Reproducing a Study of Stochastic Volatility + Market Inefficiency

>>> Fun with Multi Linear Regression

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Original Study:

FEDERAL RESERVE BANK OF SAN FRANCISCO

WORKING PAPER SERIES

Examining the Sources of Excess Return Predictability: Stochastic Volatility or Market Inefficiency?

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Working Paper 2018-14
https://www.frbsf.org/economic-research/publications/working-papers/2018/14/

Stochastic Volatility

sto·chas·tic

/stəˈkastik/
adjective
TECHNICAL
1. randomly determined; having a random probability distribution or pattern that may be analyzed statistically but may not be predicted precisely.

[the volatility of asset prices is not constant]

The efficient-market hypothesis is a theory that asset prices fully reflect all available information.

A direct implication is that it is impossible to "beat the market" consistently on a risk-adjusted basis since market prices should only react to new information.

Findings:

>>> Not Investment Advice

“

We show that the sentiment-momentum variable is positively correlated with fluctuations in Google searches for the term “stock market,” suggesting that the sentiment-momentum variable helps to predict excess returns because it captures shifts in investor attention, particularly during stock market declines.

“

Data Sources:

Variance Risk Premium: https://sites.google.com/site/haozhouspersonalhomepage

EOM Nominal S&P, Nominal Dividends / Nominal Risk Free Rate: http://www.hec.unil.ch/agoyal/

University of Michigan Consumer Sentiment: http://www.sca.isr.umich.edu/

Google Trends: https://trends.google.com/trends/?geo=US

Quandl API: https://www.quandl.com/

Yahoo Finance: https://finance.yahoo.com/

Study Covers 1990-03 through 2017-12

Key Terms & Independent Variables:

index: S&P 500

price-dividend ratio index closing value / cumulative nominal dividends >> “ **pd** ”

fed funds rate delta 12 month change in federal funds rate >> “ **ff12_D** ”

variance risk premium 3 month moving average in difference between implied volatility from option on the index and realized volatility of the index >> “ **vrp3** ”

fed funds rate delta 12 month change in federal funds rate >> “ **ff12_D** ”

consumer sentiment delta 12 month change in UM Consumer Sentiment >> “ **sent12_D** ”

excess stock return delta 1 month change in excess return (over the risk free rate) - a measure of return momentum >> “ **ersf_D** ”

interaction consumer sentiment delta X excess stock return delta >> “ **sent_x_ersf_D** ”

google search term momentum change in 1 month change in volume of google searches for the term “Stock Market” >> “ **Google_D2**”

Target Variable:

excess return in month t+1 12 month change in federal funds rate >> “ **ersf_t1** ”

Results from Data Cleaning

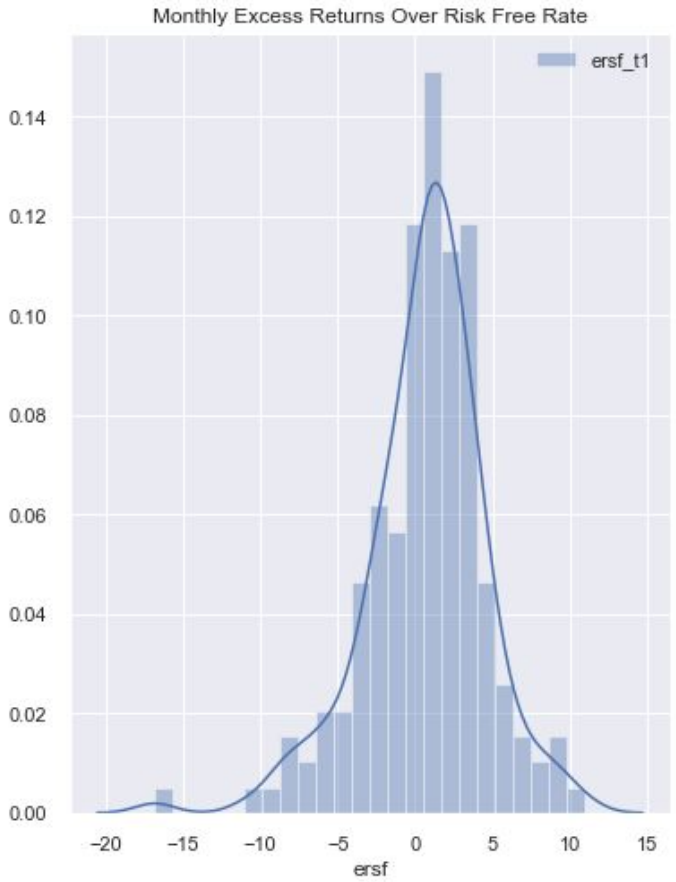
Scorecard

	Study	Reproduction
ersf mean	0.57	0.65
pd mean	52.4	52.05
vrp3 mean	16.2	17.4
ff12 delta mean	-0.29	-0.29
sentiment delta mean	0.18	0.18
ersf delta mean	0.002	0.009
sentD X ersfD mean	-3.57	-3.63

Results from initial data gathering and cleaning resulted in near-parity with the study, with the exception of variables related to the Excess Return;

Unclear where calculation differs at this time.

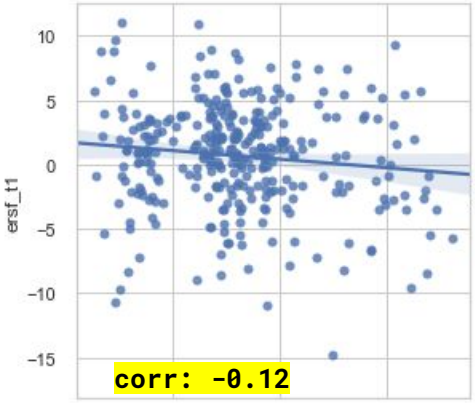
Distribution of Monthly Returns

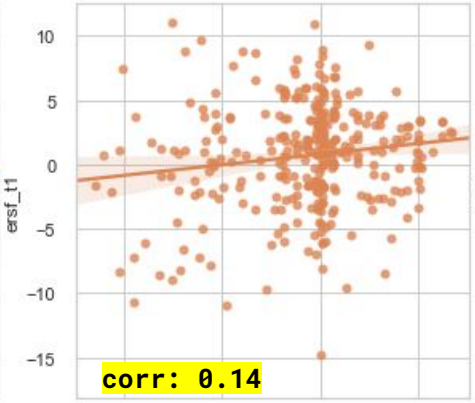


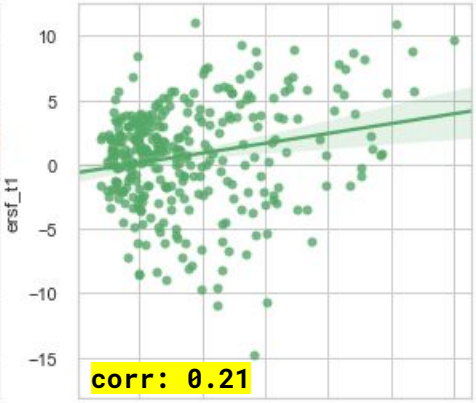
Mean: 0.65
Standard Deviation: 4.1

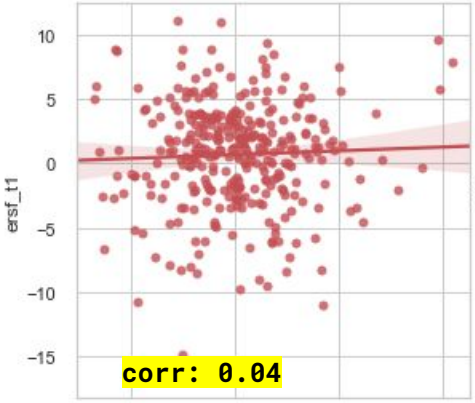
Minimum: -16.8%
Maximum: 10.9%

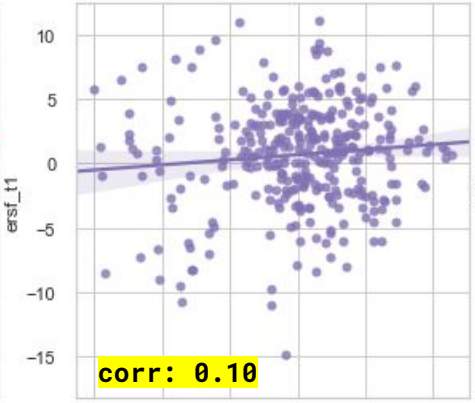
Correlation Plots target variable vs. independent variables

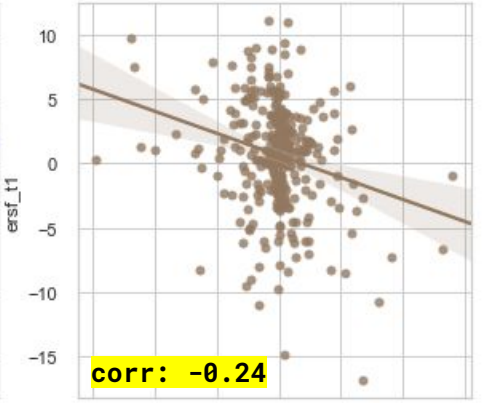












Baseline Model

price-dividend / federal funds rate / variance risk premium / sentiment change (12mo) X return momentum

OLS (Statsmodel)

Dep. Variable:	ersf_t1	**R-squared:**	0.174
Model:	OLS	**Adj. R-squared:**	0.164
Method:	Least Squares	**F-statistic:**	17.29
Date:	Sun, 21 Apr 2019	**Prob (F-statistic):**	6.93E-13
Time:	23:03:43	**Log-Likelihood:**	-913.55
No. Observations:	334	**AIC:**	1837
Df Residuals:	329	**BIC:**	1856
Df Model:	4		
Covariance Type:	nonrobust		

	coef	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
Intercept	1.914	0.831	2.305	0.022	0.281	3.548
pd	-0.057	0.015	-3.777	0.000	-0.087	-0.027
ff12_D	0.870	0.162	5.352	0.000	0.550	1.189
vrp3	0.110	0.020	5.391	0.000	0.070	0.150
sent_x_ersf_D	-0.014	0.004	-3.844	0.000	-0.021	-0.007

Omnibus:	29.202	**Durbin-Watson:**	2.026
Prob(Omnibus):	0	**Jarque-Bera (JB):**	38.189
Skew:	-0.648	**Prob(JB):**	5.10E-09
Kurtosis:	4.031	**Cond. No.**	238

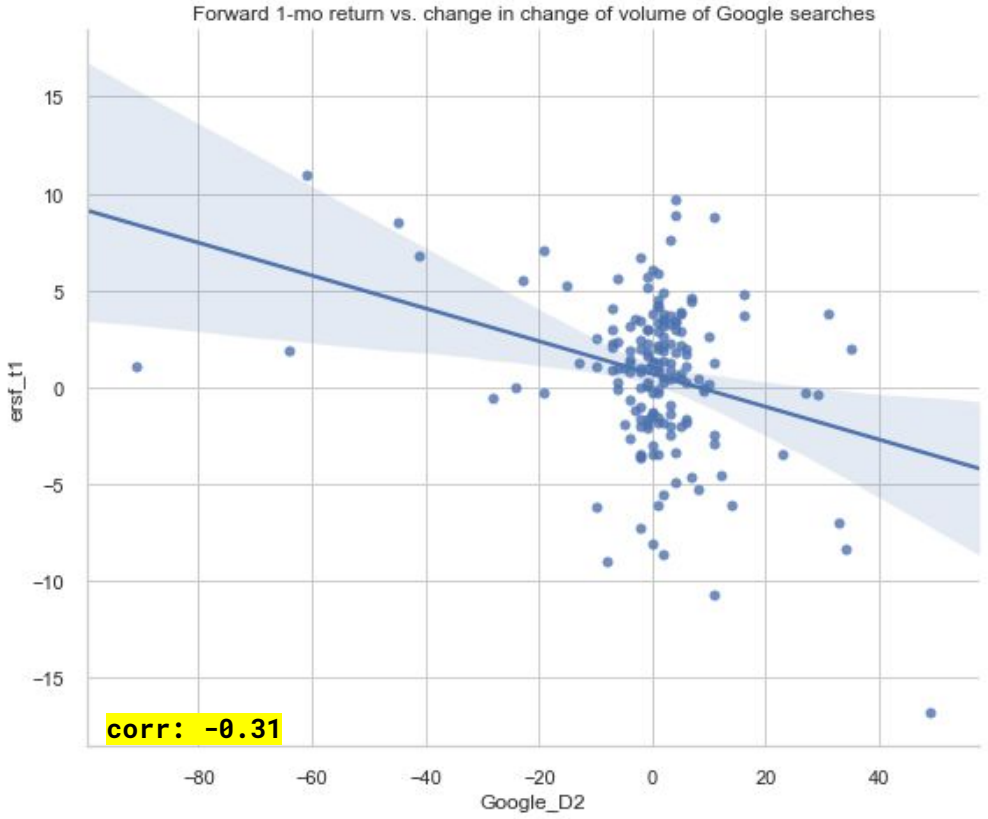
Original Study R-Squared: 17.3%

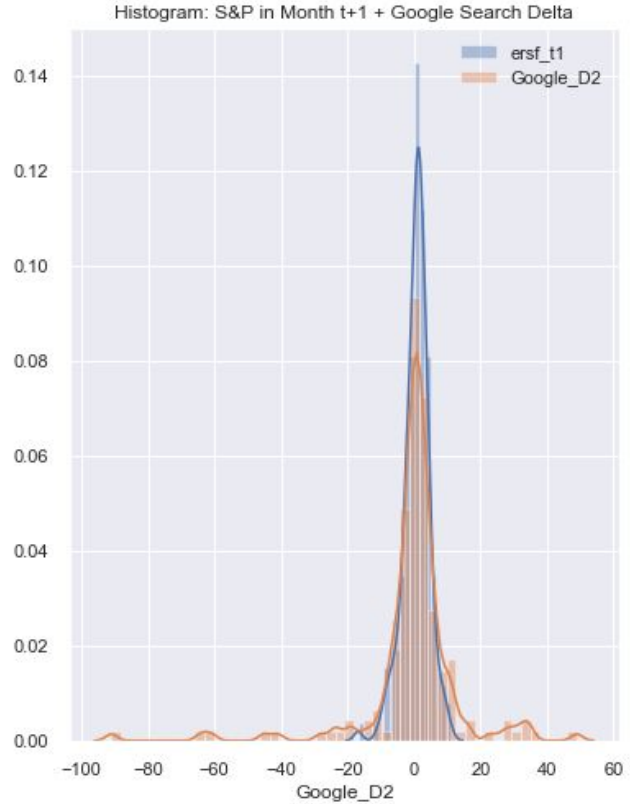
The original study included the ersf_D and sent12_D variables in their regression model;

Excluded here as p-values were fairly high, with minimal impact on the R-Squared value.

Adding Change in Volume of Google Searches

google search term momentum change in 1 month change in volume of google searches for the term “Stock Market” >> “ **Google_D** ”





Final Model

price-dividend / federal funds rate / variance risk premium / sentiment change (12mo) X return momentum / Google Delta

OLS (Statsmodel)

Dep. Variable:	ersf_t1	**R-squared:**	0.346
Model:	OLS	**Adj. R-squared:**	0.325
Method:	Least Squares	**F-statistic:**	17.11
Date:	Mon, 22 Apr 2019	**Prob (F-statistic):**	1.42E-13
Time:	15:37:07	**Log-Likelihood:**	-431.12
No. Observations:	168	**AIC:**	874.2
Df Residuals:	162	**BIC:**	893
Df Model:	5		
Covariance Type:	nonrobust		

coef	std err	t	P>|t|	[0.025	0.975]	
Intercept	6.0136	3.044	1.976	0.0500	0.003	12.025
pd	-0.1419	0.057	-2.509	0.0130	-0.254	-0.03
ff12_D	1.6373	0.28	5.85	0.0000	1.085	2.19
vrp3	0.1383	0.029	4.759	0.0000	0.081	0.196
sent_x_ersf_D	-0.0094	0.004	-2.176	0.0310	-0.018	-0.001
Google_D2	-0.0742	0.017	-4.295	0.0000	-0.108	-0.04

Omnibus:	5.931	**Durbin-Watson:**	1.882
Prob(Omnibus):	0.052	**Jarque-Bera (JB):**	5.853
Skew:	-0.457	**Prob(JB):**	0.0536
Kurtosis:	3.025	**Cond. No.**	724

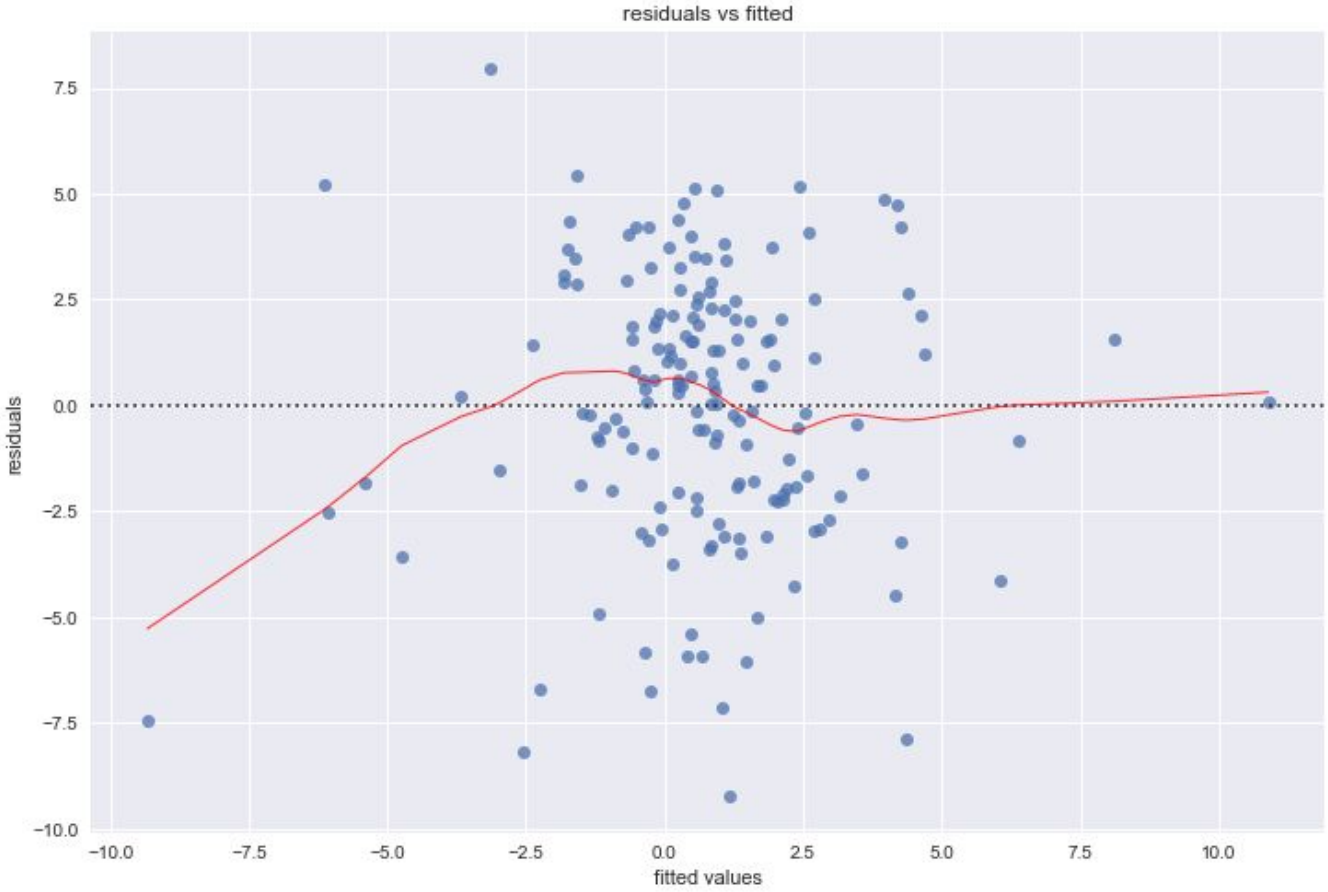
Original Study R-Squared: 34.2%

The original study included the ersf_D and sent12_D variables in their regression model;

Excluded here as p-values were fairly high, with minimal impact on the R-Squared value.

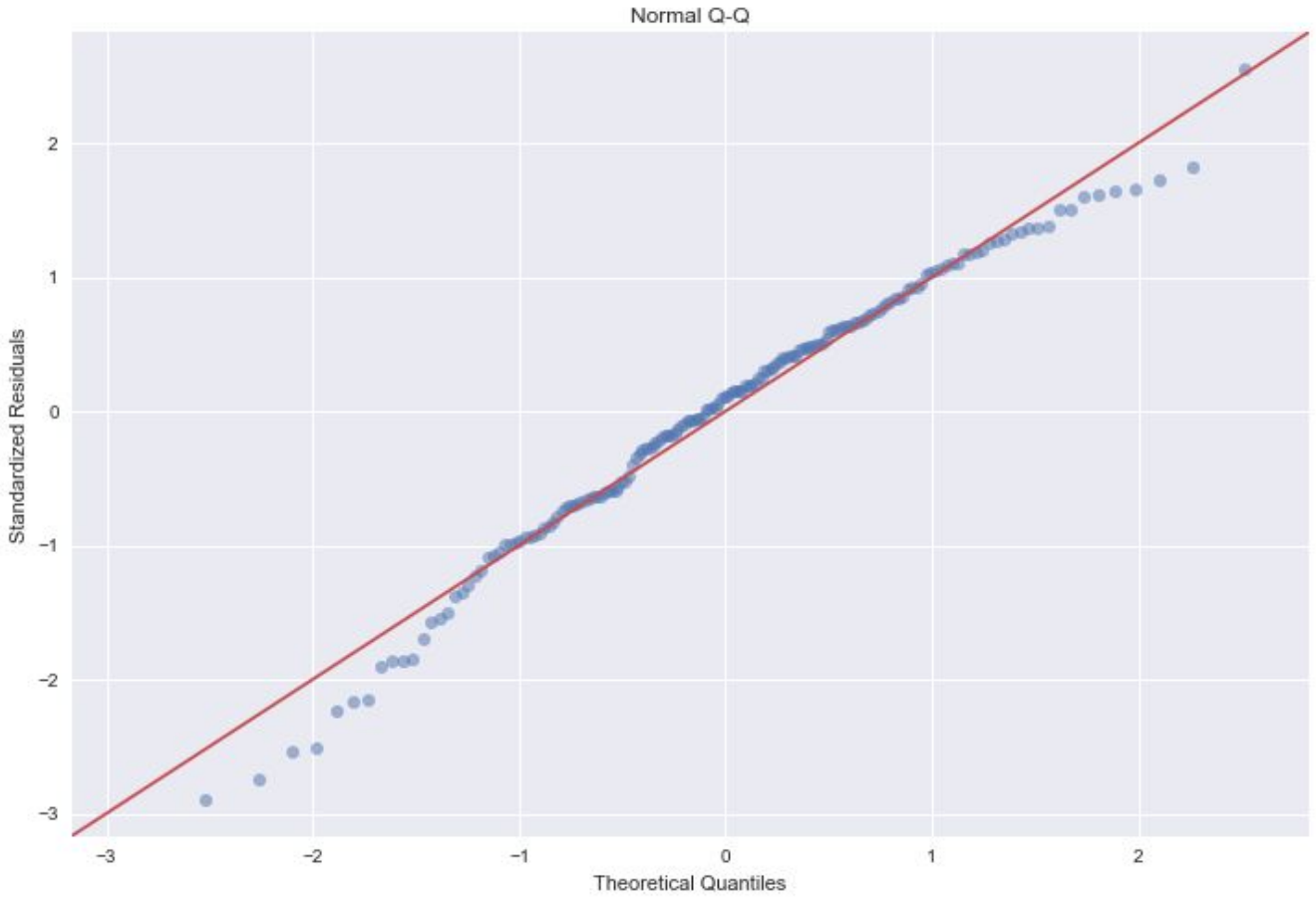
Different Timeframe:
Google Trends not available until 2004. Covers 2004-01 through 2017-12.

Final Model - Residuals vs. Fitted Values



The residual plots are fairly well distributed around the horizontal line, with no discernible pattern; a linear regression model appears to be appropriate.

Final Model - QQ Plot



The QQ Plot shows indicates that the residuals are fairly normally distributed, with some significant outliers towards the tails.

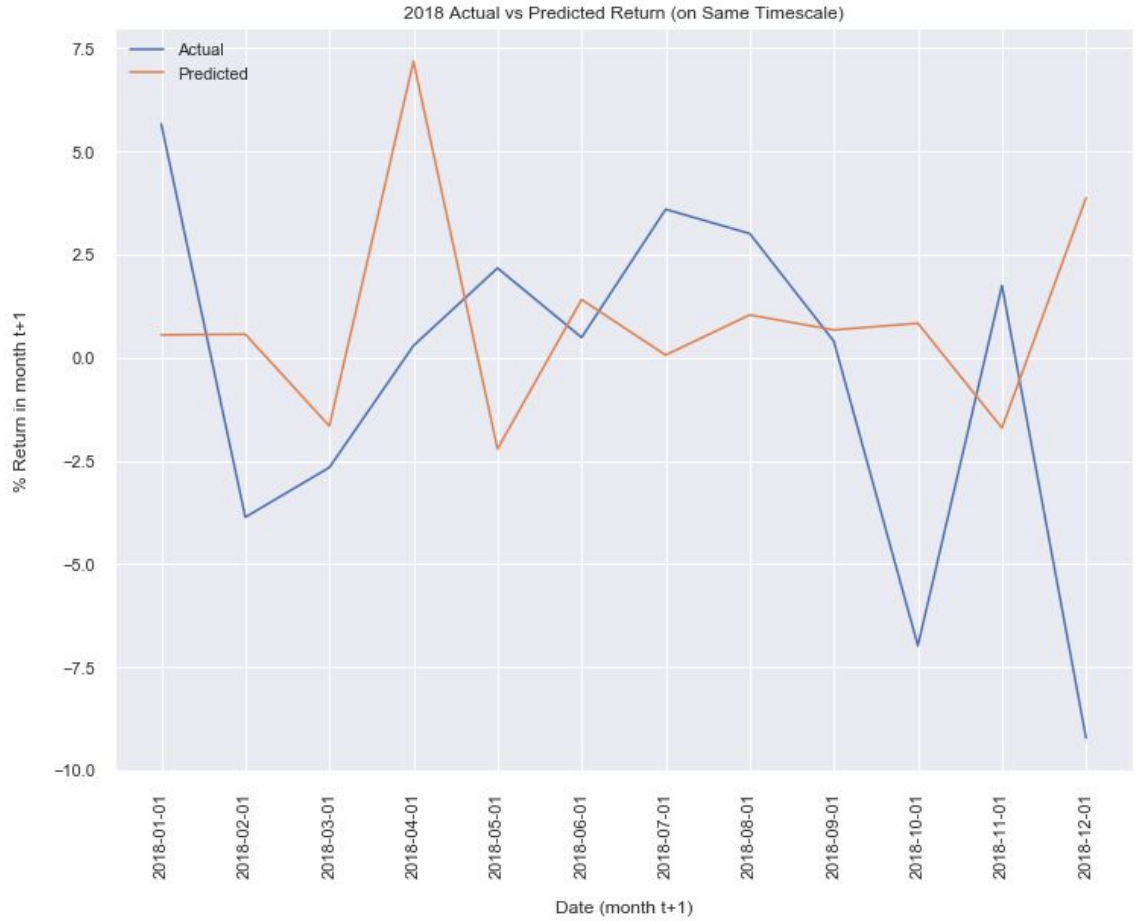
Predicting 2018 Forward Month Stock Returns

Running the Final Model on Untrained 2018 Data:

Applying a simple "Buy / Sell" Signal. If the Predicted Return is > 0, Buy (or Hold), if Predicted Return is < 0, Sell. Following this signal would have resulted in a -7.4% return on the year versus a -6.3% return with a pure "Buy and Hold" strategy. The amount show the results of investing $10,000 on 12/31/2017, and following the monthly signal. While this is a useful heuristic for applying the model, the actual model Root Mean Squared Error was fairly high, at 5.6% (compared to 3.15% on the Trained Dataset).

month	pred_ret_next_mo	ersf	invested	correct	model	actual
2018-01	0.55	5.66	TRUE	TRUE	$10,566	$10,566
2018-02	0.57	-3.88	TRUE	FALSE	$10,155	$10,155
2018-03	-1.66	-2.67	FALSE	TRUE	$10,155	$9,884
2018-04	7.18	0.28	TRUE	TRUE	$10,184	$9,912
2018-05	-2.21	2.16	FALSE	FALSE	$10,184	$10,126
2018-06	1.41	0.49	TRUE	TRUE	$10,233	$10,175
2018-07	0.06	3.60	TRUE	TRUE	$10,601	$10,541
2018-08	1.04	3.01	TRUE	TRUE	$10,920	$10,858
2018-09	0.67	0.40	TRUE	TRUE	$10,964	$10,902
2018-10	0.83	-6.98	TRUE	FALSE	$10,199	$10,141
2018-11	-1.70	1.76	FALSE	FALSE	$10,199	$10,319
2018-12	3.88	-9.21	TRUE	FALSE	$9,259	$9,368
					-7.41%	**-6.32%**

Predicting 2018 Forward Month Stock Returns



The Model failed to predict some of the extreme market moves in 2018 and predicted some unusual, extreme moves as well.

The negative 9.6% return in December has a Z-Score of -2.54 compared to the mean return from 2004 - 2017, with only a 1.1% probability of such an extreme move in either direction.

Next Steps:

Incorporate Additional Variables:

- Volume Weighted Moving Average
- Twitter Sentiment
- Breadth - Advance / Decline
- Sentiment - Put / Call Ratios