# VIX Futures Prediction with Deep Learning Model-LSTM

Abstract

The main asset we focused on this subject is the VIX Spot Index , also known as the measure of the stock market's expectation of volatility implied by S&P 500 index options. However, VIX index is un-investable, here we chose 1-month constant maturity VIX Futures as an alternative.

Deep Learning Model

– LSTM for Asset Price Prediction

Traditional neural networks are unable to deal with time series data, so RNN (Recurrent Neural Networks) comes in mind. And LSTM (Long-Short – Term-Memory) is a very special kind of RNN which works better than the original one. Here we provide a simple introduction of the LSTM model.
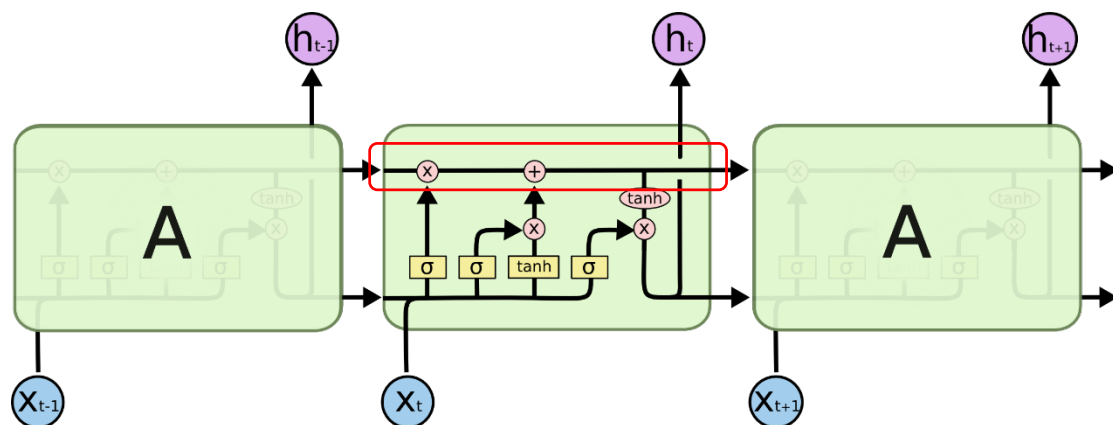
The diagram above is a simple structure of the LSTM , and we'll walkthrough it roughly to simplify the complexity of the model.

Xt : Input   ht : Cell Output   Cell

The yellow rectangle can be considered as a ''Gate'' for information filtering, σ& tanh are represented as activation functions in order to determine a selection between 'keep' & 'delete' the information. After using gradient descent & backpropagation , we gained a nice set of weights to

minimize the **Loss Function**, then we <mark>calculate and add them</mark>, integrating it to the Information Flow. Finally, we proceed to the next cell.

For more information, please refer to the reference below :
https://colah.github.io/posts/2015-08-Understanding-LSTMs/

Now, get back to our heading – Price Prediction. We apply a really simple
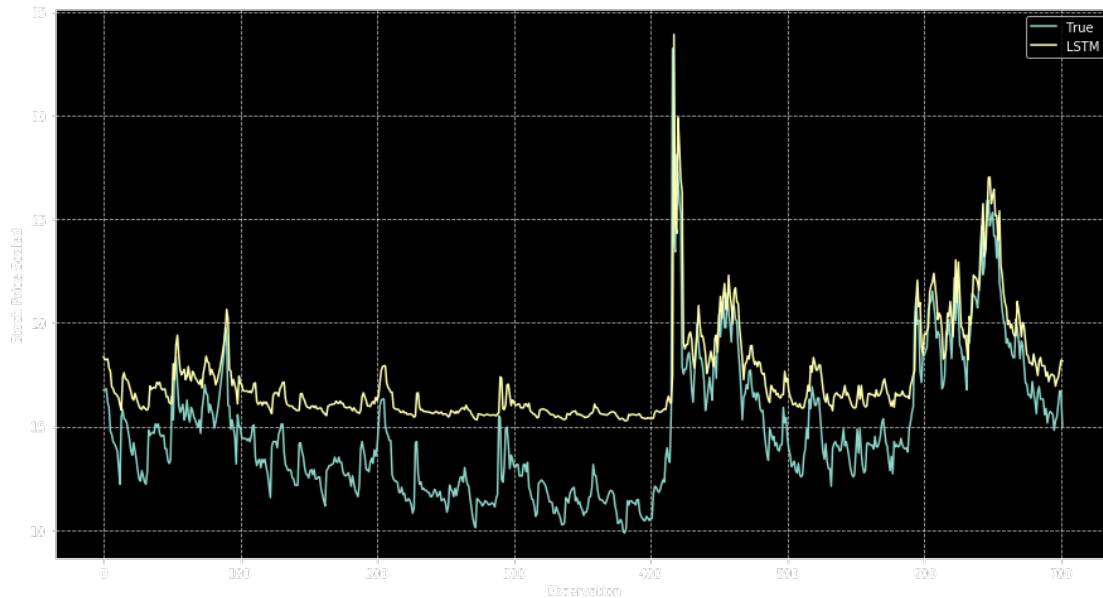
LSTM model to our dataset and take previous asset price as input to predict the forward price. Showing the results below :

Although the LSTM model we build could not precisely predict the exact price, it could still forecast the trend to some degree.

However, by digging into more related articles we can find out that our results are just optical illusions and not due to learning something useful. LSTM just use a value very close to the previous day closing price as prediction for the next day value. This is what would be expected by a model that has no predictive ability.

In order to solve the problem mentioned above, we try to create more features as input variables that are somewhat correlated to our asset but not direct related to historical prices.

Dataset Breakout and Features

Our data sources for this paper are Option Metrics and VixCentral.

Option Metrics was used for the VIX options data and VixCentral from VIX futures data. Since the data of time periods for VIX options and VIX futures have different length, we truncated our data : from 2008-08-01 to 2016-04-29. And now we will do a simple introduction for our input variables.

Input variables	Number of Input variables
Term Structure	15
Vol. Surface Skewness	48
VIX Spot Index & MA Signal	4
VVIX	2
Output Variables	Number of Output variables
VIX 1-month Futures 1 Day Forward	1

Term Structure *(15 inputs variables)* :

Term structure of VIX Futures represents the spread between futures uncertainty from different maturities of the futures contract. The VIX Futures is usually in contango. This occurs during less volatile or normal market conditions. The volatility across maturities is upward sloping with a longer maturity, which means the curve of its structure should slope upward. As market volatility increased, market is in backwardation, Short-term volatility is much higher than longer-term volatility, which means the curve of its structure should slope downward.
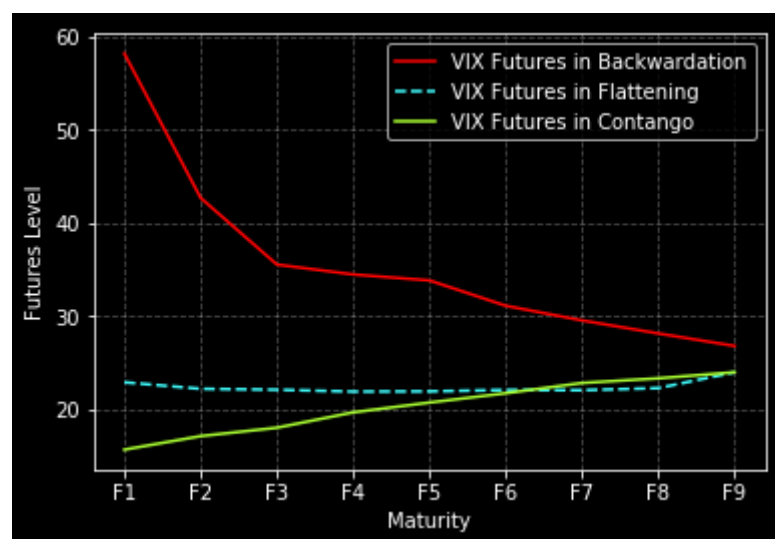

The term structure spreads are all combinations of 2, 3, 4, 5, 6, 7.

Vol. Surface Skewness *(48 inputs variables)* :

By retrieving data from Option Metrics's Volatility Surface, we can extract the volatility smile of VIX options. Skew represents the uncertainty or fear of a downside event at a particular maturity or time. The skew is the difference in implied volatility between the two strikes at a particular maturity. Unlike most stocks and indices where puts generally have high skew, calls generally have higher skew for the VIX, since the VIX is negatively correlated to the returns of the S&P 500.

However, our data from Option Metrics's is incomplete, so we have to roughly create our volatility smile from implied strike price which used to be strike price. By taking different maturities ('1-mth': 30 days, '2-mth': 60 days, '3-mth': 91 days, '6-mth': 182 days, '9-mth': 273 days, '12-mth': 365 days) and different VIX Strike price percentage subtraction (('120.0%', '80.0%'), ('100.0%', '80.0%'), ('120.0%', '100.0%'), ('150.0%', '100.0%')) as combination, we can create a total of 48 inputs in both calls and puts. In consideration of missing value of implied volatility for a certain % of Implied Strike price, we apply interpolation & extrapolation to create them.
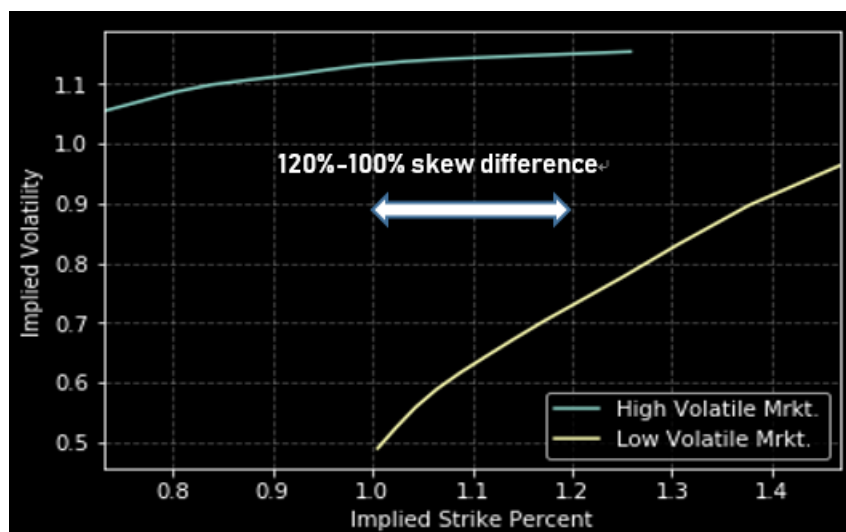

The figure above shows that while market is in high volatile, the skewness is much flatter than market in low volatile. However, we should have an ideal result that shows the skewness while market is in high volatile is much steeper than market in low volatile. The reason to cause this problem is due to using Implied Strike Price instead of Strike Price.

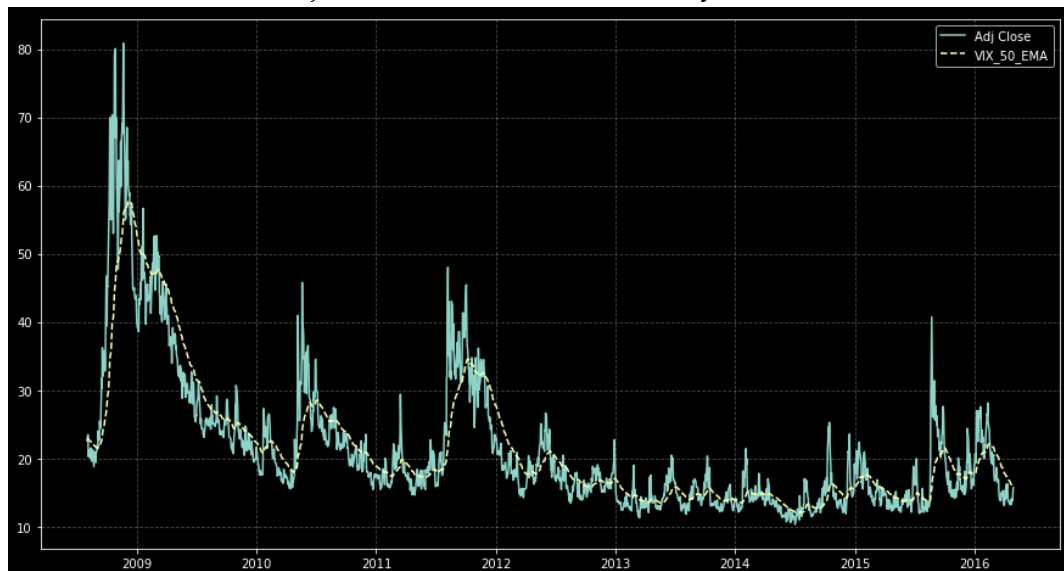### VIX Spot Index & MA Signals   *(4 inputs variables)* :

There are 4 inputs related to VIX Spot Index. One of them is VIX Spot

Index itself and the others are moving average signals calculated by VIX Spot Index with different period of time (14 days, 50 days, 100 days are commonly used in market).

Flow Chart
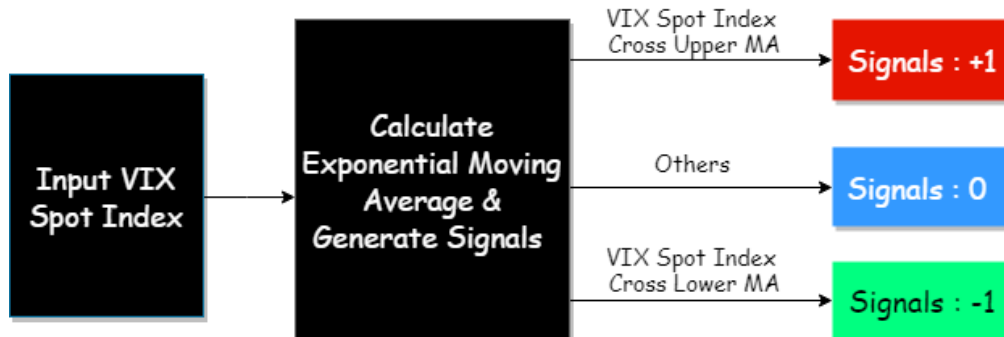
Adj Close Price of VIX & 50 days EMA

VVIX *(2 inputs)* :

VVIX (VIX of VIX) is a measure of the volatility of the Chicago Board Options Exchange (CBOE) Volatility Index (VIX). The CBOE VIX measures the short-term volatility of S&P 500 indexes, and VVIX measures the volatility of the price of the VIX. VVIX, then, can indicate when VIX isn't very volatile, and so isn't foreseeing much volatility in SPX. This can happen when VIX is relatively low. Alternatively, a high VVIX suggests VIX might be more volatile in the future, which in turn can indicate a market belief that SPX might also be more volatile.

We take Adjusted Closing Price of VVIX and its High-Low Intraday Spread as features in this study.

VVIX Adjusted Close Price
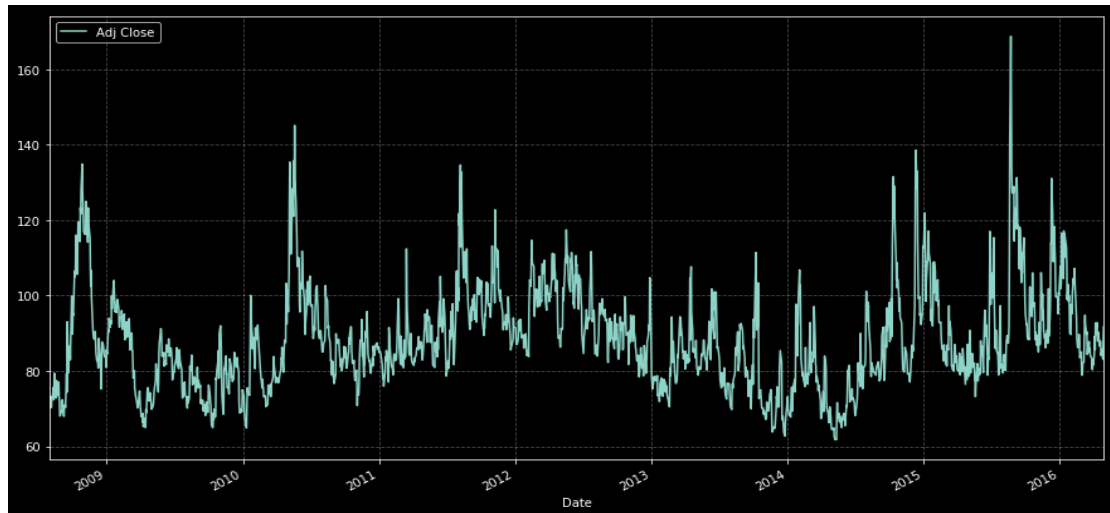
Showing the Result

By observing the test set predicted results, we can tell that LSTM can be used to improve VIX Futures price prediction to some degree. In usual times, the predicted price from the model has little difference to real world price. While the market has a large scale jump, the model will be too sensitive to the market jump, so in this case, the predicted price will have large difference to the real world price.