Financial Econometrics 2

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Import data again

```
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.1     v stringr   1.5.1
## v ggplot2   3.5.2     v tibble    3.3.0
## v lubridate 1.9.4     v tidyr     1.3.1
## v purrr     1.1.0
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(xts)
```

```
## Loading required package: zoo
##
## Attaching package: 'zoo'
##
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
##
##
## ############################ Warning from 'xts' package ##########################
## #                                                                                #
## # The dplyr lag() function breaks how base R's lag() function is supposed to  #
## # work, which breaks lag(my_xts). Calls to lag(my_xts) that you type or       #
## # source() into this session won't work correctly.                               #
## #                                                                                #
## # Use stats::lag() to make sure you're not using dplyr::lag(), or you can add #
## # conflictRules('dplyr', exclude = 'lag') to your .Rprofile to stop           #
## # dplyr from breaking base R's lag() function.                                   #
## #                                                                                #
## # Code in packages is not affected. It's protected by R's namespace mechanism #
## # Set `options(xts.warn_dplyr_breaks_lag = FALSE)` to suppress this warning.  #
## #                                                                                #
## ##################################################################################
```

```
##
## Attaching package: 'xts'
##
## The following objects are masked from 'package:dplyr':
##
##     first, last
```

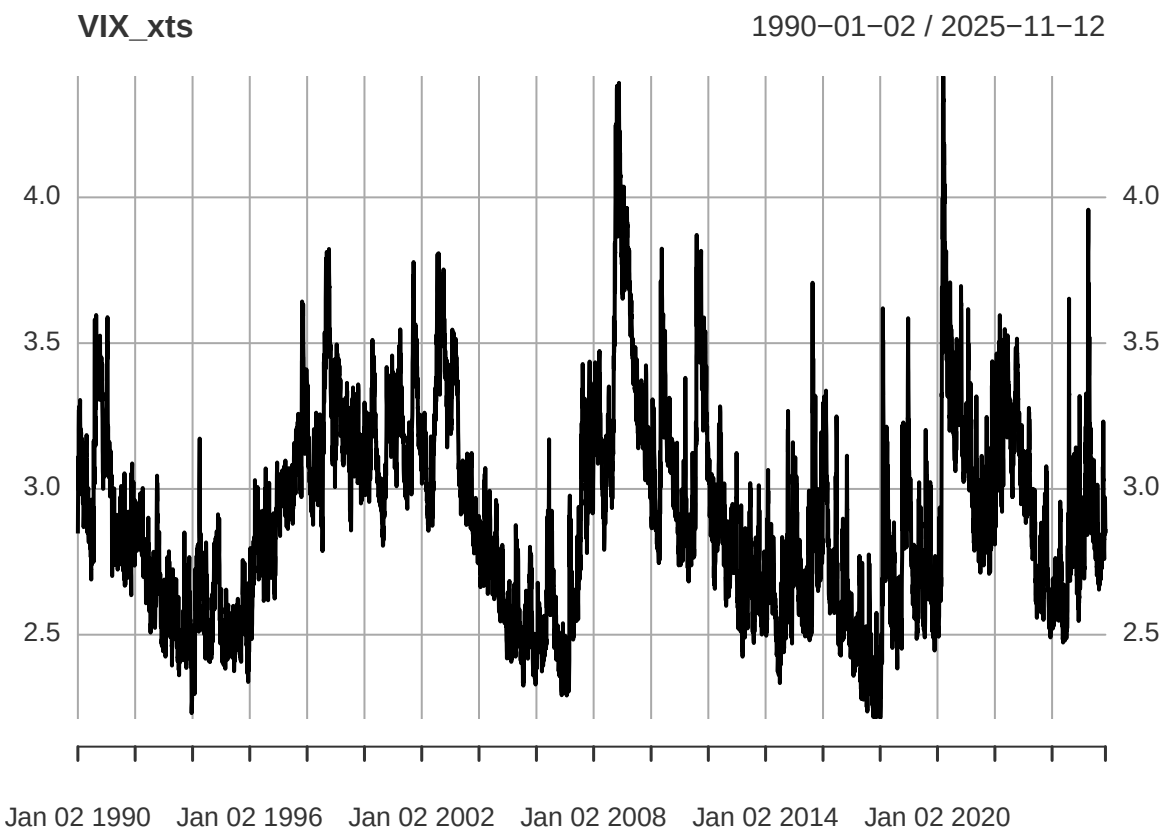
```
library(dynlm)
```

```
## Warning: package 'dynlm' was built under R version 4.5.2
```

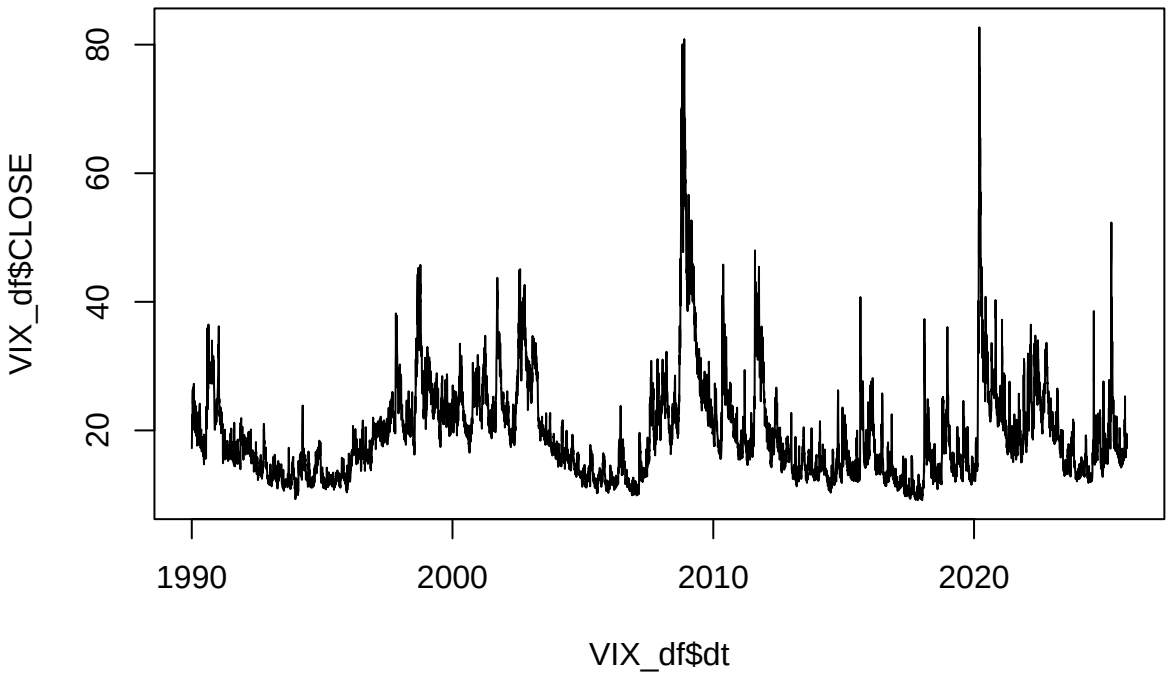
```
VIX_df <- read_csv("C:\\Users\\bluee\\Downloads\\VIX_History (1).csv")
```

```
## Rows: 9057 Columns: 5
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr (1): DATE
## dbl (4): OPEN, HIGH, LOW, CLOSE
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
VIX_df$logclose <-log(VIX_df$CLOSE)

VIX_df$dt <- as.Date(VIX_df$DATE, format="%m/%d/%Y")

VIX_xts <- xts(VIX_df$logclose, order.by =   VIX_df$dt)
plot(VIX_xts)
```

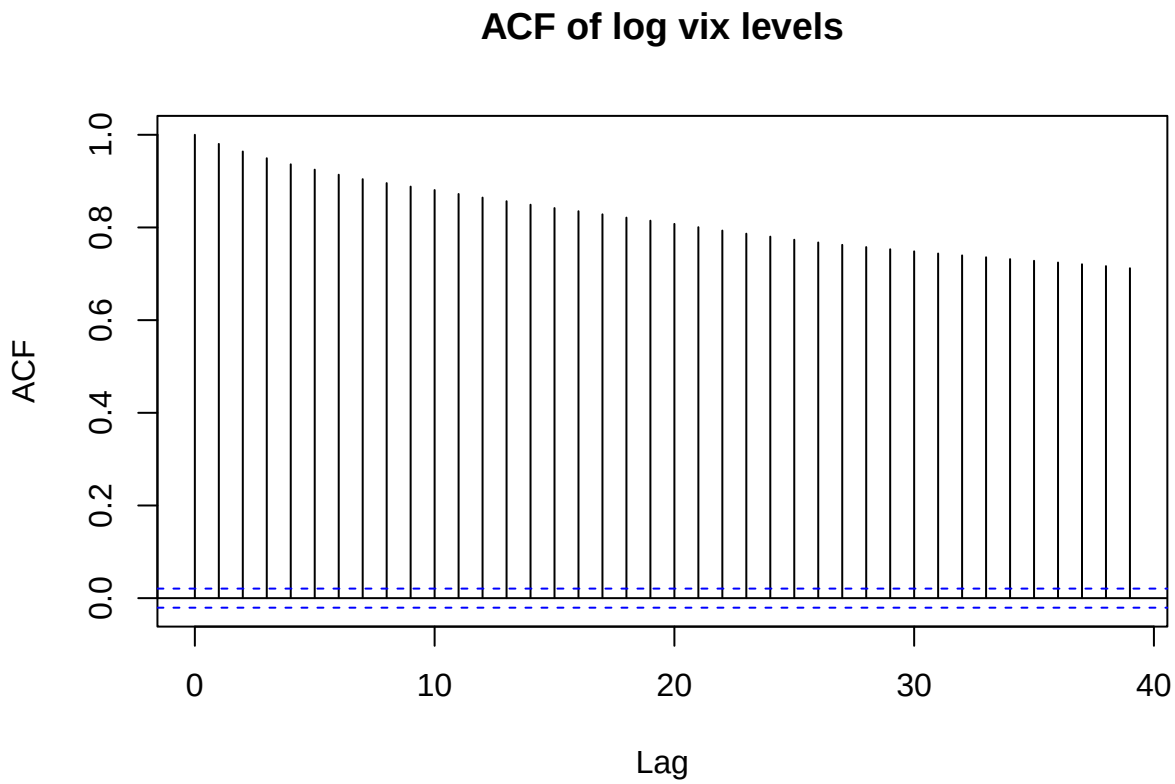



```
plot(x=VIX_df$dt, y= VIX_df$CLOSE,type="l")
```

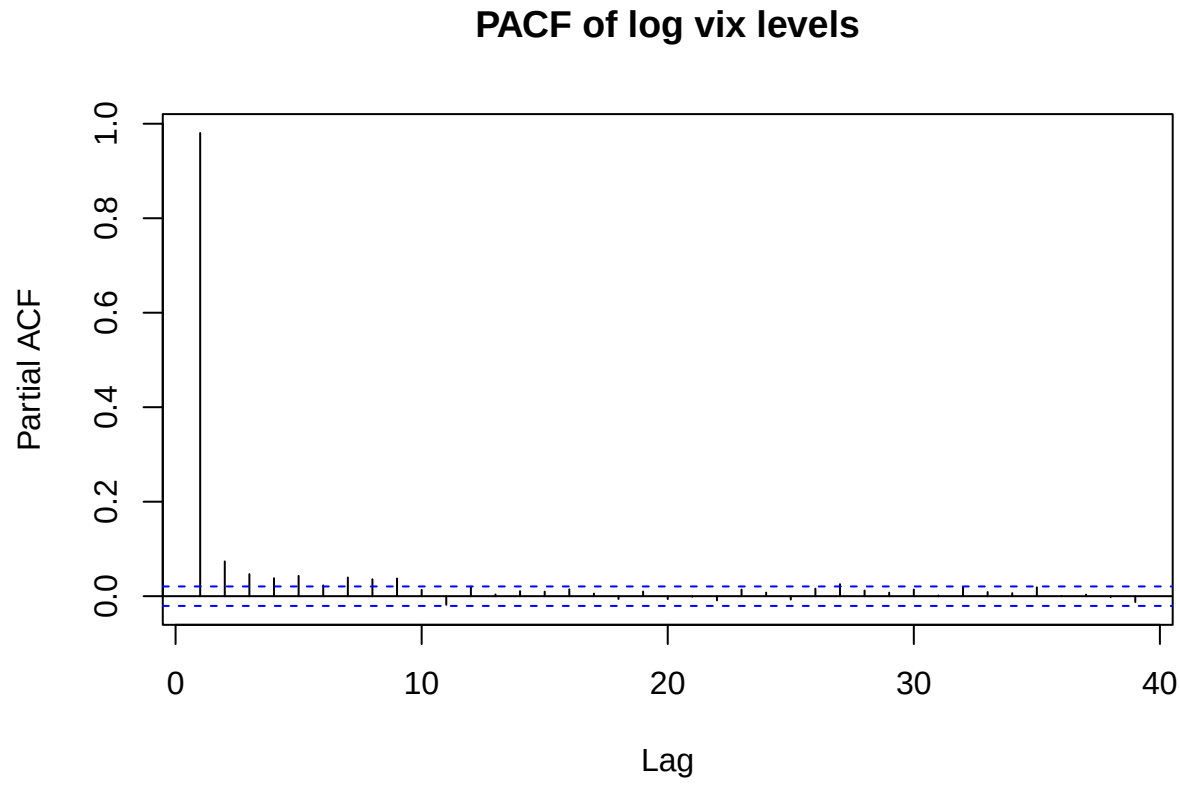


Compute the autocorrelation function log returns, I will use a for loop up to a one business month (23 day) lag.

```r
acf(VIX_xts, main ="ACF of log vix levels"  )
```




```r
pacf(VIX_xts, main ="PACF of log vix levels")
```



```r
library(tseries)
```

```
## Warning: package 'tseries' was built under R version 4.5.2
```

```
## Registered S3 method overwritten by 'quantmod':
##   method            from
##   as.zoo.data.frame zoo
```

```r
library(modelsummary)
```

```
## Warning: package 'modelsummary' was built under R version 4.5.2
```

```r
library(forecast)
```

```
## Warning: package 'forecast' was built under R version 4.5.2
```

```r
adf.test(VIX_xts)
```

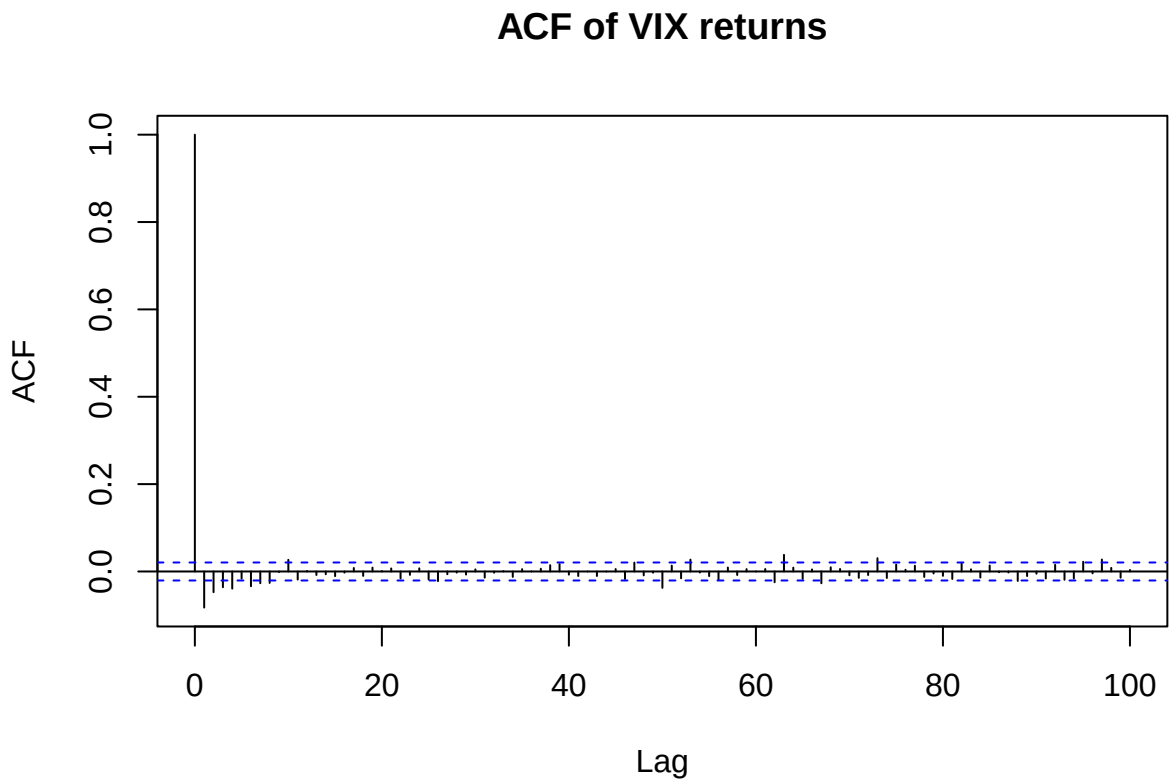
```
## Warning in adf.test(VIX_xts): p-value smaller than printed p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  VIX_xts
## Dickey-Fuller = -6.0748, Lag order = 20, p-value = 0.01
## alternative hypothesis: stationary
```

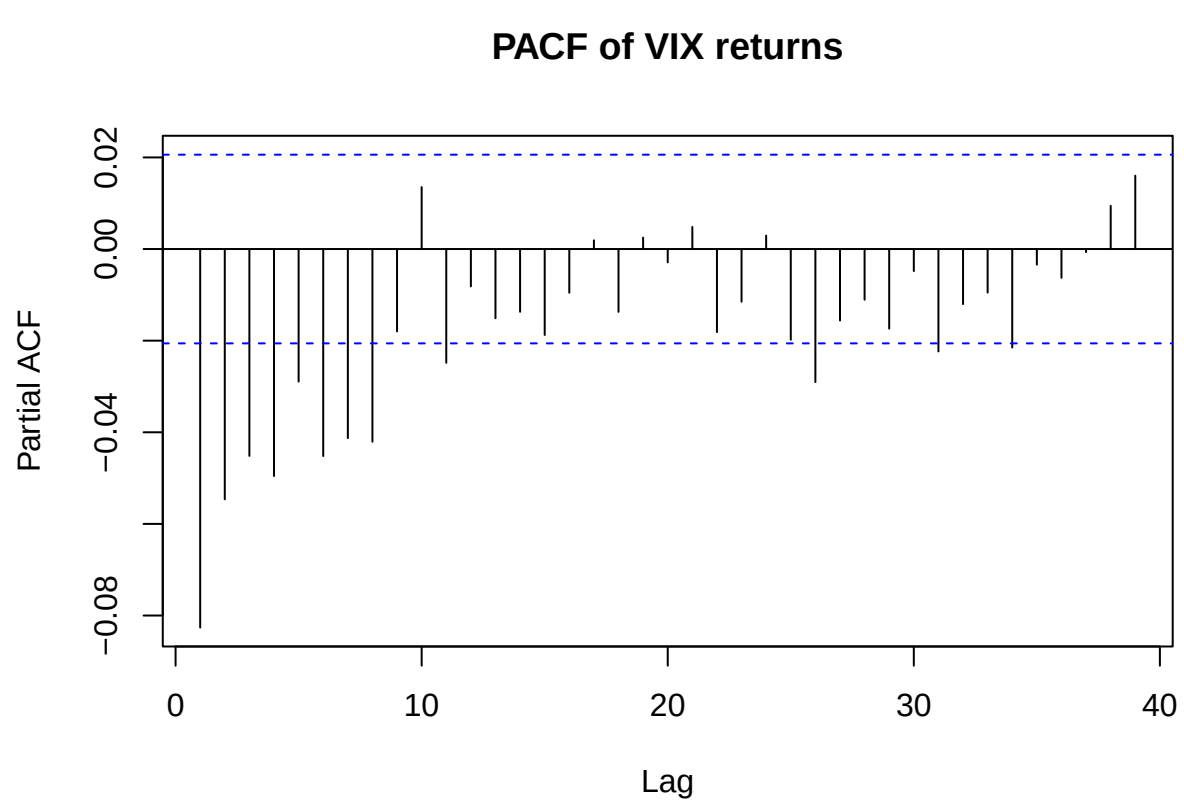
```r
levels_model<- arima(VIX_xts, order=c(1,0,0))
print(levels_model$coef)
```

```
##       ar1 intercept
## 0.9803572 2.9047148
```

```r
VIX_returns <- VIX_xts -lag(VIX_xts,1)
acf(VIX_returns, na.action = na.pass ,type="correlation", main ="ACF of VIX returns", lag.max = 100)
```




```
pacf(VIX_returns, na.action = na.pass, main ="PACF of VIX returns")
```



```r
returns_model <- ar(VIX_returns, aic= TRUE, na.action =na.pass)
print(returns_model)
```

```
##
## Call:
## ar(x = VIX_returns, aic = TRUE, na.action = na.pass)
##
## Coefficients:
##       1        2        3        4        5        6        7        8
## -0.0984  -0.0693  -0.0588  -0.0608  -0.0400  -0.0531  -0.0473  -0.0443
##       9       10       11
## -0.0184   0.0111  -0.0248
##
## Order selected 11  sigma^2 estimated as  0.004516
```

```r
Box.test(VIX_returns, lag=11, type="Ljung-Box")
```

```
##
##  Box-Ljung test
##
## data:  VIX_returns
## X-squared = 143.15, df = 11, p-value < 2.2e-16
```

```r
colnames(VIX_returns) <- "VIX_returns"

VIX_zoo <- as.zoo(VIX_returns)

regress <- dynlm(VIX_returns ~ L(VIX_returns, 1) + I(L(VIX_returns, 1)^2), data = VIX_zoo)


summary(regress)
```

```
##
## Time series regression with "zoo" data:
## Start = 1990-01-04, End = 2025-11-12
##
## Call:
## dynlm(formula = VIX_returns ~ L(VIX_returns, 1) + I(L(VIX_returns,
##     1)^2), data = VIX_zoo)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.43358 -0.03802 -0.00467  0.03188  0.80129
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              0.0013589  0.0007536   1.803   0.0714 .
## L(VIX_returns, 1)       -0.0629906  0.0110727  -5.689 1.32e-08 ***
## I(L(VIX_returns, 1)^2) -0.2956711  0.0547910  -5.396 6.97e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 0.06757 on 9052 degrees of freedom
##   (1 observation deleted due to missingness)
## Multiple R-squared:  0.01001,    Adjusted R-squared:  0.009794
## F-statistic: 45.78 on 2 and 9052 DF,  p-value: < 2.2e-16
```

```
library(stargazer)
```

```
## Warning: package 'stargazer' was built under R version 4.5.2
```

```
##
## Please cite as:
```

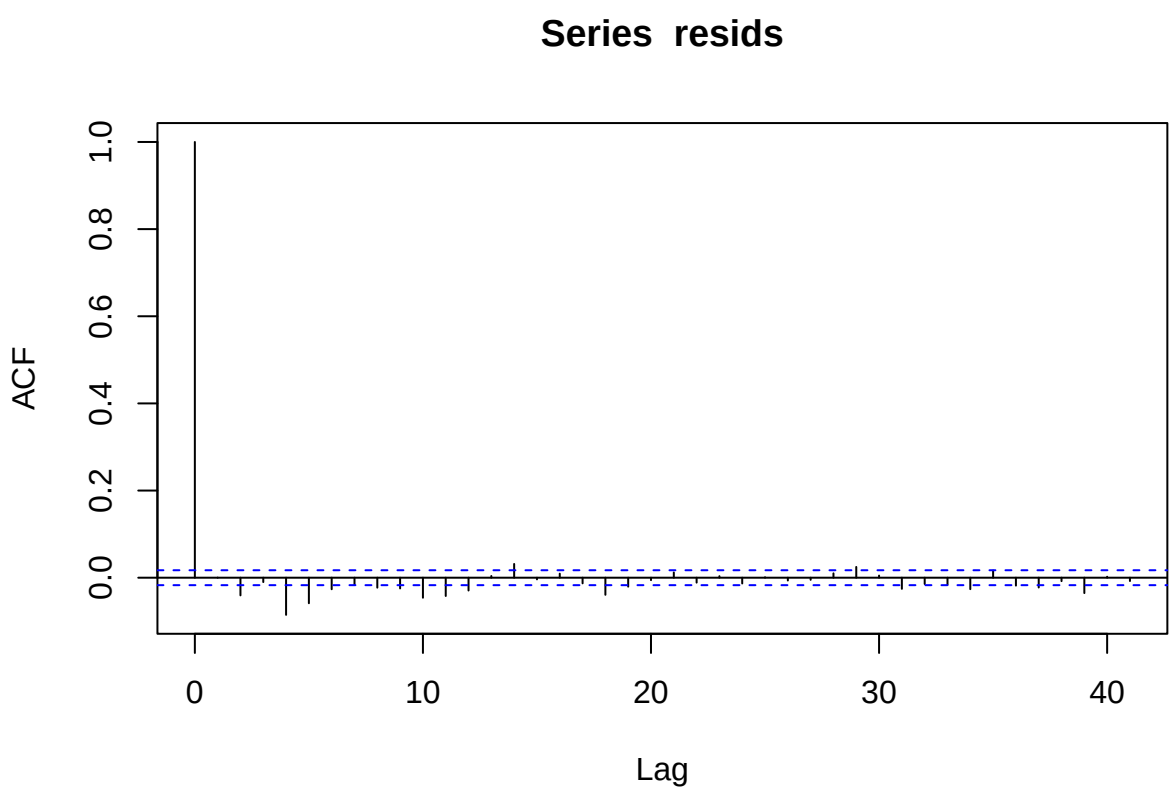
```
##  Hlavac, Marek (2022). stargazer: Well-Formatted Regression and Summary Statistics Tables.
```

```
##  R package version 5.2.3. https://CRAN.R-project.org/package=stargazer
```

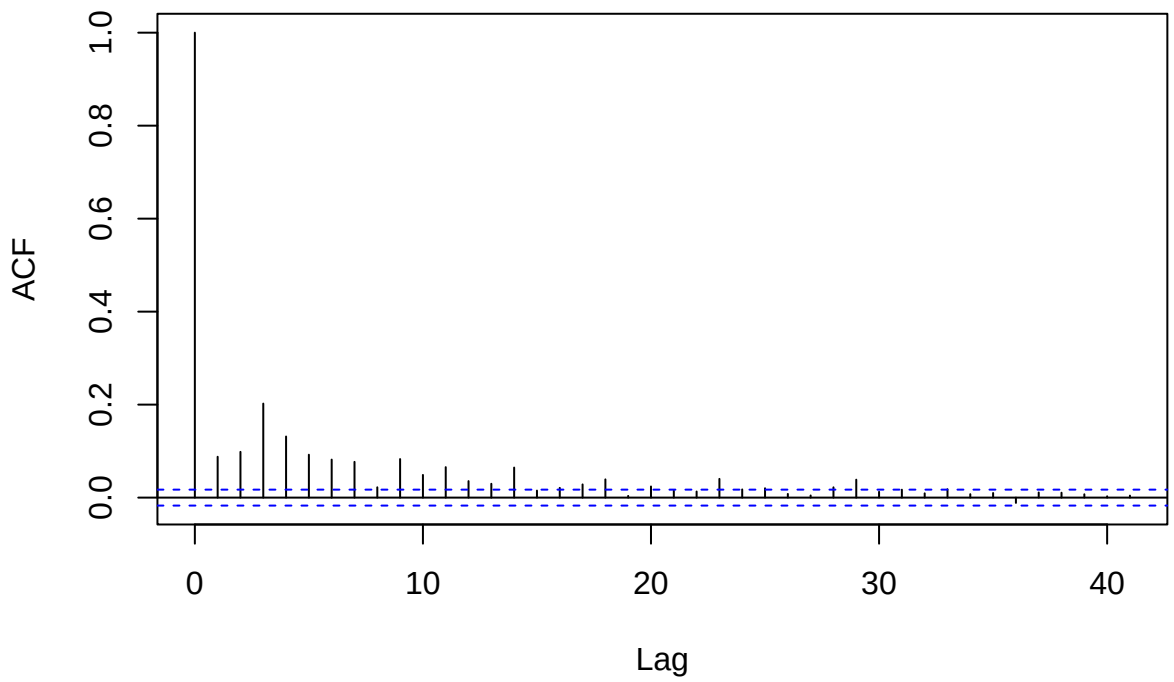
```
stargazer(regress, type="latex")
```

```
##
## % Table created by stargazer v.5.2.3 by Marek Hlavac, Social Policy Institute. E-mail: marek.hlavac a
## % Date and time: Wed, Nov 19, 2025 - 11:30:12 PM
## \begin{table}[!htbp] \centering
##   \caption{}
##   \label{}
## \begin{tabular}{@{\extracolsep{5pt}}lc}
## \\[-1.8ex]\hline
## \hline \\[-1.8ex]
##  & \multicolumn{1}{c}{\textit{Dependent variable:}} \\
## \cline{2-2}
## \\[-1.8ex] & VIX\_returns \\
## \hline \\[-1.8ex]
##  L(VIX\_returns, 1) & $-$0.063$^{***}$ \\
##   & (0.011) \\
##   & \\
##  I(L(VIX\_returns, 1)$\hat{\mkern6mu}$2) & $-$0.296$^{***}$ \\
##   & (0.055) \\
##   & \\
##  Constant & 0.001$^{*}$ \\
##   & (0.001) \\
##   & \\
## \hline \\[-1.8ex]
## Observations & 9,055 \\
## R$^{2}$ & 0.010 \\
## Adjusted R$^{2}$ & 0.010 \\
## Residual Std. Error & 0.068 (df = 9052) \\
## F Statistic & 45.777$^{***}$ (df = 2; 9052) \\
## \hline
## \hline \\[-1.8ex]
## \textit{Note:}  & \multicolumn{1}{r}{$^{*}$p$<$0.1; $^{**}$p$<$0.05; $^{***}$p$<$0.01} \\
## \end{tabular}
## \end{table}
```

```r
resids <- residuals(regress)

sqresid <- resids^2

acf(resids, na.action = na.pass)
```




```r
acf(sqresid, na.action = na.pass)
```




```
resids_df <- fortify.zoo(resids)
```

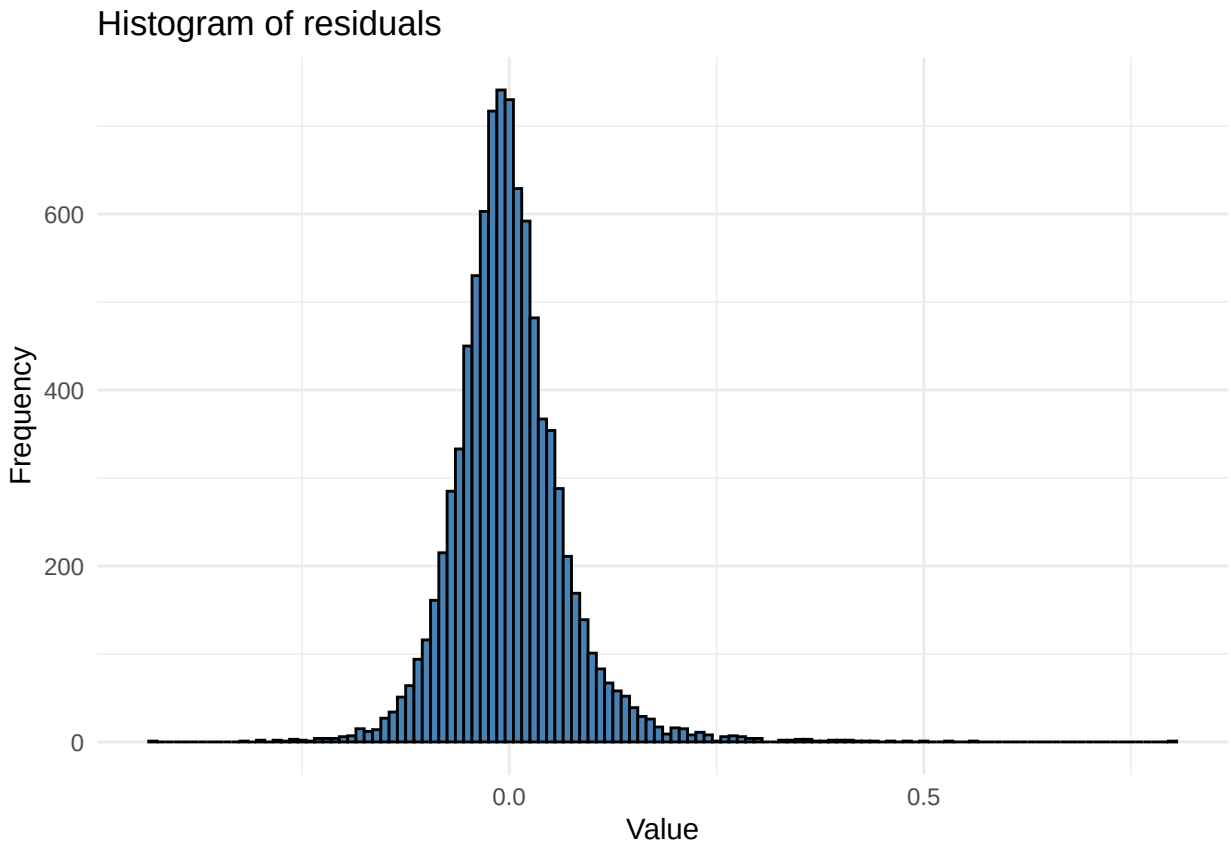
```
avg<- mean(resids_df)
```

```
## Warning in mean.default(resids_df): argument is not numeric or logical:
## returning NA
```

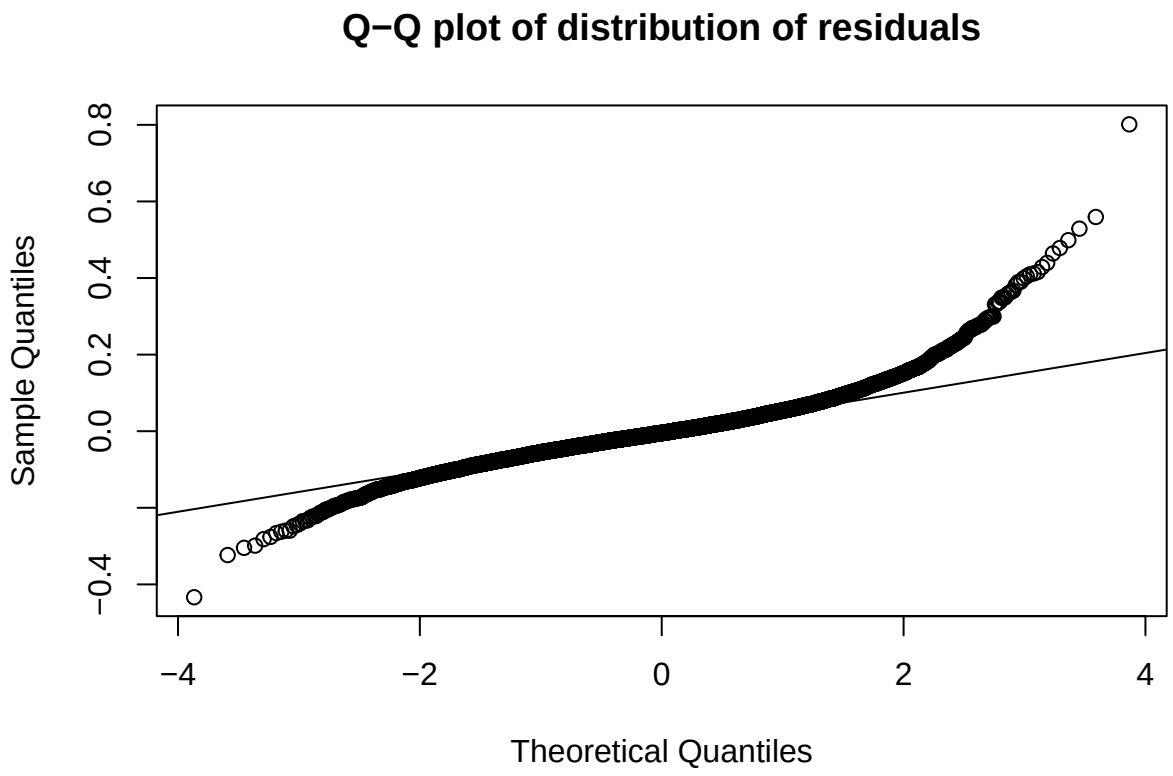
```
std_dev <- sqrt(var(resids_df))
```

```
## Warning in var(resids_df): NAs introduced by coercion
```

```
ggplot(resids_df, aes(x = resids)) +

  geom_histogram(binwidth = .01, fill = "steelblue", color = "black") +
  labs(title = "Histogram of residuals",
       x = "Value",
       y = "Frequency") +

  theme_minimal()
```




```
qqnorm(resids_df$resids, main="Q-Q plot of distribution of residuals")
qqline(resids_df$resids)
```



Create many day changes.

```
library(xts)



# --- Parameters ---
max_h <- 100   # maximum horizon

# --- Loop through horizons and create separate xts objects ---
for (h in 1:max_h) {
  n <- NROW(VIX_returns)
  split_idx <- split(1:n, ceiling(seq_along(VIX_returns) / h))

  # Sum log returns over non-overlapping blocks
  cum_ret <- sapply(split_idx, function(i) sum(VIX_returns[i]))

  # Use last date of each block
  cum_dates <- index(VIX_returns)[sapply(split_idx, tail, 1)]

  # Create xts for this horizon
  cum_xts <- xts(cum_ret, order.by = cum_dates)
  colnames(cum_xts) <- paste0("cum_", h, "d")

  # Dynamically assign name like cum_xts_5
  assign(paste0("cum_xts_", h), cum_xts)
}

# --- Example: check some of them ---
head(cum_xts_1)
```

```
##                 cum_1d
## 1990-01-02          NA
## 1990-01-03 0.053639727
## 1990-01-04 0.055079411
## 1990-01-05 0.045265800
## 1990-01-08 0.007431295
## 1990-01-09 0.091443790
```

```
head(cum_xts_5)
```

```
##                  cum_5d
## 1990-01-08           NA
## 1990-01-15  0.262440197
## 1990-01-22  0.013574869
## 1990-01-29 -0.009785550
## 1990-02-05 -0.074573576
## 1990-02-12 -0.006541315
```

```
head(cum_xts_10)
```

```
##                 cum_10d
```

```
## 1990-01-15           NA
## 1990-01-29  0.003789319
## 1990-02-12 -0.081114891
## 1990-02-27 -0.071838825
## 1990-03-13 -0.075023739
## 1990-03-27 -0.001902045
```

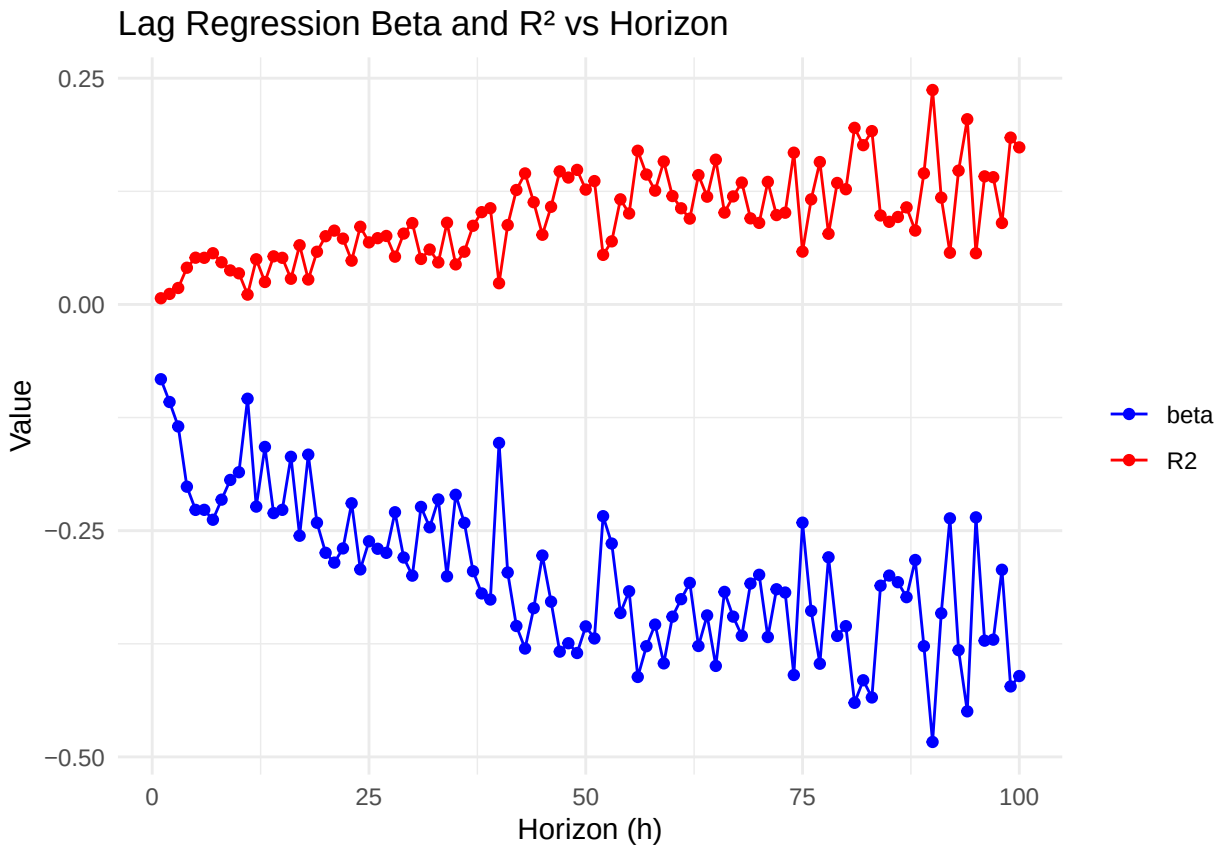
create linear regression

```
##         horizon        beta    t_stat      p_value n_obs
## 1     cum_xts_1 -0.08262946 -7.889201 3.394521e-15  9056
## 2    cum_xts_10 -0.18542896 -5.667289 1.951607e-08   905
## 3   cum_xts_100 -0.41063463 -4.274216 4.891855e-05    90
## 4    cum_xts_11 -0.10417105 -2.998651 2.793719e-03   823
## 5    cum_xts_12 -0.22339896 -6.280690 5.703020e-10   754
## 6    cum_xts_13 -0.15744519 -4.196976 3.057155e-05   696
## 7    cum_xts_14 -0.23058119 -6.008671 3.132410e-09   646
## 8    cum_xts_15 -0.22698221 -5.708571 1.792480e-08   603
## 9    cum_xts_16 -0.16835122 -4.053730 5.750383e-05   566
## 10   cum_xts_17 -0.25561002 -6.086280 2.220682e-09   532
## 11   cum_xts_18 -0.16596376 -3.763003 1.877916e-04   503
## 12   cum_xts_19 -0.24122766 -5.406830 1.019728e-07   476
## 13    cum_xts_2 -0.10778942 -7.294238 3.528148e-13  4528
## 14   cum_xts_20 -0.27446023 -6.050942 3.039120e-09   452
## 15   cum_xts_21 -0.28528342 -6.164664 1.634180e-09   431
## 16   cum_xts_22 -0.26961326 -5.657786 2.890971e-08   411
## 17   cum_xts_23 -0.21970932 -4.452581 1.109285e-05   393
## 18   cum_xts_24 -0.29283270 -5.927168 7.005291e-09   377
## 19   cum_xts_25 -0.26172053 -5.141290 4.493767e-07   362
## 20   cum_xts_26 -0.26998899 -5.220360 3.091665e-07   348
## 21   cum_xts_27 -0.27449489 -5.212943 3.274302e-07   335
## 22   cum_xts_28 -0.22961676 -4.222854 3.147874e-05   323
## 23   cum_xts_29 -0.27965600 -5.123210 5.300037e-07   312
## 24    cum_xts_3 -0.13481472 -7.472159 1.027699e-13  3018
## 25   cum_xts_30 -0.29968582 -5.425172 1.199773e-07   301
## 26   cum_xts_31 -0.22371572 -3.911067 1.145882e-04   292
## 27   cum_xts_32 -0.24627617 -4.252115 2.888833e-05   283
## 28   cum_xts_33 -0.21548463 -3.633805 3.340251e-04   274
## 29   cum_xts_34 -0.30046177 -5.108333 6.250756e-07   266
## 30   cum_xts_35 -0.21034456 -3.435467 6.903926e-04   258
## 31   cum_xts_36 -0.24136820 -3.917754 1.156261e-04   251
## 32   cum_xts_37 -0.29477800 -4.790179 2.912861e-06   244
## 33   cum_xts_38 -0.31934851 -5.165630 5.111501e-07   238
## 34   cum_xts_39 -0.32609989 -5.220036 4.008786e-07   232
## 35    cum_xts_4 -0.20140545 -9.777154 3.849143e-22  2264
## 36   cum_xts_40 -0.15306387 -2.313407 2.161116e-02   226
## 37   cum_xts_41 -0.29621734 -4.567382 8.277269e-06   220
## 38   cum_xts_42 -0.35533849 -5.540090 8.909179e-08   215
## 39   cum_xts_43 -0.38024652 -5.920077 1.320666e-08   210
## 40   cum_xts_44 -0.33565929 -5.071811 8.896992e-07   205
## 41   cum_xts_45 -0.27747278 -4.063774 6.959304e-05   201
## 42   cum_xts_46 -0.32848843 -4.830924 2.762700e-06   196
## 43   cum_xts_47 -0.38369267 -5.708274 4.357808e-08   192
## 44   cum_xts_48 -0.37435965 -5.492695 1.294987e-07   188
```

```
## 45   cum_xts_49 -0.38518911 -5.622606 7.024148e-08   184
## 46    cum_xts_5 -0.22703253 -9.923105 1.236908e-22  1811
## 47   cum_xts_50 -0.35577428 -5.086341 9.202330e-07   181
## 48   cum_xts_51 -0.36908245 -5.240593 4.591561e-07   177
## 49   cum_xts_52 -0.23399498 -3.148020 1.939947e-03   174
## 50   cum_xts_53 -0.26426191 -3.537912 5.223676e-04   170
## 51   cum_xts_54 -0.34094213 -4.642414 7.019655e-06   167
## 52   cum_xts_55 -0.31696213 -4.241812 3.729598e-05   164
## 53   cum_xts_56 -0.41163725 -5.685425 6.143626e-08   161
## 54   cum_xts_57 -0.37765955 -5.097192 9.918755e-07   158
## 55   cum_xts_58 -0.35376544 -4.691183 5.978062e-06   156
## 56   cum_xts_59 -0.39664445 -5.304474 3.981188e-07   153
## 57    cum_xts_6 -0.22697688 -9.044373 4.514939e-19  1509
## 58   cum_xts_60 -0.34502785 -4.472658 1.535770e-05   150
## 59   cum_xts_61 -0.32570208 -4.151717 5.606054e-05   148
## 60   cum_xts_62 -0.30770057 -3.871256 1.641204e-04   146
## 61   cum_xts_63 -0.37744242 -4.832316 3.500709e-06   143
## 62   cum_xts_64 -0.34363346 -4.318763 2.977969e-05   141
## 63   cum_xts_65 -0.39945330 -5.089209 1.172170e-06   139
## 64   cum_xts_66 -0.31765861 -3.890369 1.569722e-04   137
## 65   cum_xts_67 -0.34498728 -4.229903 4.340780e-05   135
## 66   cum_xts_68 -0.36617072 -4.498271 1.502150e-05   133
## 67   cum_xts_69 -0.30842256 -3.667956 3.572824e-04   131
## 68    cum_xts_7 -0.23792306 -8.797058 4.414319e-18  1293
## 69   cum_xts_70 -0.29875025 -3.532205 5.766168e-04   129
## 70   cum_xts_71 -0.36757361 -4.407155 2.241362e-05   127
## 71   cum_xts_72 -0.31473415 -3.656273 3.788074e-04   125
## 72   cum_xts_73 -0.31836589 -3.694197 3.324642e-04   124
## 73   cum_xts_74 -0.40949104 -4.896602 3.100645e-06   122
## 74   cum_xts_75 -0.24113473 -2.692713 8.127978e-03   120
## 75   cum_xts_76 -0.33862005 -3.903996 1.593106e-04   119
## 76   cum_xts_77 -0.39702631 -4.613836 1.041903e-05   117
## 77   cum_xts_78 -0.27942663 -3.094126 2.488115e-03   116
## 78   cum_xts_79 -0.36630552 -4.148610 6.575449e-05   114
## 79    cum_xts_8 -0.21572783 -7.429399 2.147080e-13  1132
## 80   cum_xts_80 -0.35551371 -4.006039 1.125721e-04   113
## 81   cum_xts_81 -0.44018991 -5.117154 1.357891e-06   111
## 82   cum_xts_82 -0.41530942 -4.780606 5.605419e-06   110
## 83   cum_xts_83 -0.43430848 -5.011293 2.175306e-06   109
## 84   cum_xts_84 -0.31076893 -3.367161 1.065501e-03   107
## 85   cum_xts_85 -0.29961050 -3.216680 1.733458e-03   106
## 86   cum_xts_86 -0.30694890 -3.303242 1.318766e-03   105
## 87   cum_xts_87 -0.32347228 -3.483173 7.339246e-04   104
## 88   cum_xts_88 -0.28239308 -2.966696 3.773676e-03   102
## 89   cum_xts_89 -0.37762338 -4.075447 9.338550e-05   101
## 90    cum_xts_9 -0.19394612 -6.260467 5.681237e-10  1006
## 91   cum_xts_90 -0.48349023 -5.488523 3.238605e-07   100
## 92   cum_xts_91 -0.34130125 -3.584635 5.327376e-04    99
## 93   cum_xts_92 -0.23636151 -2.399433 1.837155e-02    98
## 94   cum_xts_93 -0.38203323 -4.038724 1.096773e-04    97
## 95   cum_xts_94 -0.44967049 -4.891974 4.172581e-06    96
## 96   cum_xts_95 -0.23527971 -2.349589 2.093302e-02    95
## 97   cum_xts_96 -0.37154251 -3.873181 2.021560e-04    94
## 98   cum_xts_97 -0.37043127 -3.837453 2.305853e-04    93
```

```
## 99   cum_xts_98 -0.29317255 -2.967052 3.860936e-03    92
## 100  cum_xts_99 -0.42214079 -4.460009 2.410721e-05    91
```

```r
coef_summary$R2 <- sapply(names(reg_results), function(name) {
  model_sum <- reg_results[[name]]

  if (is.null(model_sum) || all(is.na(model_sum))) {
    return(NA)
  } else {
    return(model_sum$r.squared)
  }
})



coef_summary$h <- as.numeric(sub("cum_xts_", "", coef_summary$horizon))


library(ggplot2)
library(tidyr)

# Reshape data for plotting
plot_data <- coef_summary %>%
  select(h, beta, R2) %>%
  pivot_longer(cols = c("beta", "R2"), names_to = "metric", values_to = "value")

ggplot(plot_data, aes(x = h, y = value, color = metric)) +
  geom_line() +
  geom_point() +
  scale_color_manual(values = c("blue", "red")) +
  labs(x = "Horizon (h)", y = "Value", color = "",
       title = "Lag Regression Beta and R² vs Horizon") +
  theme_minimal()
```


Lag Regression Beta and R² vs Horizon
0.25
0.00
−0.25
−0.50
Value
0
25
50
75
100
Horizon (h)
beta
R2