Fitting Models of VIX on Realized Volatility

Using Cross Validation

Last Updated: 2025-04-24

How to Run The R Markdown (RMD) File

For the R Markdown file, it is recommended to be opened using RStudio with the latest version of R.

Each of the following items listed is an R package that needs to be installed by running the command `install.packages("package-name")` in the Console before running the file. The commands `library(package-name)` in the RMD file then loads the package into the session.

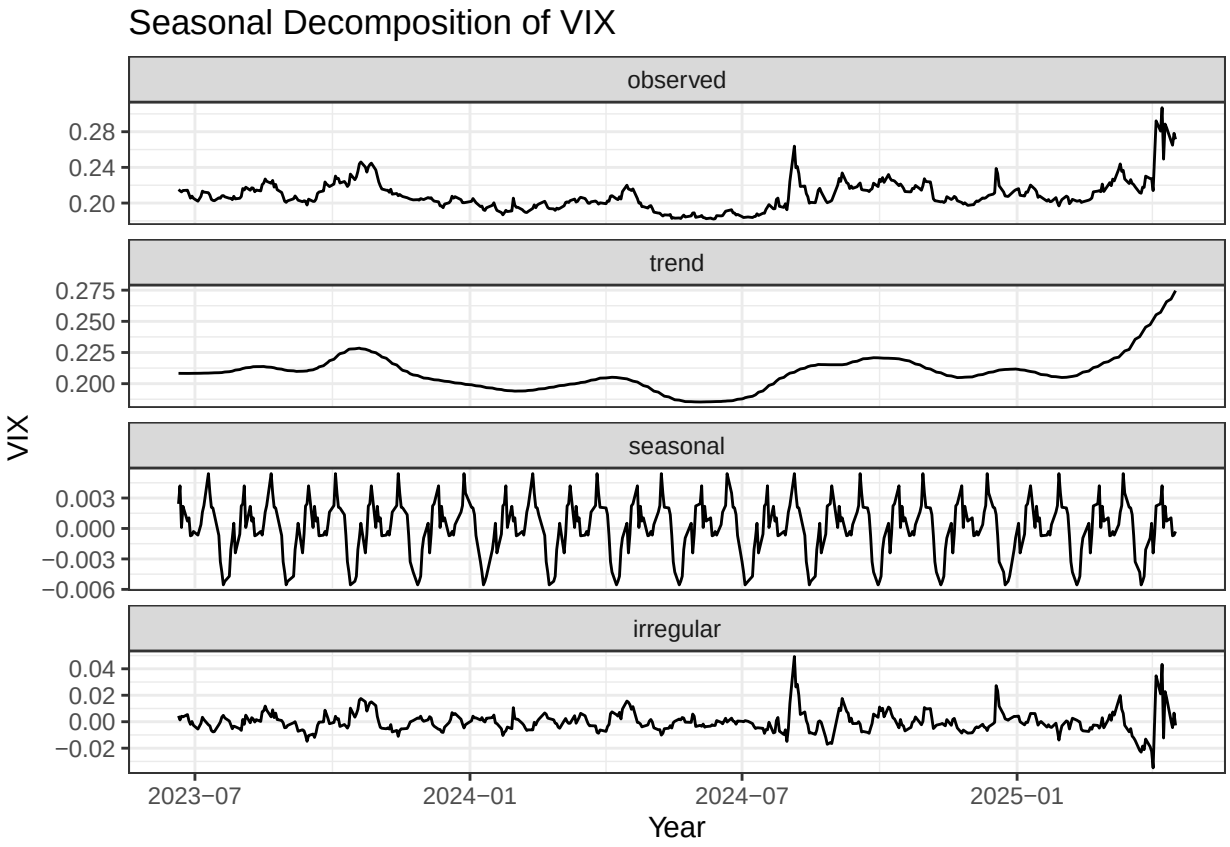
- **tidyverse**: for nice data transformation functions and for making clean plots
- **tidyquant**: for retrieving data about stock prices from Yahoo Finance easily
- **ggseas**: for plotting seasonal decomposition
- **zoo**: for dealing with time series data (ex. rolling averages)
- **np**: for fitting kernel regressions
- **mgcv**: for fitting generalized additive models

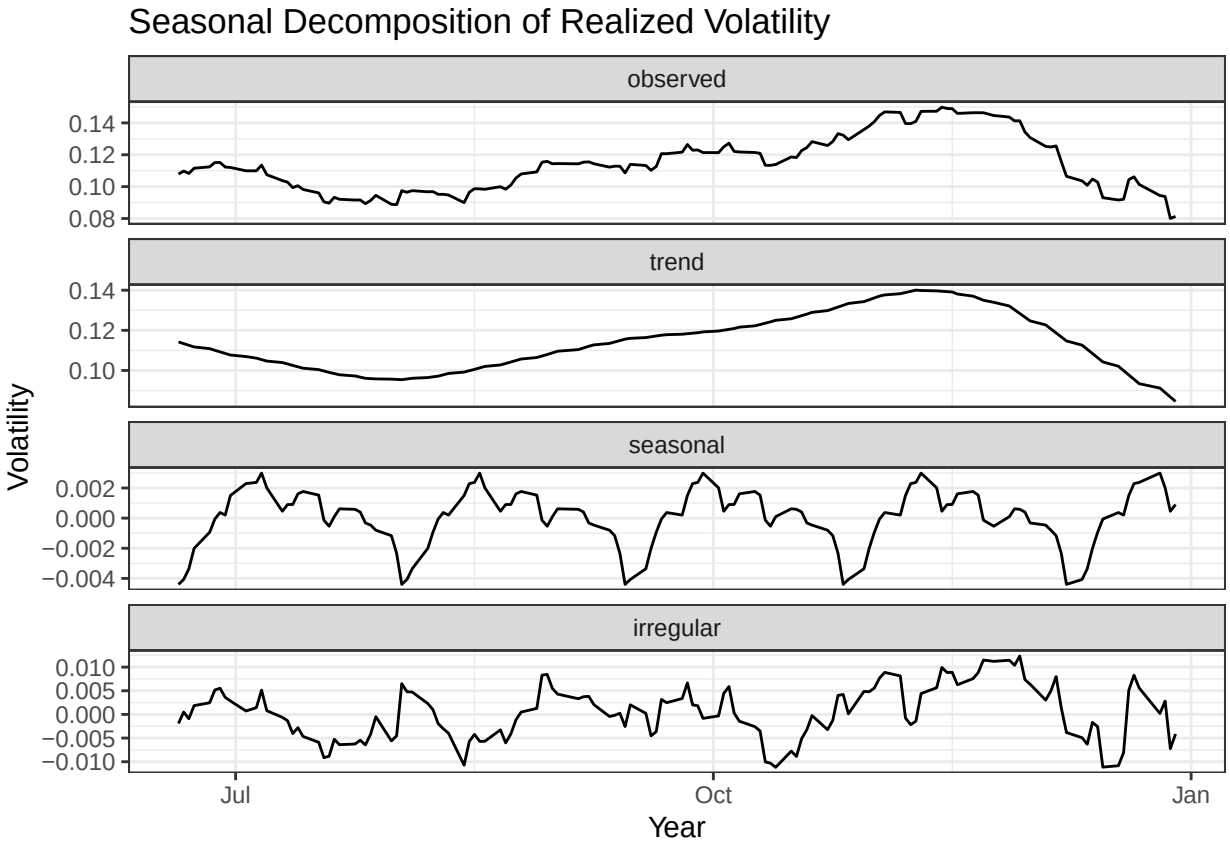
To see any documentation about the built-in functions used, you can use the `help()` command in the Console in RStudio.

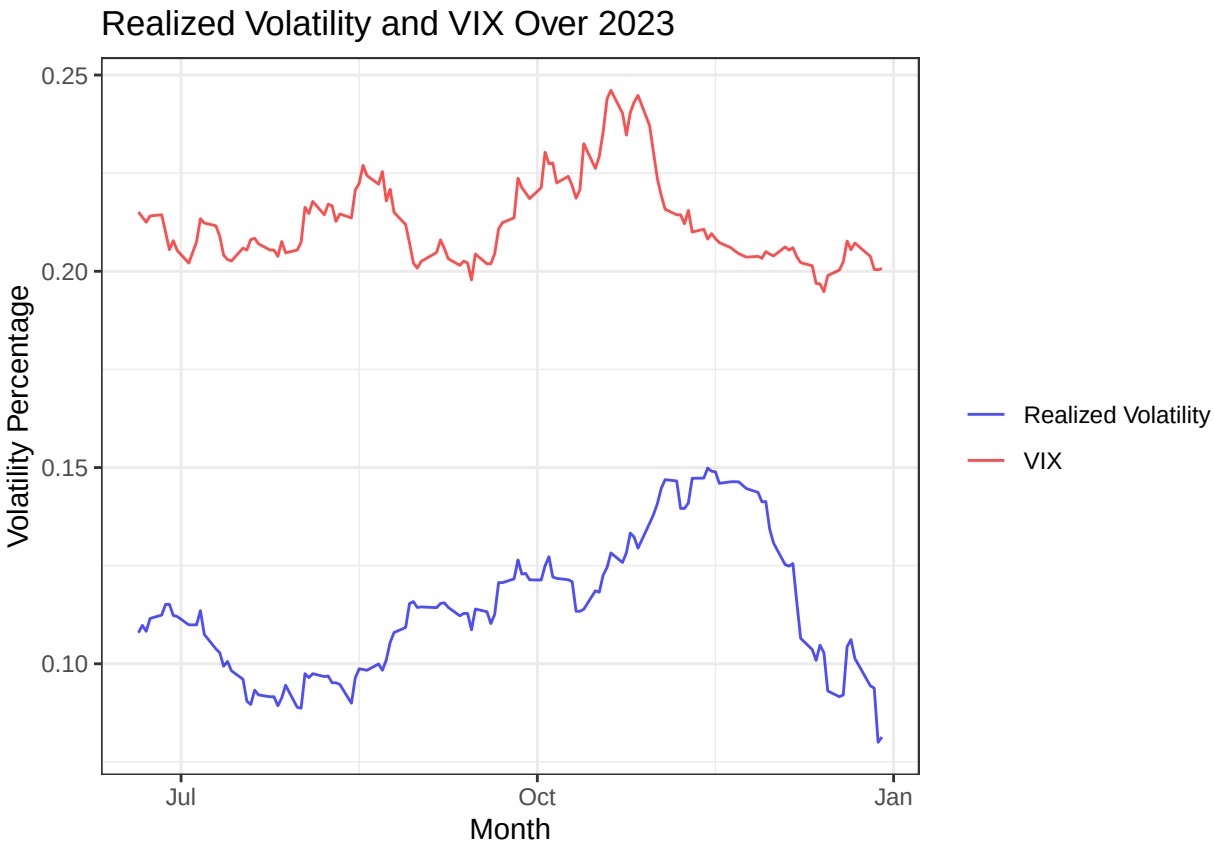
About This File & Code

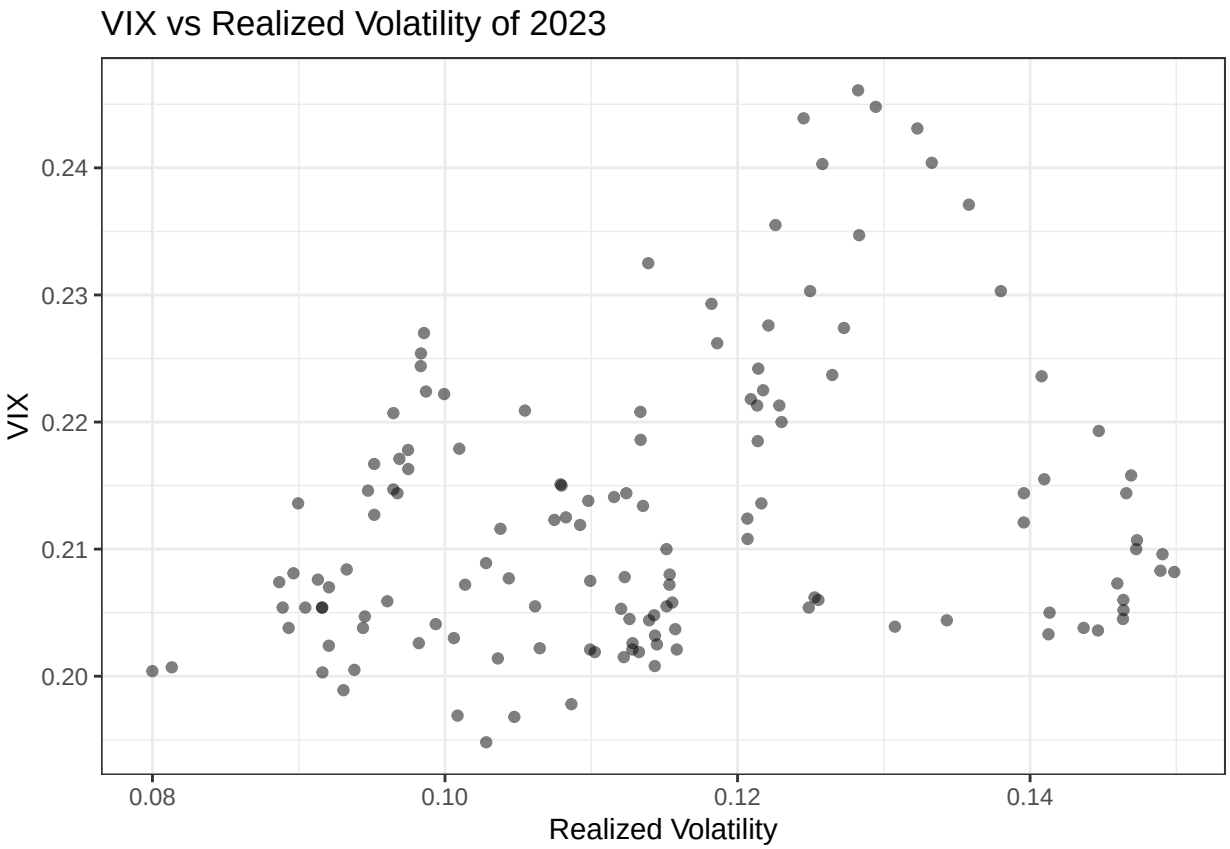
Here, we study the relationship between the VIX1Y index and the realized volatility of the S&P500 (SPY) stock prices by fitting regression models where the realized volatility is the predictor variable and the VIX1Y is the response. We want to examine whether we can predict the VIX by solely regressing on the realized volatility of the S&P500 and if so, which model is able to make the best predictions. We will fit regression models that don't take the time dependency into consideration to see whether time plays a role in the relationship between the VIX and the realized volatility. Some of these models include ordinary linear regression models, generalized additive models (GAM), and kernel regression. Note that when fitting these models, we will be using cross validation to minimize the root mean squared error (RMSE) of the model.

The Data


Seasonal Decomposition of VIX
observed
trend
seasonal
irregular
VIX
0.28
0.24
0.20
0.275
0.250
0.225
0.200
0.003
0.000
−0.003
−0.006
0.04
0.02
0.00
−0.02
2023−07
2024−01
2024−07
2025−01
Year


Seasonal Decomposition of Realized Volatility
observed
trend
seasonal
irregular
Volatility
0.14
0.12
0.10
0.08
0.002
0.000
−0.002
−0.004
0.010
0.005
0.000
−0.005
−0.010
Jul
Oct
Jan
Year


Realized Volatility and VIX Over 2023
0.25
0.20
0.15
0.10
Volatility Percentage
Jul
Oct
Jan
Month
Realized Volatility
VIX


VIX vs Realized Volatility of 2023
VIX
0.24
0.23
0.22
0.21
0.20
0.08
0.10
0.12
0.14
Realized Volatility

Fitting the Models

The following is a table of the cross-validated root mean squared errors (RMSE) from each of the models fitted:

Model	Cross Validated RMSE
Linear Model	0.01087
Kernel	0.009109
GAM	0.009045

Summary Outputs for linear regression

```
##
## Call:
## lm(formula = vix ~ rolling_vol_annual, data = filter(vix_volatility,
##     date %in% output_cv.lm$train))
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.016418 -0.008695 -0.003154  0.006792  0.030989
##
## Coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)         0.19547    0.00660   29.62  < 2e-16 ***
## rolling_vol_annual  0.15313    0.05693    2.69  0.00818 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.01108 on 119 degrees of freedom
## Multiple R-squared:  0.05731,    Adjusted R-squared:  0.04939
## F-statistic: 7.235 on 1 and 119 DF,  p-value: 0.008177
```

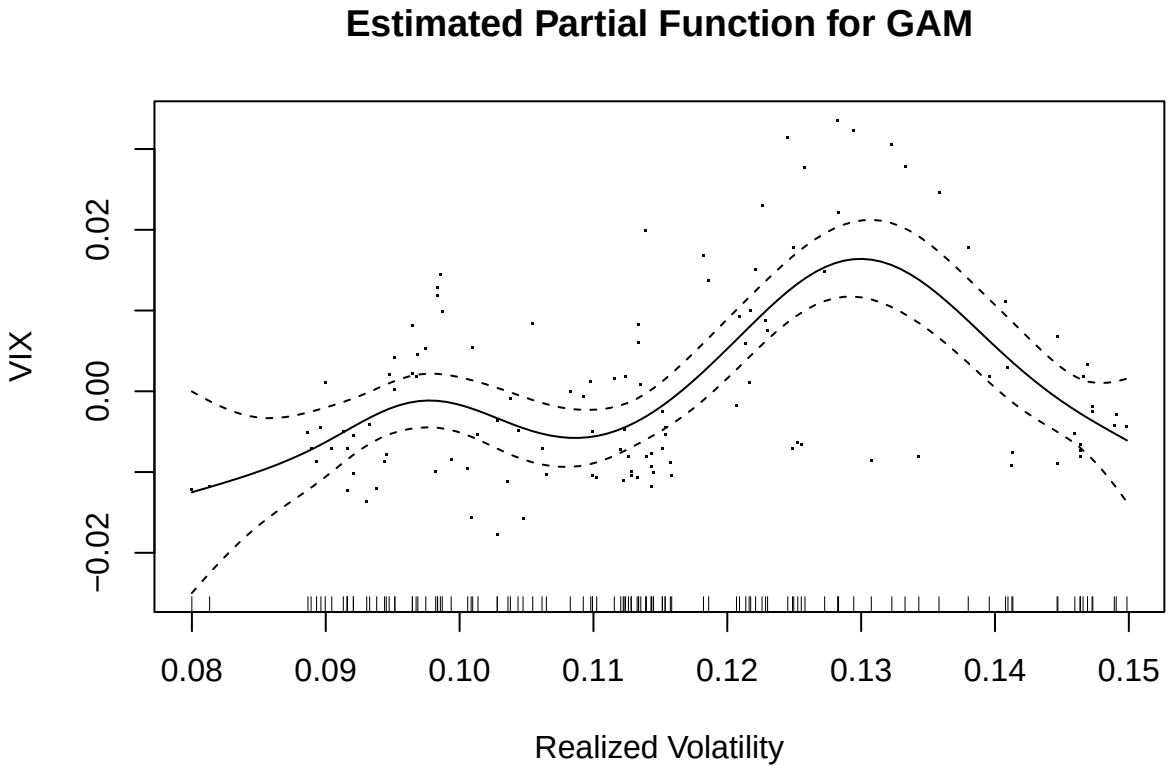
Summary Outputs for kernel regression

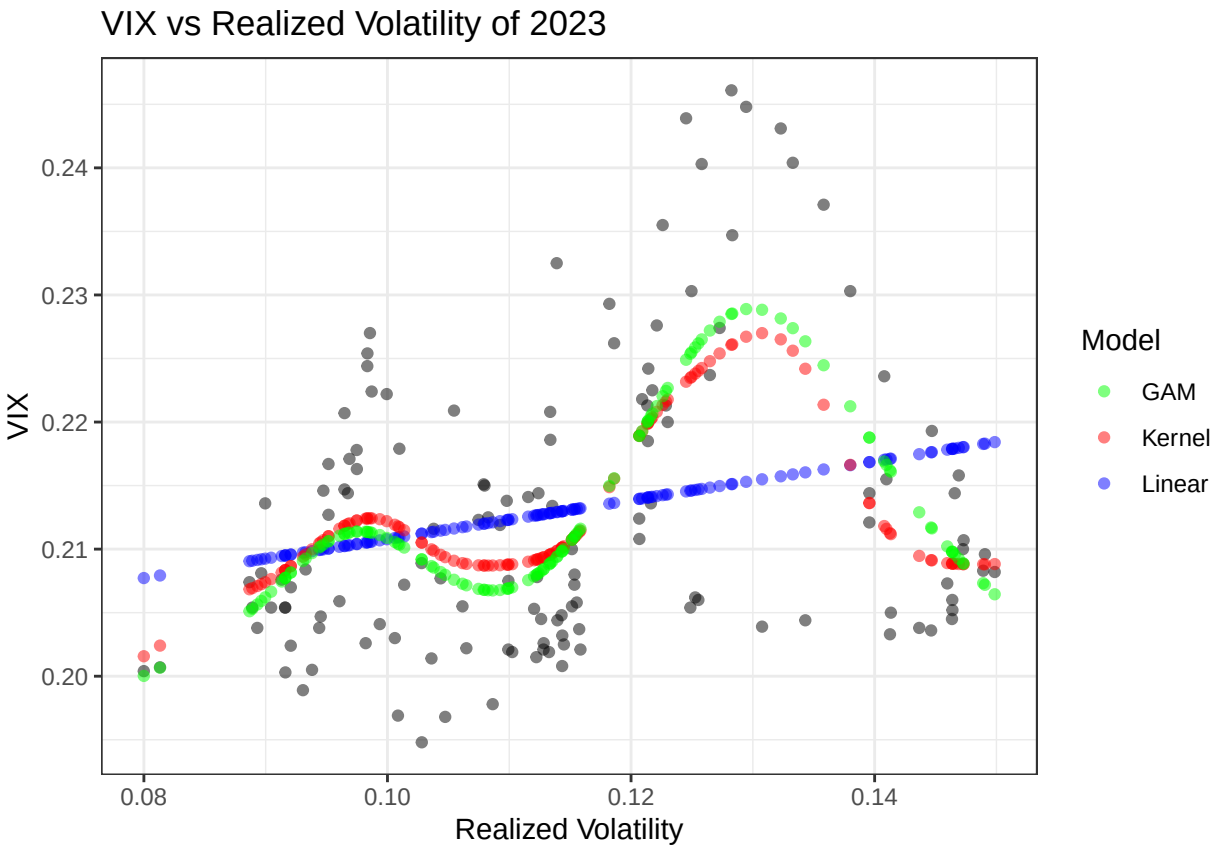
```
##
## Regression Data: 122 training points, in 1 variable(s)
##               rolling_vol_annual
## Bandwidth(s):        0.003928782
##
## Kernel Regression Estimator: Local-Constant
## Bandwidth Type: Fixed
## Residual standard error: 0.008812989
## R-squared: 0.3881666
##
## Continuous Kernel Type: Second-Order Gaussian
## No. Continuous Explanatory Vars.: 1
```

Summary Outputs for GAM

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## vix ~ s(rolling_vol_annual)
##
## Parametric coefficients:
##              Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept) 0.2125298  0.0008307   255.8   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                         edf Ref.df     F p-value
## s(rolling_vol_annual) 6.19   7.34 9.608  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.368   Deviance explained = 40.1%
## GCV = 8.8773e-05  Scale est. = 8.3497e-05  n = 121
```




VIX vs Realized Volatility of 2023
VIX
0.24
0.23
0.22
0.21
0.20
0.08
0.10
0.12
0.14
Realized Volatility
Model
GAM
Kernel
Linear