Empirical Analysis of AMZN Microstructure Data

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Importation

Import the required libraries.

```
library(highfrequency)
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.2     v readr     2.1.4
## v forcats   1.0.0     v stringr   1.5.0
## v ggplot2   3.4.2     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.0
## v purrr     1.0.1
## -- 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 ###################################
## # We noticed you have dplyr installed. 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 enter or source() into this session won't     #
## # work correctly.                                                             #
## #                                                                             #
## # All package code is unaffected because it is protected by the R namespace  #
## # mechanism.                                                                  #
## #                                                                             #
## # Set `options(xts.warn_dplyr_breaks_lag = FALSE)` to suppress this warning.  #
## #                                                                             #
## # You can 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.                                #
```

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

```r
library(lubridate)
```

Data Pre-Processing

Load and pre-process the TAQ data.

```r
# Write file path for data.
file_path <- 'C://Users//sbhatia2//OneDrive - stevens.edu//Desktop//amzn_tick_history_01_04_2023.csv'

# Read in TAQ data.
data <- read.csv(file_path)

head(data)
```

```
##    X.RIC Alias.Underlying.RIC       Domain                        Date.Time
## 1 AMZN.O                   NA Market Price 2023-01-04T03:58:00.155637244-05
## 2 AMZN.O                   NA Market Price 2023-01-04T03:58:00.359739567-05
## 3 AMZN.O                   NA Market Price 2023-01-04T03:59:00.072066759-05
## 4 AMZN.O                   NA Market Price 2023-01-04T03:59:00.072066759-05
## 5 AMZN.O                   NA Market Price 2023-01-04T03:59:00.119497840-05
## 6 AMZN.O                   NA Market Price 2023-01-04T03:59:00.119497840-05
##             Type Ex.Cntrb.ID LOC Price Volume Market.VWAP Buyer.ID Bid.Price
## 1 Mkt. Condition              NA    NA     NA          NA                 NA
## 2 Mkt. Condition              NA    NA     NA          NA                 NA
## 3 Mkt. Condition              NA    NA     NA          NA                 NA
## 4          Quote              NA    NA     NA          NA                 NA
## 5 Mkt. Condition              NA    NA     NA          NA                 NA
## 6          Quote              NA    NA     NA          NA                 NA
##   Bid.Size No..Buyers Seller.ID Ask.Price Ask.Size No..Sellers
## 1       NA         NA                  NA       NA          NA
## 2       NA         NA                  NA       NA          NA
## 3       NA         NA                  NA       NA          NA
## 4       NA         NA                  NA       NA          NA
## 5       NA         NA                  NA       NA          NA
## 6       NA         NA                  NA       NA          NA
##                                                       Qualifiers Seq..No.
## 1                                          [GV4_FLAG];   [PRC_QL2]       NA
## 2                                          [GV4_FLAG];   [PRC_QL2]       NA
## 3                                        CLS[PRC_QL3];   [PRC_QL2]       NA
## 4 CLS[PRC_QL_CD];CLS[PRC_QL3];[GV1_TEXT];Exhausted Bid and Ask[USER]       NA
## 5                                        CLS[PRC_QL3];   [PRC_QL2]       NA
## 6 CLS[PRC_QL_CD];CLS[PRC_QL3];[GV1_TEXT];Exhausted Bid and Ask[USER]       NA
##            Exch.Time Block.Trd PE.Ratio Yield Bid.Yld Ask.Yld ISMA.Bid.Yld
## 1                           NA        NA    NA      NA      NA           NA
## 2                           NA        NA    NA      NA      NA           NA
## 3                           NA        NA    NA      NA      NA           NA
## 4 08:59:00.051000000        NA        NA    NA      NA      NA           NA
```

```
## 5                            NA        NA    NA      NA      NA           NA
## 6 08:59:00.099000000         NA        NA    NA      NA      NA           NA
##   ISMA.Ask.Yld Duration Mod.Durtn BPV Convexity Bench.Spd Swp.Spd Asst.Swp.Spd
## 1           NA       NA        NA  NA        NA        NA      NA           NA
## 2           NA       NA        NA  NA        NA        NA      NA           NA
## 3           NA       NA        NA  NA        NA        NA      NA           NA
## 4           NA       NA        NA  NA        NA        NA      NA           NA
## 5           NA       NA        NA  NA        NA        NA      NA           NA
## 6           NA       NA        NA  NA        NA        NA      NA           NA
##   Swap.Point UpLim.Price LoLim.Price Theo..Price Parity Premium Bid.Imp..Vol
## 1         NA          NA          NA          NA     NA      NA           NA
## 2         NA          NA          NA          NA     NA      NA           NA
## 3         NA          NA          NA          NA     NA      NA           NA
## 4         NA          NA          NA          NA     NA      NA           NA
## 5         NA          NA          NA          NA     NA      NA           NA
## 6         NA          NA          NA          NA     NA      NA           NA
##   Ask.Imp..Vol Imp..Vol. Crack Top Freight.Pr. Offer Actual Prior Revised
## 1           NA        NA    NA  NA          NA    NA     NA    NA      NA
## 2           NA        NA    NA  NA          NA    NA     NA    NA      NA
## 3           NA        NA    NA  NA          NA    NA     NA    NA      NA
## 4           NA        NA    NA  NA          NA    NA     NA    NA      NA
## 5           NA        NA    NA  NA          NA    NA     NA    NA      NA
## 6           NA        NA    NA  NA          NA    NA     NA    NA      NA
##   Forecast Frcst.High Frcst.Low No..Frcts       Date Bid.Tic Tick.Dir. Open
## 1       NA         NA        NA        NA                 NA             NA
## 2       NA         NA        NA        NA                 NA             NA
## 3       NA         NA        NA        NA                 NA             NA
## 4       NA         NA        NA        NA 2023-01-04      NA             NA
## 5       NA         NA        NA        NA                 NA             NA
## 6       NA         NA        NA        NA 2023-01-04      NA             NA
##   High Low Open.Interest Bench.Price Open.Yld High.Yld Low.Yld Acc..Volume
## 1   NA  NA            NA          NA       NA       NA      NA          NA
## 2   NA  NA            NA          NA       NA       NA      NA          NA
## 3   NA  NA            NA          NA       NA       NA      NA          NA
## 4   NA  NA            NA          NA       NA       NA      NA          NA
## 5   NA  NA            NA          NA       NA       NA      NA          NA
## 6   NA  NA            NA          NA       NA       NA      NA          NA
##   Turnover Volatility Strike Mid.Price Advancing.Issues Declining.Issues
## 1       NA         NA     NA        NA               NA               NA
## 2       NA         NA     NA        NA               NA               NA
## 3       NA         NA     NA        NA               NA               NA
## 4       NA         NA     NA        NA               NA               NA
## 5       NA         NA     NA        NA               NA               NA
## 6       NA         NA     NA        NA               NA               NA
##   Unchanged.Issues Total.Issues Advancing.Volume Declining.Volume
## 1               NA           NA               NA               NA
## 2               NA           NA               NA               NA
## 3               NA           NA               NA               NA
## 4               NA           NA               NA               NA
## 5               NA           NA               NA               NA
## 6               NA           NA               NA               NA
##   Unchanged.Volume Total.Volume New.Highs New.Lows Total.Moves
## 1               NA           NA        NA       NA          NA
## 2               NA           NA        NA       NA          NA
```

```
## 3              NA           NA         NA       NA          NA
## 4              NA           NA         NA       NA          NA
## 5              NA           NA         NA       NA          NA
## 6              NA           NA         NA       NA          NA
##   Percentage.Change Advancing.Moves Declining.Moves Unchanged.Moves
## 1                NA              NA              NA              NA
## 2                NA              NA              NA              NA
## 3                NA              NA              NA              NA
## 4                NA              NA              NA              NA
## 5                NA              NA              NA              NA
## 6                NA              NA              NA              NA
##   Strong.Market Weak.Market Changed.Market Market.Volatility Original.Date
## 1            NA          NA             NA                NA            NA
## 2            NA          NA             NA                NA            NA
## 3            NA          NA             NA                NA            NA
## 4            NA          NA             NA                NA            NA
## 5            NA          NA             NA                NA            NA
## 6            NA          NA             NA                NA            NA
##   Final.NAV X30.Day.ATM.IV.Call X60.Day.ATM.IV.Call X90.Day.ATM.IV.Call
## 1        NA                  NA                  NA                  NA
## 2        NA                  NA                  NA                  NA
## 3        NA                  NA                  NA                  NA
## 4        NA                  NA                  NA                  NA
## 5        NA                  NA                  NA                  NA
## 6        NA                  NA                  NA                  NA
##   X30.Day.ATM.IV.Put X60.Day.ATM.IV.Put X90.Day.ATM.IV.Put Background.Reference
## 1                 NA                 NA                 NA                   NA
## 2                 NA                 NA                 NA                   NA
## 3                 NA                 NA                 NA                   NA
## 4                 NA                 NA                 NA                   NA
## 5                 NA                 NA                 NA                   NA
## 6                 NA                 NA                 NA                   NA
##   Original.Price Original.Volume Original.Seq..No. Original.Exch.Time
## 1             NA              NA                NA                 NA
## 2             NA              NA                NA                 NA
## 3             NA              NA                NA                 NA
## 4             NA              NA                NA                 NA
## 5             NA              NA                NA                 NA
## 6             NA              NA                NA                 NA
##   Bid.Spread Ask.Spread Reference.Price Paired.Quantity Imbalance.Quantity
## 1         NA         NA              NA              NA                 NA
## 2         NA         NA              NA              NA                 NA
## 3         NA         NA              NA              NA                 NA
## 4         NA         NA              NA              NA                 NA
## 5         NA         NA              NA              NA                 NA
## 6         NA         NA              NA              NA                 NA
##   Far.Clearing.Price Near.Clearing.Price Option.Adjusted.Spread.Bid Z.Spread
## 1                 NA                  NA                         NA       NA
## 2                 NA                  NA                         NA       NA
## 3                 NA                  NA                         NA       NA
## 4                 NA                  NA                         NA       NA
## 5                 NA                  NA                         NA       NA
## 6                 NA                  NA                         NA       NA
##   Conversion.Premium Conversion.Ratio Percentage.Daily.Return
```

```
## 1                 NA               NA                      NA
## 2                 NA               NA                      NA
## 3                 NA               NA                      NA
## 4                 NA               NA                      NA
## 5                 NA               NA                      NA
## 6                 NA               NA                      NA
##   Interpolated.CDS.Basis Interpolated.CDS.Spread Closest.to.Maturity.CDS.Basis
## 1                     NA                       NA                            NA
## 2                     NA                       NA                            NA
## 3                     NA                       NA                            NA
## 4                     NA                       NA                            NA
## 5                     NA                       NA                            NA
## 6                     NA                       NA                            NA
##   Delta Fair.Price Bond.Floor Edge YTW YTB Simple.Margin Discount.Margin
## 1    NA         NA         NA   NA  NA  NA            NA              NA
## 2    NA         NA         NA   NA  NA  NA            NA              NA
## 3    NA         NA         NA   NA  NA  NA            NA              NA
## 4    NA         NA         NA   NA  NA  NA            NA              NA
## 5    NA         NA         NA   NA  NA  NA            NA              NA
## 6    NA         NA         NA   NA  NA  NA            NA              NA
##   X1M.Basis.Asset.Swap.Spread X3M.Basis.Asset.Swap.Spread
## 1                          NA                          NA
## 2                          NA                          NA
## 3                          NA                          NA
## 4                          NA                          NA
## 5                          NA                          NA
## 6                          NA                          NA
##   X6M.Basis.Asset.Swap.Spread Accumulated.Ask.Order Accumulated.Ask.Order.Size
## 1                          NA                    NA                         NA
## 2                          NA                    NA                         NA
## 3                          NA                    NA                         NA
## 4                          NA                    NA                         NA
## 5                          NA                    NA                         NA
## 6                          NA                    NA                         NA
##   Accumulated.Bid.Order Accumulated.Bid.Order.Size Ask.Compound.Yield
## 1                    NA                         NA                 NA
## 2                    NA                         NA                 NA
## 3                    NA                         NA                 NA
## 4                    NA                         NA                 NA
## 5                    NA                         NA                 NA
## 6                    NA                         NA                 NA
##   Ask.Dealer.Count Ask.Market.Maker.Id Asset.Swap.Spread.Ask
## 1               NA                                        NA
## 2               NA                                        NA
## 3               NA                                        NA
## 4               NA                                        NA
## 5               NA                                        NA
## 6               NA                                        NA
##   Asset.Swap.Spread.Bid Average.Price Base.Correlation Basis.Point.Volatility
## 1                    NA            NA               NA                     NA
## 2                    NA            NA               NA                     NA
## 3                    NA            NA               NA                     NA
## 4                    NA            NA               NA                     NA
## 5                    NA            NA               NA                     NA
```

```
## 6                    NA             NA                NA                      NA
##   Benchmark.Spread.Ask Benchmark.Spread.Bid Benchmark.Yield Bid.Compound.Yield
## 1                   NA                   NA              NA                 NA
## 2                   NA                   NA              NA                 NA
## 3                   NA                   NA              NA                 NA
## 4                   NA                   NA              NA                 NA
## 5                   NA                   NA              NA                 NA
## 6                   NA                   NA              NA                 NA
##   Bid.Dealer.Count Bid.Market.Maker.Id Breakeven.Inflation Cap.Premium
## 1               NA                                      NA          NA
## 2               NA                                      NA          NA
## 3               NA                                      NA          NA
## 4               NA                                      NA          NA
## 5               NA                                      NA          NA
## 6               NA                                      NA          NA
##   Carry.Roll.down.Total CDS.Dollar.Value.Of.1.Basis.Pt Commodity.Basis
## 1                    NA                             NA              NA
## 2                    NA                             NA              NA
## 3                    NA                             NA              NA
## 4                    NA                             NA              NA
## 5                    NA                             NA              NA
## 6                    NA                             NA              NA
##   Compound.Yield Constant.Maturity.Yield Conversion.Factor Convexity.Bias
## 1             NA                      NA                NA             NA
## 2             NA                      NA                NA             NA
## 3             NA                      NA                NA             NA
## 4             NA                      NA                NA             NA
## 5             NA                      NA                NA             NA
## 6             NA                      NA                NA             NA
##   Cost.of.Carry Daily.Quota.Remaining.Balance Dealing.Code Default.Probability
## 1            NA                            NA           NA                  NA
## 2            NA                            NA           NA                  NA
## 3            NA                            NA           NA                  NA
## 4            NA                            NA           NA                  NA
## 5            NA                            NA           NA                  NA
## 6            NA                            NA           NA                  NA
##   Discount.Ask Discount.Bid Discount.Factor Discount.Margin.Ask
## 1           NA           NA              NA                  NA
## 2           NA           NA              NA                  NA
## 3           NA           NA              NA                  NA
## 4           NA           NA              NA                  NA
## 5           NA           NA              NA                  NA
## 6           NA           NA              NA                  NA
##   Discount.Margin.Bid Discount.Rate Display.Name Energy.Netback Energy.Swing
## 1                  NA            NA           NA             NA           NA
## 2                  NA            NA           NA             NA           NA
## 3                  NA            NA           NA             NA           NA
## 4                  NA            NA           NA             NA           NA
## 5                  NA            NA           NA             NA           NA
## 6                  NA            NA           NA             NA           NA
##   Energy.Variance Exch.For.Physical.Vol Exch.For.Swaps.Vol
## 1              NA                    NA                 NA
## 2              NA                    NA                 NA
## 3              NA                    NA                 NA
```

```
## 4             NA                    NA                NA
## 5             NA                    NA                NA
## 6             NA                    NA                NA
##   Final.Physical.Notification Fixed.Coupon Fixing.Date Fixing.Value
## 1                          NA           NA          NA           NA
## 2                          NA           NA          NA           NA
## 3                          NA           NA          NA           NA
## 4                          NA           NA          NA           NA
## 5                          NA           NA          NA           NA
## 6                          NA           NA          NA           NA
##   Floor.Premium Forecast.Avg.Swap.Pts Forecast.Mean Forecast.Median
## 1            NA                    NA            NA              NA
## 2            NA                    NA            NA              NA
## 3            NA                    NA            NA              NA
## 4            NA                    NA            NA              NA
## 5            NA                    NA            NA              NA
## 6            NA                    NA            NA              NA
##   Forecast.Std.Deviation Forward.Rate Futures.Basis Futures.Risk
## 1                     NA           NA            NA           NA
## 2                     NA           NA            NA           NA
## 3                     NA           NA            NA           NA
## 4                     NA           NA            NA           NA
## 5                     NA           NA            NA           NA
## 6                     NA           NA            NA           NA
##   Fwd.Outright.Ask Fwd.Outright.Bid Gamma Implied.Correlation Implied.Repo.Rate
## 1               NA               NA    NA                  NA                NA
## 2               NA               NA    NA                  NA                NA
## 3               NA               NA    NA                  NA                NA
## 4               NA               NA    NA                  NA                NA
## 5               NA               NA    NA                  NA                NA
## 6               NA               NA    NA                  NA                NA
##   Implied.Yield Index.Skew Max.Export.Limit Max.Import.Limit Mean.Reversion
## 1            NA         NA               NA               NA             NA
## 2            NA         NA               NA               NA             NA
## 3            NA         NA               NA               NA             NA
## 4            NA         NA               NA               NA             NA
## 5            NA         NA               NA               NA             NA
## 6            NA         NA               NA               NA             NA
##   Mid.Spread Mid.Yield Number.of.Trades Odd.Lot.Trade.Price
## 1         NA        NA               NA                  NA
## 2         NA        NA               NA                  NA
## 3         NA        NA               NA                  NA
## 4         NA        NA               NA                  NA
## 5         NA        NA               NA                  NA
## 6         NA        NA               NA                  NA
##   Odd.Lot.Trade.Turnover Odd.Lot.Trade.Volume Option.Adjusted.Spread
## 1                     NA                   NA                     NA
## 2                     NA                   NA                     NA
## 3                     NA                   NA                     NA
## 4                     NA                   NA                     NA
## 5                     NA                   NA                     NA
## 6                     NA                   NA                     NA
##   Option.Adjusted.Spread.Ask Orderbook.VWAP Original.Acc..Volume Original.Yield
## 1                         NA             NA                   NA             NA
```

```
## 2                         NA             NA                   NA             NA
## 3                         NA             NA                   NA             NA
## 4                         NA             NA                   NA             NA
## 5                         NA             NA                   NA             NA
## 6                         NA             NA                   NA             NA
##   Par.Yield Present.Value.of.Basis.Point Quscnt.Physical.Notification
## 1        NA                           NA                           NA
## 2        NA                           NA                           NA
## 3        NA                           NA                           NA
## 4        NA                           NA                           NA
## 5        NA                           NA                           NA
## 6        NA                           NA                           NA
##   Real.Yield.Ask Real.Yield.Bid Recovery.Rate Reference.Bond.Yield
## 1             NA             NA            NA                   NA
## 2             NA             NA            NA                   NA
## 3             NA             NA            NA                   NA
## 4             NA             NA            NA                   NA
## 5             NA             NA            NA                   NA
## 6             NA             NA            NA                   NA
##   Refinery.Mgn.Crack Refinery.Mgn.Top Reserve.Vol Roll.down Running.Spread
## 1                 NA               NA          NA        NA             NA
## 2                 NA               NA          NA        NA             NA
## 3                 NA               NA          NA        NA             NA
## 4                 NA               NA          NA        NA             NA
## 5                 NA               NA          NA        NA             NA
## 6                 NA               NA          NA        NA             NA
##   Seasonal.Normal.Demand Short.Rate.Volatility Source.Reference
## 1                     NA                    NA               NA
## 2                     NA                    NA               NA
## 3                     NA                    NA               NA
## 4                     NA                    NA               NA
## 5                     NA                    NA               NA
## 6                     NA                    NA               NA
##   Sovereign.Spread Swap.Premium Swap.Rate Swap.Spread.Ask Swap.Spread.Bid
## 1               NA           NA        NA              NA              NA
## 2               NA           NA        NA              NA              NA
## 3               NA           NA        NA              NA              NA
## 4               NA           NA        NA              NA              NA
## 5               NA           NA        NA              NA              NA
## 6               NA           NA        NA              NA              NA
##   Swap.Yield Theoretical.Price.Ask Theoretical.Price.Bid Theoretical.Price.Mid
## 1         NA                    NA                    NA                    NA
## 2         NA                    NA                    NA                    NA
## 3         NA                    NA                    NA                    NA
## 4         NA                    NA                    NA                    NA
## 5         NA                    NA                    NA                    NA
## 6         NA                    NA                    NA                    NA
##   Theoretical.Spread.Ask Theoretical.Spread.Bid Theoretical.Spread.Mid Theta
## 1                     NA                     NA                     NA    NA
## 2                     NA                     NA                     NA    NA
## 3                     NA                     NA                     NA    NA
## 4                     NA                     NA                     NA    NA
## 5                     NA                     NA                     NA    NA
## 6                     NA                     NA                     NA    NA
```

```
##   Total.Buy.Value Total.Buy.Volume Total.Demand Total.Sell.Value
## 1              NA               NA           NA               NA
## 2              NA               NA           NA               NA
## 3              NA               NA           NA               NA
## 4              NA               NA           NA               NA
## 5              NA               NA           NA               NA
## 6              NA               NA           NA               NA
##   Total.Sell.Volume Trade.Price.Currency Unique.Trade.Identification
## 1                NA                   NA                          NA
## 2                NA                   NA                          NA
## 3                NA                   NA                          NA
## 4                NA                   NA                          NA
## 5                NA                   NA                          NA
## 6                NA                   NA                          NA
##   Yield.To.Call Yield.to.Maturity Yield.to.Maturity.Ask Yield.to.Maturity.Bid
## 1            NA                NA                    NA                    NA
## 2            NA                NA                    NA                    NA
## 3            NA                NA                    NA                    NA
## 4            NA                NA                    NA                    NA
## 5            NA                NA                    NA                    NA
## 6            NA                NA                    NA                    NA
##   Yield.To.Put Zero.Yield Aggressive.Order.Condition Categorisation.of.Trades
## 1           NA         NA                         NA                       NA
## 2           NA         NA                         NA                       NA
## 3           NA         NA                         NA                       NA
## 4           NA         NA                         NA                       NA
## 5           NA         NA                         NA                       NA
## 6           NA         NA                         NA                       NA
##   Effective.Convexity Effective.Duration Fair.Value Fair.Value.Accuracy.Measure
## 1                  NA                 NA         NA                          NA
## 2                  NA                 NA         NA                          NA
## 3                  NA                 NA         NA                          NA
## 4                  NA                 NA         NA                          NA
## 5                  NA                 NA         NA                          NA
## 6                  NA                 NA         NA                          NA
##   Fair.Value.Consistency.Score Fair.Value.DV01 Fair.Value.Spread
## 1                           NA              NA                NA
## 2                           NA              NA                NA
## 3                           NA              NA                NA
## 4                           NA              NA                NA
## 5                           NA              NA                NA
## 6                           NA              NA                NA
##   Fair.Value.Volume Fair.Value.Yield Flows Forward.Future.Risk Gross.Basis
## 1                NA               NA    NA                  NA          NA
## 2                NA               NA    NA                  NA          NA
## 3                NA               NA    NA                  NA          NA
## 4                NA               NA    NA                  NA          NA
## 5                NA               NA    NA                  NA          NA
## 6                NA               NA    NA                  NA          NA
##   Halt.Reason Hedge.Ratio Imbalance.Activity.Type Imbalance.Side
## 1          NA          NA                      NA             NA
## 2          NA          NA                      NA             NA
## 3          NA          NA                      NA             NA
## 4          NA          NA                      NA             NA
```

```
## 5          NA          NA                       NA             NA
## 6          NA          NA                       NA             NA
##   Imbalance.Variation.Indicator Indicative.Auction.Price
## 1                            NA                       NA
## 2                            NA                       NA
## 3                            NA                       NA
## 4                            NA                       NA
## 5                            NA                       NA
## 6                            NA                       NA
##   Indicative.Auction.Volume Instrument.Description Invoice.Price Invoice.Spread
## 1                        NA                     NA            NA             NA
## 2                        NA                     NA            NA             NA
## 3                        NA                     NA            NA             NA
## 4                        NA                     NA            NA             NA
## 5                        NA                     NA            NA             NA
## 6                        NA                     NA            NA             NA
##   LULD.Indicator MMT.Classification Net.Basis Net.Change Original.Buyer.Id
## 1                                NA        NA         NA                NA
## 2                                NA        NA         NA                NA
## 3                                NA        NA         NA                NA
## 4                                NA        NA         NA                NA
## 5                                NA        NA         NA                NA
## 6                                NA        NA         NA                NA
##   Original.Primary.Activity Original.RIC.of.Last.Eligible.Trade
## 1                        NA                                  NA
## 2                        NA                                  NA
## 3                        NA                                  NA
## 4                        NA                                  NA
## 5                        NA                                  NA
## 6                        NA                                  NA
##   Original.Seller.Id Original.Trade.Sequence.Number
## 1                 NA                             NA
## 2                 NA                             NA
## 3                 NA                             NA
## 4                 NA                             NA
## 5                 NA                             NA
## 6                 NA                             NA
##   Original.Unique.Trade.Identification Primary.Activity
## 1                                   NA               NA
## 2                                   NA               NA
## 3                                   NA               NA
## 4                                   NA               NA
## 5                                   NA               NA
## 6                                   NA               NA
##   RIC.of.Last.Eligible.Trade Short.Sale.Restriction.Indicator
## 1                         NA
## 2                         NA
## 3                         NA
## 4                         NA                                N
## 5                         NA
## 6                         NA                                N
##   Spread.to.Treasury Trade.Sequence.Number Trade.Yield Trading.Status
## 1                 NA                    NA          NA             NA
## 2                 NA                    NA          NA             NA
```

```
## 3                  NA                     NA           NA              NA
## 4                  NA                     NA           NA              NA
## 5                  NA                     NA           NA              NA
## 6                  NA                     NA           NA              NA
##   Change.Type Old.Value New.Value ISIN Unique.Quote.Identification Rho Vega
## 1          NA        NA        NA   NA                          NA  NA   NA
## 2          NA        NA        NA   NA                          NA  NA   NA
## 3          NA        NA        NA   NA                          NA  NA   NA
## 4          NA        NA        NA   NA                          NA  NA   NA
## 5          NA        NA        NA   NA                          NA  NA   NA
## 6          NA        NA        NA   NA                          NA  NA   NA
```

```r
tail(data)
```

```
##          X.RIC Alias.Underlying.RIC       Domain
## 2485749 AMZN.O                   NA Market Price
## 2485750 AMZN.O                   NA Market Price
## 2485751 AMZN.O                   NA Market Price
## 2485752 AMZN.O                   NA Market Price
## 2485753 AMZN.O                   NA Market Price
## 2485754 AMZN.O                   NA Market Price
##                                Date.Time           Type Ex.Cntrb.ID LOC Price
## 2485749 2023-01-04T19:59:56.784115908-05          Trade         ADF  NA  86.6
## 2485750 2023-01-04T19:59:58.467762816-05          Quote              NA    NA
## 2485751 2023-01-04T19:59:59.587878662-05          Quote              NA    NA
## 2485752 2023-01-04T19:59:59.735352466-05          Quote              NA    NA
## 2485753 2023-01-04T20:00:00.075582497-05 Mkt. Condition              NA    NA
## 2485754 2023-01-04T20:37:56.843389994-05          Trade              NA    NA
##         Volume Market.VWAP Buyer.ID Bid.Price Bid.Size No..Buyers Seller.ID
## 2485749    200          NA              86.55       32         NA
## 2485750     NA          NA      PSE     86.55       42         NA       PSE
## 2485751     NA          NA      PSE     86.55       42         NA       PSE
## 2485752     NA          NA      PSE     86.55       42         NA       PSE
## 2485753     NA          NA                 NA       NA         NA
## 2485754     NA          NA                 NA       NA         NA
##         Ask.Price Ask.Size No..Sellers
## 2485749     86.60       29          NA
## 2485750     86.60       29          NA
## 2485751     86.60       28          NA
## 2485752     86.57        9          NA
## 2485753        NA       NA          NA
## 2485754        NA       NA          NA
##                                                        Qualifiers Seq..No.
## 2485749       Q[IRG_SUBIND];@ T[GV4_TEXT];132[IRGCOND];[GV3_TEXT]  6086672
## 2485750                            [PRC_QL_CD];   [PRC_QL3];[GV1_TEXT]       NA
## 2485751                            [PRC_QL_CD];   [PRC_QL3];[GV1_TEXT]       NA
## 2485752                            [PRC_QL_CD];   [PRC_QL3];[GV1_TEXT]       NA
## 2485753 C  [INST_PHASE];CX[PERIOD_CDE];CX[PERIOD_CD2];AGX[PRC_QL2]       NA
## 2485754                                                                  NA
##                  Exch.Time Block.Trd PE.Ratio Yield Bid.Yld Ask.Yld
## 2485749 00:59:56.768000000        NA       NA    NA      NA      NA
## 2485750 00:59:58.453000000        NA       NA    NA      NA      NA
## 2485751 00:59:59.570000000        NA       NA    NA      NA      NA
## 2485752 00:59:59.720000000        NA       NA    NA      NA      NA
## 2485753                           NA       NA    NA      NA      NA
```

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## 2485754                          NA       NA    NA      NA      NA
##         ISMA.Bid.Yld ISMA.Ask.Yld Duration Mod.Durtn BPV Convexity Bench.Spd
## 2485749           NA           NA       NA        NA  NA        NA        NA
## 2485750           NA           NA       NA        NA  NA        NA        NA
## 2485751           NA           NA       NA        NA  NA        NA        NA
## 2485752           NA           NA       NA        NA  NA        NA        NA
## 2485753           NA           NA       NA        NA  NA        NA        NA
## 2485754           NA           NA       NA        NA  NA        NA        NA
##         Swp.Spd Asst.Swp.Spd Swap.Point UpLim.Price LoLim.Price Theo..Price
## 2485749      NA           NA         NA           0           0          NA
## 2485750      NA           NA         NA           0           0          NA
## 2485751      NA           NA         NA           0           0          NA
## 2485752      NA           NA         NA           0           0          NA
## 2485753      NA           NA         NA          NA          NA          NA
## 2485754      NA           NA         NA          NA          NA          NA
##         Parity Premium Bid.Imp..Vol Ask.Imp..Vol Imp..Vol. Crack Top
## 2485749     NA      NA           NA           NA        NA    NA  NA
## 2485750     NA      NA           NA           NA        NA    NA  NA
## 2485751     NA      NA           NA           NA        NA    NA  NA
## 2485752     NA      NA           NA           NA        NA    NA  NA
## 2485753     NA      NA           NA           NA        NA    NA  NA
## 2485754     NA      NA           NA           NA    0.5299    NA  NA
##         Freight.Pr. Offer Actual Prior Revised Forecast Frcst.High Frcst.Low
## 2485749          NA    NA     NA    NA      NA       NA         NA        NA
## 2485750          NA    NA     NA    NA      NA       NA         NA        NA
## 2485751          NA    NA     NA    NA      NA       NA         NA        NA
## 2485752          NA    NA     NA    NA      NA       NA         NA        NA
## 2485753          NA    NA     NA    NA      NA       NA         NA        NA
## 2485754          NA    NA     NA    NA      NA       NA         NA        NA
##         No..Frcts       Date Bid.Tic Tick.Dir.  Open  High   Low Open.Interest
## 2485749        NA 2023-01-05      NA           86.55 86.98 83.36            NA
## 2485750        NA 2023-01-05      NA              NA    NA    NA            NA
## 2485751        NA 2023-01-05      NA              NA    NA    NA            NA
## 2485752        NA 2023-01-05      NA              NA    NA    NA            NA
## 2485753        NA                 NA              NA    NA    NA            NA
## 2485754        NA                 NA              NA    NA    NA            NA
##         Bench.Price Open.Yld High.Yld Low.Yld Acc..Volume Turnover Volatility
## 2485749          NA       NA       NA      NA    68885123       NA         NA
## 2485750          NA       NA       NA      NA          NA       NA         NA
## 2485751          NA       NA       NA      NA          NA       NA         NA
## 2485752          NA       NA       NA      NA          NA       NA         NA
## 2485753          NA       NA       NA      NA          NA       NA         NA
## 2485754          NA       NA       NA      NA          NA       NA         NA
##         Strike Mid.Price Advancing.Issues Declining.Issues Unchanged.Issues
## 2485749     NA        NA               NA               NA               NA
## 2485750     NA        NA               NA               NA               NA
## 2485751     NA        NA               NA               NA               NA
## 2485752     NA        NA               NA               NA               NA
## 2485753     NA        NA               NA               NA               NA
## 2485754     NA        NA               NA               NA               NA
##         Total.Issues Advancing.Volume Declining.Volume Unchanged.Volume
## 2485749           NA               NA               NA               NA
## 2485750           NA               NA               NA               NA
## 2485751           NA               NA               NA               NA
```

```
## 2485752          NA               NA               NA               NA
## 2485753          NA               NA               NA               NA
## 2485754          NA               NA               NA               NA
##         Total.Volume New.Highs New.Lows Total.Moves Percentage.Change
## 2485749           NA        NA       NA          NA                NA
## 2485750           NA        NA       NA          NA                NA
## 2485751           NA        NA       NA          NA                NA
## 2485752           NA        NA       NA          NA                NA
## 2485753           NA        NA       NA          NA                NA
## 2485754           NA        NA       NA          NA                NA
##         Advancing.Moves Declining.Moves Unchanged.Moves Strong.Market
## 2485749              NA              NA              NA            NA
## 2485750              NA              NA              NA            NA
## 2485751              NA              NA              NA            NA
## 2485752              NA              NA              NA            NA
## 2485753              NA              NA              NA            NA
## 2485754              NA              NA              NA            NA
##         Weak.Market Changed.Market Market.Volatility Original.Date Final.NAV
## 2485749          NA             NA                NA            NA        NA
## 2485750          NA             NA                NA            NA        NA
## 2485751          NA             NA                NA            NA        NA
## 2485752          NA             NA                NA            NA        NA
## 2485753          NA             NA                NA            NA        NA
## 2485754          NA             NA                NA            NA        NA
##         X30.Day.ATM.IV.Call X60.Day.ATM.IV.Call X90.Day.ATM.IV.Call
## 2485749                  NA                  NA                  NA
## 2485750                  NA                  NA                  NA
## 2485751                  NA                  NA                  NA
## 2485752                  NA                  NA                  NA
## 2485753                  NA                  NA                  NA
## 2485754                  NA                  NA                  NA
##         X30.Day.ATM.IV.Put X60.Day.ATM.IV.Put X90.Day.ATM.IV.Put
## 2485749                 NA                 NA                 NA
## 2485750                 NA                 NA                 NA
## 2485751                 NA                 NA                 NA
## 2485752                 NA                 NA                 NA
## 2485753                 NA                 NA                 NA
## 2485754                 NA                 NA                 NA
##         Background.Reference Original.Price Original.Volume Original.Seq..No.
## 2485749                   NA             NA              NA                NA
## 2485750                   NA             NA              NA                NA
## 2485751                   NA             NA              NA                NA
## 2485752                   NA             NA              NA                NA
## 2485753                   NA             NA              NA                NA
## 2485754                   NA             NA              NA                NA
##         Original.Exch.Time Bid.Spread Ask.Spread Reference.Price
## 2485749                 NA         NA         NA              NA
## 2485750                 NA         NA         NA              NA
## 2485751                 NA         NA         NA              NA
## 2485752                 NA         NA         NA              NA
## 2485753                 NA         NA         NA              NA
## 2485754                 NA         NA         NA              NA
##         Paired.Quantity Imbalance.Quantity Far.Clearing.Price
## 2485749              NA                 NA                 NA
```

```
## 2485750             NA                 NA                 NA
## 2485751             NA                 NA                 NA
## 2485752             NA                 NA                 NA
## 2485753             NA                 NA                 NA
## 2485754             NA                 NA                 NA
##         Near.Clearing.Price Option.Adjusted.Spread.Bid Z.Spread
## 2485749                  NA                         NA       NA
## 2485750                  NA                         NA       NA
## 2485751                  NA                         NA       NA
## 2485752                  NA                         NA       NA
## 2485753                  NA                         NA       NA
## 2485754                  NA                         NA       NA
##         Conversion.Premium Conversion.Ratio Percentage.Daily.Return
## 2485749                 NA               NA                      NA
## 2485750                 NA               NA                      NA
## 2485751                 NA               NA                      NA
## 2485752                 NA               NA                      NA
## 2485753                 NA               NA                      NA
## 2485754                 NA               NA                      NA
##         Interpolated.CDS.Basis Interpolated.CDS.Spread
## 2485749                     NA                      NA
## 2485750                     NA                      NA
## 2485751                     NA                      NA
## 2485752                     NA                      NA
## 2485753                     NA                      NA
## 2485754                     NA                      NA
##         Closest.to.Maturity.CDS.Basis Delta Fair.Price Bond.Floor Edge YTW YTB
## 2485749                            NA    NA         NA         NA   NA  NA  NA
## 2485750                            NA    NA         NA         NA   NA  NA  NA
## 2485751                            NA    NA         NA         NA   NA  NA  NA
## 2485752                            NA    NA         NA         NA   NA  NA  NA
## 2485753                            NA    NA         NA         NA   NA  NA  NA
## 2485754                            NA    NA         NA         NA   NA  NA  NA
##         Simple.Margin Discount.Margin X1M.Basis.Asset.Swap.Spread
## 2485749            NA              NA                          NA
## 2485750            NA              NA                          NA
## 2485751            NA              NA                          NA
## 2485752            NA              NA                          NA
## 2485753            NA              NA                          NA
## 2485754            NA              NA                          NA
##         X3M.Basis.Asset.Swap.Spread X6M.Basis.Asset.Swap.Spread
## 2485749                          NA                          NA
## 2485750                          NA                          NA
## 2485751                          NA                          NA
## 2485752                          NA                          NA
## 2485753                          NA                          NA
## 2485754                          NA                          NA
##         Accumulated.Ask.Order Accumulated.Ask.Order.Size Accumulated.Bid.Order
## 2485749                    NA                         NA                    NA
## 2485750                    NA                         NA                    NA
## 2485751                    NA                         NA                    NA
## 2485752                    NA                         NA                    NA
## 2485753                    NA                         NA                    NA
## 2485754                    NA                         NA                    NA
```

```
##         Accumulated.Bid.Order.Size Ask.Compound.Yield Ask.Dealer.Count
## 2485749                         NA                 NA               NA
## 2485750                         NA                 NA               NA
## 2485751                         NA                 NA               NA
## 2485752                         NA                 NA               NA
## 2485753                         NA                 NA               NA
## 2485754                         NA                 NA               NA
##         Ask.Market.Maker.Id Asset.Swap.Spread.Ask Asset.Swap.Spread.Bid
## 2485749                                        NA                    NA
## 2485750                 PSE                    NA                    NA
## 2485751                 PSE                    NA                    NA
## 2485752                 PSE                    NA                    NA
## 2485753                                        NA                    NA
## 2485754                                        NA                    NA
##         Average.Price Base.Correlation Basis.Point.Volatility
## 2485749            NA               NA                     NA
## 2485750            NA               NA                     NA
## 2485751            NA               NA                     NA
## 2485752            NA               NA                     NA
## 2485753            NA               NA                     NA
## 2485754            NA               NA                     NA
##         Benchmark.Spread.Ask Benchmark.Spread.Bid Benchmark.Yield
## 2485749                   NA                   NA              NA
## 2485750                   NA                   NA              NA
## 2485751                   NA                   NA              NA
## 2485752                   NA                   NA              NA
## 2485753                   NA                   NA              NA
## 2485754                   NA                   NA              NA
##         Bid.Compound.Yield Bid.Dealer.Count Bid.Market.Maker.Id
## 2485749                 NA               NA
## 2485750                 NA               NA                 PSE
## 2485751                 NA               NA                 PSE
## 2485752                 NA               NA                 PSE
## 2485753                 NA               NA
## 2485754                 NA               NA
##         Breakeven.Inflation Cap.Premium Carry.Roll.down.Total
## 2485749                  NA          NA                    NA
## 2485750                  NA          NA                    NA
## 2485751                  NA          NA                    NA
## 2485752                  NA          NA                    NA
## 2485753                  NA          NA                    NA
## 2485754                  NA          NA                    NA
##         CDS.Dollar.Value.Of.1.Basis.Pt Commodity.Basis Compound.Yield
## 2485749                             NA              NA             NA
## 2485750                             NA              NA             NA
## 2485751                             NA              NA             NA
## 2485752                             NA              NA             NA
## 2485753                             NA              NA             NA
## 2485754                             NA              NA             NA
##         Constant.Maturity.Yield Conversion.Factor Convexity.Bias Cost.of.Carry
## 2485749                      NA                NA             NA            NA
## 2485750                      NA                NA             NA            NA
## 2485751                      NA                NA             NA            NA
## 2485752                      NA                NA             NA            NA
```

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## 2485753                      NA                NA              NA             NA
## 2485754                      NA                NA              NA             NA
##         Daily.Quota.Remaining.Balance Dealing.Code Default.Probability
## 2485749                            NA           NA                  NA
## 2485750                            NA           NA                  NA
## 2485751                            NA           NA                  NA
## 2485752                            NA           NA                  NA
## 2485753                            NA           NA                  NA
## 2485754                            NA           NA                  NA
##         Discount.Ask Discount.Bid Discount.Factor Discount.Margin.Ask
## 2485749           NA           NA              NA                  NA
## 2485750           NA           NA              NA                  NA
## 2485751           NA           NA              NA                  NA
## 2485752           NA           NA              NA                  NA
## 2485753           NA           NA              NA                  NA
## 2485754           NA           NA              NA                  NA
##         Discount.Margin.Bid Discount.Rate Display.Name Energy.Netback
## 2485749                  NA            NA           NA             NA
## 2485750                  NA            NA           NA             NA
## 2485751                  NA            NA           NA             NA
## 2485752                  NA            NA           NA             NA
## 2485753                  NA            NA           NA             NA
## 2485754                  NA            NA           NA             NA
##         Energy.Swing Energy.Variance Exch.For.Physical.Vol Exch.For.Swaps.Vol
## 2485749           NA              NA                    NA                 NA
## 2485750           NA              NA                    NA                 NA
## 2485751           NA              NA                    NA                 NA
## 2485752           NA              NA                    NA                 NA
## 2485753           NA              NA                    NA                 NA
## 2485754           NA              NA                    NA                 NA
##         Final.Physical.Notification Fixed.Coupon Fixing.Date Fixing.Value
## 2485749                          NA           NA          NA           NA
## 2485750                          NA           NA          NA           NA
## 2485751                          NA           NA          NA           NA
## 2485752                          NA           NA          NA           NA
## 2485753                          NA           NA          NA           NA
## 2485754                          NA           NA          NA           NA
##         Floor.Premium Forecast.Avg.Swap.Pts Forecast.Mean Forecast.Median
## 2485749            NA                    NA            NA              NA
## 2485750            NA                    NA            NA              NA
## 2485751            NA                    NA            NA              NA
## 2485752            NA                    NA            NA              NA
## 2485753            NA                    NA            NA              NA
## 2485754            NA                    NA            NA              NA
##         Forecast.Std.Deviation Forward.Rate Futures.Basis Futures.Risk
## 2485749                     NA           NA            NA           NA
## 2485750                     NA           NA            NA           NA
## 2485751                     NA           NA            NA           NA
## 2485752                     NA           NA            NA           NA
## 2485753                     NA           NA            NA           NA
## 2485754                     NA           NA            NA           NA
##         Fwd.Outright.Ask Fwd.Outright.Bid Gamma Implied.Correlation
## 2485749               NA               NA    NA                  NA
## 2485750               NA               NA    NA                  NA
```

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## 2485751               NA               NA    NA                NA
## 2485752               NA               NA    NA                NA
## 2485753               NA               NA    NA                NA
## 2485754               NA               NA    NA                NA
##         Implied.Repo.Rate Implied.Yield Index.Skew Max.Export.Limit
## 2485749                NA            NA         NA               NA
## 2485750                NA            NA         NA               NA
## 2485751                NA            NA         NA               NA
## 2485752                NA            NA         NA               NA
## 2485753                NA            NA         NA               NA
## 2485754                NA            NA         NA               NA
##         Max.Import.Limit Mean.Reversion Mid.Spread Mid.Yield Number.of.Trades
## 2485749               NA             NA         NA        NA               NA
## 2485750               NA             NA         NA        NA               NA
## 2485751               NA             NA         NA        NA               NA
## 2485752               NA             NA         NA        NA               NA
## 2485753               NA             NA         NA        NA               NA
## 2485754               NA             NA         NA        NA               NA
##         Odd.Lot.Trade.Price Odd.Lot.Trade.Turnover Odd.Lot.Trade.Volume
## 2485749                  NA                     NA                   NA
## 2485750                  NA                     NA                   NA
## 2485751                  NA                     NA                   NA
## 2485752                  NA                     NA                   NA
## 2485753                  NA                     NA                   NA
## 2485754                  NA                     NA                   NA
##         Option.Adjusted.Spread Option.Adjusted.Spread.Ask Orderbook.VWAP
## 2485749                     NA                         NA             NA
## 2485750                     NA                         NA             NA
## 2485751                     NA                         NA             NA
## 2485752                     NA                         NA             NA
## 2485753                     NA                         NA             NA
## 2485754                     NA                         NA             NA
##         Original.Acc..Volume Original.Yield Par.Yield
## 2485749                   NA             NA        NA
## 2485750                   NA             NA        NA
## 2485751                   NA             NA        NA
## 2485752                   NA             NA        NA
## 2485753                   NA             NA        NA
## 2485754                   NA             NA        NA
##         Present.Value.of.Basis.Point Quscnt.Physical.Notification
## 2485749                           NA                           NA
## 2485750                           NA                           NA
## 2485751                           NA                           NA
## 2485752                           NA                           NA
## 2485753                           NA                           NA
## 2485754                           NA                           NA
##         Real.Yield.Ask Real.Yield.Bid Recovery.Rate Reference.Bond.Yield
## 2485749             NA             NA            NA                   NA
## 2485750             NA             NA            NA                   NA
## 2485751             NA             NA            NA                   NA
## 2485752             NA             NA            NA                   NA
## 2485753             NA             NA            NA                   NA
## 2485754             NA             NA            NA                   NA
##         Refinery.Mgn.Crack Refinery.Mgn.Top Reserve.Vol Roll.down
```

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## 2485749              NA              NA          NA        NA
## 2485750              NA              NA          NA        NA
## 2485751              NA              NA          NA        NA
## 2485752              NA              NA          NA        NA
## 2485753              NA              NA          NA        NA
## 2485754              NA              NA          NA        NA
##         Running.Spread Seasonal.Normal.Demand Short.Rate.Volatility
## 2485749           NA                    NA                    NA
## 2485750           NA                    NA                    NA
## 2485751           NA                    NA                    NA
## 2485752           NA                    NA                    NA
## 2485753           NA                    NA                    NA
## 2485754           NA                    NA                    NA
##         Source.Reference Sovereign.Spread Swap.Premium Swap.Rate
## 2485749             NA               NA           NA        NA
## 2485750             NA               NA           NA        NA
## 2485751             NA               NA           NA        NA
## 2485752             NA               NA           NA        NA
## 2485753             NA               NA           NA        NA
## 2485754             NA               NA           NA        NA
##         Swap.Spread.Ask Swap.Spread.Bid Swap.Yield Theoretical.Price.Ask
## 2485749            NA              NA         NA                    NA
## 2485750            NA              NA         NA                    NA
## 2485751            NA              NA         NA                    NA
## 2485752            NA              NA         NA                    NA
## 2485753            NA              NA         NA                    NA
## 2485754            NA              NA         NA                    NA
##         Theoretical.Price.Bid Theoretical.Price.Mid Theoretical.Spread.Ask
## 2485749                  NA                    NA                     NA
## 2485750                  NA                    NA                     NA
## 2485751                  NA                    NA                     NA
## 2485752                  NA                    NA                     NA
## 2485753                  NA                    NA                     NA
## 2485754                  NA                    NA                     NA
##         Theoretical.Spread.Bid Theoretical.Spread.Mid Theta Total.Buy.Value
## 2485749                   NA                     NA    NA             NA
## 2485750                   NA                     NA    NA             NA
## 2485751                   NA                     NA    NA             NA
## 2485752                   NA                     NA    NA             NA
## 2485753                   NA                     NA    NA             NA
## 2485754                   NA                     NA    NA             NA
##         Total.Buy.Volume Total.Demand Total.Sell.Value Total.Sell.Volume
## 2485749             NA           NA               NA                NA
## 2485750             NA           NA               NA                NA
## 2485751             NA           NA               NA                NA
## 2485752             NA           NA               NA                NA
## 2485753             NA           NA               NA                NA
## 2485754             NA           NA               NA                NA
##         Trade.Price.Currency Unique.Trade.Identification Yield.To.Call
## 2485749                 NA                     213416            NA
## 2485750                 NA                         NA            NA
## 2485751                 NA                         NA            NA
## 2485752                 NA                         NA            NA
## 2485753                 NA                         NA            NA
```

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## 2485754                   NA                          NA            NA
##         Yield.to.Maturity Yield.to.Maturity.Ask Yield.to.Maturity.Bid
## 2485749                NA                    NA                    NA
## 2485750                NA                    NA                    NA
## 2485751                NA                    NA                    NA
## 2485752                NA                    NA                    NA
## 2485753                NA                    NA                    NA
## 2485754                NA                    NA                    NA
##         Yield.To.Put Zero.Yield Aggressive.Order.Condition
## 2485749           NA         NA                         NA
## 2485750           NA         NA                         NA
## 2485751           NA         NA                         NA
## 2485752           NA         NA                         NA
## 2485753           NA         NA                         NA
## 2485754           NA         NA                         NA
##         Categorisation.of.Trades Effective.Convexity Effective.Duration
## 2485749                       NA                  NA                 NA
## 2485750                       NA                  NA                 NA
## 2485751                       NA                  NA                 NA
## 2485752                       NA                  NA                 NA
## 2485753                       NA                  NA                 NA
## 2485754                       NA                  NA                 NA
##         Fair.Value Fair.Value.Accuracy.Measure Fair.Value.Consistency.Score
## 2485749         NA                          NA                           NA
## 2485750         NA                          NA                           NA
## 2485751         NA                          NA                           NA
## 2485752         NA                          NA                           NA
## 2485753         NA                          NA                           NA
## 2485754         NA                          NA                           NA
##         Fair.Value.DV01 Fair.Value.Spread Fair.Value.Volume Fair.Value.Yield
## 2485749              NA                NA                NA               NA
## 2485750              NA                NA                NA               NA
## 2485751              NA                NA                NA               NA
## 2485752              NA                NA                NA               NA
## 2485753              NA                NA                NA               NA
## 2485754              NA                NA                NA               NA
##         Flows Forward.Future.Risk Gross.Basis Halt.Reason Hedge.Ratio
## 2485749    NA                  NA          NA          NA          NA
## 2485750    NA                  NA          NA          NA          NA
## 2485751    NA                  NA          NA          NA          NA
## 2485752    NA                  NA          NA          NA          NA
## 2485753    NA                  NA          NA          NA          NA
## 2485754    NA                  NA          NA          NA          NA
##         Imbalance.Activity.Type Imbalance.Side Imbalance.Variation.Indicator
## 2485749                      NA             NA                            NA
## 2485750                      NA             NA                            NA
## 2485751                      NA             NA                            NA
## 2485752                      NA             NA                            NA
## 2485753                      NA             NA                            NA
## 2485754                      NA             NA                            NA
##         Indicative.Auction.Price Indicative.Auction.Volume
## 2485749                       NA                        NA
## 2485750                       NA                        NA
## 2485751                       NA                        NA
```

```
## 2485752                      NA                        NA
## 2485753                      NA                        NA
## 2485754                      NA                        NA
##         Instrument.Description Invoice.Price Invoice.Spread LULD.Indicator
## 2485749                     NA            NA             NA
## 2485750                     NA            NA             NA
## 2485751                     NA            NA             NA
## 2485752                     NA            NA             NA
## 2485753                     NA            NA             NA
## 2485754                     NA            NA             NA
##         MMT.Classification Net.Basis Net.Change Original.Buyer.Id
## 2485749                 NA        NA         NA                NA
## 2485750                 NA        NA         NA                NA
## 2485751                 NA        NA         NA                NA
## 2485752                 NA        NA         NA                NA
## 2485753                 NA        NA         NA                NA
## 2485754                 NA        NA         NA                NA
##         Original.Primary.Activity Original.RIC.of.Last.Eligible.Trade
## 2485749                        NA                                  NA
## 2485750                        NA                                  NA
## 2485751                        NA                                  NA
## 2485752                        NA                                  NA
## 2485753                        NA                                  NA
## 2485754                        NA                                  NA
##         Original.Seller.Id Original.Trade.Sequence.Number
## 2485749                 NA                             NA
## 2485750                 NA                             NA
## 2485751                 NA                             NA
## 2485752                 NA                             NA
## 2485753                 NA                             NA
## 2485754                 NA                             NA
##         Original.Unique.Trade.Identification Primary.Activity
## 2485749                                   NA               NA
## 2485750                                   NA               NA
## 2485751                                   NA               NA
## 2485752                                   NA               NA
## 2485753                                   NA               NA
## 2485754                                   NA               NA
##         RIC.of.Last.Eligible.Trade Short.Sale.Restriction.Indicator
## 2485749                         NA
## 2485750                         NA                                N
## 2485751                         NA                                N
## 2485752                         NA                                N
## 2485753                         NA
## 2485754                         NA
##         Spread.to.Treasury Trade.Sequence.Number Trade.Yield Trading.Status
## 2485749                 NA                    NA          NA             NA
## 2485750                 NA                    NA          NA             NA
## 2485751                 NA                    NA          NA             NA
## 2485752                 NA                    NA          NA             NA
## 2485753                 NA                    NA          NA             NA
## 2485754                 NA                    NA          NA             NA
##         Change.Type Old.Value New.Value ISIN Unique.Quote.Identification Rho
## 2485749          NA        NA        NA   NA                          NA  NA
```

```
## 2485750          NA         NA         NA   NA                            NA   NA
## 2485751          NA         NA         NA   NA                            NA   NA
## 2485752          NA         NA         NA   NA                            NA   NA
## 2485753          NA         NA         NA   NA                            NA   NA
## 2485754          NA         NA         NA   NA                            NA   NA
##         Vega
## 2485749   NA
## 2485750   NA
## 2485751   NA
## 2485752   NA
## 2485753   NA
## 2485754   NA
```

```r
# Display columns of dataset.
colnames(data)
```

```
##   [1] "X.RIC"
##   [2] "Alias.Underlying.RIC"
##   [3] "Domain"
##   [4] "Date.Time"
##   [5] "Type"
##   [6] "Ex.Cntrb.ID"
##   [7] "LOC"
##   [8] "Price"
##   [9] "Volume"
##  [10] "Market.VWAP"
##  [11] "Buyer.ID"
##  [12] "Bid.Price"
##  [13] "Bid.Size"
##  [14] "No..Buyers"
##  [15] "Seller.ID"
##  [16] "Ask.Price"
##  [17] "Ask.Size"
##  [18] "No..Sellers"
##  [19] "Qualifiers"
##  [20] "Seq..No."
##  [21] "Exch.Time"
##  [22] "Block.Trd"
##  [23] "PE.Ratio"
##  [24] "Yield"
##  [25] "Bid.Yld"
##  [26] "Ask.Yld"
##  [27] "ISMA.Bid.Yld"
##  [28] "ISMA.Ask.Yld"
##  [29] "Duration"
##  [30] "Mod.Durtn"
##  [31] "BPV"
##  [32] "Convexity"
##  [33] "Bench.Spd"
##  [34] "Swp.Spd"
##  [35] "Asst.Swp.Spd"
##  [36] "Swap.Point"
##  [37] "UpLim.Price"
##  [38] "LoLim.Price"
##  [39] "Theo..Price"
```

```
##  [40] "Parity"
##  [41] "Premium"
##  [42] "Bid.Imp..Vol"
##  [43] "Ask.Imp..Vol"
##  [44] "Imp..Vol."
##  [45] "Crack"
##  [46] "Top"
##  [47] "Freight.Pr."
##  [48] "Offer"
##  [49] "Actual"
##  [50] "Prior"
##  [51] "Revised"
##  [52] "Forecast"
##  [53] "Frcst.High"
##  [54] "Frcst.Low"
##  [55] "No..Frcts"
##  [56] "Date"
##  [57] "Bid.Tic"
##  [58] "Tick.Dir."
##  [59] "Open"
##  [60] "High"
##  [61] "Low"
##  [62] "Open.Interest"
##  [63] "Bench.Price"
##  [64] "Open.Yld"
##  [65] "High.Yld"
##  [66] "Low.Yld"
##  [67] "Acc..Volume"
##  [68] "Turnover"
##  [69] "Volatility"
##  [70] "Strike"
##  [71] "Mid.Price"
##  [72] "Advancing.Issues"
##  [73] "Declining.Issues"
##  [74] "Unchanged.Issues"
##  [75] "Total.Issues"
##  [76] "Advancing.Volume"
##  [77] "Declining.Volume"
##  [78] "Unchanged.Volume"
##  [79] "Total.Volume"
##  [80] "New.Highs"
##  [81] "New.Lows"
##  [82] "Total.Moves"
##  [83] "Percentage.Change"
##  [84] "Advancing.Moves"
##  [85] "Declining.Moves"
##  [86] "Unchanged.Moves"
##  [87] "Strong.Market"
##  [88] "Weak.Market"
##  [89] "Changed.Market"
##  [90] "Market.Volatility"
##  [91] "Original.Date"
##  [92] "Final.NAV"
##  [93] "X30.Day.ATM.IV.Call"
```

```
##  [94] "X60.Day.ATM.IV.Call"
##  [95] "X90.Day.ATM.IV.Call"
##  [96] "X30.Day.ATM.IV.Put"
##  [97] "X60.Day.ATM.IV.Put"
##  [98] "X90.Day.ATM.IV.Put"
##  [99] "Background.Reference"
## [100] "Original.Price"
## [101] "Original.Volume"
## [102] "Original.Seq..No."
## [103] "Original.Exch.Time"
## [104] "Bid.Spread"
## [105] "Ask.Spread"
## [106] "Reference.Price"
## [107] "Paired.Quantity"
## [108] "Imbalance.Quantity"
## [109] "Far.Clearing.Price"
## [110] "Near.Clearing.Price"
## [111] "Option.Adjusted.Spread.Bid"
## [112] "Z.Spread"
## [113] "Conversion.Premium"
## [114] "Conversion.Ratio"
## [115] "Percentage.Daily.Return"
## [116] "Interpolated.CDS.Basis"
## [117] "Interpolated.CDS.Spread"
## [118] "Closest.to.Maturity.CDS.Basis"
## [119] "Delta"
## [120] "Fair.Price"
## [121] "Bond.Floor"
## [122] "Edge"
## [123] "YTW"
## [124] "YTB"
## [125] "Simple.Margin"
## [126] "Discount.Margin"
## [127] "X1M.Basis.Asset.Swap.Spread"
## [128] "X3M.Basis.Asset.Swap.Spread"
## [129] "X6M.Basis.Asset.Swap.Spread"
## [130] "Accumulated.Ask.Order"
## [131] "Accumulated.Ask.Order.Size"
## [132] "Accumulated.Bid.Order"
## [133] "Accumulated.Bid.Order.Size"
## [134] "Ask.Compound.Yield"
## [135] "Ask.Dealer.Count"
## [136] "Ask.Market.Maker.Id"
## [137] "Asset.Swap.Spread.Ask"
## [138] "Asset.Swap.Spread.Bid"
## [139] "Average.Price"
## [140] "Base.Correlation"
## [141] "Basis.Point.Volatility"
## [142] "Benchmark.Spread.Ask"
## [143] "Benchmark.Spread.Bid"
## [144] "Benchmark.Yield"
## [145] "Bid.Compound.Yield"
## [146] "Bid.Dealer.Count"
## [147] "Bid.Market.Maker.Id"
```

```
## [148] "Breakeven.Inflation"
## [149] "Cap.Premium"
## [150] "Carry.Roll.down.Total"
## [151] "CDS.Dollar.Value.Of.1.Basis.Pt"
## [152] "Commodity.Basis"
## [153] "Compound.Yield"
## [154] "Constant.Maturity.Yield"
## [155] "Conversion.Factor"
## [156] "Convexity.Bias"
## [157] "Cost.of.Carry"
## [158] "Daily.Quota.Remaining.Balance"
## [159] "Dealing.Code"
## [160] "Default.Probability"
## [161] "Discount.Ask"
## [162] "Discount.Bid"
## [163] "Discount.Factor"
## [164] "Discount.Margin.Ask"
## [165] "Discount.Margin.Bid"
## [166] "Discount.Rate"
## [167] "Display.Name"
## [168] "Energy.Netback"
## [169] "Energy.Swing"
## [170] "Energy.Variance"
## [171] "Exch.For.Physical.Vol"
## [172] "Exch.For.Swaps.Vol"
## [173] "Final.Physical.Notification"
## [174] "Fixed.Coupon"
## [175] "Fixing.Date"
## [176] "Fixing.Value"
## [177] "Floor.Premium"
## [178] "Forecast.Avg.Swap.Pts"
## [179] "Forecast.Mean"
## [180] "Forecast.Median"
## [181] "Forecast.Std.Deviation"
## [182] "Forward.Rate"
## [183] "Futures.Basis"
## [184] "Futures.Risk"
## [185] "Fwd.Outright.Ask"
## [186] "Fwd.Outright.Bid"
## [187] "Gamma"
## [188] "Implied.Correlation"
## [189] "Implied.Repo.Rate"
## [190] "Implied.Yield"
## [191] "Index.Skew"
## [192] "Max.Export.Limit"
## [193] "Max.Import.Limit"
## [194] "Mean.Reversion"
## [195] "Mid.Spread"
## [196] "Mid.Yield"
## [197] "Number.of.Trades"
## [198] "Odd.Lot.Trade.Price"
## [199] "Odd.Lot.Trade.Turnover"
## [200] "Odd.Lot.Trade.Volume"
## [201] "Option.Adjusted.Spread"
```

```
## [202] "Option.Adjusted.Spread.Ask"
## [203] "Orderbook.VWAP"
## [204] "Original.Acc..Volume"
## [205] "Original.Yield"
## [206] "Par.Yield"
## [207] "Present.Value.of.Basis.Point"
## [208] "Quscnt.Physical.Notification"
## [209] "Real.Yield.Ask"
## [210] "Real.Yield.Bid"
## [211] "Recovery.Rate"
## [212] "Reference.Bond.Yield"
## [213] "Refinery.Mgn.Crack"
## [214] "Refinery.Mgn.Top"
## [215] "Reserve.Vol"
## [216] "Roll.down"
## [217] "Running.Spread"
## [218] "Seasonal.Normal.Demand"
## [219] "Short.Rate.Volatility"
## [220] "Source.Reference"
## [221] "Sovereign.Spread"
## [222] "Swap.Premium"
## [223] "Swap.Rate"
## [224] "Swap.Spread.Ask"
## [225] "Swap.Spread.Bid"
## [226] "Swap.Yield"
## [227] "Theoretical.Price.Ask"
## [228] "Theoretical.Price.Bid"
## [229] "Theoretical.Price.Mid"
## [230] "Theoretical.Spread.Ask"
## [231] "Theoretical.Spread.Bid"
## [232] "Theoretical.Spread.Mid"
## [233] "Theta"
## [234] "Total.Buy.Value"
## [235] "Total.Buy.Volume"
## [236] "Total.Demand"
## [237] "Total.Sell.Value"
## [238] "Total.Sell.Volume"
## [239] "Trade.Price.Currency"
## [240] "Unique.Trade.Identification"
## [241] "Yield.To.Call"
## [242] "Yield.to.Maturity"
## [243] "Yield.to.Maturity.Ask"
## [244] "Yield.to.Maturity.Bid"
## [245] "Yield.To.Put"
## [246] "Zero.Yield"
## [247] "Aggressive.Order.Condition"
## [248] "Categorisation.of.Trades"
## [249] "Effective.Convexity"
## [250] "Effective.Duration"
## [251] "Fair.Value"
## [252] "Fair.Value.Accuracy.Measure"
## [253] "Fair.Value.Consistency.Score"
## [254] "Fair.Value.DV01"
## [255] "Fair.Value.Spread"
```

```
## [256] "Fair.Value.Volume"
## [257] "Fair.Value.Yield"
## [258] "Flows"
## [259] "Forward.Future.Risk"
## [260] "Gross.Basis"
## [261] "Halt.Reason"
## [262] "Hedge.Ratio"
## [263] "Imbalance.Activity.Type"
## [264] "Imbalance.Side"
## [265] "Imbalance.Variation.Indicator"
## [266] "Indicative.Auction.Price"
## [267] "Indicative.Auction.Volume"
## [268] "Instrument.Description"
## [269] "Invoice.Price"
## [270] "Invoice.Spread"
## [271] "LULD.Indicator"
## [272] "MMT.Classification"
## [273] "Net.Basis"
## [274] "Net.Change"
## [275] "Original.Buyer.Id"
## [276] "Original.Primary.Activity"
## [277] "Original.RIC.of.Last.Eligible.Trade"
## [278] "Original.Seller.Id"
## [279] "Original.Trade.Sequence.Number"
## [280] "Original.Unique.Trade.Identification"
## [281] "Primary.Activity"
## [282] "RIC.of.Last.Eligible.Trade"
## [283] "Short.Sale.Restriction.Indicator"
## [284] "Spread.to.Treasury"
## [285] "Trade.Sequence.Number"
## [286] "Trade.Yield"
## [287] "Trading.Status"
## [288] "Change.Type"
## [289] "Old.Value"
## [290] "New.Value"
## [291] "ISIN"
## [292] "Unique.Quote.Identification"
## [293] "Rho"
## [294] "Vega"
```

```r
head(data$Bid.Price)
```

```
## [1] NA NA NA NA NA NA
```

```r
tail(data$Bid.Price)
```

```
## [1] 86.55 86.55 86.55 86.55    NA    NA
```

```r
head(data$Ask.Price)
```

```
## [1] NA NA NA NA NA NA
```

```r
tail(data$Ask.Price)
```

```
## [1] 86.60 86.60 86.60 86.57    NA    NA
```

```r
# Remove rows with NA Bid/Ask/Trade prices.
cleaned_data <- data[!is.na(data$Bid.Price) & !is.na(data$Ask.Price) & !is.na(data$Price), ]
```

```r
head(cleaned_data)
```

```
##     X.RIC Alias.Underlying.RIC       Domain                        Date.Time
## 24 AMZN.O                   NA Market Price 2023-01-04T04:00:00.155803724-05
## 25 AMZN.O                   NA Market Price 2023-01-04T04:00:00.155803724-05
## 30 AMZN.O                   NA Market Price 2023-01-04T04:00:00.155803724-05
## 31 AMZN.O                   NA Market Price 2023-01-04T04:00:00.155803724-05
## 32 AMZN.O                   NA Market Price 2023-01-04T04:00:00.155803724-05
## 33 AMZN.O                   NA Market Price 2023-01-04T04:00:00.159769858-05
##     Type Ex.Cntrb.ID LOC Price Volume Market.VWAP Buyer.ID Bid.Price Bid.Size
## 24 Trade         DEX  NA 86.57      2          NA               86.8        3
## 25 Trade         DEX  NA 86.57     50          NA               86.8        3
## 30 Trade         DEX  NA 86.59    125          NA               86.8        3
## 31 Trade         DEX  NA 86.60    100          NA               86.8        3
## 32 Trade         DEX  NA 86.60     75          NA               86.8        3
## 33 Trade         DEX  NA 86.57      1          NA               86.8        3
##    No..Buyers Seller.ID Ask.Price Ask.Size No..Sellers
## 24         NA               86.59        1          NA
## 25         NA               86.59        1          NA
## 30         NA               86.64        7          NA
## 31         NA               86.64        7          NA
## 32         NA               86.64        7          NA
## 33         NA               86.64        7          NA
##                                              Qualifiers Seq..No.
## 24 [IRG_SUBIND];@ TI[GV4_TEXT];ODT[IRGCOND];[GV3_TEXT]     2022
## 25 [IRG_SUBIND];@ TI[GV4_TEXT];ODT[IRGCOND];[GV3_TEXT]     2023
## 30  [IRG_SUBIND];@ T[GV4_TEXT];132[IRGCOND];[GV3_TEXT]     2024
## 31  [IRG_SUBIND];@ T[GV4_TEXT];132[IRGCOND];[GV3_TEXT]     2025
## 32 [IRG_SUBIND];@ TI[GV4_TEXT];ODT[IRGCOND];[GV3_TEXT]     2026
## 33 [IRG_SUBIND];@ TI[GV4_TEXT];ODT[IRGCOND];[GV3_TEXT]     2027
##             Exch.Time Block.Trd PE.Ratio Yield Bid.Yld Ask.Yld ISMA.Bid.Yld
## 24 09:00:00.045000000        NA       NA    NA      NA      NA           NA
## 25 09:00:00.051000000        NA       NA    NA      NA      NA           NA
## 30 09:00:00.052000000        NA       NA    NA      NA      NA           NA
## 31 09:00:00.052000000        NA       NA    NA      NA      NA           NA
## 32 09:00:00.052000000        NA       NA    NA      NA      NA           NA
## 33 09:00:00.053000000        NA       NA    NA      NA      NA           NA
##    ISMA.Ask.Yld Duration Mod.Durtn BPV Convexity Bench.Spd Swp.Spd Asst.Swp.Spd
## 24           NA       NA        NA  NA        NA        NA      NA           NA
## 25           NA       NA        NA  NA        NA        NA      NA           NA
## 30           NA       NA        NA  NA        NA        NA      NA           NA
## 31           NA       NA        NA  NA        NA        NA      NA           NA
## 32           NA       NA        NA  NA        NA        NA      NA           NA
## 33           NA       NA        NA  NA        NA        NA      NA           NA
##    Swap.Point UpLim.Price LoLim.Price Theo..Price Parity Premium Bid.Imp..Vol
## 24         NA          NA          NA          NA     NA      NA           NA
## 25         NA          NA          NA          NA     NA      NA           NA
## 30         NA          NA          NA          NA     NA      NA           NA
## 31         NA          NA          NA          NA     NA      NA           NA
## 32         NA          NA          NA          NA     NA      NA           NA
## 33         NA          NA          NA          NA     NA      NA           NA
##    Ask.Imp..Vol Imp..Vol. Crack Top Freight.Pr. Offer Actual Prior Revised
## 24           NA        NA    NA  NA          NA    NA     NA    NA      NA
```

```
## 25          NA        NA    NA  NA          NA    NA     NA    NA      NA
## 30          NA        NA    NA  NA          NA    NA     NA    NA      NA
## 31          NA        NA    NA  NA          NA    NA     NA    NA      NA
## 32          NA        NA    NA  NA          NA    NA     NA    NA      NA
## 33          NA        NA    NA  NA          NA    NA     NA    NA      NA
##    Forecast Frcst.High Frcst.Low No..Frcts       Date Bid.Tic Tick.Dir. Open
## 24       NA         NA        NA        NA 2023-01-04      NA             NA
## 25       NA         NA        NA        NA 2023-01-04      NA             NA
## 30       NA         NA        NA        NA 2023-01-04      NA             NA
## 31       NA         NA        NA        NA 2023-01-04      NA             NA
## 32       NA         NA        NA        NA 2023-01-04      NA             NA
## 33       NA         NA        NA        NA 2023-01-04      NA             NA
##    High Low Open.Interest Bench.Price Open.Yld High.Yld Low.Yld Acc..Volume
## 24   NA  NA            NA          NA       NA       NA      NA         140
## 25   NA  NA            NA          NA       NA       NA      NA         190
## 30   NA  NA            NA          NA       NA       NA      NA         315
## 31   NA  NA            NA          NA       NA       NA      NA         415
## 32   NA  NA            NA          NA       NA       NA      NA         490
## 33   NA  NA            NA          NA       NA       NA      NA         491
##    Turnover Volatility Strike Mid.Price Advancing.Issues Declining.Issues
## 24       NA         NA     NA        NA               NA               NA
## 25       NA         NA     NA        NA               NA               NA
## 30       NA         NA     NA        NA               NA               NA
## 31       NA         NA     NA        NA               NA               NA
## 32       NA         NA     NA        NA               NA               NA
## 33       NA         NA     NA        NA               NA               NA
##    Unchanged.Issues Total.Issues Advancing.Volume Declining.Volume
## 24               NA           NA               NA               NA
## 25               NA           NA               NA               NA
## 30               NA           NA               NA               NA
## 31               NA           NA               NA               NA
## 32               NA           NA               NA               NA
## 33               NA           NA               NA               NA
##    Unchanged.Volume Total.Volume New.Highs New.Lows Total.Moves
## 24               NA           NA        NA       NA          NA
## 25               NA           NA        NA       NA          NA
## 30               NA           NA        NA       NA          NA
## 31               NA           NA        NA       NA          NA
## 32               NA           NA        NA       NA          NA
## 33               NA           NA        NA       NA          NA
##    Percentage.Change Advancing.Moves Declining.Moves Unchanged.Moves
## 24                NA              NA              NA              NA
## 25                NA              NA              NA              NA
## 30                NA              NA              NA              NA
## 31                NA              NA              NA              NA
## 32                NA              NA              NA              NA
## 33                NA              NA              NA              NA
##    Strong.Market Weak.Market Changed.Market Market.Volatility Original.Date
## 24            NA          NA             NA                NA            NA
## 25            NA          NA             NA                NA            NA
## 30            NA          NA             NA                NA            NA
## 31            NA          NA             NA                NA            NA
## 32            NA          NA             NA                NA            NA
## 33            NA          NA             NA                NA            NA
```

```
##    Final.NAV X30.Day.ATM.IV.Call X60.Day.ATM.IV.Call X90.Day.ATM.IV.Call
## 24        NA                  NA                  NA                  NA
## 25        NA                  NA                  NA                  NA
## 30        NA                  NA                  NA                  NA
## 31        NA                  NA                  NA                  NA
## 32        NA                  NA                  NA                  NA
## 33        NA                  NA                  NA                  NA
##    X30.Day.ATM.IV.Put X60.Day.ATM.IV.Put X90.Day.ATM.IV.Put
## 24                 NA                 NA                 NA
## 25                 NA                 NA                 NA
## 30                 NA                 NA                 NA
## 31                 NA                 NA                 NA
## 32                 NA                 NA                 NA
## 33                 NA                 NA                 NA
##    Background.Reference Original.Price Original.Volume Original.Seq..No.
## 24                   NA             NA              NA                NA
## 25                   NA             NA              NA                NA
## 30                   NA             NA              NA                NA
## 31                   NA             NA              NA                NA
## 32                   NA             NA              NA                NA
## 33                   NA             NA              NA                NA
##    Original.Exch.Time Bid.Spread Ask.Spread Reference.Price Paired.Quantity
## 24                 NA         NA         NA              NA              NA
## 25                 NA         NA         NA              NA              NA
## 30                 NA         NA         NA              NA              NA
## 31                 NA         NA         NA              NA              NA
## 32                 NA         NA         NA              NA              NA
## 33                 NA         NA         NA              NA              NA
##    Imbalance.Quantity Far.Clearing.Price Near.Clearing.Price
## 24                 NA                 NA                  NA
## 25                 NA                 NA                  NA
## 30                 NA                 NA                  NA
## 31                 NA                 NA                  NA
## 32                 NA                 NA                  NA
## 33                 NA                 NA                  NA
##    Option.Adjusted.Spread.Bid Z.Spread Conversion.Premium Conversion.Ratio
## 24                         NA       NA                 NA               NA
## 25                         NA       NA                 NA               NA
## 30                         NA       NA                 NA               NA
## 31                         NA       NA                 NA               NA
## 32                         NA       NA                 NA               NA
## 33                         NA       NA                 NA               NA
##    Percentage.Daily.Return Interpolated.CDS.Basis Interpolated.CDS.Spread
## 24                      NA                     NA                      NA
## 25                      NA                     NA                      NA
## 30                      NA                     NA                      NA
## 31                      NA                     NA                      NA
## 32                      NA                     NA                      NA
## 33                      NA                     NA                      NA
##    Closest.to.Maturity.CDS.Basis Delta Fair.Price Bond.Floor Edge YTW YTB
## 24                            NA    NA         NA         NA   NA  NA  NA
## 25                            NA    NA         NA         NA   NA  NA  NA
## 30                            NA    NA         NA         NA   NA  NA  NA
## 31                            NA    NA         NA         NA   NA  NA  NA
```

```
## 32                          NA    NA         NA         NA   NA  NA  NA
## 33                          NA    NA         NA         NA   NA  NA  NA
##    Simple.Margin Discount.Margin X1M.Basis.Asset.Swap.Spread
## 24            NA              NA                          NA
## 25            NA              NA                          NA
## 30            NA              NA                          NA
## 31            NA              NA                          NA
## 32            NA              NA                          NA
## 33            NA              NA                          NA
##    X3M.Basis.Asset.Swap.Spread X6M.Basis.Asset.Swap.Spread
## 24                          NA                          NA
## 25                          NA                          NA
## 30                          NA                          NA
## 31                          NA                          NA
## 32                          NA                          NA
## 33                          NA                          NA
##    Accumulated.Ask.Order Accumulated.Ask.Order.Size Accumulated.Bid.Order
## 24                    NA                         NA                    NA
## 25                    NA                         NA                    NA
## 30                    NA                         NA                    NA
## 31                    NA                         NA                    NA
## 32                    NA                         NA                    NA
## 33                    NA                         NA                    NA
##    Accumulated.Bid.Order.Size Ask.Compound.Yield Ask.Dealer.Count
## 24                         NA                 NA               NA
## 25                         NA                 NA               NA
## 30                         NA                 NA               NA
## 31                         NA                 NA               NA
## 32                         NA                 NA               NA
## 33                         NA                 NA               NA
##    Ask.Market.Maker.Id Asset.Swap.Spread.Ask Asset.Swap.Spread.Bid
## 24                                        NA                    NA
## 25                                        NA                    NA
## 30                                        NA                    NA
## 31                                        NA                    NA
## 32                                        NA                    NA
## 33                                        NA                    NA
##    Average.Price Base.Correlation Basis.Point.Volatility Benchmark.Spread.Ask
## 24            NA               NA                     NA                   NA
## 25            NA               NA                     NA                   NA
## 30            NA               NA                     NA                   NA
## 31            NA               NA                     NA                   NA
## 32            NA               NA                     NA                   NA
## 33            NA               NA                     NA                   NA
##    Benchmark.Spread.Bid Benchmark.Yield Bid.Compound.Yield Bid.Dealer.Count
## 24                   NA              NA                 NA               NA
## 25                   NA              NA                 NA               NA
## 30                   NA              NA                 NA               NA
## 31                   NA              NA                 NA               NA
## 32                   NA              NA                 NA               NA
## 33                   NA              NA                 NA               NA
##    Bid.Market.Maker.Id Breakeven.Inflation Cap.Premium Carry.Roll.down.Total
## 24                                      NA          NA                    NA
## 25                                      NA          NA                    NA
```

```
## 30                                    NA          NA                     NA
## 31                                    NA          NA                     NA
## 32                                    NA          NA                     NA
## 33                                    NA          NA                     NA
##    CDS.Dollar.Value.Of.1.Basis.Pt Commodity.Basis Compound.Yield
## 24                             NA              NA             NA
## 25                             NA              NA             NA
## 30                             NA              NA             NA
## 31                             NA              NA             NA
## 32                             NA              NA             NA
## 33                             NA              NA             NA
##    Constant.Maturity.Yield Conversion.Factor Convexity.Bias Cost.of.Carry
## 24                      NA                NA             NA            NA
## 25                      NA                NA             NA            NA
## 30                      NA                NA             NA            NA
## 31                      NA                NA             NA            NA
## 32                      NA                NA             NA            NA
## 33                      NA                NA             NA            NA
##    Daily.Quota.Remaining.Balance Dealing.Code Default.Probability Discount.Ask
## 24                            NA           NA                  NA           NA
## 25                            NA           NA                  NA           NA
## 30                            NA           NA                  NA           NA
## 31                            NA           NA                  NA           NA
## 32                            NA           NA                  NA           NA
## 33                            NA           NA                  NA           NA
##    Discount.Bid Discount.Factor Discount.Margin.Ask Discount.Margin.Bid
## 24           NA              NA                  NA                  NA
## 25           NA              NA                  NA                  NA
## 30           NA              NA                  NA                  NA
## 31           NA              NA                  NA                  NA
## 32           NA              NA                  NA                  NA
## 33           NA              NA                  NA                  NA
##    Discount.Rate Display.Name Energy.Netback Energy.Swing Energy.Variance
## 24            NA           NA             NA           NA              NA
## 25            NA           NA             NA           NA              NA
## 30            NA           NA             NA           NA              NA
## 31            NA           NA             NA           NA              NA
## 32            NA           NA             NA           NA              NA
## 33            NA           NA             NA           NA              NA
##    Exch.For.Physical.Vol Exch.For.Swaps.Vol Final.Physical.Notification
## 24                    NA                 NA                          NA
## 25                    NA                 NA                          NA
## 30                    NA                 NA                          NA
## 31                    NA                 NA                          NA
## 32                    NA                 NA                          NA
## 33                    NA                 NA                          NA
##    Fixed.Coupon Fixing.Date Fixing.Value Floor.Premium Forecast.Avg.Swap.Pts
## 24           NA          NA           NA            NA                    NA
## 25           NA          NA           NA            NA                    NA
## 30           NA          NA           NA            NA                    NA
## 31           NA          NA           NA            NA                    NA
## 32           NA          NA           NA            NA                    NA
## 33           NA          NA           NA            NA                    NA
##    Forecast.Mean Forecast.Median Forecast.Std.Deviation Forward.Rate
```

```
## 24           NA             NA                    NA          NA
## 25           NA             NA                    NA          NA
## 30           NA             NA                    NA          NA
## 31           NA             NA                    NA          NA
## 32           NA             NA                    NA          NA
## 33           NA             NA                    NA          NA
##    Futures.Basis Futures.Risk Fwd.Outright.Ask Fwd.Outright.Bid Gamma
## 24           NA           NA               NA               NA    NA
## 25           NA           NA               NA               NA    NA
## 30           NA           NA               NA               NA    NA
## 31           NA           NA               NA               NA    NA
## 32           NA           NA               NA               NA    NA
## 33           NA           NA               NA               NA    NA
##    Implied.Correlation Implied.Repo.Rate Implied.Yield Index.Skew
## 24                  NA                NA            NA         NA
## 25                  NA                NA            NA         NA
## 30                  NA                NA            NA         NA
## 31                  NA                NA            NA         NA
## 32                  NA                NA            NA         NA
## 33                  NA                NA            NA         NA
##    Max.Export.Limit Max.Import.Limit Mean.Reversion Mid.Spread Mid.Yield
## 24               NA               NA             NA         NA        NA
## 25               NA               NA             NA         NA        NA
## 30               NA               NA             NA         NA        NA
## 31               NA               NA             NA         NA        NA
## 32               NA               NA             NA         NA        NA
## 33               NA               NA             NA         NA        NA
##    Number.of.Trades Odd.Lot.Trade.Price Odd.Lot.Trade.Turnover
## 24               NA                  NA                     NA
## 25               NA                  NA                     NA
## 30               NA                  NA                     NA
## 31               NA                  NA                     NA
## 32               NA                  NA                     NA
## 33               NA                  NA                     NA
##    Odd.Lot.Trade.Volume Option.Adjusted.Spread Option.Adjusted.Spread.Ask
## 24                   NA                     NA                         NA
## 25                   NA                     NA                         NA
## 30                   NA                     NA                         NA
## 31                   NA                     NA                         NA
## 32                   NA                     NA                         NA
## 33                   NA                     NA                         NA
##    Orderbook.VWAP Original.Acc..Volume Original.Yield Par.Yield
## 24             NA                   NA             NA        NA
## 25             NA                   NA             NA        NA
## 30             NA                   NA             NA        NA
## 31             NA                   NA             NA        NA
## 32             NA                   NA             NA        NA
## 33             NA                   NA             NA        NA
##    Present.Value.of.Basis.Point Quscnt.Physical.Notification Real.Yield.Ask
## 24                           NA                           NA             NA
## 25                           NA                           NA             NA
## 30                           NA                           NA             NA
## 31                           NA                           NA             NA
## 32                           NA                           NA             NA
```

```
## 33                        NA                           NA             NA
##    Real.Yield.Bid Recovery.Rate Reference.Bond.Yield Refinery.Mgn.Crack
## 24             NA            NA                   NA                 NA
## 25             NA            NA                   NA                 NA
## 30             NA            NA                   NA                 NA
## 31             NA            NA                   NA                 NA
## 32             NA            NA                   NA                 NA
## 33             NA            NA                   NA                 NA
##    Refinery.Mgn.Top Reserve.Vol Roll.down Running.Spread Seasonal.Normal.Demand
## 24               NA          NA        NA             NA                     NA
## 25               NA          NA        NA             NA                     NA
## 30               NA          NA        NA             NA                     NA
## 31               NA          NA        NA             NA                     NA
## 32               NA          NA        NA             NA                     NA
## 33               NA          NA        NA             NA                     NA
##    Short.Rate.Volatility Source.Reference Sovereign.Spread Swap.Premium
## 24                    NA               NA               NA           NA
## 25                    NA               NA               NA           NA
## 30                    NA               NA               NA           NA
## 31                    NA               NA               NA           NA
## 32                    NA               NA               NA           NA
## 33                    NA               NA               NA           NA
##    Swap.Rate Swap.Spread.Ask Swap.Spread.Bid Swap.Yield Theoretical.Price.Ask
## 24        NA              NA              NA         NA                    NA
## 25        NA              NA              NA         NA                    NA
## 30        NA              NA              NA         NA                    NA
## 31        NA              NA              NA         NA                    NA
## 32        NA              NA              NA         NA                    NA
## 33        NA              NA              NA         NA                    NA
##    Theoretical.Price.Bid Theoretical.Price.Mid Theoretical.Spread.Ask
## 24                    NA                    NA                     NA
## 25                    NA                    NA                     NA
## 30                    NA                    NA                     NA
## 31                    NA                    NA                     NA
## 32                    NA                    NA                     NA
## 33                    NA                    NA                     NA
##    Theoretical.Spread.Bid Theoretical.Spread.Mid Theta Total.Buy.Value
## 24                     NA                     NA    NA              NA
## 25                     NA                     NA    NA              NA
## 30                     NA                     NA    NA              NA
## 31                     NA                     NA    NA              NA
## 32                     NA                     NA    NA              NA
## 33                     NA                     NA    NA              NA
##    Total.Buy.Volume Total.Demand Total.Sell.Value Total.Sell.Volume
## 24               NA           NA               NA                NA
## 25               NA           NA               NA                NA
## 30               NA           NA               NA                NA
## 31               NA           NA               NA                NA
## 32               NA           NA               NA                NA
## 33               NA           NA               NA                NA
##    Trade.Price.Currency Unique.Trade.Identification Yield.To.Call
## 24                   NA                           1            NA
## 25                   NA                           2            NA
## 30                   NA                           3            NA
```

```
## 31                  NA                           4            NA
## 32                  NA                           5            NA
## 33                  NA                           6            NA
##    Yield.to.Maturity Yield.to.Maturity.Ask Yield.to.Maturity.Bid Yield.To.Put
## 24                NA                    NA                    NA           NA
## 25                NA                    NA                    NA           NA
## 30                NA                    NA                    NA           NA
## 31                NA                    NA                    NA           NA
## 32                NA                    NA                    NA           NA
## 33                NA                    NA                    NA           NA
##    Zero.Yield Aggressive.Order.Condition Categorisation.of.Trades
## 24         NA                         NA                       NA
## 25         NA                         NA                       NA
## 30         NA                         NA                       NA
## 31         NA                         NA                       NA
## 32         NA                         NA                       NA
## 33         NA                         NA                       NA
##    Effective.Convexity Effective.Duration Fair.Value
## 24                  NA                 NA         NA
## 25                  NA                 NA         NA
## 30                  NA                 NA         NA
## 31                  NA                 NA         NA
## 32                  NA                 NA         NA
## 33                  NA                 NA         NA
##    Fair.Value.Accuracy.Measure Fair.Value.Consistency.Score Fair.Value.DV01
## 24                          NA                           NA              NA
## 25                          NA                           NA              NA
## 30                          NA                           NA              NA
## 31                          NA                           NA              NA
## 32                          NA                           NA              NA
## 33                          NA                           NA              NA
##    Fair.Value.Spread Fair.Value.Volume Fair.Value.Yield Flows
## 24                NA                NA               NA    NA
## 25                NA                NA               NA    NA
## 30                NA                NA               NA    NA
## 31                NA                NA               NA    NA
## 32                NA                NA               NA    NA
## 33                NA                NA               NA    NA
##    Forward.Future.Risk Gross.Basis Halt.Reason Hedge.Ratio
## 24                  NA          NA          NA          NA
## 25                  NA          NA          NA          NA
## 30                  NA          NA          NA          NA
## 31                  NA          NA          NA          NA
## 32                  NA          NA          NA          NA
## 33                  NA          NA          NA          NA
##    Imbalance.Activity.Type Imbalance.Side Imbalance.Variation.Indicator
## 24                      NA             NA                            NA
## 25                      NA             NA                            NA
## 30                      NA             NA                            NA
## 31                      NA             NA                            NA
## 32                      NA             NA                            NA
## 33                      NA             NA                            NA
##    Indicative.Auction.Price Indicative.Auction.Volume Instrument.Description
## 24                       NA                        NA                     NA
```

```
## 25                    NA                        NA                    NA
## 30                    NA                        NA                    NA
## 31                    NA                        NA                    NA
## 32                    NA                        NA                    NA
## 33                    NA                        NA                    NA
##    Invoice.Price Invoice.Spread LULD.Indicator MMT.Classification Net.Basis
## 24            NA             NA                                NA        NA
## 25            NA             NA                                NA        NA
## 30            NA             NA                                NA        NA
## 31            NA             NA                                NA        NA
## 32            NA             NA                                NA        NA
## 33            NA             NA                                NA        NA
##    Net.Change Original.Buyer.Id Original.Primary.Activity
## 24         NA                NA                        NA
## 25         NA                NA                        NA
## 30         NA                NA                        NA
## 31         NA                NA                        NA
## 32         NA                NA                        NA
## 33         NA                NA                        NA
##    Original.RIC.of.Last.Eligible.Trade Original.Seller.Id
## 24                                  NA                 NA
## 25                                  NA                 NA
## 30                                  NA                 NA
## 31                                  NA                 NA
## 32                                  NA                 NA
## 33                                  NA                 NA
##    Original.Trade.Sequence.Number Original.Unique.Trade.Identification
## 24                             NA                                   NA
## 25                             NA                                   NA
## 30                             NA                                   NA
## 31                             NA                                   NA
## 32                             NA                                   NA
## 33                             NA                                   NA
##    Primary.Activity RIC.of.Last.Eligible.Trade Short.Sale.Restriction.Indicator
## 24               NA                         NA
## 25               NA                         NA
## 30               NA                         NA
## 31               NA                         NA
## 32               NA                         NA
## 33               NA                         NA
##    Spread.to.Treasury Trade.Sequence.Number Trade.Yield Trading.Status
## 24                 NA                    NA          NA             NA
## 25                 NA                    NA          NA             NA
## 30                 NA                    NA          NA             NA
## 31                 NA                    NA          NA             NA
## 32                 NA                    NA          NA             NA
## 33                 NA                    NA          NA             NA
##    Change.Type Old.Value New.Value ISIN Unique.Quote.Identification Rho Vega
## 24          NA        NA        NA   NA                          NA  NA   NA
## 25          NA        NA        NA   NA                          NA  NA   NA
## 30          NA        NA        NA   NA                          NA  NA   NA
## 31          NA        NA        NA   NA                          NA  NA   NA
## 32          NA        NA        NA   NA                          NA  NA   NA
## 33          NA        NA        NA   NA                          NA  NA   NA
```

```r
tail(cleaned_data)
```

```
##          X.RIC Alias.Underlying.RIC       Domain
## 2485741 AMZN.O                   NA Market Price
## 2485742 AMZN.O                   NA Market Price
## 2485744 AMZN.O                   NA Market Price
## 2485746 AMZN.O                   NA Market Price
## 2485748 AMZN.O                   NA Market Price
## 2485749 AMZN.O                   NA Market Price
##                                Date.Time  Type Ex.Cntrb.ID LOC Price Volume
## 2485741 2023-01-04T19:59:56.247341287-05 Trade         ADF  NA 86.60     20
## 2485742 2023-01-04T19:59:56.387360681-05 Trade         ADF  NA 86.60     29
## 2485744 2023-01-04T19:59:56.560107482-05 Trade         PSE  NA 86.56    100
## 2485746 2023-01-04T19:59:56.560107482-05 Trade         ADF  NA 86.56    100
## 2485748 2023-01-04T19:59:56.784115908-05 Trade         PSE  NA 86.60    300
## 2485749 2023-01-04T19:59:56.784115908-05 Trade         ADF  NA 86.60    200
##         Market.VWAP Buyer.ID Bid.Price Bid.Size No..Buyers Seller.ID Ask.Price
## 2485741          NA              86.56        2         NA                86.6
## 2485742          NA              86.56        2         NA                86.6
## 2485744          NA              86.56        1         NA                86.6
## 2485746          NA              86.55       32         NA                86.6
## 2485748          NA              86.55       32         NA                86.6
## 2485749          NA              86.55       32         NA                86.6
##         Ask.Size No..Sellers
## 2485741       32          NA
## 2485742       32          NA
## 2485744       32          NA
## 2485746       32          NA
## 2485748       29          NA
## 2485749       29          NA
##                                                Qualifiers Seq..No.
## 2485741 Q[IRG_SUBIND];@ TI[GV4_TEXT];ODT[IRGCOND];[GV3_TEXT]  6086667
## 2485742 Q[IRG_SUBIND];@ TI[GV4_TEXT];ODT[IRGCOND];[GV3_TEXT]  6086668
## 2485744   [IRG_SUBIND];@ T[GV4_TEXT];132[IRGCOND];[GV3_TEXT]  6086669
## 2485746  Q[IRG_SUBIND];@ T[GV4_TEXT];132[IRGCOND];[GV3_TEXT]  6086670
## 2485748   [IRG_SUBIND];@ T[GV4_TEXT];132[IRGCOND];[GV3_TEXT]  6086671
## 2485749  Q[IRG_SUBIND];@ T[GV4_TEXT];132[IRGCOND];[GV3_TEXT]  6086672
##                  Exch.Time Block.Trd PE.Ratio Yield Bid.Yld Ask.Yld
## 2485741 00:59:56.230000000        NA       NA    NA      NA      NA
## 2485742 00:59:56.370000000        NA       NA    NA      NA      NA
## 2485744 00:59:56.542000000        NA       NA    NA      NA      NA
## 2485746 00:59:56.543000000        NA       NA    NA      NA      NA
## 2485748 00:59:56.766000000        NA       NA    NA      NA      NA
## 2485749 00:59:56.768000000        NA       NA    NA      NA      NA
##         ISMA.Bid.Yld ISMA.Ask.Yld Duration Mod.Durtn BPV Convexity Bench.Spd
## 2485741           NA           NA       NA        NA  NA        NA        NA
## 2485742           NA           NA       NA        NA  NA        NA        NA
## 2485744           NA           NA       NA        NA  NA        NA        NA
## 2485746           NA           NA       NA        NA  NA        NA        NA
## 2485748           NA           NA       NA        NA  NA        NA        NA
## 2485749           NA           NA       NA        NA  NA        NA        NA
##         Swp.Spd Asst.Swp.Spd Swap.Point UpLim.Price LoLim.Price Theo..Price
## 2485741      NA           NA         NA           0           0          NA
## 2485742      NA           NA         NA           0           0          NA
```

```
## 2485744      NA           NA         NA          0           0          NA
## 2485746      NA           NA         NA          0           0          NA
## 2485748      NA           NA         NA          0           0          NA
## 2485749      NA           NA         NA          0           0          NA
##         Parity Premium Bid.Imp..Vol Ask.Imp..Vol Imp..Vol. Crack Top
## 2485741     NA      NA           NA           NA        NA    NA  NA
## 2485742     NA      NA           NA           NA        NA    NA  NA
## 2485744     NA      NA           NA           NA        NA    NA  NA
## 2485746     NA      NA           NA           NA        NA    NA  NA
## 2485748     NA      NA           NA           NA        NA    NA  NA
## 2485749     NA      NA           NA           NA        NA    NA  NA
##         Freight.Pr. Offer Actual Prior Revised Forecast Frcst.High Frcst.Low
## 2485741          NA    NA     NA    NA      NA       NA         NA        NA
## 2485742          NA    NA     NA    NA      NA       NA         NA        NA
## 2485744          NA    NA     NA    NA      NA       NA         NA        NA
## 2485746          NA    NA     NA    NA      NA       NA         NA        NA
## 2485748          NA    NA     NA    NA      NA       NA         NA        NA
## 2485749          NA    NA     NA    NA      NA       NA         NA        NA
##         No..Frcts       Date Bid.Tic Tick.Dir.  Open  High   Low Open.Interest
## 2485741        NA 2023-01-05      NA           86.55 86.98 83.36            NA
## 2485742        NA 2023-01-05      NA           86.55 86.98 83.36            NA
## 2485744        NA 2023-01-05      NA           86.55 86.98 83.36            NA
## 2485746        NA 2023-01-05      NA           86.55 86.98 83.36            NA
## 2485748        NA 2023-01-05      NA           86.55 86.98 83.36            NA
## 2485749        NA 2023-01-05      NA           86.55 86.98 83.36            NA
##         Bench.Price Open.Yld High.Yld Low.Yld Acc..Volume Turnover Volatility
## 2485741          NA       NA       NA      NA    68884394       NA         NA
## 2485742          NA       NA       NA      NA    68884423       NA         NA
## 2485744          NA       NA       NA      NA    68884523       NA         NA
## 2485746          NA       NA       NA      NA    68884623       NA         NA
## 2485748          NA       NA       NA      NA    68884923       NA         NA
## 2485749          NA       NA       NA      NA    68885123       NA         NA
##         Strike Mid.Price Advancing.Issues Declining.Issues Unchanged.Issues
## 2485741     NA        NA               NA               NA               NA
## 2485742     NA        NA               NA               NA               NA
## 2485744     NA        NA               NA               NA               NA
## 2485746     NA        NA               NA               NA               NA
## 2485748     NA        NA               NA               NA               NA
## 2485749     NA        NA               NA               NA               NA
##         Total.Issues Advancing.Volume Declining.Volume Unchanged.Volume
## 2485741           NA               NA               NA               NA
## 2485742           NA               NA               NA               NA
## 2485744           NA               NA               NA               NA
## 2485746           NA               NA               NA               NA
## 2485748           NA               NA               NA               NA
## 2485749           NA               NA               NA               NA
##         Total.Volume New.Highs New.Lows Total.Moves Percentage.Change
## 2485741           NA        NA       NA          NA                NA
## 2485742           NA        NA       NA          NA                NA
## 2485744           NA        NA       NA          NA                NA
## 2485746           NA        NA       NA          NA                NA
## 2485748           NA        NA       NA          NA                NA
## 2485749           NA        NA       NA          NA                NA
##         Advancing.Moves Declining.Moves Unchanged.Moves Strong.Market
```

```
## 2485741              NA              NA              NA             NA
## 2485742              NA              NA              NA             NA
## 2485744              NA              NA              NA             NA
## 2485746              NA              NA              NA             NA
## 2485748              NA              NA              NA             NA
## 2485749              NA              NA              NA             NA
##         Weak.Market Changed.Market Market.Volatility Original.Date Final.NAV
## 2485741          NA             NA                NA            NA        NA
## 2485742          NA             NA                NA            NA        NA
## 2485744          NA             NA                NA            NA        NA
## 2485746          NA             NA                NA            NA        NA
## 2485748          NA             NA                NA            NA        NA
## 2485749          NA             NA                NA            NA        NA
##         X30.Day.ATM.IV.Call X60.Day.ATM.IV.Call X90.Day.ATM.IV.Call
## 2485741                  NA                  NA                  NA
## 2485742                  NA                  NA                  NA
## 2485744                  NA                  NA                  NA
## 2485746                  NA                  NA                  NA
## 2485748                  NA                  NA                  NA
## 2485749                  NA                  NA                  NA
##         X30.Day.ATM.IV.Put X60.Day.ATM.IV.Put X90.Day.ATM.IV.Put
## 2485741                 NA                 NA                 NA
## 2485742                 NA                 NA                 NA
## 2485744                 NA                 NA                 NA
## 2485746                 NA                 NA                 NA
## 2485748                 NA                 NA                 NA
## 2485749                 NA                 NA                 NA
##         Background.Reference Original.Price Original.Volume Original.Seq..No.
## 2485741                   NA             NA              NA                NA
## 2485742                   NA             NA              NA                NA
## 2485744                   NA             NA              NA                NA
## 2485746                   NA             NA              NA                NA
## 2485748                   NA             NA              NA                NA
## 2485749                   NA             NA              NA                NA
##         Original.Exch.Time Bid.Spread Ask.Spread Reference.Price
## 2485741                 NA         NA         NA              NA
## 2485742                 NA         NA         NA              NA
## 2485744                 NA         NA         NA              NA
## 2485746                 NA         NA         NA              NA
## 2485748                 NA         NA         NA              NA
## 2485749                 NA         NA         NA              NA
##         Paired.Quantity Imbalance.Quantity Far.Clearing.Price
## 2485741              NA                 NA                 NA
## 2485742              NA                 NA                 NA
## 2485744              NA                 NA                 NA
## 2485746              NA                 NA                 NA
## 2485748              NA                 NA                 NA
## 2485749              NA                 NA                 NA
##         Near.Clearing.Price Option.Adjusted.Spread.Bid Z.Spread
## 2485741                  NA                         NA       NA
## 2485742                  NA                         NA       NA
## 2485744                  NA                         NA       NA
## 2485746                  NA                         NA       NA
## 2485748                  NA                         NA       NA
```

```
## 2485749                  NA                          NA       NA
##         Conversion.Premium Conversion.Ratio Percentage.Daily.Return
## 2485741                 NA               NA                      NA
## 2485742                 NA               NA                      NA
## 2485744                 NA               NA                      NA
## 2485746                 NA               NA                      NA
## 2485748                 NA               NA                      NA
## 2485749                 NA               NA                      NA
##         Interpolated.CDS.Basis Interpolated.CDS.Spread
## 2485741                     NA                      NA
## 2485742                     NA                      NA
## 2485744                     NA                      NA
## 2485746                     NA                      NA
## 2485748                     NA                      NA
## 2485749                     NA                      NA
##         Closest.to.Maturity.CDS.Basis Delta Fair.Price Bond.Floor Edge YTW YTB
## 2485741                            NA    NA         NA         NA   NA  NA  NA
## 2485742                            NA    NA         NA         NA   NA  NA  NA
## 2485744                            NA    NA         NA         NA   NA  NA  NA
## 2485746                            NA    NA         NA         NA   NA  NA  NA
## 2485748                            NA    NA         NA         NA   NA  NA  NA
## 2485749                            NA    NA         NA         NA   NA  NA  NA
##         Simple.Margin Discount.Margin X1M.Basis.Asset.Swap.Spread
## 2485741            NA              NA                          NA
## 2485742            NA              NA                          NA
## 2485744            NA              NA                          NA
## 2485746            NA              NA                          NA
## 2485748            NA              NA                          NA
## 2485749            NA              NA                          NA
##         X3M.Basis.Asset.Swap.Spread X6M.Basis.Asset.Swap.Spread
## 2485741                          NA                          NA
## 2485742                          NA                          NA
## 2485744                          NA                          NA
## 2485746                          NA                          NA
## 2485748                          NA                          NA
## 2485749                          NA                          NA
##         Accumulated.Ask.Order Accumulated.Ask.Order.Size Accumulated.Bid.Order
## 2485741                    NA                         NA                    NA
## 2485742                    NA                         NA                    NA
## 2485744                    NA                         NA                    NA
## 2485746                    NA                         NA                    NA
## 2485748                    NA                         NA                    NA
## 2485749                    NA                         NA                    NA
##         Accumulated.Bid.Order.Size Ask.Compound.Yield Ask.Dealer.Count
## 2485741                         NA                 NA               NA
## 2485742                         NA                 NA               NA
## 2485744                         NA                 NA               NA
## 2485746                         NA                 NA               NA
## 2485748                         NA                 NA               NA
## 2485749                         NA                 NA               NA
##         Ask.Market.Maker.Id Asset.Swap.Spread.Ask Asset.Swap.Spread.Bid
## 2485741                                        NA                    NA
## 2485742                                        NA                    NA
## 2485744                                        NA                    NA
```

```
## 2485746                                    NA                    NA
## 2485748                                    NA                    NA
## 2485749                                    NA                    NA
##         Average.Price Base.Correlation Basis.Point.Volatility
## 2485741            NA               NA                     NA
## 2485742            NA               NA                     NA
## 2485744            NA               NA                     NA
## 2485746            NA               NA                     NA
## 2485748            NA               NA                     NA
## 2485749            NA               NA                     NA
##         Benchmark.Spread.Ask Benchmark.Spread.Bid Benchmark.Yield
## 2485741                   NA                   NA              NA
## 2485742                   NA                   NA              NA
## 2485744                   NA                   NA              NA
## 2485746                   NA                   NA              NA
## 2485748                   NA                   NA              NA
## 2485749                   NA                   NA              NA
##         Bid.Compound.Yield Bid.Dealer.Count Bid.Market.Maker.Id
## 2485741                 NA               NA
## 2485742                 NA               NA
## 2485744                 NA               NA
## 2485746                 NA               NA
## 2485748                 NA               NA
## 2485749                 NA               NA
##         Breakeven.Inflation Cap.Premium Carry.Roll.down.Total
## 2485741                  NA          NA                    NA
## 2485742                  NA          NA                    NA
## 2485744                  NA          NA                    NA
## 2485746                  NA          NA                    NA
## 2485748                  NA          NA                    NA
## 2485749                  NA          NA                    NA
##         CDS.Dollar.Value.Of.1.Basis.Pt Commodity.Basis Compound.Yield
## 2485741                             NA              NA             NA
## 2485742                             NA              NA             NA
## 2485744                             NA              NA             NA
## 2485746                             NA              NA             NA
## 2485748                             NA              NA             NA
## 2485749                             NA              NA             NA
##         Constant.Maturity.Yield Conversion.Factor Convexity.Bias Cost.of.Carry
## 2485741                      NA                NA             NA            NA
## 2485742                      NA                NA             NA            NA
## 2485744                      NA                NA             NA            NA
## 2485746                      NA                NA             NA            NA
## 2485748                      NA                NA             NA            NA
## 2485749                      NA                NA             NA            NA
##         Daily.Quota.Remaining.Balance Dealing.Code Default.Probability
## 2485741                            NA           NA                  NA
## 2485742                            NA           NA                  NA
## 2485744                            NA           NA                  NA
## 2485746                            NA           NA                  NA
## 2485748                            NA           NA                  NA
## 2485749                            NA           NA                  NA
##         Discount.Ask Discount.Bid Discount.Factor Discount.Margin.Ask
## 2485741           NA           NA              NA                  NA
```

```
## 2485742           NA           NA              NA                  NA
## 2485744           NA           NA              NA                  NA
## 2485746           NA           NA              NA                  NA
## 2485748           NA           NA              NA                  NA
## 2485749           NA           NA              NA                  NA
##         Discount.Margin.Bid Discount.Rate Display.Name Energy.Netback
## 2485741                  NA            NA           NA             NA
## 2485742                  NA            NA           NA             NA
## 2485744                  NA            NA           NA             NA
## 2485746                  NA            NA           NA             NA
## 2485748                  NA            NA           NA             NA
## 2485749                  NA            NA           NA             NA
##         Energy.Swing Energy.Variance Exch.For.Physical.Vol Exch.For.Swaps.Vol
## 2485741           NA              NA                    NA                 NA
## 2485742           NA              NA                    NA                 NA
## 2485744           NA              NA                    NA                 NA
## 2485746           NA              NA                    NA                 NA
## 2485748           NA              NA                    NA                 NA
## 2485749           NA              NA                    NA                 NA
##         Final.Physical.Notification Fixed.Coupon Fixing.Date Fixing.Value
## 2485741                          NA           NA          NA           NA
## 2485742                          NA           NA          NA           NA
## 2485744                          NA           NA          NA           NA
## 2485746                          NA           NA          NA           NA
## 2485748                          NA           NA          NA           NA
## 2485749                          NA           NA          NA           NA
##         Floor.Premium Forecast.Avg.Swap.Pts Forecast.Mean Forecast.Median
## 2485741            NA                    NA            NA              NA
## 2485742            NA                    NA            NA              NA
## 2485744            NA                    NA            NA              NA
## 2485746            NA                    NA            NA              NA
## 2485748            NA                    NA            NA              NA
## 2485749            NA                    NA            NA              NA
##         Forecast.Std.Deviation Forward.Rate Futures.Basis Futures.Risk
## 2485741                     NA           NA            NA           NA
## 2485742                     NA           NA            NA           NA
## 2485744                     NA           NA            NA           NA
## 2485746                     NA           NA            NA           NA
## 2485748                     NA           NA            NA           NA
## 2485749                     NA           NA            NA           NA
##         Fwd.Outright.Ask Fwd.Outright.Bid Gamma Implied.Correlation
## 2485741               NA               NA    NA                  NA
## 2485742               NA               NA    NA                  NA
## 2485744               NA               NA    NA                  NA
## 2485746               NA               NA    NA                  NA
## 2485748               NA               NA    NA                  NA
## 2485749               NA               NA    NA                  NA
##         Implied.Repo.Rate Implied.Yield Index.Skew Max.Export.Limit
## 2485741                NA            NA         NA               NA
## 2485742                NA            NA         NA               NA
## 2485744                NA            NA         NA               NA
## 2485746                NA            NA         NA               NA
## 2485748                NA            NA         NA               NA
## 2485749                NA            NA         NA               NA
```

```
##         Max.Import.Limit Mean.Reversion Mid.Spread Mid.Yield Number.of.Trades
## 2485741               NA             NA         NA        NA               NA
## 2485742               NA             NA         NA        NA               NA
## 2485744               NA             NA         NA        NA               NA
## 2485746               NA             NA         NA        NA               NA
## 2485748               NA             NA         NA        NA               NA
## 2485749               NA             NA         NA        NA               NA
##         Odd.Lot.Trade.Price Odd.Lot.Trade.Turnover Odd.Lot.Trade.Volume
## 2485741                  NA                     NA                   NA
## 2485742                  NA                     NA                   NA
## 2485744                  NA                     NA                   NA
## 2485746                  NA                     NA                   NA
## 2485748                  NA                     NA                   NA
## 2485749                  NA                     NA                   NA
##         Option.Adjusted.Spread Option.Adjusted.Spread.Ask Orderbook.VWAP
## 2485741                     NA                         NA             NA
## 2485742                     NA                         NA             NA
## 2485744                     NA                         NA             NA
## 2485746                     NA                         NA             NA
## 2485748                     NA                         NA             NA
## 2485749                     NA                         NA             NA
##         Original.Acc..Volume Original.Yield Par.Yield
## 2485741                   NA             NA        NA
## 2485742                   NA             NA        NA
## 2485744                   NA             NA        NA
## 2485746                   NA             NA        NA
## 2485748                   NA             NA        NA
## 2485749                   NA             NA        NA
##         Present.Value.of.Basis.Point Quscnt.Physical.Notification
## 2485741                           NA                           NA
## 2485742                           NA                           NA
## 2485744                           NA                           NA
## 2485746                           NA                           NA
## 2485748                           NA                           NA
## 2485749                           NA                           NA
##         Real.Yield.Ask Real.Yield.Bid Recovery.Rate Reference.Bond.Yield
## 2485741             NA             NA            NA                   NA
## 2485742             NA             NA            NA                   NA
## 2485744             NA             NA            NA                   NA
## 2485746             NA             NA            NA                   NA
## 2485748             NA             NA            NA                   NA
## 2485749             NA             NA            NA                   NA
##         Refinery.Mgn.Crack Refinery.Mgn.Top Reserve.Vol Roll.down
## 2485741                 NA               NA          NA        NA
## 2485742                 NA               NA          NA        NA
## 2485744                 NA               NA          NA        NA
## 2485746                 NA               NA          NA        NA
## 2485748                 NA               NA          NA        NA
## 2485749                 NA               NA          NA        NA
##         Running.Spread Seasonal.Normal.Demand Short.Rate.Volatility
## 2485741             NA                     NA                    NA
## 2485742             NA                     NA                    NA
## 2485744             NA                     NA                    NA
## 2485746             NA                     NA                    NA
```

```
## 2485748            NA                     NA                     NA
## 2485749            NA                     NA                     NA
##         Source.Reference Sovereign.Spread Swap.Premium Swap.Rate
## 2485741               NA               NA           NA        NA
## 2485742               NA               NA           NA        NA
## 2485744               NA               NA           NA        NA
## 2485746               NA               NA           NA        NA
## 2485748               NA               NA           NA        NA
## 2485749               NA               NA           NA        NA
##         Swap.Spread.Ask Swap.Spread.Bid Swap.Yield Theoretical.Price.Ask
## 2485741              NA              NA         NA                    NA
## 2485742              NA              NA         NA                    NA
## 2485744              NA              NA         NA                    NA
## 2485746              NA              NA         NA                    NA
## 2485748              NA              NA         NA                    NA
## 2485749              NA              NA         NA                    NA
##         Theoretical.Price.Bid Theoretical.Price.Mid Theoretical.Spread.Ask
## 2485741                    NA                    NA                     NA
## 2485742                    NA                    NA                     NA
## 2485744                    NA                    NA                     NA
## 2485746                    NA                    NA                     NA
## 2485748                    NA                    NA                     NA
## 2485749                    NA                    NA                     NA
##         Theoretical.Spread.Bid Theoretical.Spread.Mid Theta Total.Buy.Value
## 2485741                     NA                     NA    NA              NA
## 2485742                     NA                     NA    NA              NA
## 2485744                     NA                     NA    NA              NA
## 2485746                     NA                     NA    NA              NA
## 2485748                     NA                     NA    NA              NA
## 2485749                     NA                     NA    NA              NA
##         Total.Buy.Volume Total.Demand Total.Sell.Value Total.Sell.Volume
## 2485741               NA           NA               NA                NA
## 2485742               NA           NA               NA                NA
## 2485744               NA           NA               NA                NA
## 2485746               NA           NA               NA                NA
## 2485748               NA           NA               NA                NA
## 2485749               NA           NA               NA                NA
##         Trade.Price.Currency Unique.Trade.Identification Yield.To.Call
## 2485741                   NA                      213413            NA
## 2485742                   NA                      213414            NA
## 2485744                   NA                       58215            NA
## 2485746                   NA                      213415            NA
## 2485748                   NA                       58216            NA
## 2485749                   NA                      213416            NA
##         Yield.to.Maturity Yield.to.Maturity.Ask Yield.to.Maturity.Bid
## 2485741                NA                    NA                    NA
## 2485742                NA                    NA                    NA
## 2485744                NA                    NA                    NA
## 2485746                NA                    NA                    NA
## 2485748                NA                    NA                    NA
## 2485749                NA                    NA                    NA
##         Yield.To.Put Zero.Yield Aggressive.Order.Condition
## 2485741           NA         NA                         NA
## 2485742           NA         NA                         NA
```

```
## 2485744          NA         NA                        NA
## 2485746          NA         NA                        NA
## 2485748          NA         NA                        NA
## 2485749          NA         NA                        NA
##         Categorisation.of.Trades Effective.Convexity Effective.Duration
## 2485741                       NA                  NA                 NA
## 2485742                       NA                  NA                 NA
## 2485744                       NA                  NA                 NA
## 2485746                       NA                  NA                 NA
## 2485748                       NA                  NA                 NA
## 2485749                       NA                  NA                 NA
##         Fair.Value Fair.Value.Accuracy.Measure Fair.Value.Consistency.Score
## 2485741         NA                          NA                           NA
## 2485742         NA                          NA                           NA
## 2485744         NA                          NA                           NA
## 2485746         NA                          NA                           NA
## 2485748         NA                          NA                           NA
## 2485749         NA                          NA                           NA
##         Fair.Value.DV01 Fair.Value.Spread Fair.Value.Volume Fair.Value.Yield
## 2485741              NA                NA                NA               NA
## 2485742              NA                NA                NA               NA
## 2485744              NA                NA                NA               NA
## 2485746              NA                NA                NA               NA
## 2485748              NA                NA                NA               NA
## 2485749              NA                NA                NA               NA
##         Flows Forward.Future.Risk Gross.Basis Halt.Reason Hedge.Ratio
## 2485741    NA                  NA          NA          NA          NA
## 2485742    NA                  NA          NA          NA          NA
## 2485744    NA                  NA          NA          NA          NA
## 2485746    NA                  NA          NA          NA          NA
## 2485748    NA                  NA          NA          NA          NA
## 2485749    NA                  NA          NA          NA          NA
##         Imbalance.Activity.Type Imbalance.Side Imbalance.Variation.Indicator
## 2485741                      NA             NA                            NA
## 2485742                      NA             NA                            NA
## 2485744                      NA             NA                            NA
## 2485746                      NA             NA                            NA
## 2485748                      NA             NA                            NA
## 2485749                      NA             NA                            NA
##         Indicative.Auction.Price Indicative.Auction.Volume
## 2485741                       NA                        NA
## 2485742                       NA                        NA
## 2485744                       NA                        NA
## 2485746                       NA                        NA
## 2485748                       NA                        NA
## 2485749                       NA                        NA
##         Instrument.Description Invoice.Price Invoice.Spread LULD.Indicator
## 2485741                     NA            NA             NA
## 2485742                     NA            NA             NA
## 2485744                     NA            NA             NA
## 2485746                     NA            NA             NA
## 2485748                     NA            NA             NA
## 2485749                     NA            NA             NA
##         MMT.Classification Net.Basis Net.Change Original.Buyer.Id
```

```
## 2485741                NA        NA         NA                NA
## 2485742                NA        NA         NA                NA
## 2485744                NA        NA         NA                NA
## 2485746                NA        NA         NA                NA
## 2485748                NA        NA         NA                NA
## 2485749                NA        NA         NA                NA
##         Original.Primary.Activity Original.RIC.of.Last.Eligible.Trade
## 2485741                        NA                                  NA
## 2485742                        NA                                  NA
## 2485744                        NA                                  NA
## 2485746                        NA                                  NA
## 2485748                        NA                                  NA
## 2485749                        NA                                  NA
##         Original.Seller.Id Original.Trade.Sequence.Number
## 2485741                 NA                             NA
## 2485742                 NA                             NA
## 2485744                 NA                             NA
## 2485746                 NA                             NA
## 2485748                 NA                             NA
## 2485749                 NA                             NA
##         Original.Unique.Trade.Identification Primary.Activity
## 2485741                                   NA               NA
## 2485742                                   NA               NA
## 2485744                                   NA               NA
## 2485746                                   NA               NA
## 2485748                                   NA               NA
## 2485749                                   NA               NA
##         RIC.of.Last.Eligible.Trade Short.Sale.Restriction.Indicator
## 2485741                         NA
## 2485742                         NA
## 2485744                         NA
## 2485746                         NA
## 2485748                         NA
## 2485749                         NA
##         Spread.to.Treasury Trade.Sequence.Number Trade.Yield Trading.Status
## 2485741                 NA                    NA          NA             NA
## 2485742                 NA                    NA          NA             NA
## 2485744                 NA                    NA          NA             NA
## 2485746                 NA                    NA          NA             NA
## 2485748                 NA                    NA          NA             NA
## 2485749                 NA                    NA          NA             NA
##         Change.Type Old.Value New.Value ISIN Unique.Quote.Identification Rho
## 2485741          NA        NA        NA   NA                          NA  NA
## 2485742          NA        NA        NA   NA                          NA  NA
## 2485744          NA        NA        NA   NA                          NA  NA
## 2485746          NA        NA        NA   NA                          NA  NA
## 2485748          NA        NA        NA   NA                          NA  NA
## 2485749          NA        NA        NA   NA                          NA  NA
##         Vega
## 2485741   NA
## 2485742   NA
## 2485744   NA
## 2485746   NA
## 2485748   NA
```

```
## 2485749   NA
```

```r
# Convert Exchange Time column to be compatible with xts object.
cleaned_data$Exch.Time <- as.POSIXct(paste("2000-01-01", cleaned_data$Exch.Time))

# Convert dataframe into xts object.
amzn_xts <- xts(cleaned_data[,-which(names(cleaned_data) == "Exch.Time")], order.by = cleaned_data$Exch

# Rename Bid, Ask, and Symbol columns to match correct format.
names(amzn_xts)[names(amzn_xts) == 'Bid.Price'] <- 'BID'
names(amzn_xts)[names(amzn_xts) == 'Ask.Price'] <- 'OFR'
names(amzn_xts)[names(amzn_xts) == 'X.RIC'] <- 'SYMBOL'

head(amzn_xts)
```

```
##                     SYMBOL Alias.Underlying.RIC       Domain
## 2000-01-01 00:00:03 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:06 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:08 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:11 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:15 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:16 AMZN.O                 <NA> Market Price
##                                          Date.Time  Type Ex.Cntrb.ID  LOC
## 2000-01-01 00:00:03 2023-01-04T19:00:03.076109677-05 Trade         PSE <NA>
## 2000-01-01 00:00:06 2023-01-04T19:00:06.952061118-05 Trade         PSE <NA>
## 2000-01-01 00:00:08 2023-01-04T19:00:08.031318592-05 Trade         PSE <NA>
## 2000-01-01 00:00:11 2023-01-04T19:00:11.472162067-05 Trade         PSE <NA>
## 2000-01-01 00:00:15 2023-01-04T19:00:15.747299783-05 Trade         ADF <NA>
## 2000-01-01 00:00:16 2023-01-04T19:00:16.276026224-05 Trade         PSE <NA>
##                        Price  Volume Market.VWAP Buyer.ID   BID Bid.Size
## 2000-01-01 00:00:03 86.65000       3        <NA>          86.65        2
## 2000-01-01 00:00:06 86.65000     200        <NA>          86.60        7
## 2000-01-01 00:00:08 86.65000      41        <NA>          86.60        7
## 2000-01-01 00:00:11 86.65000       2        <NA>          86.60        7
## 2000-01-01 00:00:15 86.65000       2        <NA>          86.60        7
## 2000-01-01 00:00:16 86.65000     200        <NA>          86.60        7
##                     No..Buyers Seller.ID   OFR Ask.Size No..Sellers
## 2000-01-01 00:00:03       <NA>           86.67       20        <NA>
## 2000-01-01 00:00:06       <NA>           86.68       23        <NA>
## 2000-01-01 00:00:08       <NA>           86.68       23        <NA>
## 2000-01-01 00:00:11       <NA>           86.68       25        <NA>
## 2000-01-01 00:00:15       <NA>           86.65        2        <NA>
## 2000-01-01 00:00:16       <NA>           86.68       26        <NA>
##                                                             Qualifiers
## 2000-01-01 00:00:03 [IRG_SUBIND];@FTI[GV4_TEXT];   [IRGCOND];X[GV3_TEXT]
## 2000-01-01 00:00:06  [IRG_SUBIND];@FT[GV4_TEXT];SWT[IRGCOND];X[GV3_TEXT]
## 2000-01-01 00:00:08  [IRG_SUBIND];@ TI[GV4_TEXT];ODT[IRGCOND];[GV3_TEXT]
## 2000-01-01 00:00:11 [IRG_SUBIND];@FTI[GV4_TEXT];   [IRGCOND];X[GV3_TEXT]
## 2000-01-01 00:00:15 Q[IRG_SUBIND];@ TI[GV4_TEXT];ODT[IRGCOND];[GV3_TEXT]
## 2000-01-01 00:00:16   [IRG_SUBIND];@ T[GV4_TEXT];132[IRGCOND];[GV3_TEXT]
##                     Seq..No. Block.Trd PE.Ratio Yield Bid.Yld Ask.Yld
## 2000-01-01 00:00:03  6079493      <NA>     <NA>  <NA>    <NA>    <NA>
## 2000-01-01 00:00:06  6079496      <NA>     <NA>  <NA>    <NA>    <NA>
## 2000-01-01 00:00:08  6079497      <NA>     <NA>  <NA>    <NA>    <NA>
## 2000-01-01 00:00:11  6079500      <NA>     <NA>  <NA>    <NA>    <NA>
```

```
## 2000-01-01 00:00:15  6079503      <NA>     <NA>  <NA>    <NA>    <NA>
## 2000-01-01 00:00:16  6079506      <NA>     <NA>  <NA>    <NA>    <NA>
##                     ISMA.Bid.Yld ISMA.Ask.Yld Duration Mod.Durtn  BPV Convexity
## 2000-01-01 00:00:03         <NA>         <NA>     <NA>      <NA> <NA>      <NA>
## 2000-01-01 00:00:06         <NA>         <NA>     <NA>      <NA> <NA>      <NA>
## 2000-01-01 00:00:08         <NA>         <NA>     <NA>      <NA> <NA>      <NA>
## 2000-01-01 00:00:11         <NA>         <NA>     <NA>      <NA> <NA>      <NA>
## 2000-01-01 00:00:15         <NA>         <NA>     <NA>      <NA> <NA>      <NA>
## 2000-01-01 00:00:16         <NA>         <NA>     <NA>      <NA> <NA>      <NA>
##                     Bench.Spd Swp.Spd Asst.Swp.Spd Swap.Point UpLim.Price
## 2000-01-01 00:00:03      <NA>    <NA>         <NA>       <NA>        0.00
## 2000-01-01 00:00:06      <NA>    <NA>         <NA>       <NA>        0.00
## 2000-01-01 00:00:08      <NA>    <NA>         <NA>       <NA>        0.00
## 2000-01-01 00:00:11      <NA>    <NA>         <NA>       <NA>        0.00
## 2000-01-01 00:00:15      <NA>    <NA>         <NA>       <NA>        0.00
## 2000-01-01 00:00:16      <NA>    <NA>         <NA>       <NA>        0.00
##                     LoLim.Price Theo..Price Parity Premium Bid.Imp..Vol
## 2000-01-01 00:00:03        0.00        <NA>   <NA>    <NA>         <NA>
## 2000-01-01 00:00:06        0.00        <NA>   <NA>    <NA>         <NA>
## 2000-01-01 00:00:08        0.00        <NA>   <NA>    <NA>         <NA>
## 2000-01-01 00:00:11        0.00        <NA>   <NA>    <NA>         <NA>
## 2000-01-01 00:00:15        0.00        <NA>   <NA>    <NA>         <NA>
## 2000-01-01 00:00:16        0.00        <NA>   <NA>    <NA>         <NA>
##                     Ask.Imp..Vol Imp..Vol. Crack  Top Freight.Pr. Offer Actual
## 2000-01-01 00:00:03         <NA>      <NA>  <NA> <NA>        <NA>  <NA>   <NA>
## 2000-01-01 00:00:06         <NA>      <NA>  <NA> <NA>        <NA>  <NA>   <NA>
## 2000-01-01 00:00:08         <NA>      <NA>  <NA> <NA>        <NA>  <NA>   <NA>
## 2000-01-01 00:00:11         <NA>      <NA>  <NA> <NA>        <NA>  <NA>   <NA>
## 2000-01-01 00:00:15         <NA>      <NA>  <NA> <NA>        <NA>  <NA>   <NA>
## 2000-01-01 00:00:16         <NA>      <NA>  <NA> <NA>        <NA>  <NA>   <NA>
##                     Prior Revised Forecast Frcst.High Frcst.Low No..Frcts
## 2000-01-01 00:00:03  <NA>    <NA>     <NA>       <NA>      <NA>      <NA>
## 2000-01-01 00:00:06  <NA>    <NA>     <NA>       <NA>      <NA>      <NA>
## 2000-01-01 00:00:08  <NA>    <NA>     <NA>       <NA>      <NA>      <NA>
## 2000-01-01 00:00:11  <NA>    <NA>     <NA>       <NA>      <NA>      <NA>
## 2000-01-01 00:00:15  <NA>    <NA>     <NA>       <NA>      <NA>      <NA>
## 2000-01-01 00:00:16  <NA>    <NA>     <NA>       <NA>      <NA>      <NA>
##                           Date Bid.Tic Tick.Dir.  Open    High     Low
## 2000-01-01 00:00:03 2023-01-05    <NA>           86.55 86.9800 83.3600
## 2000-01-01 00:00:06 2023-01-05    <NA>           86.55 86.9800 83.3600
## 2000-01-01 00:00:08 2023-01-05    <NA>           86.55 86.9800 83.3600
## 2000-01-01 00:00:11 2023-01-05    <NA>           86.55 86.9800 83.3600
## 2000-01-01 00:00:15 2023-01-05    <NA>           86.55 86.9800 83.3600
## 2000-01-01 00:00:16 2023-01-05    <NA>           86.55 86.9800 83.3600
##                     Open.Interest Bench.Price Open.Yld High.Yld Low.Yld
## 2000-01-01 00:00:03          <NA>        <NA>     <NA>     <NA>    <NA>
## 2000-01-01 00:00:06          <NA>        <NA>     <NA>     <NA>    <NA>
## 2000-01-01 00:00:08          <NA>        <NA>     <NA>     <NA>    <NA>
## 2000-01-01 00:00:11          <NA>        <NA>     <NA>     <NA>    <NA>
## 2000-01-01 00:00:15          <NA>        <NA>     <NA>     <NA>    <NA>
## 2000-01-01 00:00:16          <NA>        <NA>     <NA>     <NA>    <NA>
##                     Acc..Volume Turnover Volatility Strike Mid.Price
## 2000-01-01 00:00:03    68681102     <NA>       <NA>   <NA>      <NA>
## 2000-01-01 00:00:06    68681302     <NA>       <NA>   <NA>      <NA>
```

```
## 2000-01-01 00:00:08    68681343     <NA>       <NA>   <NA>      <NA>
## 2000-01-01 00:00:11    68681345     <NA>       <NA>   <NA>      <NA>
## 2000-01-01 00:00:15    68681347     <NA>       <NA>   <NA>      <NA>
## 2000-01-01 00:00:16    68681547     <NA>       <NA>   <NA>      <NA>
##                     Advancing.Issues Declining.Issues Unchanged.Issues
## 2000-01-01 00:00:03             <NA>             <NA>             <NA>
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```

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```

Liquidity Analysis

Perform core liquidity analysis for the project.

Price Computation Retrieve and compute the bid, ask, trade, and mid prices.

```r
# Determine number of trades in dataset.
num_of_trades <- nrow(amzn_xts)

paste("Total number of trades for AMZN on 01/04/2023:", num_of_trades)
```

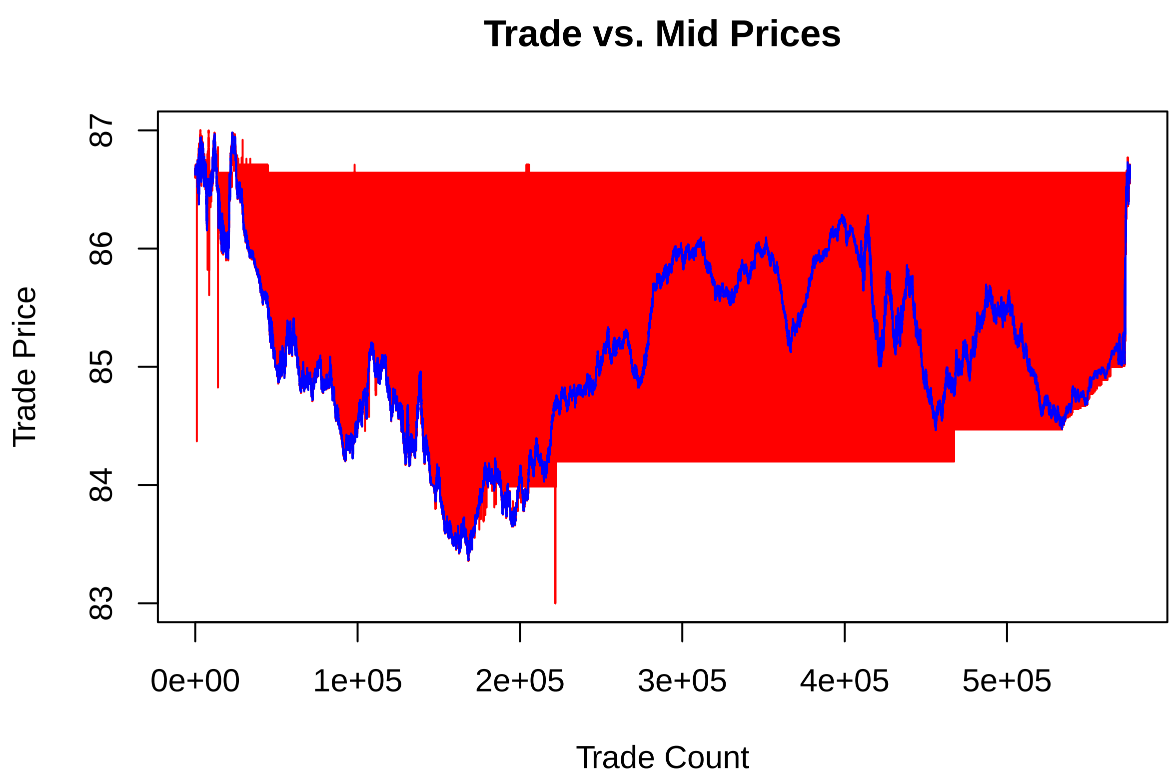
```
## [1] "Total number of trades for AMZN on 01/04/2023: 575733"
```

```r
# Retrieve trade, bid, and ask prices.
prices <- as.numeric(amzn_xts$Price)
bids <- as.numeric(amzn_xts$BID)
asks <- as.numeric(amzn_xts$OFR)

# Compute the mid price as the average of the bid and ask prices.
mids <- (bids + asks) * 0.5
```

Trade vs. Mid Price Plotting Plot the trade vs. mid prices.

```r
plot(prices, type="l", col="red", main="Trade vs. Mid Prices",
     xlab="Trade Count",
     ylab="Trade Price")
lines(mids, type="l", col="blue")
```



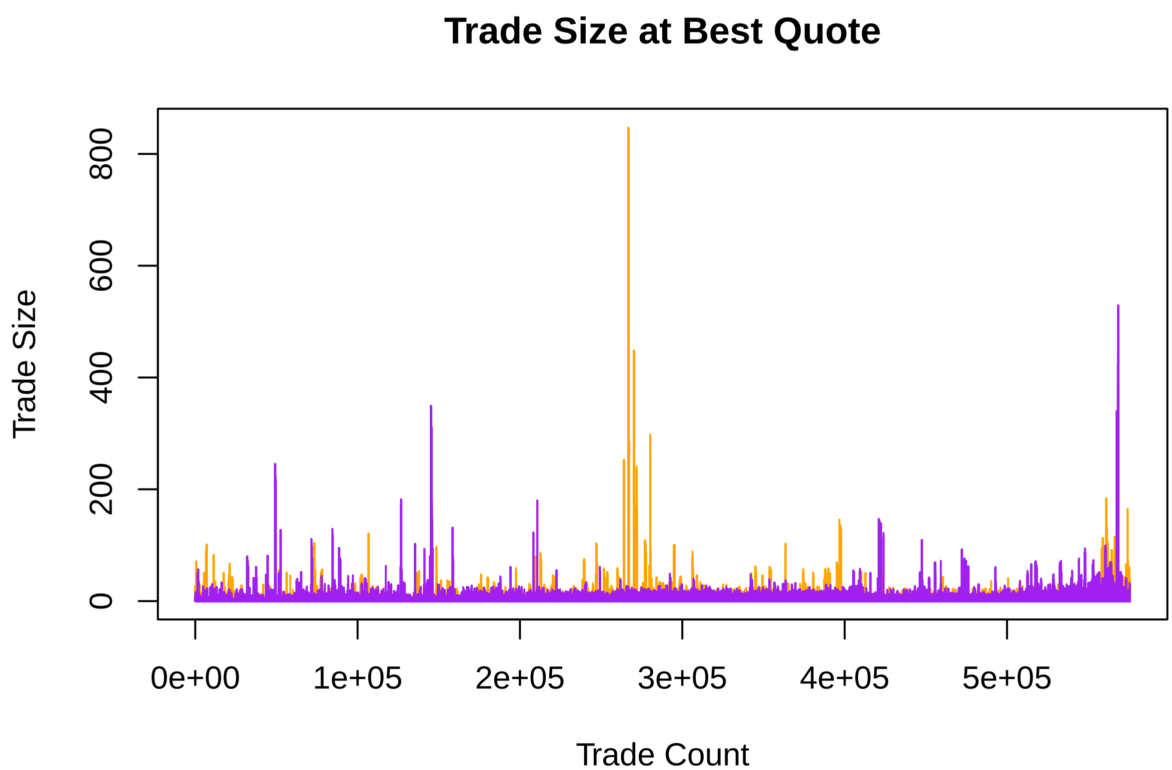
Size Computation Retrieve and compute the bid and ask sizes as well as the LOB imbalances.

```r
# Retrieve bid and ask sizes.
bid_size <- as.numeric(amzn_xts$Bid.Size)
ask_size <- as.numeric(amzn_xts$Ask.Size)
```

```r
# Compute the LOB imbalance at each time step as the sum of the bid and ask sizes.
LOB_imbalance <- bid_size + ask_size
```

Trade Size Plotting Plot the trade sizes.

```r
plot(ask_size, col="orange", type="h",
     ylab="Trade Size",
     xlab="Trade Count", main="Trade Size at Best Quote")
lines(bid_size, col="purple", type="h")
```



Liquidity Measures Compute the relevant liquidity measures.

```r
# Retrieve liquidity measures.
liquidity_measures <- getLiquidityMeasures(amzn_xts)

# Compute the Quoted Spread.
quoted_spread <- mean(as.numeric(liquidity_measures$quotedSpread))

quoted_spread
```

```
## [1] 0.01512349
```

```r
# Compute the Effective Spread.
effective_spread <- mean(as.numeric(liquidity_measures$effectiveSpread))

effective_spread
```

```
## [1] 0.03655411
```

```r
# Compute the Realized Spread.
realized_spread <- mean(na.omit(as.numeric(liquidity_measures$realizedSpread)))

realized_spread
```

```
## [1] 0.02876561
```

```r
# Compute the Price Impact.
price_impact <- mean(na.omit(as.numeric(liquidity_measures$priceImpact)))

price_impact
```

```
## [1] 0.00389478
```

Time Bucket Analysis

Perform analysis on each hour in the dataset.

```r
## Split dataset into 24 buckets (24 hours) for analysis.

# amzn_data_list <- list()
#
# for (i in 0:23)
# {
#   # Construct the time range string.
#   start_hour <- sprintf("%02d:00", i)
#   end_hour <- end_hour <- ifelse(i == 23, "23:59:59", sprintf("%02d:00", i + 1))
#   time_range <- paste("T", start_hour, "/", "T", end_hour, sep = "")
#
#   # Subset amzn_xts and store in the list.
#   amzn_data_list[[paste("amzn_xts_", i + 1, sep = "")]] <- amzn_data_list[time_range]
# }
#
# amzn_data_list

amzn_xts_1 <- amzn_xts["T00:00/T01:00"]
amzn_xts_2 <- amzn_xts["T01:00/T02:00"]
amzn_xts_3 <- amzn_xts["T02:00/T03:00"]
amzn_xts_4 <- amzn_xts["T03:00/T04:00"]
amzn_xts_5 <- amzn_xts["T04:00/T05:00"]
amzn_xts_6 <- amzn_xts["T05:00/T06:00"]
amzn_xts_7 <- amzn_xts["T06:00/T07:00"]
amzn_xts_8 <- amzn_xts["T07:00/T08:00"]
amzn_xts_9 <- amzn_xts["T08:00/T09:00"]
amzn_xts_10 <- amzn_xts["T09:00/T10:00"]
amzn_xts_11 <- amzn_xts["T10:00/T11:00"]
amzn_xts_12 <- amzn_xts["T11:00/T12:00"]
amzn_xts_13 <- amzn_xts["T12:00/T13:00"]
amzn_xts_14 <- amzn_xts["T13:00/T14:00"]
amzn_xts_15 <- amzn_xts["T14:00/T15:00"]
amzn_xts_16 <- amzn_xts["T15:00/T16:00"]
amzn_xts_17 <- amzn_xts["T16:00/T17:00"]
amzn_xts_18 <- amzn_xts["T17:00/T18:00"]
amzn_xts_19 <- amzn_xts["T18:00/T19:00"]
```

```r
amzn_xts_20 <- amzn_xts["T19:00/T20:00"]
amzn_xts_21 <- amzn_xts["T20:00/T21:00"]
amzn_xts_22 <- amzn_xts["T21:00/T22:00"]
amzn_xts_23 <- amzn_xts["T22:00/T23:00"]
amzn_xts_24 <- amzn_xts["T23:00/T23:59:59"]

head(amzn_xts_1)
```

```
##                     SYMBOL Alias.Underlying.RIC       Domain
## 2000-01-01 00:00:03 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:06 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:08 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:11 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:15 AMZN.O                 <NA> Market Price
## 2000-01-01 00:00:16 AMZN.O                 <NA> Market Price
##                                            Date.Time  Type Ex.Cntrb.ID  LOC
## 2000-01-01 00:00:03 2023-01-04T19:00:03.076109677-05 Trade         PSE <NA>
## 2000-01-01 00:00:06 2023-01-04T19:00:06.952061118-05 Trade         PSE <NA>
## 2000-01-01 00:00:08 2023-01-04T19:00:08.031318592-05 Trade         PSE <NA>
## 2000-01-01 00:00:11 2023-01-04T19:00:11.472162067-05 Trade         PSE <NA>
## 2000-01-01 00:00:15 2023-01-04T19:00:15.747299783-05 Trade         ADF <NA>
## 2000-01-01 00:00:16 2023-01-04T19:00:16.276026224-05 Trade         PSE <NA>
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## 2000-01-01 00:00:06 86.65000     200        <NA>          86.60        7
## 2000-01-01 00:00:08 86.65000      41        <NA>          86.60        7
## 2000-01-01 00:00:11 86.65000       2        <NA>          86.60        7
## 2000-01-01 00:00:15 86.65000       2        <NA>          86.60        7
## 2000-01-01 00:00:16 86.65000     200        <NA>          86.60        7
##                     No..Buyers Seller.ID   OFR Ask.Size No..Sellers
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## 2000-01-01 00:00:15 Q[IRG_SUBIND];@ TI[GV4_TEXT];ODT[IRGCOND];[GV3_TEXT]
## 2000-01-01 00:00:16   [IRG_SUBIND];@ T[GV4_TEXT];132[IRGCOND];[GV3_TEXT]
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```

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```

```
## Calculate liquidity measures for each subset.

liquidity_1 <- getLiquidityMeasures(amzn_xts_1)
liquidity_2 <- getLiquidityMeasures(amzn_xts_2)
liquidity_3 <- getLiquidityMeasures(amzn_xts_3)
liquidity_4 <- getLiquidityMeasures(amzn_xts_4)
liquidity_5 <- getLiquidityMeasures(amzn_xts_5)
liquidity_6 <- getLiquidityMeasures(amzn_xts_6)
liquidity_7 <- getLiquidityMeasures(amzn_xts_7)
liquidity_8 <- getLiquidityMeasures(amzn_xts_8)
liquidity_9 <- getLiquidityMeasures(amzn_xts_9)
```

```r
liquidity_10 <- getLiquidityMeasures(amzn_xts_10)
liquidity_11 <- getLiquidityMeasures(amzn_xts_11)
liquidity_12 <- getLiquidityMeasures(amzn_xts_12)
liquidity_13 <- getLiquidityMeasures(amzn_xts_13)
liquidity_14 <- getLiquidityMeasures(amzn_xts_14)
liquidity_15 <- getLiquidityMeasures(amzn_xts_15)
liquidity_16 <- getLiquidityMeasures(amzn_xts_16)
liquidity_17 <- getLiquidityMeasures(amzn_xts_17)
liquidity_18 <- getLiquidityMeasures(amzn_xts_18)
liquidity_19 <- getLiquidityMeasures(amzn_xts_19)
liquidity_20 <- getLiquidityMeasures(amzn_xts_20)
liquidity_21 <- getLiquidityMeasures(amzn_xts_21)
liquidity_22 <- getLiquidityMeasures(amzn_xts_22)
liquidity_23 <- getLiquidityMeasures(amzn_xts_23)
liquidity_24 <- getLiquidityMeasures(amzn_xts_24)

# # Initialize an empty list to store the liquidity measures.
# liquidity_measures_list <- list()

# # Loop through 24 subsets,
# for (i in 1:24) {
#   # Construct the variable name for each amzn_xts_*
#   xts_var_name <- paste("amzn_xts_", i, sep = "")
#
#   # Use get() to retrieve the xts object and calculate the liquidity measures.
#   liquidity_measures_list[[paste("liquidity_", i, sep = "")]] <- getLiquidityMeasures(get(xts_var_nam
# }
```

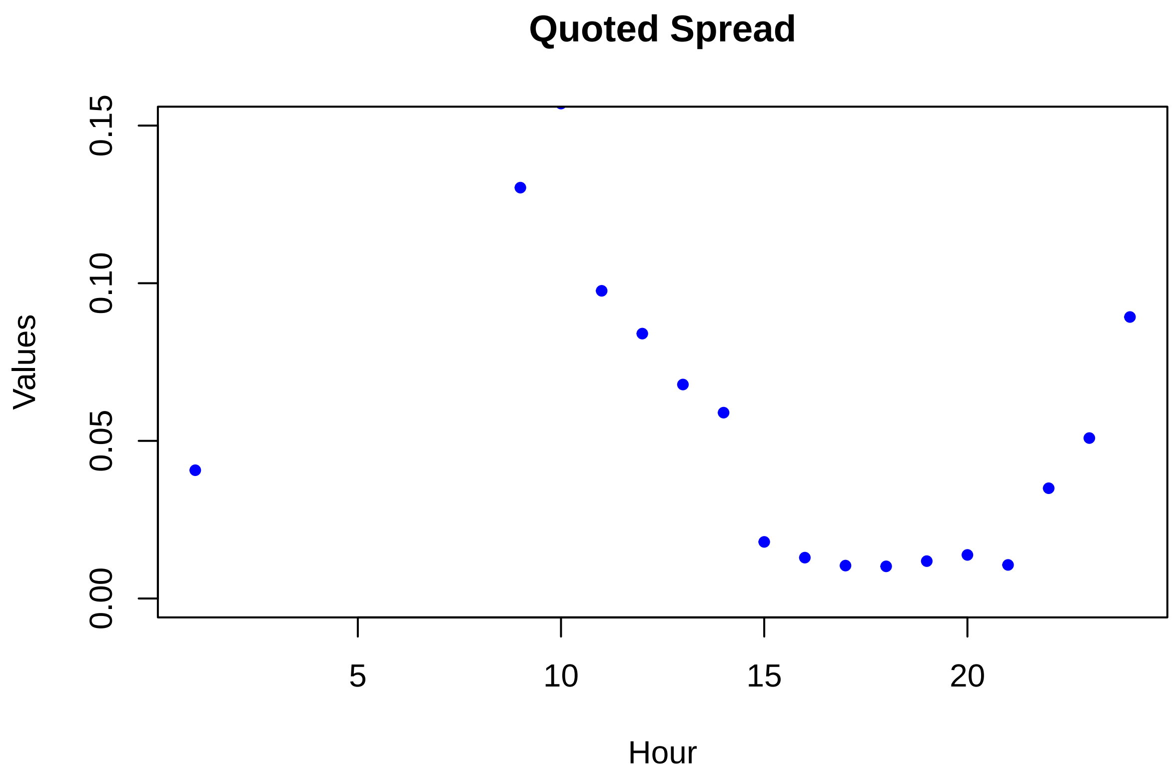
Quoted Spread Calculation Calculated quoted spread for each hour.

```r
## Calculate Quoted Spread for each bucket.

# Initialize an empty vector to store the quoted spread means.
quoted_spread_hr <- numeric(24)

# Loop through 24 hours.
for (i in 1:24) {
  # Construct the variable name as a string.
  var_name <- paste("liquidity_", i, sep = "")

  # Use get() to retrieve the dataframe and calculate the mean quoted spread.
  quoted_spread_hr[i] <- mean(as.numeric(get(var_name)$quotedSpread), na.rm = TRUE)
}

quoted_spread_hr
```

```
##  [1] 0.04068116        NaN        NaN        NaN        NaN        NaN
##  [7]        NaN        NaN 0.13031746 0.15699330 0.09759420 0.08401734
## [13] 0.06786622 0.05894439 0.01794931 0.01295927 0.01043155 0.01019991
## [19] 0.01184737 0.01382093 0.01064357 0.03497011 0.05088099 0.08928669
```

Quoted Spread Plotting Plot quoted spread for each hour.

```r
# Plot Quoted Spread for 24 hours.
plot(1:24, quoted_spread_hr, type="p", pch=20, col="blue", main="Quoted Spread",
     xlab = "Hour", ylab = "Values", ylim = c(0,0.15))
```



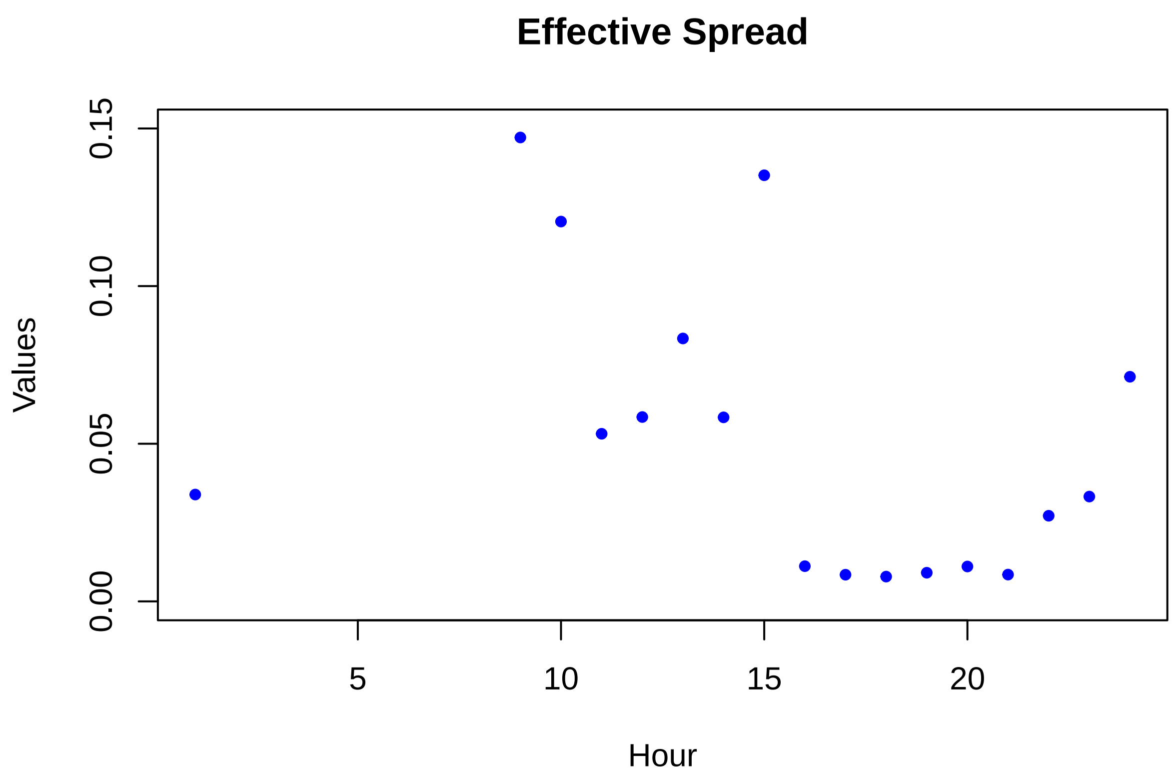
Effective Spread Calculation Calculated effective spread for each hour.

```r
## Calculate Effective Spread for each bucket.

# Initialize an empty vector to store the effective spread means.
effective_spread_hr <- numeric(24)

# Loop through 24 hours.
for (i in 1:24) {
  # Construct the variable name as a string.
  var_name <- paste("liquidity_", i, sep = "")

  # Use get() to retrieve the dataframe and calculate the mean quoted spread.
  effective_spread_hr[i] <- mean(as.numeric(get(var_name)$effectiveSpread), na.rm = TRUE)
}

effective_spread_hr
```

```
##  [1] 0.033885700         NaN         NaN         NaN         NaN         NaN
##  [7]         NaN         NaN 0.147142857 0.120477387 0.053159420 0.058468208
## [13] 0.083390050 0.058367702 0.135155833 0.011162538 0.008454183 0.007855181
## [19] 0.009078966 0.011062543 0.008486380 0.027158412 0.033240495 0.071242091
```

Effective Spread Plotting Plot quoted spread for each hour.

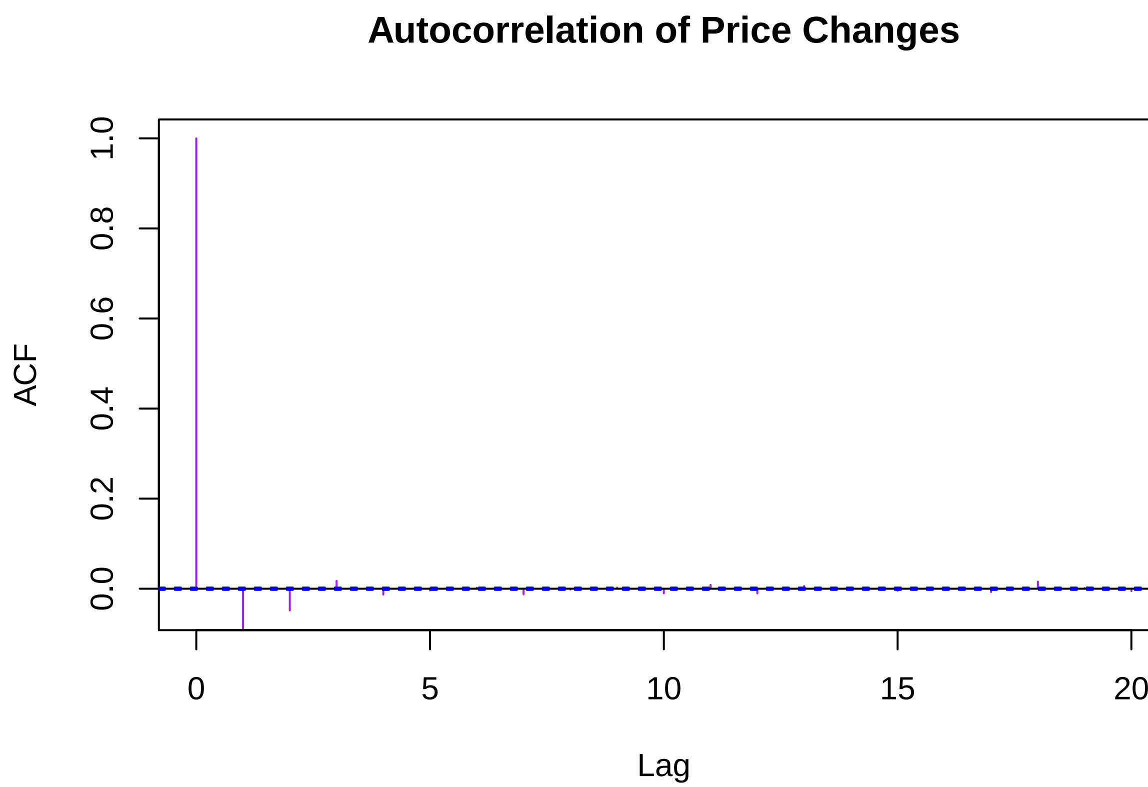
```
# Plot Quoted Spread for 24 hours.
plot(1:24, effective_spread_hr, type="p", pch=20, col="blue", main="Effective Spread",
     xlab = "Hour", ylab = "Values", ylim = c(0,0.15))
```



Volatility Estimate

The following section estimates the volatility using various methods.

```
prices <- as.numeric(amzn_xts$Price)

# Calculate price differences.
price_difference <- diff(prices)

# Display autocorrelation of price differences.
covpr <- acf(price_difference, lag.max=20, type="correlation", plot=FALSE)

plot(covpr, col="purple", ylim = c(-0.05,1), main = "Autocorrelation of Price Changes")
```



Roll Model Estimate

```
## Calculate parameters and estimates for Roll's Model.

covpr <- acf(price_difference, lag.max=20, type="covariance", plot=FALSE)

gamma0 <- sd(price_difference)^2

gamma0
```

```
## [1] 0.005261148
```

```
gamma1 <- covpr$acf[2]

gamma1
```

```
## [1] -0.00224291
```

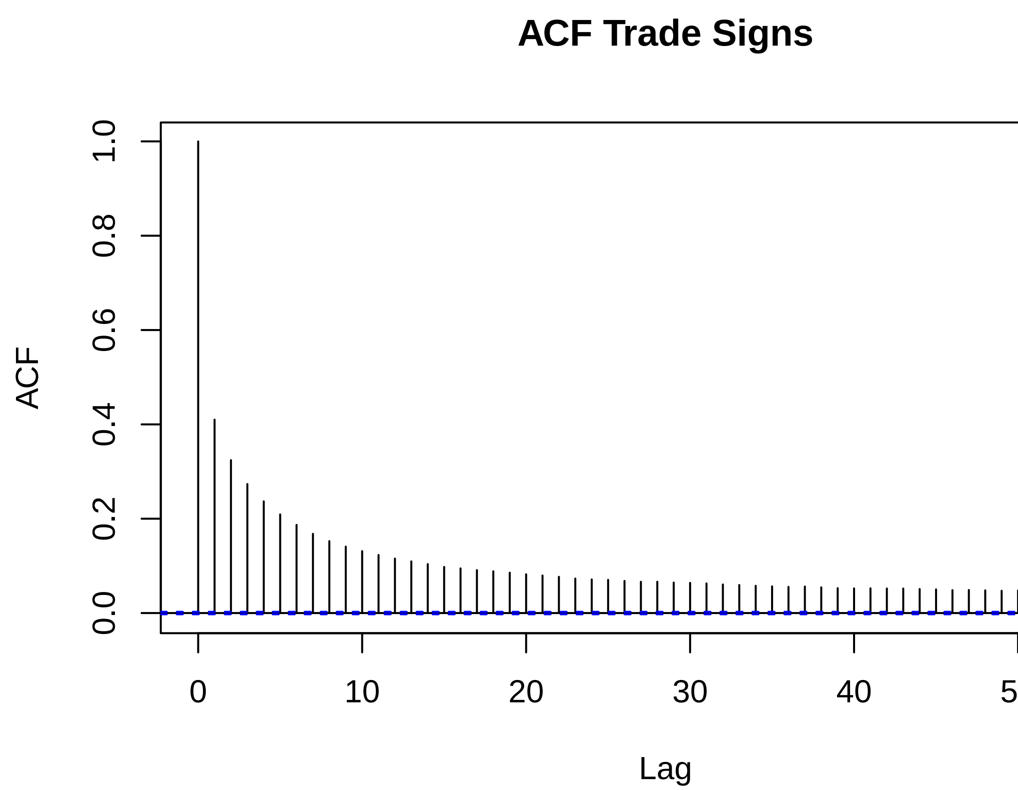
```
cparam <- sqrt(-covpr$acf[2])

cparam
```

```
## [1] 0.04735937
```

```
sig2u <- gamma0 + 2*gamma1

sigu <- sqrt(sig2u)

sigu
```

```
## [1] 0.02784472
```

```r
# Retrieve trade signs.
trade_signs <- getTradeDirection(amzn_xts)

acf_TS <- acf(trade_signs, main="ACF Trade Signs")
```



Improved Roll Model Estimate

```r
trade_signs_diff <- diff(trade_signs)

mid_diff <- diff(mids)

fit_lm <- lm(price_difference ~ mid_diff + trade_signs_diff)

fit_lm$coeff[3]
```

```
## trade_signs_diff
##       0.00953869
```

```r
realized_var <- function(q)
{
  rCov(diff(prices, lag = q, differences = 1)) / q
}

realized_var_df <- NULL

for(q in 1:200)
```

```
{
  realized_var_df <- c(realized_var_df, realized_var(q))
}

trades_per_five <- num_of_trades * 5 / 1440
realized_var_five <- realized_var(trades_per_five)

realized_var_five
```

Signature Plot

```
## [1] 11.41892
```

```
# Realized volatility sampling trades per five minutes.
sqrt(realized_var_five)
```

```
## [1] 3.379189
```

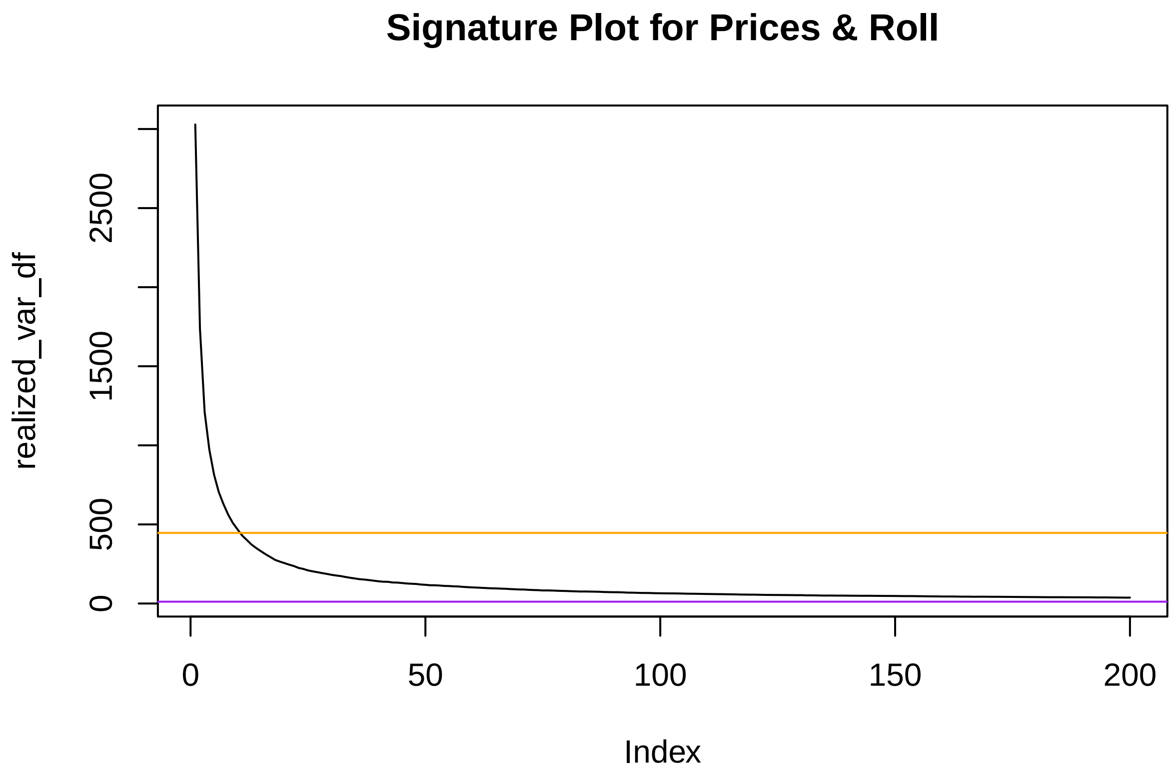
```
realized_volatility_roll <- sig2u * num_of_trades
realized_volatility_roll
```

```
## [1] 446.3821
```

```
sqrt(realized_volatility_roll)
```

```
## [1] 21.12776
```

```
plot(realized_var_df, type ="l",  main="Signature Plot for Prices & Roll")
abline(h = realized_var_five,col="purple")
abline(h = realized_volatility_roll,col="orange")
```



PIN (Probability of Informed Trading)

Compute the Probability of Informed Trading (PIN) based on this formula:

$$PIN = \frac{\alpha\mu}{\alpha\mu + \epsilon_B + \epsilon_S}$$

```
library(InfoTrad)
```

```
##
## Attaching package: 'InfoTrad'

## The following object is masked from 'package:base':
##
##     print
```

```
head(trade_signs)
```

```
## [1] -1  1  1  1  1  1
```

```
tail(trade_signs)
```

```
## [1]  1  1 -1 -1 -1  1
```

```
trade_direction <- matrix(trade_signs)

buy_side <- which(trade_direction > 0)

head(buy_side)
```

```
## [1] 2 3 4 5 6 7
```

```r
buy_trades_df <- data.frame(
  BuyIndex <- buy_side,
  BuyPrice <- amzn_xts$Price[buy_side]
)

head(buy_trades_df)
```

```
##                        BuyIndex....buy_side    Price
## X2000.01.01.00.00.06                      2 86.65000
## X2000.01.01.00.00.08                      3 86.65000
## X2000.01.01.00.00.11                      4 86.65000
## X2000.01.01.00.00.15                      5 86.65000
## X2000.01.01.00.00.16                      6 86.65000
## X2000.01.01.00.00.21                      7 86.68000
```

```r
sell_side <- which(trade_direction < 0)

head(sell_side)
```

```
## [1]  1  9 11 12 13 14
```

```r
sell_trades_df <- data.frame(
  SellIndex <- sell_side,
  SellPrice <- amzn_xts$Price[sell_side]
)

head(sell_trades_df)
```

```
##                          SellIndex....sell_side    Price
## X2000.01.01.00.00.03                          1 86.65000
## X2000.01.01.00.00.22                          9 86.65000
## X2000.01.01.00.00.25                         11 86.65000
## X2000.01.01.00.00.25.1                       12 86.65000
## X2000.01.01.00.00.27                         13 86.60000
## X2000.01.01.00.00.27.1                       14 86.65000
```

```r
num_buy_side <- length(matrix(buy_side))

num_buy_side
```

```
## [1] 305231
```

```r
num_sell_side <- length(trade_direction) - length(matrix(buy_side))

num_sell_side
```

```
## [1] 270502
```

```r
num_of_trades <- cbind(num_buy_side, num_sell_side)

num_of_trades
```

```
##      num_buy_side num_sell_side
## [1,]       305231        270502
```

```r
# EHO_out <- EHO(as.numeric(buy_trades_df$Price), as.numeric(sell_trades_df$Price))
#
```

```r
# model <- optim(initial_param, EHO_out, gr = NULL, method = c("Nelder-Mead"), hessian = FALSE)

pin_likelihood <- function(params)
{
    epsilon <- params[1]
    mu <- params[2]
    alpha <- params[3]
    delta <- params[4]

    lambda_b <- alpha * mu + epsilon
    lambda_s <- (1 - alpha) * mu + epsilon

    # Calculating the Poisson probabilities
    L_b <- dpois(num_of_trades[,1], lambda_b)
    L_s <- dpois(num_of_trades[,2], lambda_s)

    # To avoid log(0), we add a small number
    L <- L_b * L_s + 1e-10

    # Negative log-likelihood
    result <- -sum(log(L))

    return(result)
}

initial_params <- c(0.5, 0.5, 0.5, 0.5)

result <- optim(initial_params, pin_likelihood, method = "L-BFGS-B",
                lower = c(0,0,0,0), upper = c(1,1,Inf,Inf))

optim_params <- result$par
alpha_hat <- optim_params[3]
mu_hat <- optim_params[2]
epsilon_hat <- optim_params[1]

pin <- (alpha_hat * mu_hat) / (alpha_hat * mu_hat + 2 * epsilon_hat)

pin
```

```
## [1] 0.2
```