differs in one point from the yellow one. The MC-Sharpe-Ratio threshold is set to 0.2. The strategy stays also in very quiet times on the sideline. It try's to avoid the calm before the storm. But sometimes it's the calm before the calm and it misses also potential profit. The final value is 1,144,381\$ (+128.9%) with a Sharpe-Ratio of 1.22 and a drawdown of 12.1%.



Graphic-23: VXX Weekly Call with delta in [0.3,0.4] from 2011-05-06 to 2015-03-26

In Graphic-23 the Calls are more OTM. Delta must be between 0.3 to 0.4. Otherwise the strategies are identical to Graphic-22.

The final value of the red-strategy (no exit condition) is 1,119,976\$ (+124.0%) with a Sharpe-Ratio of 1.24 and a drawdown of 12.4%.

For the yellow strategy (exit at 97.5% quantile) the final value is 1,084,065\$ (+116.8%) with a Sharpe-Ratio of 1.25 and a drawdown of 10.4%.

For the green strategy (IVTS entry and exit) the final value is 819,512\$ (+63.9%) a Sharpe-Ratio of 1.16 and a drawdown of 7.2%.

The blue strategy (MC-Sharpe greater than 0.2) has a final value of 986,843\$ (+97.4%) with a Sharpe-Ratio of 1.22 and a drawdown of 10.4%.

The overall picture is quite similar. The final value is due to the lower option-price reduced. But the risk-adjusted performance is slightly superior.

12) VXX Weekly Call-Spreads:

The situation is similar to the VIX options strategies in paragraph 7 and 8. The historic losses of the Call write strategy are not dramatic. But naked written options are generally not for the fainthearted. As in 8 the alternative is a spread. One goes the lower strike short and the higher strike long. The maturity is the same. The maximum loss is restricted by the strike-differences. The problem is again the positive slope of the smile. The long Call with the higher strike is – measured in IV – more expensive. Graphic-24 shows the performance of a spread where the short position has a delta of 0.4 (actually the option which delta is closest to 0.4) and the long position has a delta of 0.2. The other parameters are the same than for the naked Call strategy of paragraph 11.

The red-strategy (no exit condition) has a final value of 756,127\$ (+51.2%) with a Sharpe-Ratio of 1.06 and a maximum relative drawdown of 10.7%.

For the yellow strategy (exit at 97.5% quantile) the final value is 733,052\$ (+46.6%) with a Sharpe-Ratio of 1.07 and a drawdown of 10.0%

For the green strategy (IVTS entry and exit) the final value is 685,146\$ (+37.0%) a Sharpe-Ratio of 0.99 and a drawdown of 6.6%.

The blue strategy (MC-Sharpe greater than 0.2) has a final value of 772,533\$ (+54.5%) a Sharpe-Ratio of 1.14 and a drawdown of 7%. The strategy is on the right time on the sideline. This can of course also be good historic luck.

In Graphic-25 the long Call is far OTM. It has – like in the VIX spread - a delta of 0.1. Otherwise the strategies are identical to Graphic-24.

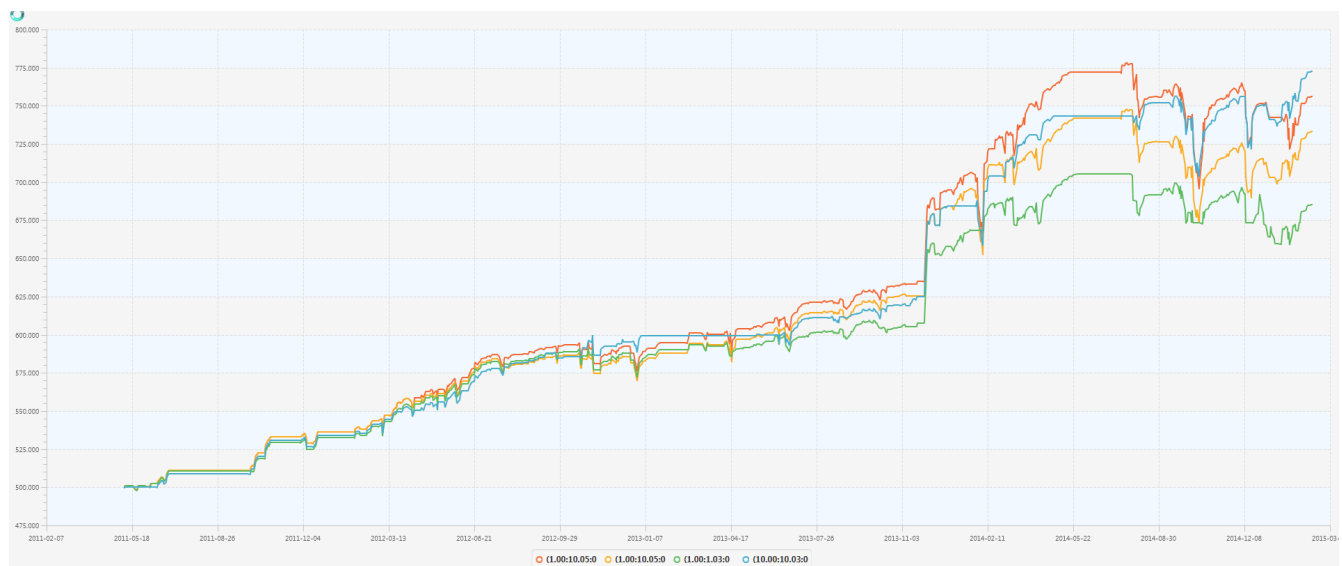
The red-strategy (no exit condition) has a final value of 921,559\$ (+84.3%) with a Sharpe-Ratio of 1.15 and a maximum relative drawdown of 11.9%.

For the yellow strategy (exit at 97.5% quantile) the final value is 902,954\$ (+80.6%) with a Sharpe-Ratio of 1.07 and a drawdown of 10.0%

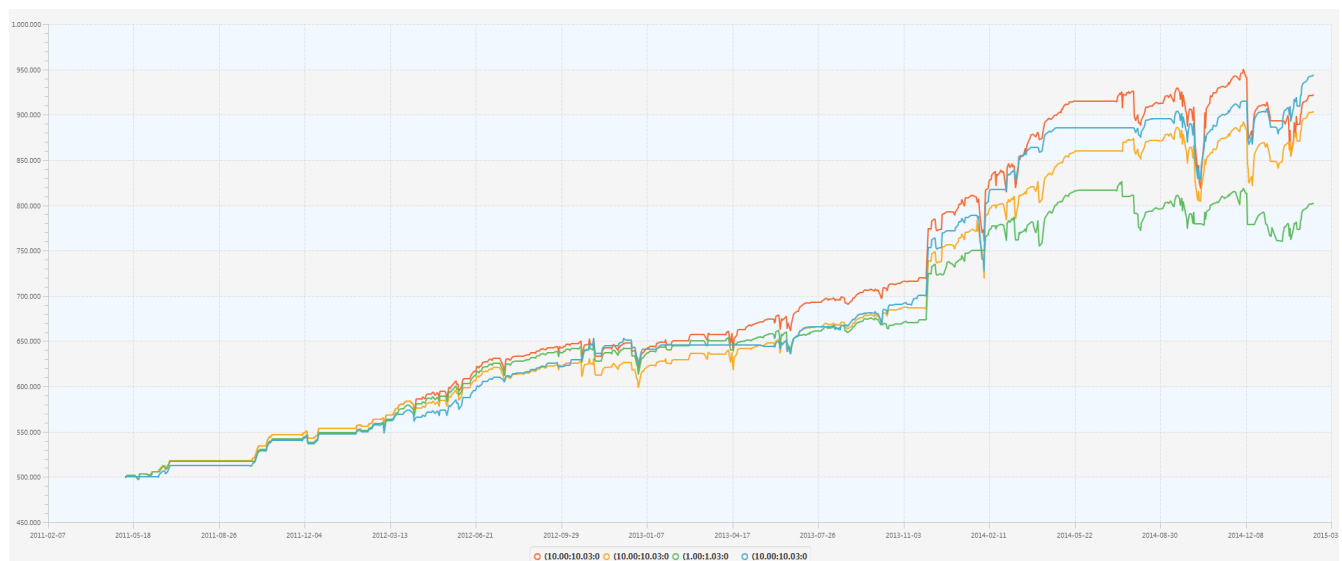
For the green strategy (IVTS entry and exit) the final value is 801,983\$ (+60.4%) a Sharpe-Ratio of 1.10 and a drawdown of 8.1%.

The blue strategy (MC-Sharpe greater than 0.2) has a final value of 943,144\$ (+88.6%) a Sharpe-Ratio of 1.20 and a drawdown of 8.4%

The far OTM protection with a delta of 0.1 seems to be superior to the closer protection with delta 0.2.



Graphic-24: VXX Call-Spread with delta 0.4/0.2 from 2011-05-06 to 2015-03-26



Graphic-25: VXX Call-Spread with delta 0.4/0.1 from 2011-05-06 to 2015-03-26

12) VXX Weekly Covered Put-Writing:

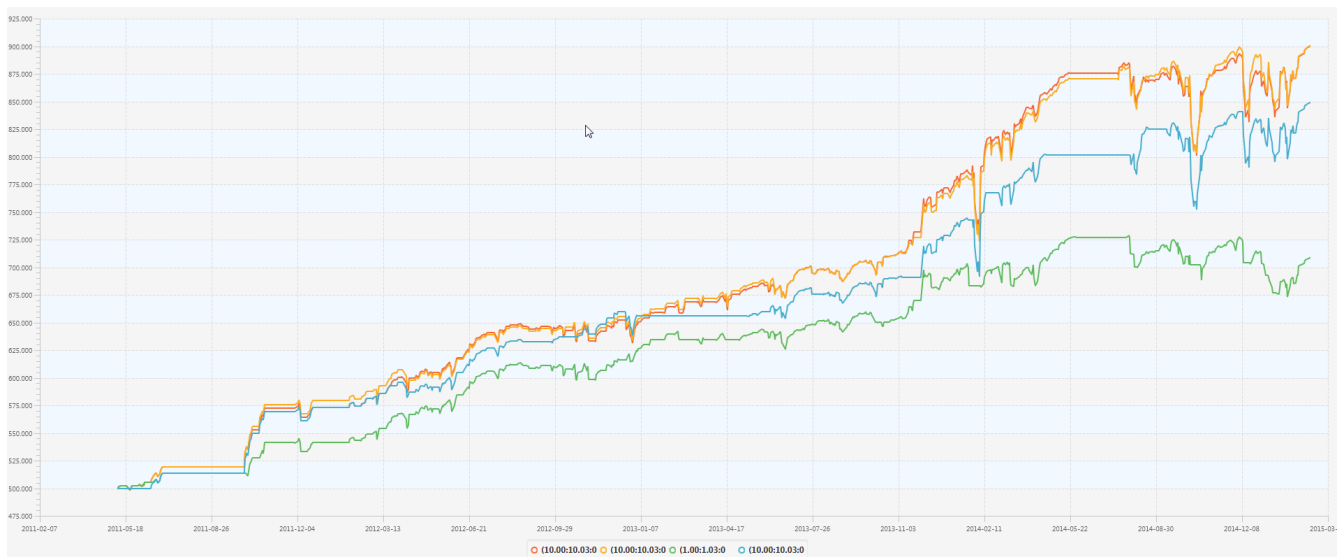
As already noted in paragraph 9 covered Puts have a similar payoff than Call-Writing. The leverage was set to 1.0%. For an index value of 500,000\$ one writes 50 Puts and goes 5000 ETN's short. The other conditions are the same as in the previous paragraphs. The delta of the Puts is between -0.5 and -0.3. One selects the Put with the best MC-Sharpe-Ratio.

The red-strategy (no exit condition) has a final value of 900,152\$ (+80.0%) with a Sharpe-Ratio of 1.13 and a max. relative drawdown of 9.5%.

For the yellow strategy (exit at 97.5% quantile) the final value is 900,485\$ (+80.1%) with a Sharpe-Ratio of 1.13 and a drawdown of 9.5%. The exit condition has only a minor influence.

For the green strategy (IVTS entry and exit) the final value is 708,748\$ (+41.7%) with a Sharpe-Ratio of 0.98 and a drawdown of 7.6%.

The blue strategy (MC-Sharpe greater than 0.2) has a final value of 849,365\$, a Sharpe-Ratio of 1.11



Graphic-26: VXX Covered Put with delta in $[-0.5, -0.3]$ from 2011-05-06 to 2015-03-26

and a drawdown of 9.4%.

The performance and the risk of the Covered Puts is between the naked Call writing and the Call-Spreads. The strategy seems to be an interesting compromise.

13) Trading VXX with nearest neighbors prediction:

After reading the original version of this paper Johannes Bruski suggested to analyze a strategy presented by Jev Kuznetsov in [25]. Kuznetsov defines 2 signals:

$$\text{Premium}_t = \text{VIX}_t - \text{realizedVol}_{10,t} \quad (15)$$

$$\text{Delta}_t = \text{VIX}_t - \text{VXV}_t \quad (16)$$

The premium is the difference between the VIX and the realized Volatility measured with the Yang-Zhang volatility estimator [26]. This estimator takes also high-low-open into account. It is the most efficient known estimator. The realized volatility is measured over a window of 10 trading days.

The Delta is similar to the IVTS in (16). Only the difference and not the quotient is used.

One builds from this two signals a K-Nearest Regression to predict the return of the next trading day.

If the forecast is positive, one goes the VXX long, otherwise short.

The author performs the calculation with the K-Nearest Regression of the scikit Python library. But he does not specify the exact method-parameters. With $k=80$ he got an impressive (unbelievable) Sharpe-Ratio of 2.3. With the original definitions in (15) and (16) I was not able to produce any reasonable performance. Using the difference is also not very logical. Hence I used instead the quotient and turned the VIX and the realizedVol around.

$$\text{Premium}_t = \text{realizedVol}_{10,t} / \text{VIX}_t \quad (17)$$

$$\text{Delta}_t = \text{VIX}_t / \text{VXV}_t \quad (18)$$

Delta is now the IVTS. Besides this the two series are normalized to mean 0 and standard-deviation 1. The euclidean distance was used for the similarity calculation.

Note: The normalization step is probably automatically done by the scikit library. The euclidean distance is also the scikit default.

The two signals in (17) and (18) have a very low correlation. This is due to the lag of the realized Volatility. If one uses equation (15) and (16) the Premium and Delta are negatively correlated. If one changes the window length for the Yang-Zhang estimator the correlation changes too. It gets negative for a longer window and positive for a shorter one. The 10 days length is clearly the optimal setting.

The overall trading parameters - initial value, the leverage and the trading costs - are the same than in paragraph 10.

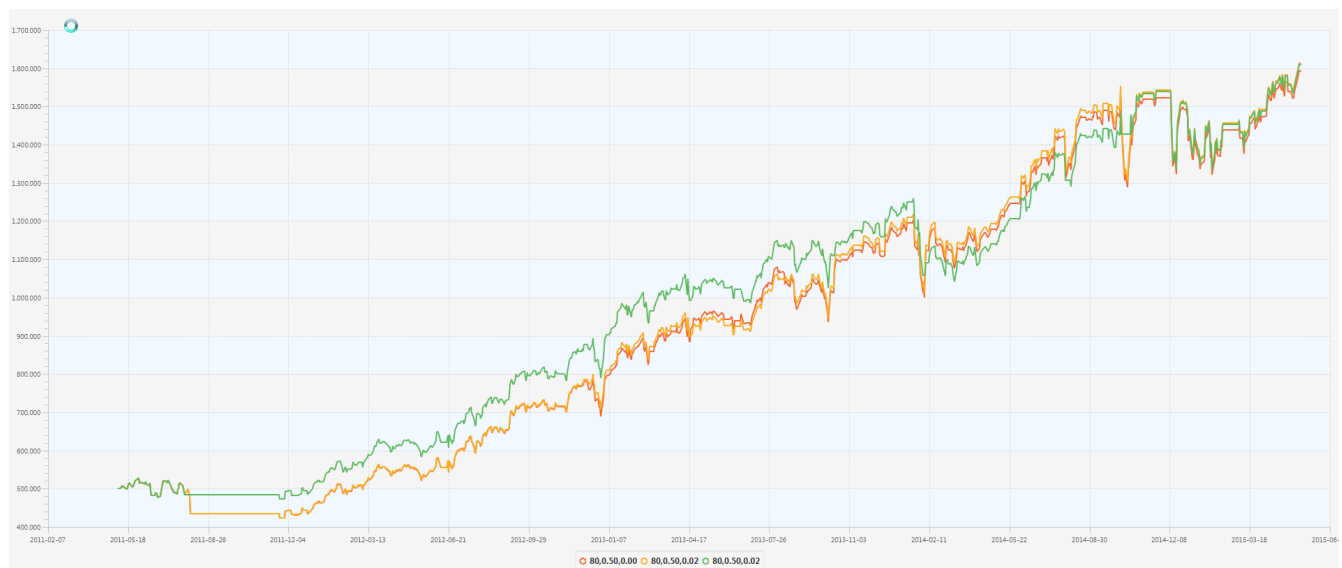
In the red strategy of Graphic-27 one goes the VXX short, if the K-Nearest Regression predicts a negative return. Additional more than 50% of the nearest values must also be negative. Or with other words the mean and the median of the prediction must be negative. Once a position is entered one predicts for the next day. If the entry condition is still valid, one keeps the position for another day. Otherwise the position is closed. The position is not rebalanced. Usually a position is only hold for a few days. The final value of this strategy is 1,592,757\$ (+218.6%) with a Sharpe-Ratio of 1.0 and a maximum relative drawdown of 19.7%.

For the yellow strategy the expected return must be – for the entry and the exit condition - smaller than -0.2%. This improves the performance slightly to 1,612,750\$ (+222.6%) with a Sharpe-Ratio of 1.02 and a drawdown of 19.7%.

The green strategy combines the yellow approach with the IVTS signal. At entry the IVTS must be additionally below 1.0 and the position is always closed if the IVTS is above 1.03. The final value is 1,608,672\$ (+221.7%) with a Sharpe-Ratio of 1.05 and a Drawdown of 17.3%. The main effect is the exit condition. Losses are earlier closed.

The forecaster is on par with the approach in paragraph 10. But it should be noted, that the results are very sensitive to the parameter settings. The results for $k=70$ or 90 are already significantly worse. I tried also a weighted K-Nearest Regression with a quadratic kernel. The result is somewhat worse, but it is more robust for $k \geq 80$.

I tried also the Manhattan- and the multiplicative distance. The results are for the euclidean distance clearly superior.



Graphic-27: VXX KNearest $k=80$ from 2011-05-06 to 2015-05-21 Short only

Kuznetsov traded in [25] short and long. One stays in Graphic-27 on the sideline if the prediction is positive (or above -0.2% for the yellow and green strategies).

For the red strategy in Graphic-28 one goes long if the mean and the median of the prediction are positive. The final value is 1,810,471\$ (+262.1%) with a Sharpe-Ratio of 0.97 and a drawdown of 23.6%.

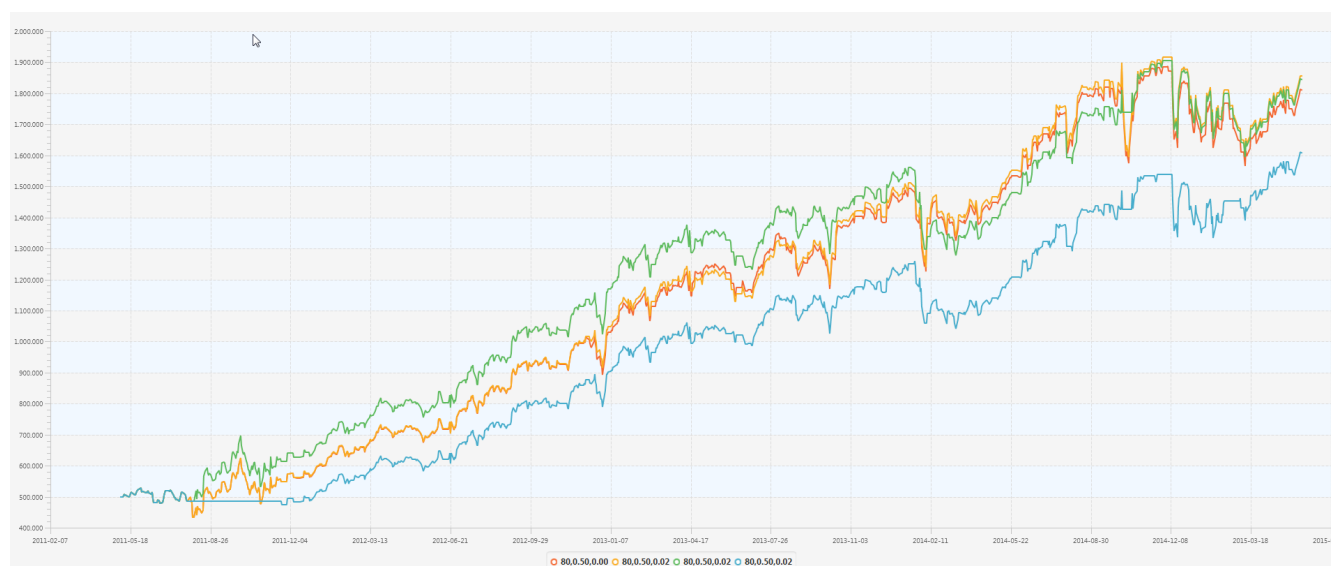
For the yellow strategy the mean must be above 0.2%. If the prediction is between -0.2% and +0.2% the strategy is on the sideline. The final value is 1,854,873\$ (+271.0%) with a Sharpe-Ratio of 0.99 and a drawdown of 23.6%.

The green strategy adds additionally the IVTS condition of above. But this is only applied to the short position. The final value is 1,844,677\$ (+268.9%) with a Sharpe-Ratio of 0.96 and a drawdown of 23.6%.

The blue line is for comparison the best strategy (green) of Graphic-27.

Going long increases the final value, but it does not improve the risk-adjusted performance. A long position is only profitable in a high-volatility regime. There are large ups- and downs.

The performance of this strategy is far from the original claims of the author. His original setting does not work at all. But it is in the reformulated version worth to consider. I have concerns about the stability. Using $k=70$ or $k=90$ should have only a minor influence. But in fact the result is significantly worse.



Graphic-28: VXX KNearest $k=80$ from 2011-05-06 to 2015-05-21 Long-Short

Conclusion:

The VIX model is no magic bullet, but it reflects some features of the VIX. It is especially helpful to find reasonable entry points and to avoid bad ones. For some of the strategies also the exit bounds boost the performance.

The question which strategy is best can not be answered in a clear cut way. The yellow strategy in Graphic-18 (VIX Call Spread with 0.4/0.1 delta) has with 1.30 the highest Sharpe-Ratio. But it depends on the risk-profile, on trading details and broker fees which one is really best. Past results are also only a hint for future performance. In any case the Sibyl-Fund toolbox of interesting VIX strategies has been considerably extended.

References:

- [1] Bailey D., Borwein J., Lopez de Prado M., Zhu Q.: Pseudo-Mathematics and Financial Charlatanism: The Effects of Backtest Overfitting on Out-Of-Sample Performance.
- [2] Donninger Ch.: Scenario-Generation with IVTS Block-Sampling. Sibyl-Working-Paper, Oct. 2012
- [3] Donninger Ch.: Boosting the SPY with the VXX: The Daiquiri Strategy. Sibyl-Working-Paper, April 2013
- [4] Donninger Ch.: Improving the S&P Dynamic VIX Futures Index: The Mojito 3.0 Strategy. Sibyl-Working-Paper, Dec 2013
- [5] Donninger Ch.: VIX Futures Basis Trading: The Calvados-Strategy 2.0, Sibyl-Working-Paper, Rev. 1, 2014-01-21
- [6] Donninger Ch.: Smarter than the Options-Market? A Real-Measure GARCH Option Pricing Model with Volatility Regime Simulation. Sibyl-Working-Paper, March 2014
- [7] Donninger Ch.: Hedging Adaptive Put Writing with VIX Futures: The Affenpinscher Strategy. Sibyl-Working-Paper, Revision 1: 2014-06-18
- [8] Donninger Ch.: Trading the patience of Mrs. Yellen. A short VIX-Futures strategy for FOMC announcement days. Sibyl-Working-Paper, Revision 1: 2015-01-05
- [9] Ahoniemi K.: Modeling and Forecasting the VIX Index, July 17, 2008
- [10] Qunfang Bao: Mean-Reverting Logarithmic Modeling of VIX, March 2013
- [11] Grünbichler A., Longstaff F.: Valuing futures and options on volatility. May 1995
- [12] Detemple J., Osakwe C.: The valuation of volatility options. European Finance Review, 2000, 4, 21-50.
- [13] Smith W.: On the Simulation and Estimation of the Mean-Reverting Ornstein-Uhlenbeck Process. Especially as Applied to Commodities Markets and Modeling. Version 1.01, February 2010
- [14] Wilcox R.: Introduction to Robust Estimation, Chap. 10.2 Theil–Sen Estimator, Academic Press, 2005.
- [15] Barone-Adesi G., Engle R., Mancini L.: A GARCH Option Pricing Model with Filtered Historical Simulation. Review of Financial Studies, Vol. 21, 2008, 1223-1258.
- [16] Zhang J., Shu J., Brenner M.: The New Market of Volatility Trading. Final Version: September 2009
- [17] Morgan Stanley Quantitative and Derivative Strategies. A Guide to VIX Futures and Options. QDS Vega Times, March 28, 2011.
- [18] Mina J., Xiao J.: Return to RiskMetrics: The Evolution of a Standard. April 2001.
- [19] S&P: S&P VIX Futures Indices Methodology, Jan. 2015
- [20] Alexander C., Korovilas D.: The Hazards of Volatility Diversification, February 2011.
- [21] Bennet C.: Trading Volatility, Correlation, Term Structure and Skew. 2014
- [22] Bailey D. et. al.: Backtest overfitting demonstration tool: an online interface, April 2015
- [23] Harvey C., Liu Y., Zhu Heqing: ... and the Cross-Section of Expected Returns, April 2015
- [24] Wilmott P.: Frequently Asked Questions in Quantitative Finance. September 2009
- [25] Kuznetsov J.: Trading VXX with nearest neighbors prediction. November 17, 2014, <http://tradingwithpython.blogspot.co.at/2014/11/trading-vxx-with-nearest-neighbors.html>
- [26] Yang D., Zhang Q.: Drift-Independent Volatility Estimation Based on High, Low, Open and Close-Prices. Journal of Business, 2000, Vol. 73, No. 3.

Appendix A) Results Table:

Graphic/Color	Final Result	Percentage	Sharpe-Ratio	Drawdown
12/red	773455	54,7	0,58	22,2
12/yellow	867070	73,4	0,69	20,8
12/green	869475	73,9	0,87	14,8
13/red	662480	32,5	1,05	5,8
13/yellow	567170	13,4	0,64	6,0
14/red	1061880	112,4	0,55	54,7
14/yellow	1071991	114,4	0,59	54,7
14/green	1209980	142,0	0,79	32,4
15/red	1517540	203,5	1,05	17,3
15/yellow	1637630	227,5	1,10	17,3
15/green	1209980	142,0	0,79	32,4
16/red	998682	99,7	1,24	9,8
16/yellow	1011302	102,3	1,23	7,6
17/red	851830	70,4	1,25	7,5
17/yellow	897640	79,5	1,28	5,2
17/green	927215	85,4	1,29	5,2
18/red	730522	46,1	0,64	26,4
18/yellow	866570	73,3	1,30	6,5
18/green	807370	61,5	1,27	4,7
18/blue	829760	66,0	1,29	3,6
19/red	1101420	120,3	0,97	20,4
19/yellow	1213530	142,7	1,09	13,5
19/green	1321180	164,2	1,11	13,5
20/red	1169055	133,8	0,59	45,2
20/yellow	1432109	186,4	0,85	27,6
20/green	1749835	250,0	0,94	19,5
21/red	1749835	250,0	0,94	19,5
21/yellow	1432049	186,4	1,06	12,3
22/red	1279687	155,9	1,22	14,5
22/yellow	1271850	154,4	1,24	12,1
22/green	892821	78,6	1,13	7,7
22/blue	1144381	128,9	1,22	12,1
23/red	1119976	124,0	1,24	12,4
23/yellow	1084065	116,8	1,25	10,4
23/green	819512	63,9	1,16	7,2
23/blue	986843	97,4	1,22	10,4
24/red	756127	51,2	1,06	10,7
24/yellow	733052	46,6	1,07	10,0
24/green	685146	37,0	0,99	6,6
24/blue	772533	54,5	1,14	7,0
25/red	921559	84,3	1,15	11,9
25/yellow	902954	80,6	1,07	10,0
25/green	801983	60,4	1,10	8,1
25/blue	943144	88,6	1,20	8,4
26/red	900152	80,0	1,13	9,5
26/yellow	900485	80,1	1,13	9,5
26/green	708748	41,7	0,98	7,6
26/blue	849365	69,9	1,11	9,4
27/red	1592757	218,6	1,00	19,7
27/yellow	1612750	222,6	1,02	19,7
27/green	1608672	221,7	1,05	17,3
28/red	1810471	262,1	0,97	23,6
28/yellow	1854873	271,0	0,99	23,6
28/green	1844677	268,9	0,96	23,6

Appendix B) Some Remarks to the Backtest Critique:

Bailey et al. present in [1] some valid points against backtest results. They have implemented a nice online tool which finds for a simple technical trading rule parameter settings with an impressive Sharpe-Ratio ([22]). One can enter the time series of AAPL, GOOG, a looser like TWTR or any other ticker and gets always nice backtest profits. But the parameters are for each ticker different. Harvey, Liu and Zhu argue in [23] that probably most of the Cross-Section of Returns literature is garbage. Cross-Section results are much easier to get than satisfaction. One can try always an additional factor and finds with enough trial and error a significant Cross-Sectional result.

I have investigated in the past several papers and found – in contrast to the original authors – no reasonable or at least no impressive results. The VIX-VSTOXX and the VIX Futures calendar spread trading are examples of this. In this case the original author did not provide any performance data at all. He just claims nice profits. The calendar spread is for another reason instructive. The performance is without trading costs quite interesting, but the strategy loses its attractiveness after one takes the trading costs into account. In a lot of papers the authors use the mid-prices of the bid-ask spread. This is in my view not realistic. The spread goes usually to the fast HF-guys or the market maker. It is much more realistic to assume that one pays the spread.

Sometimes a paper uses data from the far past. The paper is published in 2014, but the data are from 1998 to 2006. Reading such a paper is a waste of time. One knows without further testing that the strategy capsizes in the 2008 crash. The authors have at least to explain why their data are not up-to-date.

One can turn the argument also around. A lot of papers claim that a market is efficient, one can't make extra profits. Actually the authors can only show that **they** have made no profits. If someone plays on the Poker-Server and makes no profit, his poker skills may be too low.

Note: There exists for poker a Nash-equilibrium. Even if a very skilled player would know it, he would not follow the equilibrium strategy. The Nash-equilibrium usually does not efficiently exploit stupidities of less skilled players. A Nash-equilibrium snake would have never tried to convince Eve to eat the apple.

There is another simple time-savings rule. If the authors use a lot of measure-theory the paper is a mathematical exercise and has no practical relevance at all. P. Wilmott has coined for this sort of publications/authors the term "Measure Theory Police". According to Wilmott the best kept secret in trading is: "The inventors/discoverers/creators of models usually don't use them. They often use simpler models instead" ([24]).

Bailey et. al. propose a rather formal solution to the backtest overfitting problem. The authors of a paper should state the number k of trials they have conducted till they found their published result. This number is used to modify/increase the significance level of their results according to the methods developed in [23].

Personally I do not publish significance levels because I consider this as a rather pointless academic exercise. There is also no claim that a strategy will have the same impressive Sharpe-Ratio as in the backtest. The results are just hints which strategies should be tried out. For this reason I have not optimized the parameters for each of the trades considered above. One uses always the same IVTS threshold of 1.0 and 1.03, although for each paragraph better values can be found. The setting of 1.0 and 1.03 works in all cases reasonable. This does not mean that it will work in real trading, but it is at least a hint that the thresholds are relative stable.

One starts trading with a reduced amount of money and once one gets some confidence that the

strategy is working in real trading life the leverage is increased. The proof of the pudding is in the eating. The backtest is furthermore an efficient tool to eliminate bad ideas. Sometimes a strategy looks reasonable at first glance, but one sees in the backtest that it can't work at all.

I am not able to publish the number of trials for this paper. First of all it is the result of an ongoing research. I know from previous experience reasonable IVTS levels, profitable maturity ranges for VIX Futures ... One would have to take this previous knowledge into account. The models have been developed in several stages. I have tried different VIX models, different relations between the index and the Future. I have used results and ideas from other authors.

The trials are also not created equal. There are some parameter settings which are clearly worse. But one has to try them out to get a feeling for the consequences of a given parameter. In the same vein the parameters are not equal. It is essential to test the impact of trading costs. But the trading costs have only for the calendar spread a significant impact. They do not change the overall picture for the other strategies.

Although some of the authors of [1] claim to work part-time for hedge-funds, I have the impression that they don't have much practical experience. Or maybe they have written the paper with the academic hat on. I can't imagine that this proposal becomes an actual requirement for plain funds business.