ONrates12022023

Hammond

2024-03-19

```
# Clear the environment
#rm(list = ls())
#rmarkdown::render("C:/Users/Owner/Documents/Research/OvernightRates/ONrates03072024v3.Rmd",envir= my_e
#rmarkdown::render("C:/Users/Owner/Documents/Research/OvernightRates/ONrates03142024draft.Rmd",envir= #
```

#Load the environment from the RDS file

'''{r, load environment volatile, echo=FALSE} my_envvolatile<- readRDS("C:/Users/Owner/Documents/Research/Overnig

```
<!--
https://rstudio.github.io/visual-markdown-editing/technical.html#:~:text=In%20raw%20markdown%2C%20you%2


Structure of article: IMRAD:
Introduction
Data
Methodology
Results and
Discussion

Conclusion
Acknowledgements
References
Supporting Materials

Discussing figures in a scientific paper is an important aspect of effectively communicating your resea
1. Introduction:
Start by introducing the figure and its purpose. Briefly explain what the figure represents and why it'
2. Figure Description:
Provide a clear and concise description of the figure. Include relevant details about the data, axes, l
3. Interpretation:
Discuss the main findings or trends depicted in the figure. Highlight significant patterns, relationshi
4. Connection to Hypotheses or Research Questions:
Relate the figure's content to the research questions or hypotheses you're addressing in your study. Ex
5. Comparison with Previous Studies:
If applicable, compare your findings in the figure with results from previous studies. Highlight simila
6. Limitations:
Address any limitations or uncertainties associated with the figure. Discuss potential sources of error
7. Implications:
Discuss the broader implications of the figure's findings. How do the results depicted in the figure co
8. Integration with Text:
Make sure to integrate your discussion of the figure smoothly within the overall flow of your paper. Re
9. Clarity and Precision:
Use clear and precise language. Avoid jargon that might confuse readers unfamiliar with your specific f
```

10. Visual Aids:
As you discuss the figure, consider referring to specific elements within the figure to guide the reade
11. Use of Citations:
If you're comparing your figure's results with those from other studies, cite those studies appropriatel
12. Repetition and Synthesis:
Ensure that the discussion of the figure complements the narrative you've established in the rest of th
Remember that your goal is to help readers understand the figure's content, its significance, and its i
-->

‘data.frame’: 1957 obs. of 36 variables:

$ Date : chr “3/4/2016” “3/7/2016” “3/8/2016” “3/9/2016” ...

$ EFFR : num 36 36 36 36 36 36 36 37 37 37 ...

$ OBFR : num 37 37 37 37 37 37 37 37 37 37 ...

$ TGCR : num 0 0 0 0 0 0 0 0 0 0 ...

$ BGCR : num 0 0 0 0 0 0 0 0 0 0 ...

$ SOFR : num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile01_EFFR: num 34 34 32 34 35 35 35 35 35 36 ...

$ Percentile01_OBFR: num 25 15 25 25 25 25 25 29 28 15 ...

$ Percentile01_TGCR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile01_BGCR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile01_SOFR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile25_EFFR: num 36 36 36 36 36 36 36 36 36 36 ...

$ Percentile25_OBFR: num 36 36 36 36 36 36 36 36 36 36 ...

$ Percentile25_TGCR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile25_BGCR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile25_SOFR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile75_EFFR: num 37 37 37 37 37 37 37 37 37 37 ...

$ Percentile75_OBFR: num 37 37 37 37 37 37 37 37 37 37 ...

$ Percentile75_TGCR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile75_BGCR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile75_SOFR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile99_EFFR: num 52 50 50 52 75 50 50 50 50 50 ...

$ Percentile99_OBFR: num 43 43 42 43 43 43 43 42 42 42 ...

$ Percentile99_TGCR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile99_BGCR: num 0 0 0 0 0 0 0 0 0 0 ...

$ Percentile99_SOFR: num 0 0 0 0 0 0 0 0 0 0 ...

$ TargetDe : num 25 25 25 25 25 25 25 25 25 25 ...

$ TargetUe : num 50 50 50 50 50 50 50 50 50 50 ...

$ VolumeEFFR : num 75 72 72 75 72 68 67 67 63 63 ...

$ VolumeOBFR : num 325 320 327 322 331 314 304 302 299 306 ...

$ VolumeTGCR : num 0 0 0 0 0 0 0 0 0 0 ...

$ VolumeBGCR : num 0 0 0 0 0 0 0 0 0 0 ...

$ VolumeSOFR : num 0 0 0 0 0 0 0 0 0 0 ...

$ RRPONTSYAWARD : num 25 25 25 25 25 25 25 25 25 25 ...

$ IORR : num 50 50 50 50 50 50 50 50 50 50

[1] 1

[1] 1957

```
<!--
  Yes, in the code snippet you provided, you're creating a data frame `rrbp` by subsetting columns from

 However, keep in mind that `rrbp` is a new data frame, and any changes or manipulations you perform on
-->
```

```
Make sure to replace `"EFFR", "OBFR", "TGCR", "BGCR", "SOFR"` with the actual column names you want to
```

[1] "2019-07-31" "2019-10-31" "2020-03-16" "2022-03-16" "2023-12-14"
[6] "2023-12-14"

[1] "2016-03-04" "2019-08-01" "2019-11-01" "2020-03-17" "2022-03-17"
[6] "2016-03-04"

[1] "2016-03-04" "2019-08-01" "2019-11-01" "2020-03-17" "2022-03-17"
[6] "2016-03-04"

[1] "2019-07-31" "2019-10-31" "2020-03-16" "2022-03-16" "2023-12-14"
[6] "2023-12-14"

[1] “Rows in range for k = 1 : 2” “Rows in range for k = 1 : 3”
[3] “Rows in range for k = 1 : 4” “Rows in range for k = 1 : 5”
[5] “Rows in range for k = 1 : 6” “Rows in range for k = 1 : 7”
[7] “Rows in range for k = 1 : 8” “Rows in range for k = 1 : 9”
[9] “Rows in range for k = 1 : 10” “Rows in range for k = 1 : 11”
[11] “Rows in range for k = 1 : 12” “Rows in range for k = 1 : 13”
[13] “Rows in range for k = 1 : 14” “Rows in range for k = 1 : 15”
[15] “Rows in range for k = 1 : 16” “Rows in range for k = 1 : 17”
[17] “Rows in range for k = 1 : 18” “Rows in range for k = 1 : 19”
[19] “Rows in range for k = 1 : 20” “Rows in range for k = 1 : 21”
[21] “Rows in range for k = 1 : 22” “Rows in range for k = 1 : 23”
[23] “Rows in range for k = 1 : 24” “Rows in range for k = 1 : 25”
[25] “Rows in range for k = 1 : 26” “Rows in range for k = 1 : 27”
[27] “Rows in range for k = 1 : 28” “Rows in range for k = 1 : 29”
[29] “Rows in range for k = 1 : 30” “Rows in range for k = 1 : 31”
[31] “Rows in range for k = 1 : 32” “Rows in range for k = 1 : 33”
[33] “Rows in range for k = 1 : 34” “Rows in range for k = 1 : 35”
[35] “Rows in range for k = 1 : 36” “Rows in range for k = 1 : 37”
[37] “Rows in range for k = 1 : 38” “Rows in range for k = 1 : 39”
[39] “Rows in range for k = 1 : 40” “Rows in range for k = 1 : 41”
[41] “Rows in range for k = 1 : 42” “Rows in range for k = 1 : 43”
[43] “Rows in range for k = 1 : 44” “Rows in range for k = 1 : 45”
[45] “Rows in range for k = 1 : 46” “Rows in range for k = 1 : 47”
[47] “Rows in range for k = 1 : 48” “Rows in range for k = 1 : 49”
[49] “Rows in range for k = 1 : 50” “Rows in range for k = 1 : 51”
[51] “Rows in range for k = 1 : 52” “Rows in range for k = 1 : 53”
[53] “Rows in range for k = 1 : 54” “Rows in range for k = 1 : 55”
[55] “Rows in range for k = 1 : 56” “Rows in range for k = 1 : 57”
[57] “Rows in range for k = 1 : 58” “Rows in range for k = 1 : 59”
[59] “Rows in range for k = 1 : 60” “Rows in range for k = 1 : 61”
[61] “Rows in range for k = 1 : 62” “Rows in range for k = 1 : 63”
[63] “Rows in range for k = 1 : 64” “Rows in range for k = 1 : 65”
[65] “Rows in range for k = 1 : 66” “Rows in range for k = 1 : 67”
[67] “Rows in range for k = 1 : 68” “Rows in range for k = 1 : 69”
[69] “Rows in range for k = 1 : 70” “Rows in range for k = 1 : 71”
[71] “Rows in range for k = 1 : 72” “Rows in range for k = 1 : 73”

[1] “Rows in range for k = 2 : 860” “Rows in range for k = 2 : 861”

[3] “Rows in range for k = 2 : 862” “Rows in range for k = 2 : 863”

[5] “Rows in range for k = 2 : 864” “Rows in range for k = 2 : 865”

[7] “Rows in range for k = 2 : 866” “Rows in range for k = 2 : 867”

[9] “Rows in range for k = 2 : 868” “Rows in range for k = 2 : 869”

[11] “Rows in range for k = 2 : 870” “Rows in range for k = 2 : 871”

[13] “Rows in range for k = 2 : 872” “Rows in range for k = 2 : 873”

[15] “Rows in range for k = 2 : 874” “Rows in range for k = 2 : 875”

[17] “Rows in range for k = 2 : 876” “Rows in range for k = 2 : 877”

[19] “Rows in range for k = 2 : 878” “Rows in range for k = 2 : 879”

[21] “Rows in range for k = 2 : 880” “Rows in range for k = 2 : 881”

[23] “Rows in range for k = 2 : 882” “Rows in range for k = 2 : 883”

[25] “Rows in range for k = 2 : 884” “Rows in range for k = 2 : 885”

[27] “Rows in range for k = 2 : 886” “Rows in range for k = 2 : 887”

[29] “Rows in range for k = 2 : 888” “Rows in range for k = 2 : 889”

[31] “Rows in range for k = 2 : 890” “Rows in range for k = 2 : 891”

[33] “Rows in range for k = 2 : 892” “Rows in range for k = 2 : 893”

[35] “Rows in range for k = 2 : 894” “Rows in range for k = 2 : 895”

[37] “Rows in range for k = 2 : 896” “Rows in range for k = 2 : 897”

[39] “Rows in range for k = 2 : 898” “Rows in range for k = 2 : 899”

[41] “Rows in range for k = 2 : 900” “Rows in range for k = 2 : 901”

[43] “Rows in range for k = 2 : 902” “Rows in range for k = 2 : 903”

[45] “Rows in range for k = 2 : 904” “Rows in range for k = 2 : 905”

[47] “Rows in range for k = 2 : 906” “Rows in range for k = 2 : 907”

[49] “Rows in range for k = 2 : 908” “Rows in range for k = 2 : 909”

[51] “Rows in range for k = 2 : 910” “Rows in range for k = 2 : 911”

[53] “Rows in range for k = 2 : 912” “Rows in range for k = 2 : 913”

[55] “Rows in range for k = 2 : 914” “Rows in range for k = 2 : 915”

[57] “Rows in range for k = 2 : 916” “Rows in range for k = 2 : 917”

[59] “Rows in range for k = 2 : 918” “Rows in range for k = 2 : 919”

[61] “Rows in range for k = 2 : 920” “Rows in range for k = 2 : 921”

[63] “Rows in range for k = 2 : 922”

[1] 63 5

[1] 63 5

[1] “Rows in range for k = 3 : 924” “Rows in range for k = 3 : 925”

[3] “Rows in range for k = 3 : 926” “Rows in range for k = 3 : 927”

[5] “Rows in range for k = 3 : 928” “Rows in range for k = 3 : 929”

[7] “Rows in range for k = 3 : 930” “Rows in range for k = 3 : 931”

[9] “Rows in range for k = 3 : 932” “Rows in range for k = 3 : 933”

[11] “Rows in range for k = 3 : 934” “Rows in range for k = 3 : 935”

[13] “Rows in range for k = 3 : 936” “Rows in range for k = 3 : 937”

[15] “Rows in range for k = 3 : 938” “Rows in range for k = 3 : 939”

[17] “Rows in range for k = 3 : 940” “Rows in range for k = 3 : 941”

[19] “Rows in range for k = 3 : 942” “Rows in range for k = 3 : 943”

[21] “Rows in range for k = 3 : 944” “Rows in range for k = 3 : 945”

[23] “Rows in range for k = 3 : 946” “Rows in range for k = 3 : 947”

[25] “Rows in range for k = 3 : 948” “Rows in range for k = 3 : 949”

[27] “Rows in range for k = 3 : 950” “Rows in range for k = 3 : 951”

[29] “Rows in range for k = 3 : 952” “Rows in range for k = 3 : 953”

[31] “Rows in range for k = 3 : 954” “Rows in range for k = 3 : 955”

[33] “Rows in range for k = 3 : 956” “Rows in range for k = 3 : 957”

[35] “Rows in range for k = 3 : 958” “Rows in range for k = 3 : 959”

[37] “Rows in range for k = 3 : 960” “Rows in range for k = 3 : 961”

[39] “Rows in range for k = 3 : 962” “Rows in range for k = 3 : 963”

[41] “Rows in range for k = 3 : 964” “Rows in range for k = 3 : 965”

[43] “Rows in range for k = 3 : 966” “Rows in range for k = 3 : 967”

[45] “Rows in range for k = 3 : 968” “Rows in range for k = 3 : 969”

[47] “Rows in range for k = 3 : 970” “Rows in range for k = 3 : 971”

[49] “Rows in range for k = 3 : 972” “Rows in range for k = 3 : 973”

[51] “Rows in range for k = 3 : 974” “Rows in range for k = 3 : 975”

[53] “Rows in range for k = 3 : 976” “Rows in range for k = 3 : 977”

[55] “Rows in range for k = 3 : 978” “Rows in range for k = 3 : 979”

[57] “Rows in range for k = 3 : 980” “Rows in range for k = 3 : 981”

[59] “Rows in range for k = 3 : 982” “Rows in range for k = 3 : 983”

[61] “Rows in range for k = 3 : 984” “Rows in range for k = 3 : 985”

[63] “Rows in range for k = 3 : 986” “Rows in range for k = 3 : 987”

[65] “Rows in range for k = 3 : 988” “Rows in range for k = 3 : 989”

[67] “Rows in range for k = 3 : 990” “Rows in range for k = 3 : 991”

[69] “Rows in range for k = 3 : 992” “Rows in range for k = 3 : 993”

[71] “Rows in range for k = 3 : 994” “Rows in range for k = 3 : 995”

[1] "Rows in range for k = 4 : 1015" "Rows in range for k = 4 : 1016"
[3] "Rows in range for k = 4 : 1017" "Rows in range for k = 4 : 1018"
[5] "Rows in range for k = 4 : 1019" "Rows in range for k = 4 : 1020"
[7] "Rows in range for k = 4 : 1021" "Rows in range for k = 4 : 1022"
[9] "Rows in range for k = 4 : 1023" "Rows in range for k = 4 : 1024"
[11] "Rows in range for k = 4 : 1025" "Rows in range for k = 4 : 1026"
[13] "Rows in range for k = 4 : 1027" "Rows in range for k = 4 : 1028"
[15] "Rows in range for k = 4 : 1029" "Rows in range for k = 4 : 1030"
[17] "Rows in range for k = 4 : 1031" "Rows in range for k = 4 : 1032"
[19] "Rows in range for k = 4 : 1033" "Rows in range for k = 4 : 1034"
[21] "Rows in range for k = 4 : 1035" "Rows in range for k = 4 : 1036"
[23] "Rows in range for k = 4 : 1037" "Rows in range for k = 4 : 1038"
[25] "Rows in range for k = 4 : 1039" "Rows in range for k = 4 : 1040"
[27] "Rows in range for k = 4 : 1041" "Rows in range for k = 4 : 1042"
[29] "Rows in range for k = 4 : 1043" "Rows in range for k = 4 : 1044"
[31] "Rows in range for k = 4 : 1045" "Rows in range for k = 4 : 1046"
[33] "Rows in range for k = 4 : 1047" "Rows in range for k = 4 : 1048"
[35] "Rows in range for k = 4 : 1049" "Rows in range for k = 4 : 1050"
[37] "Rows in range for k = 4 : 1051" "Rows in range for k = 4 : 1052"
[39] "Rows in range for k = 4 : 1053" "Rows in range for k = 4 : 1054"
[41] "Rows in range for k = 4 : 1055" "Rows in range for k = 4 : 1056"
[43] "Rows in range for k = 4 : 1057" "Rows in range for k = 4 : 1058"
[45] "Rows in range for k = 4 : 1059" "Rows in range for k = 4 : 1060"
[47] "Rows in range for k = 4 : 1061" "Rows in range for k = 4 : 1062"
[49] "Rows in range for k = 4 : 1063" "Rows in range for k = 4 : 1064"
[51] "Rows in range for k = 4 : 1065" "Rows in range for k = 4 : 1066"
[53] "Rows in range for k = 4 : 1067" "Rows in range for k = 4 : 1068"
[55] "Rows in range for k = 4 : 1069" "Rows in range for k = 4 : 1070"
[57] "Rows in range for k = 4 : 1071" "Rows in range for k = 4 : 1072"
[59] "Rows in range for k = 4 : 1073" "Rows in range for k = 4 : 1074"
[61] "Rows in range for k = 4 : 1075" "Rows in range for k = 4 : 1076"
[63] "Rows in range for k = 4 : 1077" "Rows in range for k = 4 : 1078"
[65] "Rows in range for k = 4 : 1079" "Rows in range for k = 4 : 1080"
[67] "Rows in range for k = 4 : 1081" "Rows in range for k = 4 : 1082"
[69] "Rows in range for k = 4 : 1083" "Rows in range for k = 4 : 1084"
[71] "Rows in range for k = 4 : 1085" "Rows in range for k = 4 : 1086"

[1] “Rows in range for k = 5 : 1520” “Rows in range for k = 5 : 1521”

[3] “Rows in range for k = 5 : 1522” “Rows in range for k = 5 : 1523”

[5] “Rows in range for k = 5 : 1524” “Rows in range for k = 5 : 1525”

[7] “Rows in range for k = 5 : 1526” “Rows in range for k = 5 : 1527”

[9] “Rows in range for k = 5 : 1528” “Rows in range for k = 5 : 1529”

[11] “Rows in range for k = 5 : 1530” “Rows in range for k = 5 : 1531”

[13] “Rows in range for k = 5 : 1532” “Rows in range for k = 5 : 1533”

[15] “Rows in range for k = 5 : 1534” “Rows in range for k = 5 : 1535”

[17] “Rows in range for k = 5 : 1536” “Rows in range for k = 5 : 1537”

[19] “Rows in range for k = 5 : 1538” “Rows in range for k = 5 : 1539”

[21] “Rows in range for k = 5 : 1540” “Rows in range for k = 5 : 1541”

[23] “Rows in range for k = 5 : 1542” “Rows in range for k = 5 : 1543”

[25] “Rows in range for k = 5 : 1544” “Rows in range for k = 5 : 1545”

[27] “Rows in range for k = 5 : 1546” “Rows in range for k = 5 : 1547”

[29] “Rows in range for k = 5 : 1548” “Rows in range for k = 5 : 1549”

[31] “Rows in range for k = 5 : 1550” “Rows in range for k = 5 : 1551”

[33] “Rows in range for k = 5 : 1552” “Rows in range for k = 5 : 1553”

[35] “Rows in range for k = 5 : 1554” “Rows in range for k = 5 : 1555”

[37] “Rows in range for k = 5 : 1556” “Rows in range for k = 5 : 1557”

[39] “Rows in range for k = 5 : 1558” “Rows in range for k = 5 : 1559”

[41] “Rows in range for k = 5 : 1560” “Rows in range for k = 5 : 1561”

[43] “Rows in range for k = 5 : 1562” “Rows in range for k = 5 : 1563”

[45] “Rows in range for k = 5 : 1564” “Rows in range for k = 5 : 1565”

[47] “Rows in range for k = 5 : 1566” “Rows in range for k = 5 : 1567”

[49] “Rows in range for k = 5 : 1568” “Rows in range for k = 5 : 1569”

[51] “Rows in range for k = 5 : 1570” “Rows in range for k = 5 : 1571”

[53] “Rows in range for k = 5 : 1572” “Rows in range for k = 5 : 1573”

[55] “Rows in range for k = 5 : 1574” “Rows in range for k = 5 : 1575”

[57] “Rows in range for k = 5 : 1576” “Rows in range for k = 5 : 1577”

[59] “Rows in range for k = 5 : 1578” “Rows in range for k = 5 : 1579”

[61] “Rows in range for k = 5 : 1580” “Rows in range for k = 5 : 1581”

[63] “Rows in range for k = 5 : 1582” “Rows in range for k = 5 : 1583”

[65] “Rows in range for k = 5 : 1584” “Rows in range for k = 5 : 1585”

[67] “Rows in range for k = 5 : 1586” “Rows in range for k = 5 : 1587”

[69] “Rows in range for k = 5 : 1588” “Rows in range for k = 5 : 1589”

[71] “Rows in range for k = 5 : 1590” “Rows in range for k = 5 : 1591”

[1] “Rows in range for k = 6 : 2” “Rows in range for k = 6 : 3”

[3] “Rows in range for k = 6 : 4” “Rows in range for k = 6 : 5”

[5] “Rows in range for k = 6 : 6” “Rows in range for k = 6 : 7”

[7] “Rows in range for k = 6 : 8” “Rows in range for k = 6 : 9”

[9] “Rows in range for k = 6 : 10” “Rows in range for k = 6 : 11”

[11] “Rows in range for k = 6 : 12” “Rows in range for k = 6 : 13”

[13] “Rows in range for k = 6 : 14” “Rows in range for k = 6 : 15”

[15] “Rows in range for k = 6 : 16” “Rows in range for k = 6 : 17”

[17] “Rows in range for k = 6 : 18” “Rows in range for k = 6 : 19”

[19] “Rows in range for k = 6 : 20” “Rows in range for k = 6 : 21”

[21] “Rows in range for k = 6 : 22” “Rows in range for k = 6 : 23”

[23] “Rows in range for k = 6 : 24” “Rows in range for k = 6 : 25”

[25] “Rows in range for k = 6 : 26” “Rows in range for k = 6 : 27”

[27] “Rows in range for k = 6 : 28” “Rows in range for k = 6 : 29”

[29] “Rows in range for k = 6 : 30” “Rows in range for k = 6 : 31”

[31] “Rows in range for k = 6 : 32” “Rows in range for k = 6 : 33”

[33] “Rows in range for k = 6 : 34” “Rows in range for k = 6 : 35”

[35] “Rows in range for k = 6 : 36” “Rows in range for k = 6 : 37”

[37] “Rows in range for k = 6 : 38” “Rows in range for k = 6 : 39”

[39] “Rows in range for k = 6 : 40” “Rows in range for k = 6 : 41”

[41] “Rows in range for k = 6 : 42” “Rows in range for k = 6 : 43”

[43] “Rows in range for k = 6 : 44” “Rows in range for k = 6 : 45”

[45] “Rows in range for k = 6 : 46” “Rows in range for k = 6 : 47”

[47] “Rows in range for k = 6 : 48” “Rows in range for k = 6 : 49”

[49] “Rows in range for k = 6 : 50” “Rows in range for k = 6 : 51”

[51] “Rows in range for k = 6 : 52” “Rows in range for k = 6 : 53”

[53] “Rows in range for k = 6 : 54” “Rows in range for k = 6 : 55”

[55] “Rows in range for k = 6 : 56” “Rows in range for k = 6 : 57”

[57] “Rows in range for k = 6 : 58” “Rows in range for k = 6 : 59”

[59] “Rows in range for k = 6 : 60” “Rows in range for k = 6 : 61”

[61] “Rows in range for k = 6 : 62” “Rows in range for k = 6 : 63”

[63] “Rows in range for k = 6 : 64” “Rows in range for k = 6 : 65”

[65] “Rows in range for k = 6 : 66” “Rows in range for k = 6 : 67”

[67] “Rows in range for k = 6 : 68” “Rows in range for k = 6 : 69”

[69] “Rows in range for k = 6 : 70” “Rows in range for k = 6 : 71”

[71] “Rows in range for k = 6 : 72” “Rows in range for k = 6 : 73”

Introduction
This paper asks how the Federal Reserve Bank adjustment of reserves affects volatility of theFederal Fu
which depository institutions or "banks" lend funds to each other on an overnight basis.
Daily overnight rates include the unsecured rates The effective federal funds rate (EFFR), the overnigh

The Federal funds market consists of domestic unsecured borrowings by depository institutions from othe
The EFFR is calculated as a volume-weighted median of overnight federal funds transactions. The OBFR is

Concoda private parties create deposit like instruments Evolving since the 1970s, repos, moneny market

The Tri-Party General Collateral Rate (TGCR), the base layer of repos, is a measure of rates on overnig
Repo markets $4 trillions of dollars daily. Participants in this tri repo market include primary deale

Transactions in the tri party market TGCR is centrally cleared. The BGCR is an over the counter transa
The SOFR replaces LIBOR as a benchmark overnight rate. SOFR is a broad measure of the cost of borrowin

The distributions of daily rates rates and transactions transactions, billions of dollars, their median

Through repo and reverse repo transactons, the Fed uses the tri party market TGCR for temporary interv

Discuss standard repo facility and ON RPP facility

The level of reserves in the banking system can change either because
1) because funds are transferred between reserves and non-reserve accounts at the Federal
2) changes in the US Treasury account at the Fed
3) The Federal Reserve responds to volatility in the federal funds market by adjusting the reserve
supply to keep the federal funds rate within its target range through repo and reverse repo operations

By trading securities with banks and other counterparites, these Federal Reserve purchases or sales of

To manage the build up in liquidity in reserves, the Fed initiated the policy regime of ample reserves
%stabilize FF around target rate..

Reserves went through a full expansion-contraction cycle from 2010 to late 2019 and expanded again in e
8$\%$ (2010 and 2019) to 19$\%$ (2014 and 2021) of banks' assets. These movements reflect the Federal
Reserve balance-sheet expansions in response to the 2008 and 2020 crises, as well as the interim
normalization period (2015-2019).

Relationship to other work--
Hamilton
Bertolini, Bertola, Prati ()
Gara
Benzoni
Cochrane and Piazzesi
Duffie Krishnamurthy

Ideas:
rate volatility

mean reversion or not, mean reversion around central tendency
rates quickly revert to new FF rate ann
rate dispersion as how well MP stance is communicated to economy
repo and volatility: PRTs basis trade
day effects
Fed preference for managing FFR with target, preference for offsetting volatlity
fat tails, skew, outliers
Time varying policy rules, how do innovations in rates or reserves behave
Rates vs reserve plots, a demand curve
Determine a regime change

All authors recognize key characteristics of the FFR; Spectacular outliers and autoregressive conditiona

Hamilton --
Hamilton (1996) adaption of Nelson's (1991) EGARCH model
to the conditional mean and the conditional variance of the daily Federal Funds rate (FFR), examined t

[repo increases reserves, lowers FFRreverse repo reverses reserves and raises FFR] [repo means dealer d

Transaction costs, rather minor institutional market detail, are central to the liquidity effect that e

The importance of the overnight federal funds rate, the shortest-term actively traded security- the bas

Monika Piazzesi ---
"Bond Yields and the Federal Reserve", Journal of Political Economy, Volume 113, Issue 2, April 2005, p

Piazzesi (2005) constructs a continuous-time model of the joint distribution of bond yields and the int

Both Federal Reserve and financial markets watch and depend on bond yields. Yield-based information may
That the Fed's estimated policy rule reacts to information contained in the yield curve, especially in

The short informational lag before Fed's policy decision, information available right before the FOMC m

- 1) latent factors
- the target set by the Fed is an observable factor in the model and provides a clean measure of the sh
- 2) Second, the estimated response of yields to policy shocks is strong and slowly declines only with
- 3) The estimated policy rule describes the Fed as reacting to information contained in the yield curv

- The estimated policy rule displays interest rate smoothing: the target level is autocorrelated.
- The rule also displays policy inertia: the Fed only partially adjusts the target to its desired rate.

- yield data summarize market expectations of future target moves. These market expectations are
based on a host of variables that are omitted from other rules.
yield data are available at higher frequencies and are less affected by
measurement errors than macroeconomic variables.
The model demonstrated the policy inertia, the tendency to continue same policy changes.

<!--
The "snake shaped "volatility of yields:Volatility is high for very short maturities (the head of the s

- with high-frequency data, use information about the exact timing of FOMC meetings to improve bond pri
- construct a continuous-time model of the joint distribution of bond yields and the interest rate targ

- impose no arbitrage and respects the timing of FOMC meetings. Decisions about target moves are made a
- The arrival intensity of target jumps depends on the FOMC meeting calendar and the state of the econo
- estimation methods that exploit data on the entire cross section of yields as opposed to a single short rate. Longer yields have the statistical advantage of providing important additional observations its systematic response to the state of the economy
- policy decision based on information available right before the FOMC starts its meeting. This short informational lag provides a recursive identification scheme. The scheme turns the target forecas
- method of simulated maximum likelihood (Pedersen 1995; Santa-Clara 1995) extended to jumps

- 1) latent factors
- the target set by the Fed is an observable factor in the model and provides a clean measure of the sh
- 2) Second, the estimated response of yields to policy shocks is strong and slowly declines only with
- 3) The estimated policy rule describes the Fed as reacting to information contained in the yield curv

- The estimated policy rule displays interest rate smoothing: the target level is autocorrelated.
- The rule also displays policy inertia: the Fed only partially adjusts the target to its desired rate.

- yield data summarize market expectations of future target moves. These market expectations are based on a host of variables that are omitted from other rules.
yield data are available at higher frequencies and are less affected by measurement errors than macroeconomic variables.
- 4) snake shape of the volatility curve, the standard deviation of yield changes as a function of maturity. Volatility is high for very short maturities (the head of the snake), rapidly decreases until maturities of around three months (the neck of the snake), then increases until maturities of up to two
-->

Benzoni et all.----------------------------
(Andersen, Benzoni,Lund, 2004) model the U.S. short-term interest rate 3 month Tbill with a three-facto

The mean drift may be indicative of slowly evolving inflationary expectations (Gara horiz?), time-varia

Bertolini, Bertola, Prati () and Gara () and Benzoni observe that the effect of Fed interventions on th
\begin{itemize}
\item declines in high rate regimes
\item rises end of quarter, end of year
\item falls before holidays, rises day after
\item other observations:
TS properties. Many rate changes of half percent or more (annualized), and outliers. Volatility persi
\end{itemize}

Gara Afonso --------------------------------
Gara et al model of banks' reserve demand response to shocks to reserves reveals greater sensitivity to

The slope of the demand function is negative as reserves decline. The sensitivity of rates to reserve s

\emph{Vertical shift}
Policy changes shift the curve up and down by moving its lower bound. Increases (descreases) in the (FF
\emph{Horizontal shift}
Low frequency horizontal shifts in the demand function reflect sensitivity of rates to shocks to reserv

(1): for every level of the federal funds rate, they imply an increase in the quantity of aggregate reserves demanded by the banking system. As a result of these shifts, the level of reserves at which the curve stops being flat and start displaying a negative slope may have moved over time.

These structural changes [which ?] could be interpreted as the horizontal shifts $\ast(q)$ in the demand

? The visible negative correlation between quantities (reserves) and prices (federal funds rates) sugges

? explains ONRRP: The segmentation of the federal funds market between banks and FHLBs suggests that, un
ONRRP-IORB spread and zero.

```
<!--
Gara plot: GaraAmpleReserves2022
\begin{comment}
\begin{figure}[ht]
\includegraphics[scale=1.0\textwidth]{GaraReserves.png}
% \includegraphics[scale=0.9, bb=108   268   473   567]{dailyratessample1brush.tex}
\caption{Reserves normalized by commercial deposits, Federal Fund rate EFFR-IOR spread and reserve deman
\label{fig:Gara}
%\centering
\label{fig:gara}
\end{figure}
\end{comment}

derive a function of reserve demand that measures banks' demand for liquidity  as a function of aggregat
Figure (Panel (b))  to control for changes in FOMC policy, they plot federal funds rate minus the IORB r
The visible negative correlation between quantities (reserves) and prices (federal funds rates) suggests
-->
```

Bertolini, Bertola, Prati () model of FFR volatility seeks to isolate Fed preferences for offsetting vol
They note the immediate response of other key short rates to monetary policy and other shocks. Overnight

\emph{Duffie, Krishnamurthy}
Krishnamurthy and Vissing Jorgensen find the implicit volatility of overnight reference rates is the res

Krishnamuthy provide evidence that dispersion among secured overnight rates impede passthough of monetar

Mean reverision versus dispersion?

Ample reserves paper?

Cochrane and Piazzesi -----------------------------
regress policy shocks on rates

NOTES --

```
<!--
Hamilton (1996) and others have concluded that the hypothesis that the FFR follows a martingale is inco
-->
```

Hamilton --
Hamilton (1996) adapts's Nelson's (1991) EGARCH model of daily stock return to the conditional mean and

He attributes the OMO rather interday arbitration the ability to smooth out small fluctuations in the F

Transaction costs, rather minor institutional market detail, are central to the liquidity effect that e

Monika Piazzesi --
"Bond Yields and the Federal Reserve", Journal of Political Economy, Volume 113, Issue 2, April 2005, p

Piazzesi (2005) reveals increased volatility of interest rates at all maturities ib both
FOMC meeting days and around releases of key macroeconomic aggregates in a continuous-time model of the

Both Federal Reserve decisions and financial markets watch and depend on bond yields. The estimated pol

The short informational lag before Fed's policy decision based on information available right before th
The high-frequency policy rule based on yield curve information and an arbitrage-free bond market...

The "snake shaped "volatility of yields:Volatility is high for very short maturities (the head of the s

<!--
To learn about these responses,In continuous time, the Fed’s target is a pure jump
process. Jump intensities depend on the state of the economy and
the meeting calendar of the Federal Open Market Committee. The
model has closed-form solutions for yields as functions of a few state
variables. Introducing monetary policy helps to match the whole yield
curve, because the
Policy inertia: tendency to continue same policy changes
Volatility smile
2 year UST yield

Not only do markets watch the Federal Reserve, but the reverse is also true. At its meetings, the FOMC

r short maturities, because most studies avoid dealing with the extreme volatility and the large outlie

- with high-frequency data, use information about the exact timing of FOMC meetings to improve bond pri
- construct a continuous-time model of the joint distribution of bond yields and the interest rate targ
- impose no arbitrage and respects the timing of FOMC meetings. Decisions about target moves are made a
- The arrival intensity of target jumps depends on the FOMC meeting calendar and the state of the econo
- estimation methods that exploit data on the entire cross section of yields as opposed to a single
short rate. Longer yields have the statistical advantage of providing important additional observations
its systematic response to the state of the economy
- policy decision based on information available right before the FOMC starts its meeting. This
short informational lag provides a recursive identification scheme. The scheme turns the target forecas
- method of simulated maximum likelihood (Pedersen 1995; Santa-Clara 1995) extended
to jumps

- 1) latent factors
- the target set by the Fed is an observable factor in the model and provides a clean measure of the sh
- 2) Second, the estimated response of yields to policy shocks is strong and slowly declines only with
- 3) The estimated policy rule describes the Fed as reacting to information contained in the yield curv

- The estimated policy rule displays interest rate smoothing: the target level is autocorrelated.
- The rule also displays policy inertia: the Fed only partially adjusts the target to its desired rate.

- yield data summarize market expectations of future target moves. These market expectations are
based on a host of variables that are omitted from other rules.
yield data are available at higher frequencies and are less affected by
measurement errors than macroeconomic variables.
- 4) snake shape of the volatility curve, the standard
deviation of yield changes as a function of maturity. Volatility is high
for very short maturities (the head of the snake), rapidly decreases until
maturities of around three months (the neck of the snake), then increases until maturities of up to two

Most empirical papers on monetary policy focus on the short-rate process alone. Then infer long rates by
-->

Bertolini, Bertola, Prati () and Gara () and Benzoni observe that the effect of Fed interventions on the
\begin{itemize}
\item declines in high rate regimes
\item rises end of quarter, end of year
\item falls before holidays, rises day after
\item other observations:
TS properties. Many rate changes of half percent or more (annualized), and outliers. Volatility persis
\end{itemize}

Benzoni et all.----------------------------
(Andersen, Benzoni,Lund, 2004) model the U.S. short-term interest rate 3 month Tbill with a three-factor

The mean drift may be indicative of slowly evolving inflationary expectations (Gara horiz?), time-varia

<!--
Hamilton (1996) and others have concluded that the hypothesis that the FFR follows a martingale is incon
-->

Gara Afonso --------------------------------
Gara et al model of banks' reserve demand response to shocks to reserves reveals greater sensitivity to

The slope of the demand function is negative as reserves decline. The sensitivity of rates to reserve sh

\emph{Vertical shift}
Policy changes shift the curve up and down by moving its lower bound. Increases (descreases) in the (FFR
\emph{Horizontal shift}
Low frequency horizontal shifts in the demand function reflect sensitivity of rates to shocks to reserve
(1): for every level of the federal funds rate, they imply an increase in the quantity of aggregate
reserves demanded by the banking system. As a result of these shifts, the level of reserves at which
the curve stops being flat and start displaying a negative slope may have moved over time.

These structural changes [which ?] could be interpreted as the horizontal shifts $\ast(q)$ in the demand

? The visible negative correlation between quantities (reserves) and prices (federal funds rates) sugges

? explains ONRRP: The segmentation of the federal funds market between banks and FHLBs suggests that, ur
ONRRP-IORB spread and zero.

<!--
Gara plot: GaraAmpleReserves2022
\begin{comment}
\begin{figure}[ht]
\includegraphics[scale=1.0\textwidth]{GaraReserves.png}
% \includegraphics[scale=0.9, bb=108 268 473 567]{dailyratessample1brush.tex}
\caption{Reserves normalized by commercial deposits, Federal Fund rate EFFR-IOR spread and reserve demar
\label{fig:Gara}
%\centering
\label{fig:gara}
\end{figure}
\end{comment}

derive a function of reserve demand that measures banks' demand for liquidity as a function of aggregat
Figure (Panel (b)) to control for changes in FOMC policy, they plot federal funds rate minus the IORB r
The visible negative correlation between quantities (reserves) and prices (federal funds rates) suggests
-->

Bertolini, Bertola, Prati () model of FFR volatility seeks to isolate Fed preferences for offsetting vol
They note the immediate response of other key short rates to monetary policy and other shocks. Overnight

\emph{Duffie, Krishnamurthy}
Krishnamurthy and Vissing Jorgensen propose the implicit volatility of overnight reference rates results

Duffie and Krishnamurthy.The effectiveness of monetary policy to transmit the desired stance of monetar

Krishnamuthy provide evidence that dispersion among these secured overnight rights impede passthough of

Cochrane and Piazzesi ------------------------------
regress policy shocks on rates

NOTES ---
!<--
2. Affine Term Structure Models in the Handbook of Financial Econometrics, Elsevier
Monika Piazzesi
Department of Economics, Stanford University, Stanford, California

Several aspects of bond
yields, however, set them apart from other variables typically used inVAR studies. One
aspect is that bonds are assets, and that bonds with many different maturities are traded at
the same time. Bonds with long maturities are risky when held over short horizons, and
risk-averse investors demand compensation for bearing such risk.Arbitrage opportunities
in these markets exist unless long yields are risk-adjusted expectations of average future
short rates. Movements in the cross section of yields are therefore closely tied together.
These ties show up as cross-equation restrictions in a yield-VAR. Another aspect of yields is
that they are not normally distributed, at least not until recently. This makes it difficult
to compute the risk-adjusted expected value of future short rates.

Term structure models capture exactly these aspects of bond yields. They impose the cross-equation restrictions implied by no-arbitrage and allow yields to be nonnormal.
The word "affine term structure model" is often used in different ways. I will use the word to describe any arbitrage-free model in which bond yields are affine (constant plus linear) functi
1 Affine models are thus a special class of
term structure models, which write the yield y( ) of a -period bond as
y( ) = A( ) + B( )x
for coefficients A( ) and B( ) that depend on maturity . The functions A( ) and B( ) make these yield equations consistent with each other for different values of . The functions also make the yield equations consistent with the state dynamics.

The functional form of bond yields is obtained from computing risk-adjusted expectations of future shor
vector. More concretely,the risk-adjusted process for the state vector needs to be an affine diffusion, a process with affine instantaneous mean and variance.

Why Care About Bond Yields:
forecasting
monetary policy
debt policy
derivative pricing and hedging
computed from a given
model of the yield curve (see the references in Duffie et al.,2000). Banks need to manage the risk of paying short-term interest rates on deposits while receiving long-term interest rates on loans.

policy shocks on long-term bonds outside of a yield-curve model.
More patience is required to estimate a system of yield equations in a way that ensures no-arbitrage. The cross-equation restrictions have to be derived from parameters that describe the state dynamics and risk premia. Although the model is affine in the state vector x,the functions A( ) and B( ) are nonlinear functions of the underlying parameters

Cross-equation restrictions have many advantages. First, these restrictions ensure that the yield dynamics are consistent. A( ) and B( ) make yield equations consistent with each other in the cross section and the time series.

Second, term structure models allow us to separate risk premia from expectations about future short rates.

EH under which expected excess bond returns are zero. Modified versions of the EH have been tested unde
2001).The evidence suggests that expected returns on long bonds are on average higher than on short bonds and that they are time-varying. Cross-equation restrictions are then needed to model these risk premia.
Third, unrestricted regressions imply that the number of variables needed to describe the yield curve equals the number of yields in the regression.

2. BASICS
2.1. Bond Pricing in Continuous Time
Term structure modeling determines the price of zero-coupon bonds
The pricing relation (2.2) shows that any yield-curve model consists of two ingredients:
(i) the change of measure from Q to Q* and
(ii) the dynamics of the short rate r under Q*.
In so-called factor models of the yield curve,(ii) is replaced by the following assumption:

(ii)' the short rate r is a function R(x) of x and x RN is a time-homogeneous Markov process under Q*.
This means that x is the relevant state vector, a vector of factors. This modified (ii)
assumption implies that the conditional expectation in (2.2) is some function F of time-to-maturity an
$P( )_t = F(x_t,)$.
To capture certain features of yield data (e.g., seasonalities around macroeconomic
news releases), I will later consider functions R that also depend on time t and time-inhomogeneous Marl

The payoff of zero-coupon bonds is 1 unit at maturity, so their price is
$P*{\tau}_t = E^*_t\left exp \left -\int{t}^{t+\tau} r_u du \right\right $ (2.2)
where E* denotes expectation under Q*. Standard results show that if there exists a rik-neutral probabil

The big advantage of pricing bonds (or any other assets) in continuous time is Ito's
Lemma. The lemma says that smooth functions F of some Ito process x and time t are
again Ito processes (see Duffie, 2001, Chapter 5 for details). The lemma thus preserves
the Ito property even if F is nonlinear. Ito's Lemma allows me to turn the problem
of solving the conditional expectation in (2.2) into the problem of solving a PDE for
the bond price F(x,). The trick of computing (2.2) by solving a PDE is called the
Feynman-Kac approach.

2.2. Local Expectations Hypothesis
The LEH states that the pricing relation (2.2) holds under the data-generating measure
Q. Bond yields are thus given by
LEH : $y^{\tau}_t = -log E_t [exp(-S)] /\tau $ (2.4)
where $S = \int t+ t ru du$ (as above). The LEH therefore amounts to risk-neutral pricing: the data gen
expected excess returns on long bonds are zero.
The LEH is not the same as the more prominent EH, which states that bond yields
y( )
t are expected values of average future short rates, or
EH : $y^{\tau}_t = E_t[S]/\tau$. (2.5)

The difference between the two hypotheses (2.4) and (2.5) is due to Jensen's inequality.
For example, suppose that the short rate is Gaussian under Q = Q*, which implies that
Affine Term Structure Models S is also Gaussian (as the sum of Gaussians). With this normality assumptio
which differs from (2.5) because of the variance term.

3. AFFINE MODELS
Affine term structure models make functional-form assumptions in step (ii)' of yield curve modeling, whi
risk-neutral measure. The functional form is affine in both cases:
• R(x) is affine
• x is an affine diffusion under Q*:
• the drift $\mu_x(x)$ is affine
• the variance matrix $\sigma_x(x) \sigma_x(x)$is affine.

These functional forms are for coefficients under the risk-neutral measure. In particular,
the drift $\mu_x(x)$ is affine under the data-generating measure only when $\sigma_x(x) \sigma_\xi(x)$ i
affine, which can be seen from (2.12). The next sections make these assumptions more
precise and show that bond prices F(x,) are exponential-affine in x. In this setting,
yields are thus affine in x which explains the name of this class of models.

3.1. Affine Short Rate
The functional form of the short rate is made precise in the following assumption.
Assumption 1 The short rate is given by
$r = R(x) = \delta_0 + \delta_1 x$

for $\delta_0 R$ and \delta_1 R^N $.

The choice of short-rate parameters δ_0 and δ_1 depends on the number of factors in the model.The short rate usually is the factor in one-factor models, which means $\delta_0=0$ and $\delta_1 =1 $. The short rate in one-factor models is Markov. In N-factor models, the short rate alone is not Markov, but the short rate together with N - 1 yields is typically Markov.The short rate often serves as one of the factors in multidimensional models. In this case, we still have $\delta_0=0$ and $\delta_1=(1, 0_{N-1})'$. Long yields still depend on the oth factors because the expected future path of the short rate depends on the current state x in (2.2), when the short rate covaries with these other factors under the risk-neutral measure.
-->

<!--
Bertolini, Bertola, Prati () and Gara () observe the effect of Fed interventions on the volatility in in
(Schuhlhofer et all propose efficiency in the ample reserves regime adopted (date) address the tradeoff

that daily money market rates hover around Fed targets and quickly revert to them in times of shocks.Be

Bertolini et al Time series methodology:
volatility of interest rates - rises in advance of reserve
settlement days - declines in high rate regimes - biweekly periodicity when Fed is perceived as committ

Although overnight wholesale money market rates change in response to monetary policy and other shocks,
-->

!>--
USE this in paper outline: Section II provides a brief review of the current operation of re- serve requirements and the federal funds market in the United States. Section III develops a time-series description of daily changes in the federal funds rate.
-->

<!--
Hamilton ----------------------
Section IV proposes a theoretical model of the federal funds market that could account for these features as a result of line limits, transaction costs, and weekend accounting conventions.

These results suggest that there is little, if any, interday speculation that would smooth out small fluctuations in the federal funds rate. A small temporary infusion of reserves through an overnight re- purchase agreement by the Fed's trading desk lowers that day's fed- eral funds rate by inducing movement along a schedule that repre- sents lending banks' liquidity benefit from holding excess reserves.

The ability of the repurchase agreement to affect the interest does not depend on whether the open-market operation is anticipated in advance.

A small temporary infusion of reserves through an overnight repurchase agreement by the Fed's trading

Hamilton provides valuable evidence of end-of-quarter and end-of-year effects since bank balance sheets
quarter or the last day of the year. Fridays, the federal funds market is soft. A federal funds loan on
martingale hypothesis fails, its failure might show up in part in the appearance of something different

Hamilton (1996) adapts Nelson's (1991) model of daily stock return in a model of the conditional mean ar

His empirical description of the time-series process that generates the daily federal funds rate, simultaneously modeling the conditional mean, variance, and overall shape of the probability distribution of daily changes in the federal funds rate. These results are then used to understand what happens to the federal funds rate when the Fed makes an open-market purchase

Mondays are independently estimated to be days of federal funds increases. If we accept the idea that th

I conclude that transaction costs, rather than a minor institutional detail of this particular market, lie at the heart of the liquidity effect that enables the Federal Reserve to change the interest rate on a daily basis

end-of-quarter and end-of-year effects as well. Public scrutiny of many enterprises is based on their balance sheets, which typically represent a snapshot of an institution's assets on the last day of the quarter or the last day of the year. Some institutions appear willing to hold certain assets on December 30 that they are unwilling to hold on December 31. At the end of the year, there is a surge in asset turnover and in corporations drawing on bank lines of credit, which can generate a huge demand for short-term loans of good funds around that date; see Allen and Saunders (1992) for further discussion. Again at a minimum we want to allow for increased variability of the federal funds rate at the end of the quarter and possibly temporary departures from the martingale hypothesis on these days as well

The model In modeling the conditional mean, recall that the martingale hypothesis does not restrict the process followed by it if t corresponds to the first Thursday of a maintenance period. The last day of a quarter may likewise reflect special circumstances, with limited substitutability with reserves held on the day before or after. Thus if t is the first day of a maintenance period or the first day of a quarter, I describe the conditional mean for the federal funds rate with a pth-order autoregression:

The mean
\begin{align*}
i_t=\mu_t +\sigma_t \nu_t
\mu_t = i_{t-1} + \eta_{s_t} + \beta h_t
#y¯_t = [(sum_{i}^{}(v_{i,t}) times yhat_{i,t})]/(sum_{i}^{}v_{i,t})
\end{align*}
where re s_t E {1, 2, . . ., 10} indicates which day of the maintenance period is associated with observation t.

Thus η_2 corresponds to the average change in the federal funds rate

between the first Thursday and Friday of a maintenance period,
whereas η_10 gives the average change of the federal funds rate on
settlement Wednesday. Under the martingale hypothesis, η_j = 0 for j=2, 3, .. ., 10.

To describe at', the conditional variance of the federal funds rate,
I adapt Nelson's (1991) model of daily stock returns
$log(\sigma^2_t)-\xi_{s_t}-\kappa h_t = (sum_{j=1}^{\tau}(log(\sigma^2_{t-j}) -\xi_{t-j}-\kappa h_{t-j]
(\alpha abs(\nu_{t-1})-E(abs(\nu_{t-1})) + \chi\nu_{t-1})$ or $hi or \zeta$

Empirical resultspp 38-44
He finds deviations of the FFR from the FOMC target tend to dissipate quickly. (same for other rates?)
day t:
$\mu_t = \eta_1 + i_{t-l} + \fi(i_{t-1} - i_{t - 3} + I'h_t $ (12)

the unconditional variance has the same value for days 2-7,
$ \xi_2 = \xi_2= cdot \xi_7 $ (13)
the generalized autoregressive conditional heteroskedasticity
effects are integrated:
$\delta_2 + \delta_2 + cdot + \delta_\tau= 1$

Two magnitudes most useful for describing the conditional variance are (1) the conditional variance on t

The autoregressive coefficients that characterize the first day of a new maintenance pe-
riod or new quarter take the following form: some fraction -) of
the cumulative change over the preceding two days is reversed on
day t. That is, these observations are described with the following
special case of (4):
$\mu_t = 91 + i_{t-l} + 4k(i_{t-1} - i_{t - 3} + I'h_t $ (12)
where I estimate + = - 0.81. This is clearly related to the conclusion
by Rudebusch (1994) that deviations of the funds rate from the value
targeted by the Fed tend to dissipate quickly. M

\url{https://bookdown.org/dalzelnm/bookdown-demo/mathematical-notation-in-r.html}
$Y_i \sim N(\mu, \sigma)$ makes Yi N(,)
gridExtra::grid.arrange(g1,g2, g1,g2, ncol = 2)
.
The vector h_t is a collection of zero-one dummy variables incorporating calendar effects.
Calendar effects nine elements of h_t :
t holidays (as captured by the first four elements of ht) matter for
the mean parameters (I) but not for the variance parameters (K). By
contrast, the end-of-quarter and end-of-year effects on the variance
were very dramati
j 1 Kj Meaning
1 -.028 {.00} t precedes a 1-day holiday
(.020)
2 -.031 {.00} t precedes a 3-day holiday
(.011)
3 .023 {.00} t follows a 1-day holiday
(.020)
4 .171 {.00} t follows a 3-day holiday
(.017)
5 {.00} .853 t is the last day of quarter 1, 2, 3, or 4
(.379)

6 {.00} .975 t is the last day of the year
(.765)
7 {.00} 1.550 t is the day before, on, or after the last day of quarter 1,
(.216) 2, or 3
8 {.00} {1.550} t is 2 days before, 1 day before, on, 1 day after, or 2 days
after the end of the year
9 {.185} {.00} t is day 9 but precedes a 1-day holida

MAXIMUM LIKELIHOOD ESTIMATES OF OTHER PARAMETERS IN EQUATIONS
(7), (12), AND (15)
Parameter Value Meaning
$\fi$- .811 Fraction of $i_{t-1} - i_{t-3}$ that is expected to be reversed if t is
(.021) first day of a new period
δ- .793 Weight on the previous day's log variance in determining
(.046) today's log variance
α-.316 Weight on the absolute value of the previous day's innova-
(.036) tion in determining today's log variance
$\x$ .341 Additional effect of a positive previous day's innovation in
(.083) determining today's log variance
ρ- .861 Fraction of innovations drawn from distribution 1
(.026)
j 1{1.00} Standard deviation of distribution 1
T2 2.915 Standard deviation of distribution 2
(.200

Fridays, the federal funds market is soft the eta's
A federal funds loan on a Friday has a 3-day term rather than a 1-day term, and it is not altogether surprising that if the martingale hypothesis fails, its failure might show up in part in the appearance of something different about Fridays. Likewise, days 3 and 8 are both Mondays, and both are independently estimated to be days of federal funds increases. If we accept the idea that the level of the federal funds rate tends to be a little low on Fridays, the change from Friday to Monday by implication would be bigger than average

proposes a complete empirical description of the time-series process that generates the daily federal funds rate, simultaneously modeling the conditional mean, variance, and overall shape of the probability distribution of daily changes in the federal funds rate. These results are then used to understand what happens to the federal funds rate when the Fed makes an open-market purchasThe federal funds market is a good place to start for an understanding of either finance or monetary policy. From the point of view of finance, overnight federal funds represent the shortest-term security that is actively traded and thus form the base of any term structure relation. Indeed, recent papers by Balduzzi, Bertola, and Foresi (1993), Roberds, Runkle, and Whiteman (1994), and Rudebusch (1994) suggest that several well-known puzzles in the term structure of interest rates can be resolved by tracking these relations back to daily changes in the federal funds rate.
From the point of view of monetary policy, the daily operating procedures of the Federal Reserve System are also defined in terms of the federal funds market. An open-market purchase injects neThe federal funds market is a good plac

ing of either finance or monetary policy. From the point of view of
finance, overnight federal funds represent the shortest-term security
that is actively traded and thus form the base of any term structure
relation. Indeed, recent papers by Balduzzi, Bertola, and Foresi
(1993), Roberds, Runkle, and Whiteman (1994), and Rudebusch
(1994) suggest that several well-known puzzles in the term structure
of interest rates can be resolved by tracking these relations back to
daily changes in the federal funds rate.
From the point of view of monetary policy, the daily operating
procedures of the Federal Reserve System are also defined in terms
of the federal funds market. An open-market purchase injects ne
a consensus as to the nature of predictable changes in
the federal funds rate or the economic forces that produce them.
Earlier researchers have agreed that this daily interest rate fails to
follow a martingale, However,
none of these studies made allowance for the spectacular outliers
and autoregressive conditional heteroskedasticity (ARCH) effects that
characterize these data, and apart from Campbell (1987), none of-
fered a detailed description of how the findings could be reconciled
with profit maximization by banks.
-->

!<--The reserve demand function Estimating
Gara Alonso --
The sensitivity of the federal funds rate FFR to shocks to the level of reserves is of paramount importa

time evolution of aggregate reserves normalized by banks' total assets to control for the growth of the
removing month-end data from our daily sample, supply shocks tend to dominate demand shocks.
By comparing panels (a) and (b), we can see a negative
correlation between quantities (reserves) and prices (federal funds rates), which suggests that after
removing month-end data from our daily sample, supply shocks tend to dominate demand shocks.
This is confirmed by panel (c), which plots realized rates against realized reserves and can be seen
as an approximate visualization of the reserve demand curve. It shows a clear nonlinear, downward-slopi

The curve itself, however, also moves horizontally at a low frequency. In the earlier part of
our sample, the rate sensitivity to reserve shocks fades as reserves exceed 12$\%$ of banks' assets; i
the latter part, instead, it reemerges around 13$\%$, suggesting a moderate shift to the right. Below
these thresholds, the curve's slope gets steeper as reserves decrease, consistent with the theory. A
one-percentage-point drop in normalized reserves increases the federal funds-IORB spread by 1.3
basis points (bp) in 2010 and by 1.1 bp in 2019, while having no effect in 2012-2017 and after March
3, 2020. These estimates are robust to controlling for spillovers from the repo and Treasury markets.
Results are qualitatively similar if we normalize reserves by GDP instead of banks' assets

%\emph{theory reserve demand}
bank demand: regulatory requirements and liquidity needs, such as daily payments to other institutions

Banks borrow and lend reserves in the federal funds market, typically overnight, at the federal funds r

Demand curve slope is banks's reserve demand response to shocks:
Low reserves, negative slope, reduce demand as interest rates or shocks...
As reserves keep decreasing, the slope of the curve, i.e., the sensitivity of rates to reserve shocks,
increasing scarcity value of reserves.

High reserves, 0 slope, no response
the demand curve is flat around the interest rate paid by the Federal Reserve on reserve balances (the I
Gara plot: GaraAmpleReserves2022
 -->

<!--
Andersen, Benzoni, Lund -----------------------------------
- mean drift
the mean drift may be indicative of slowly evolving inflationary expectations, time-variation in the rec

stochastic volatility factor from accommodating extreme outlier behavior.
- continuous-time model provides an excellent characterization of the U.S. short-term interest rate
- three-factor jump-diffusion model
- simultaneous and efficient inference regarding all model components which include
    - a shock to the interest rate process itself
    - a time-varying mean reversion factor
    - a stochastic volatility factor
    - a jump process.

short rate:
- governs the price of riskless fund
transfers and is thus a key determinant of the intertemporal consumption and investment decisions
of economic agents.
-impacts the expected returns of primary assets whose
excess returns (over the short rate) are functions of systematic risk exposures and associated risk
premia.
-direct input to pricing and hedging in the huge fixed income securities market and the associated tradi

main features of the U.S. short-term interest rate
- complex conditional heteroskedasticity
- fat-tailed innovations
- pronounced autocorrelation patterns

- stochastic volatility
   - critical for a good fit
   - the stochastic mean offers a more modest, but still significant, improvement.
     allow for a relatively fast mean-reversion of the short rate around a highly persistent
     time-varying central tendency process.

- mean drift
the mean drift may be indicative of slowly evolving inflationary expectations, time-variation in the rec

- jumps
 Furthermore, we find jumps to be integral to the quality of fit and to relieve the stochastic volatilit

We find that an intuitively appealing and fairly manageable continuous-time model provides
an excellent characterization of the U.S. short-term interest rate over the post Second World
War period. Our three-factor jump-diffusion model consists of elements embodied in existing
specifications, but our approach appears to be the first to successfully accommodate all such
features jointly. Moreover, we conduct simultaneous and efficient inference regarding all model
components which include a shock to the interest rate process itself, a time-varying mean reversion fact
the restrictions implied by an affine representation of the jump-diffusion system are not rejected
by the U.S. short rate data. This allows for a tractable setting for associated asset pricing

applications.

Why the short rate(s)?
The short rate governs the price of riskless fund
transfers and is thus a key determinant of the intertemporal consumption and investment decisions
of economic agents. In addition, the short rate impacts the expected returns of primary assets whose
excess returns (over the short rate) are functions of systematic risk exposures and associated risk
premia. Finally, the short rate serves as a direct input to pricing and hedging in the huge fixed incom

main features of the U.S. short-term interest rate, i.e., complex
conditional heteroskedasticity, fat-tailed innovations and pronounced autocorrelation patterns, may
be captured within an intuitively appealing and manageable continuous-time jump-diffusion setting.
Relative to earlier contributions, we explore a more general parametric class of continuous-time models
and jumps in the interest rate level.

Both of our favored models contain three factors featuring stochastic volatility, mean drift and
jumps. The inclusion of the stochastic volatility factor is critical for a good fit, whereas the stocha

Other recent contributions that have investigated the short term interest rate include Das (2002); Erak
Elerian, Chib, and Shephard (2001); Hamilton (1996); Johannes (2004); Li, Pearson, and Poteshman (2002)
-->
NOTES ---

<!--
Citations
Cochrane and Piazzesi
Benzoni
Gara
Duffie Krishnamurthy

Adam Copeland | Darrell Duffie | Yilin (David) Yang. Reserves Were Not So Ample After All. July 2021.
JEL classification: G14, D47, D8

James D. Hamilton. The Daily Market for Federal Funds. February 1996. Journal of Political Economy, Vol
<!-- Stable URL: https://www.jstor.org/stable/2138958
Published by: The University of Chicago Press pp. 26-56 -->

Piazzesi, Monika. Bond Yields and the Federal Reserve. April 2005. Journal of Political Economy, Volume

Gara Afonso, Kyungmin Kim, Antoine Martin, Ed Nosal, Simon Potter, and Sam Schulhofer-Wohl. Monetary pol
https://doi.org/10.21033/wp-2020-0

Bertolini.L, Bertola, Prati. Day-To-DaY_Monetary Policy and the Volatility of the Federal Funds Interes

Torben Gustav Andersen, Luca Benzoni,Jesper Lund. Stochastic volatility, mean drift, and jumps in the s

@article{article,
author = {Andersen, Torben and Benzoni, Luca and Lund, Jesper},
year = {2004},
month = {01},
pages = {},

title = {Stochastic volatility, mean drift, and jumps in the short-term interest rate}
}

-->
recover files rsrecovr::recovr(project_path = "all")
COMMENT on Bertolini,Bertola, Prati () observation that that volatility in the federal funds rate is lo

Results section:
Hypotheses 1 Volatility: Noteable is the high frequency of volatility of the Fed's policy rate EFFR as t

Hypotheses 2 Although overnight wholesale money market rates change in response to monetary policy and e

Hypothesis 3 The rate data provide evidence of Fed's difference preferences for offsetting volatility in

Hypothesis 4: Puzzle: The demand for each instrument, price versus volume reveals,large changes in deman

Hypothesis 5 The volatility response of overnight rates to Fed interventions is greater: the lower rese

Other:
6. volatiity of transactions
7. spreads, indicators of reserves, arbitrage
8. another research question/hypothesie

Monetary policy during the sample period 2016-2022
##
* my shocks (FFR changes under episodes)
* Romer and Romer shocks
* other external shocks to these markets

I trace the FOMC rate changes, monetary regimes, and events occurred during the six year period of our s

The QE1, QE2, and QE3 asset purchases challenged changed the bank’s ability to control short-term intere
rates. Asset purchases under QE resulted in central banks changing their overall frameworks for controll

In 2018 the FOMC adopted target rates, In 2019, the FOMC abandoned active management of scarce reserves
.

Under this ample reserves regimen The Federal Reserve manages the the policy rate, the Federal Funds rat

In the ample reserves regime. the administered rates constitute a "floor" system to manages the FFR with

The administered rates, the IOR and the ON RPP, along with an ample supply of reserves, created a corri
No bank should be borrow at a higher rate than the ONRRP. Banks and non-bank financial institutions shou

Under the Ample Reserves policy, the Federal Reserve manages the FFR within its desired range in a "floo

On October 1, 2008, Congress gave the Fed the power to pay interest on reserves (IOR) to help control th

The administered rates, the IOR and the ONRPP, (and now the repo facility) along with an ample supply o
.The IOR. The IOR is the ceiling, the ON RRP the floor. Banks have little or no incentive to lend their

By similar argument, no bank should be borrow at a higher rate than the ONRRP. Banks and non-bank fina

```
\begin{table}[h!]
\centering
\begin{tabular}{c c c}
\hline
FOMC rates changes \\
%Date & Change &(bps)   $\&$ Federal Funds Rate (pct) \\ [0.5ex]
 \hline\hline
\textbf{2015 to 2018: Returning to Normalcy, mid cycle adjustment 3/4/2016 - 7/31/2019} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
20-Dec-18 &  25 &       2.25 to 2.50\\
Sept. 27, 2018 &        25 &        2.0 to 2.25\\
Jun. 14, 2018&      25 &        1.75 to 2.0\\
22-Mar-18 &     25&     1.50 to 1.75\\
Dec. 14, 2017 &     2&  5   1.25 to 1.50\\
15-Jun-17&      25&     1.00 to 1.25\\
16-Mar-17&      25 &        0.75 to 1.00\\
Dec. 15, 2016 &     25 &        0.5 to 0.75\\
Dec. 17, 2015 &     25&     0.25 to 0.50\\
\hline
\textbf{2019  Mid-Cycle Adjustment 8/1/2019-10/31/2019} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
31-Oct-19 &     -25 &   1.50 to 1.75\\
Sept. 19, 2019&     -25&        1.75 to 2.0\\
Aug. 1, 2019&       -25 & 2.0 to 2.25\\
\hline
\textbf{2020 Coping with Covid  11/01/2019 - 3/16/2020} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
16-Mar-20&      -100&       0 to 0.25\\
3-Mar-20&       -50&        1.0 to 1.25\\
\hline
\textbf{the zero lower bound (ZLB) 3/17/2020- 3/16/2022} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
\textbf{2022 Taming Inflation 03/17/2022 - 12/29/2022} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
14-Dec-22&      50&     4.25 to 4.50\\
2-Nov-22&       75&     3.75 to 4.00\\
21-Sep-22&      75&     3.00 to 3.25\\
27-Jul-22&      75&     2.25 to 2.5\\
16-Jun-22&      75&     1.5 to 1.75\\
5-May-22&       50&     0.75 to 1.00\\
17-Mar-22&      25&     0.25 to 0.50\\
\end{tabular}
\caption{FOMC rates changes 2018 to 2022}
```

```
\label{table:FOMCratechanges}
\end{table}
# ------------ create new section on MP, shocks, etc

We examine how these shocks, changes in monetary policy (Table \ref{table:FOMCratechanges}).affect rate


Monetary policy shocks
QE date for analysis
FIND DATES, link to table and figure above
TABLE of monetary policy decisions and events
CHECK:UPDATE TABLE DO!
\emph{Which epoch, Sep 2019, Mar 2020, series of QE}
2019
March 15, 2020
March 23, 2020
June 2020
December 2020 slow purchase
November 2021
December 2021



\begin{table}[h!]
\centering
\begin{tabular}{c c c}
\hline
FOMC rates changes \\
%Date & Change &(bps)   $\&$ Federal Funds Rate (pct) \\ [0.5ex]
 \hline\hline
\textbf{2015 to 2018: Returning to Normalcy} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
20-Dec-18 &  25 &       2.25 to 2.50\\
Sept. 27, 2018 &        25 &        2.0 to 2.25\\
Jun. 14, 2018&      25 &        1.75 to 2.0\\
22-Mar-18 &     25&     1.50 to 1.75\\
Dec. 14, 2017 &     2&  5   1.25 to 1.50\\
15-Jun-17&      25&     1.00 to 1.25\\
16-Mar-17&      25 &        0.75 to 1.00\\
Dec. 15, 2016 &     25 &        0.5 to 0.75\\
Dec. 17, 2015 &     25&     0.25 to 0.50\\
\hline
\textbf{2019  Mid-Cycle Adjustment} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
31-Oct-19 &     -25 &   1.50 to 1.75\\
Sept. 19, 2019&     -25&        1.75 to 2.0\\
Aug. 1, 2019&       -25 & 2.0 to 2.25\\
\hline
\textbf{2020 Coping with Covid} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
16-Mar-20&      -100&       0 to 0.25\\
```

```
3-Mar-20&       -50&        1.0 to 1.25\\
\hline
\textbf{2022 Taming Inflation} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
14-Dec-22&      50&     4.25 to 4.50\\
2-Nov-22&       75&     3.75 to 4.00\\
21-Sep-22&      75&     3.00 to 3.25\\
27-Jul-22&      75&     2.25 to 2.5\\
16-Jun-22&      75&     1.5 to 1.75\\
5-May-22&       50&     0.75 to 1.00\\
17-Mar-22&      25&     0.25 to 0.50\\
\end{tabular}
\caption{FOMC rates changes 2018 to 2022}
\label{table:FOMCratechanges}
\end{table}

Other events or shocks that affected ratesL

EVENTS
1) 96 9/16/2019 Repo spike SOHR 2.42 +13 over 9/15, EFFR 2.23 +11
   97 9/17/2019 Repo spike    SOFR 5+                  EFFR 2.3
\url{https://www.federalreserve.gov/econres/notes/feds-notes/what-happened-in-money-markets-in-septembe
On Monday, September 16, SOFR printed at 2.43 percent, 13 basis points higher than the previous busines


2) Mar 10-18 2020  Dash for cash
121 3/8/2020 0:00 subtract 5 from coordinate
122 3/15/2020 0:00
The COVID-19 Pandemic Caused Market Disruptions across Sovereign Bond Markets
At the start of the COVID-19 pandemic in late February 2020, and in response to the economic repercussi
\url{https://libertystreeteconomics.newyorkfed.org/2022/07/the-global-dash-for-cash-in-march-2020/#:~:t


-122 March 15, 2020 On March 15, 2020, the Fed shifted the objective of QE to supporting the economy. I
 - 123 3/22/2020  March 23, 2020, it made the purchases open-ended, saying it would buy securities "in 

- June 2020 - In June 2020, the Fed set its rate of purchases to at least $\$$80 billion a month in Tre
 - December 2020 slow: The Fed updated its guidance in December 2020 to indicate it would slow these pu
 - November 2021 taper: In November 2021, judging that test had been met, the Fed began tapering its pa
 - December 2021 double taper: At the subsequent FOMC meeting in December 2021, the Fed doubled its spe

December 2020 slow purchase
November 2021
December 2021
  Table and figures display changes in the Fed funds rate and the administered rates IOR and the reward
Table \ref{table:FOMCratechanges} lists FOMC rates changes, monetary regimes, and events over the four 
\begin{table}[h!]
\centering
\begin{tabular}{c c c}
\hline
FOMC rates changes \\
%Date & Change &(bps)   $\&$ Federal Funds Rate (pct) \\ [0.5ex]
 \hline\hline
```

```
\textbf{2015 to 2018: Returning to Normalcy, mid cycle adjustment 3/4/2016 - 7/31/2019} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
20-Dec-18 &  25 &       2.25 to 2.50\\
Sept. 27, 2018 &        25 &        2.0 to 2.25\\
Jun. 14, 2018&      25 &        1.75 to 2.0\\
22-Mar-18 &     25&     1.50 to 1.75\\
Dec. 14, 2017 &     2&  5   1.25 to 1.50\\
15-Jun-17&      25&     1.00 to 1.25\\
16-Mar-17&      25 &        0.75 to 1.00\\
Dec. 15, 2016 &     25 &        0.5 to 0.75\\
Dec. 17, 2015 &     25&     0.25 to 0.50\\
\hline
\textbf{2019  Mid-Cycle Adjustment 8/1/2019-10/31/2019} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
31-Oct-19 &     -25 &   1.50 to 1.75\\
Sept. 19, 2019&     -25&        1.75 to 2.0\\
Aug. 1, 2019&       -25 & 2.0 to 2.25\\
\hline
\textbf{2020 Coping with Covid  11/01/2019 - 3/16/2020} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
16-Mar-20&      -100&       0 to 0.25\\
3-Mar-20&       -50&        1.0 to 1.25\\
\hline
\textbf{the zero lower bound (ZLB) 3/17/2020- 3/16/2022} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
\textbf{2022 Taming Inflation 03/17/2022 - 12/29/2022} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
14-Dec-22&      50&     4.25 to 4.50\\
2-Nov-22&       75&     3.75 to 4.00\\
21-Sep-22&      75&     3.00 to 3.25\\
27-Jul-22&      75&     2.25 to 2.5\\
16-Jun-22&      75&     1.5 to 1.75\\
5-May-22&       50&     0.75 to 1.00\\
17-Mar-22&      25&     0.25 to 0.50\\
\end{tabular}
\caption{FOMC rates changes 2018 to 2022}
\label{table:FOMCratechanges}
\end{table}
# ------------ create new section on MP, shocks, etc

We examine how these shocks, changes in monetary policy (Table \ref{table:FOMCratechanges}).affect rate


Monetary policy shocks
QE date for analysis
FIND DATES, link to table and figure above
TABLE of monetary policy decisions and events
CHECK:UPDATE TABLE DO!
\emph{Which epoch, Sep 2019, Mar 2020, series of QE}
```

2019
March 15, 2020
March 23, 2020
June 2020
December 2020 slow purchase
November 2021
December 2021

```
\begin{table}[h!]
\centering
\begin{tabular}{c c c}
\hline
FOMC rates changes \\
%Date & Change &(bps)   $\&$ Federal Funds Rate (pct) \\ [0.5ex]
 \hline\hline
\textbf{2015 to 2018: Returning to Normalcy} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
20-Dec-18 &  25 &       2.25 to 2.50\\
Sept. 27, 2018 &        25 &        2.0 to 2.25\\
Jun. 14, 2018&      25 &        1.75 to 2.0\\
22-Mar-18 &     25&     1.50 to 1.75\\
Dec. 14, 2017 &     2&  5   1.25 to 1.50\\
15-Jun-17&      25&     1.00 to 1.25\\
16-Mar-17&      25 &        0.75 to 1.00\\
Dec. 15, 2016 &     25 &        0.5 to 0.75\\
Dec. 17, 2015 &     25&     0.25 to 0.50\\
\hline
\textbf{2019  Mid-Cycle Adjustment} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
31-Oct-19 &     -25 &   1.50 to 1.75\\
Sept. 19, 2019&     -25&        1.75 to 2.0\\
Aug. 1, 2019&       -25 & 2.0 to 2.25\\
\hline
\textbf{2020 Coping with Covid} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
16-Mar-20&      -100&       0 to 0.25\\
3-Mar-20&       -50&        1.0 to 1.25\\
\hline
\textbf{2022 Taming Inflation} & \\
Date & Change &(bps)    $\&$ Federal Funds Rate (pct) \\ [0.5ex]
\hline
14-Dec-22&      50&     4.25 to 4.50\\
2-Nov-22&       75&     3.75 to 4.00\\
21-Sep-22&      75&     3.00 to 3.25\\
27-Jul-22&      75&     2.25 to 2.5\\
16-Jun-22&      75&     1.5 to 1.75\\
5-May-22&       50&     0.75 to 1.00\\
17-Mar-22&      25&     0.25 to 0.50\\
\end{tabular}
```

\caption{FOMC rates changes 2018 to 2022}
\label{table:FOMCratechanges}
\end{table}

Other events or shocks that affected ratesL

EVENTS
1) 96 9/16/2019 Repo spike SOHR 2.42 +13 over 9/15, EFFR 2.23 +11
   97 9/17/2019 Repo spike   SOFR 5+   EFFR 2.3
\url{https://www.federalreserve.gov/econres/notes/feds-notes/what-happened-in-money-markets-in-septembe
On Monday, September 16, SOFR printed at 2.43 percent, 13 basis points higher than the previous busines

2) Mar 10-18 2020 Dash for cash
121 3/8/2020 0:00 subtract 5 from coordinate
122 3/15/2020 0:00
The COVID-19 Pandemic Caused Market Disruptions across Sovereign Bond Markets
At the start of the COVID-19 pandemic in late February 2020, and in response to the economic repercussi
\url{https://libertystreeteconomics.newyorkfed.org/2022/07/the-global-dash-for-cash-in-march-2020/#:~:t

-122 March 15, 2020 On March 15, 2020, the Fed shifted the objective of QE to supporting the economy. I
 - 123 3/22/2020 March 23, 2020, it made the purchases open-ended, saying it would buy securities "in

- June 2020 - In June 2020, the Fed set its rate of purchases to at least $\$$80 billion a month in Tre
 - December 2020 slow: The Fed updated its guidance in December 2020 to indicate it would slow these pu
 - November 2021 taper: In November 2021, judging that test had been met, the Fed began tapering its pa
 - December 2021 double taper: At the subsequent FOMC meeting in December 2021, the Fed doubled its spe

December 2020 slow purchase
November 2021
December 2021
  Table and figures display changes in the Fed funds rate and the administered rates IOR and the reward
Table \ref{table:FOMCratechanges} lists FOMC rates changes, monetary regimes, and events over the four

Time series properties/characteristics of overnight policy, interbank rates, transactions, and reserv
We examine the time series properties of overnight reference rates and their correspondence with the Fe

Match to authors' observations
Summary of findings: Heteroskedascity, outliers, volatility, fat tails, skew
1. All. Spectacular outliers and autoregressive conditional heteroskedasticity (ARCH) effects
2. Piazzesi. "snake shaped "volatility of yields:Volatility is high
for very short maturities (the head of the snake), rapidly decreases until
maturities of around three months (the neck of the snake), then increases until maturities of up to two
3. Policy inertia (P)
4. 2 year UST yield economy medium terms, longer yields future economy (P)
5. Day effects, end of qtr, end of year (H) P says irrelevant if target is a state variable
6. Hamilton (1996) and others have concluded that the hypothesis that the FFR follows a martingale is i
7. Benzoni identify mean reversion around a central tendency. The stochastic mean allows a relatively
8. The mean drift may be indicative of slowly evolving inflationary expectations (Gara horiz?), time-va
9. Afonso. The slope of the demand function is negative as reserves decline. The sensitivity of rates t
10. \emph{Vertical shift}
Policy changes shift the curve up and down by moving its lower bound. Increases (descreases) in the (FF
11. \emph{Horizontal shift}

Low frequency horizontal shifts in the demand function reflect sensitivity of rates to shocks to reserve
(1): for every level of the federal funds rate, they imply an increase in the quantity of aggregate
reserves demanded by the banking system. As a result of these shifts, the level of reserves at which
the curve stops being flat and start displaying a negative slope may have moved over time.
These structural changes [which ?] could be interpreted as the horizontal shifts $\ast(q)$ in the demand
12. (BBP) Bertolini, Bertola, Prati () focus is the high frequency patterns of FF rate volatility that
13. Rate data provide evidence of Fed's difference preferences for offsetting volatility in the Federal
14. Quick response of other key short rates to monetary policy and other shocks. Overnight wholesale mon
15. Their model of FFR volatility seeks to isolate Fed preferences for offsetting volatility in the FFR

Spectacular outliers and autoregressive conditional heteroskedasticity (ARCH) effects that
characterize these data should not be ignored.

Piazzesi The "snake shaped "volatility of yields:Volatility is high
for very short maturities (the head of the snake), rapidly decreases until
maturities of around three months (the neck of the snake), then increases until maturities of up to two

?? which the model explains with policy inertia, tendency to continue same policy changes

curve, because the
Policy inertia: tendency to continue same policy changes
Volatility smile
2 year UST yield

Hamilton, as other authors, recognizes extreme volatility and the large outliers of short-rate data. Ham

Hamilton (1996) and others have concluded that the hypothesis that the FFR follows a martingale is inco

Benzoni identify mean reversion around a central tendency. The stochastic mean allows a relatively fast

The mean drift may be indicative of slowly evolving inflationary expectations (Gara horiz?), time-variat

Heteroskedascity, outliers, volatility, fat tails, skew

Gara et al model of banks' reserve demand response to shocks to reserves reveals greater sensitivity to

The slope of the demand function is negative as reserves decline. The sensitivity of rates to reserve sh

\emph{Vertical shift}
Policy changes shift the curve up and down by moving its lower bound. Increases (descreases) in the (FFR
\emph{Horizontal shift}
Low frequency horizontal shifts in the demand function reflect sensitivity of rates to shocks to reserve
(1): for every level of the federal funds rate, they imply an increase in the quantity of aggregate
reserves demanded by the banking system. As a result of these shifts, the level of reserves at which
the curve stops being flat and start displaying a negative slope may have moved over time.

These structural changes [which ?] could be interpreted as the horizontal shifts $\ast(q)$ in the demand

Bertolini, Bertola, Prati () focus is the high frequency patterns of FF rate volatility that survive F

They note the response of other key short rates to monetary policy and other shocks. Overnight wholesal

Their model of FFR volatility seeks to isolate Fed preferences for offsetting volatility in the FFR mar
##

Summary of findings: Heteroskedascity, outliers, volatility, fat tails, skew
1. All. Spectacular outliers and autoregressive conditional heteroskedasticity (ARCH) effects
2. Piazzesi. "snake shaped "volatility of yields:Volatility is high
for very short maturities (the head of the snake), rapidly decreases until
maturities of around three months (the neck of the snake), then increases until maturities of up to two
3. Policy inertia (P)
4. 2 year UST yield economy medium terms, longer yields future economy (P)
5. Day effects, end of qtr, end of year (H) P says irrelevant if target is a state variable
6. Hamilton (1996) and others have concluded that the hypothesis that the FFR follows a martingale is i
7. Benzoni identify mean reversion around a central tendency. The stochastic mean allows a relatively
8. The mean drift may be indicative of slowly evolving inflationary expectations (Gara horiz?), time-va
9. Afonso. The slope of the demand function is negative as reserves decline. The sensitivity of rates t
10. \emph{Vertical shift}
Policy changes shift the curve up and down by moving its lower bound. Increases (descreases) in the (FF
11. \emph{Horizontal shift}
Low frequency horizontal shifts in the demand function reflect sensitivity of rates to shocks to reserv
(1): for every level of the fe
deral funds rate, they imply an increase in the quantity of aggregate
reserves demanded by the banking system. As a result of these shifts, the level of reserves at which
the curve stops being flat and start displaying a negative slope may have moved over time.
These structural changes [which ?] could be interpreted as the horizontal shifts $\ast(q)$ in the deman
12. (BBP) Bertolini, Bertola, Prati () focus is the high frequency patterns of FF rate volatility that
13. Rate data provide evidence of Fed's difference preferences for offsetting volatility in the Federal
14. Quick response of other key short rates to monetary policy and other shocks. Overnight wholesale mo
15. Their model of FFR volatility seeks to isolate Fed preferences for offsetting volatility in the FFR

Daily overnight rates

Introduce overnight rates, EFFR, TGCR, BGCR, SOFR. sources NYFed, concoda David Gibbs
Figure 1. Visible in sample figure 1(and stats?)
Features of overnight rates closely tracking the EFFR
Vertical shifts from policy changes
Horizontal shifts, sensitivity
Policy inertia
Tendency to move together
Mean reverions (around a central tendency Benzoni) Martingale or not: Hamilton (1996) and others have c

Overnight rates are outliers, heteroskedastic, outliers present, and Extreme or high volatility of shor
Volatility relative to to prior periods (here daily)
Outliers
Rate volatility survives

Conditional heteroskedasticity (\url{https://www.investopedia.com/terms/h/heteroskedasticity.asp})
Heteroskedasticity often arises in two forms: conditional and unconditional. Conditional .
? Do my plots of log percent changes, and standard deviation of log percent changes serve

For the sample from 2016 through 2023, (Figure \@ref(fig:Daily rates 2016-2022-plot), you can see how cl
Monetary Policy across Inflation Regimes
Valeria Gargiulo, Christ ian Matthes, and Katerina Petrova
Federal Reserve Bank of New York Staff Reports, no. 1083
January 2024
\URL{https://doi.org/10.59576/sr.1083}

1. normalcy   3/4/2016   7/31/2019   1 858
2. mid cycle adjustment 8/1/2019 - 10/31/2019 737660 859 - 922
3. covid 11/1/2019   3/16/2020   923 1013
4. zlb   3/17/2020- 3/16/2022   1014-1518
4. Taming inflation 03/17/2022 - 12/14/2023 1519-1957

Rates increase steadily from _ basis points during normalcy from March 2016 through July 2019.In 2019 ra

Chat: In the sample, the average weighted median for the Effective Federal Funds Rate (EFFR) stands at

Figure \@ref(fig:sampleplot), the relationship is evident.

'data.frame': 1957 obs. of 6 variables:

$ sdate: Date, format: "2016-03-04" "2016-03-07" ...

$ EFFR : num 36 36 36 36 36 36 36 37 37 37 ...

$ OBFR : num 37 37 37 37 37 37 37 37 37 37 ...

$ TGCR : num 0 0 0 0 0 0 0 0 0 0 ...

$ BGCR : num 0 0 0 0 0 0 0 0 0 0 ...

$ SOFR : num 0 0 0 0 0 0 0 0 0 0 ...

Warning: Removed 3 rows containing missing values (`geom_point()`).

```
![Overnight rates 2016-2023](ONrates03142024draft_files/figure-latex/sampleplot-1.pdf)
```

<!--
Chatadvice
Got it:
It's important to ensure consistency between the code in your R Markdown document and the data/environme

To address this issue, you should consider the following steps:

Update the data: If you've made changes to the code that generates figures and those changes require mod

Resave the environment: If the .RDS file contains an environment or workspace that the code in your R Ma

Verify consistency: After updating the data and resaving the environment (if necessary), verify that the

```
By ensuring consistency between the code and the data/environment it relies on, you can minimize the lil


It seems that the error message is related to the assignment of values to the sdate column of a data fra

The error message suggests that the replacement operation ($<-.data.frame) is trying to replace values i

Here are some steps you can take to troubleshoot and potentially resolve the issue:

Review the relevant portion of your R Markdown document: Examine lines 1774-1786 of your R Markdown docu

Check the assignment to the sdate column: Look for any assignment operations ($<-) involving the sdate c

Inspect the data frame: Check the structure and dimensions of the data frame before and after the assign

Verify the input data: Ensure that the input data used in your R Markdown document is correct and comple

Debugging: If you're unable to identify the issue, consider adding print statements or using a debugger

Older:
Check for any problematic data points: Review the data in your meltrrbp data frame to identify any poten

Review the aesthetics and settings in your ggplot code: Double-check the aesthetics mappings and any oth

Consider adjusting plot settings: Depending on your specific requirements, you may need to adjust the pl

Debug the ggplot code: If the warning persists, try simplifying your ggplot code and gradually reintrodu

By carefully reviewing your ggplot code and data, you should be able to identify and address any issues
-->

[1] 1
[1] 1957
'data.frame':   1957 obs. of  6 variables:
 $ sdate: Date, format: "2016-03-04" "2016-03-07" ...
 $ EFFR : num  36 36 36 36 36 36 36 37 37 37 ...
 $ OBFR : num  37 37 37 37 37 37 37 37 37 37 ...
 $ TGCR : num  0 0 0 0 0 0 0 0 0 0 ...
 $ BGCR : num  0 0 0 0 0 0 0 0 0 0 ...
 $ SOFR : num  0 0 0 0 0 0 0 0 0 0 ...
NULL
'data.frame':   1957 obs. of  9 variables:
 $ EFFR            : num  36 36 36 36 36 36 36 37 37 37 ...
 $ VolumeEFFR      : num  75 72 72 75 72 68 67 67 63 63 ...
 $ TargetUe        : num  50 50 50 50 50 50 50 50 50 50 ...
 $ TargetDe        : num  25 25 25 25 25 25 25 25 25 25 ...
 $ Percentile01_EFFR: num  34 34 32 34 35 35 35 35 35 36 ...
 $ Percentile25_EFFR: num  36 36 36 36 36 36 36 36 36 36 ...
 $ Percentile75_EFFR: num  37 37 37 37 37 37 37 37 37 37 ...
 $ Percentile99_EFFR: num  52 50 50 52 75 50 50 50 50 50 ...
 $ sdate           : Date, format: "2016-03-04" "2016-03-07" ...
NULL
'data.frame':   1957 obs. of  6 variables:
 $ sdate: Date, format: "2016-03-04" "2016-03-07" ...
```

```
 $ EFFR : num  36 36 36 36 36 36 36 37 37 37 ...
 $ OBFR : num  37 37 37 37 37 37 37 37 37 37 ...
 $ TGCR : num  0 0 0 0 0 0 0 0 0 0 ...
 $ BGCR : num  0 0 0 0 0 0 0 0 0 0 ...
 $ SOFR : num  0 0 0 0 0 0 0 0 0 0 ...
```

Warning in matrix(Estats, nrow = 8, ncol = 1): data length [7] is not a sub-multiple or multiple of the number of rows [8]

```
          [,1]     [,2]     [,3]     [,4]
[1,]  78.91262 296.9484 311.2315 754.3664
[2,] 170.51610 124.8942 125.0746 129.0220
[3,] 145.51610       NA       NA       NA
[4,] 153.07001       NA       NA       NA
[5,] 156.15023 132.3551 132.3679 132.5059
[6,] 157.70669 133.2718 133.3250 136.7011
[7,] 169.06285 138.7547 141.1865 143.5335
[8,]  78.91262       NA       NA       NA
```

```
\@ref(tab:sampletable_metrics) provides a summary of the data.
% latex table generated in R 4.3.2 by xtable 1.8-4 package
% Tue Mar 19 22:27:54 2024
\begin{table}[ht]
\centering
\begin{tabular}{rlrrrr}
  \hline
 & Category & Median & IQR & RANGE & VOLUME \\
  \hline
VolumeEFFR & EFFR & 78.91 & 11.36 &  & 170.52 \\
  VolumeTGCR & TGCR & 296.95 & 5.48 &  & 124.89 \\
  VolumeBGCR & BGCR & 311.23 & 7.86 &  & 125.07 \\
  VolumeSOFR & SOFR & 754.37 & 6.83 &  & 129.02 \\
   \hline
\end{tabular}
\end{table}


<!--

How to reference figures and tables
As shown in Figure \@ref(fig:sampletable_metrics), the relationship is evident. Table

r my_plot, fig.cap=This is a plot of data, echo=FALSE
# Your plotting code here

In this example, "This is a plot of data" is the caption. When you knit your R Markdown document, R Mar
Then, when you want to reference this figure elsewhere in your document, you would use `\@ref(fig:my_pl
This way, R Markdown handles the numbering of figures automatically, ensuring consistency and accuracy 

In this example, "This is a table" is the caption for the table. When you knit your R Markdown document
Then, when you want to reference this table elsewhere in your document, you would use `\@ref(tab:my_tab
Similarly to figures, R Markdown handles the numbering of tables automatically, ensuring consistency an
```

-->

The average weighted median for the EFFR during the sample is 157 basis points (pb). The average weight

>!--
Sample characteristics, weighted average median values

```
                EFFR     TGCR     BGCR     SOFR
Rate          156.9688 132.8314 132.8482 134.0756
Volume        78.91262 296.9484 311.2315 754.3664
Upper target  170.5161 NA       NA       NA
Lower target  145.5161 NA       NA       NA
Percentile_01 153.07   124.8942 125.0746 NA
Percentile_25 156.1502 132.3551 132.3679 NA
Percentile_75 157.7067 133.2718 133.325  129.022
Percentile_99 169.0629 138.7547 141.1865 132.5059
```

--->

I describe volatility as log percent changes in rates since data are average weighted median values. the

The interquartile range (IQR), a useful measure of variability for skewed distributions. As the 75th mi

When measuring variability, statisticians prefer using the interquartile range instead of the full data

Unlike the more familiar mean and standard deviation, the interquartile range and the median are robust

The range of the data, here the 99th minus the first percentile illustrate outliers, showing where 98 p
\url{https://statisticsbyjim.com/basics/interquartile-range/}

The average weighted median for the EFFR during the sample is 157 basis points (pb). The average weight
The interquartile range (IQR) indicated half the data are clustered tightly around median rates. Half t

Estimating moments of the data show overnight rates are highly skewed with fatter tails.

The interquartile range for the money market rates TGCR and BGCR show 50 percent of the data are closel

The range of the data, the 99th minus the first percentile, is more sensitive to outliers. The range of
<!--

```
& Category & Median & IQR & RANGE \\
  \hline
  EFFR & EFFR & 156.97 & 1.56 & 15.99 \\
  OBFR & OBFR & 156.28 & 1.94 & 23.16 \\
  TGCR & TGCR & 132.83 & 0.92 & 13.86 \\
  BGCR & BBGCR & 132.85 & 0.96 & 16.11 \\
  SOFR & SOFR & 134.32 & 4.20 & 14.51 \\
```

-->

WHY IS THIS TABLE HERE TWICE SEE LINE
\@ref(tab:ratestats_sample) provides simple statistics of the data.

```
% latex table generated in R 4.3.2 by xtable 1.8-4 package
% Tue Mar 19 22:27:54 2024
\begin{table}[ht]
```

```
\centering
\begin{tabular}{rlrrrr}
  \hline
 & Category & Median & IQR & RANGE & VOLUME \\
  \hline
VolumeEFFR & EFFR & 78.91 & 11.36 &  & 170.52 \\
  VolumeTGCR & TGCR & 296.95 & 5.48 &  & 124.89 \\
  VolumeBGCR & BGCR & 311.23 & 7.86 &  & 125.07 \\
  VolumeSOFR & SOFR & 754.37 & 6.83 &  & 129.02 \\
   \hline
\end{tabular}
\end{table}
```

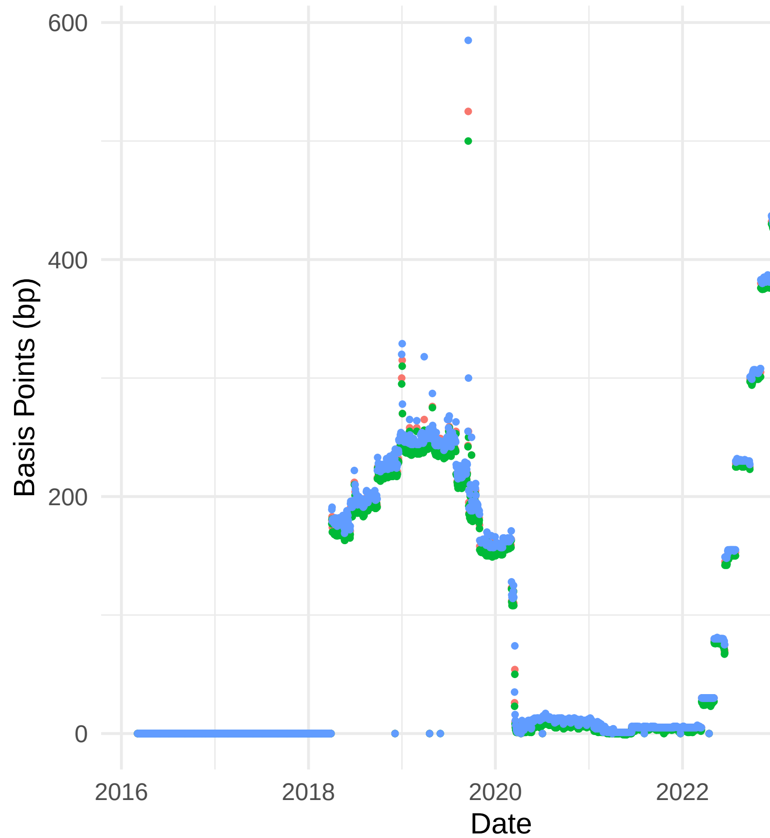
As shown in Figure \@ref(fig:sampleplot_characteristics), the relationship is evident. Table

Figure \@ref(fig:FOMC targets and EFFR)

Warning: Removed 465 rows containing missing values (`geom_point()`).

```
![EFFR, FOMC targets 2016-2023](ONrates03142024draft_files/figure-latex/FOMC targets and EFFR-1.pdf)
```

```
quantiles and boxplot?
Figure \@ref(fig:EFFR and quantiles)
{r EFFR and quantiles, fig.cap= "EFFR and quantiles 2016-2023",echo=FALSE}
#Access the data frame stored in the environment
my_effr <- my_enveffr$melteffr
```



(see Figure @ref(fig:SOFR, FOMC targets 2016-2023-plot)

(see Figure @ref(fig:Overnight rates quantiles 2016-2023)

(see Figure @ref(fig:Overnight rates boxplot)

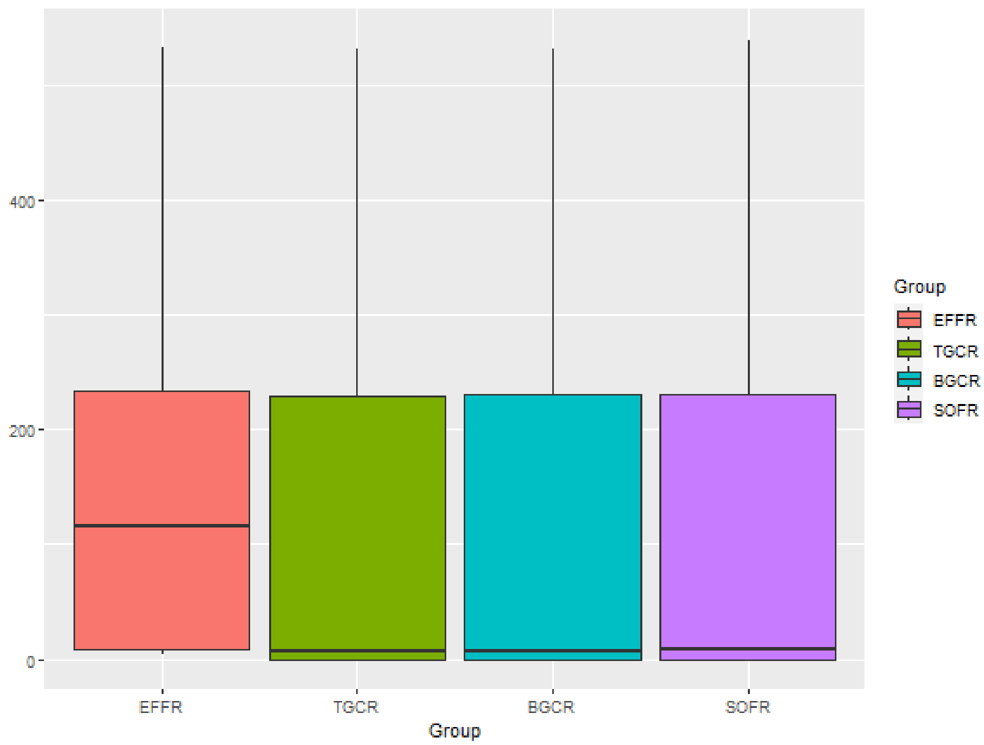
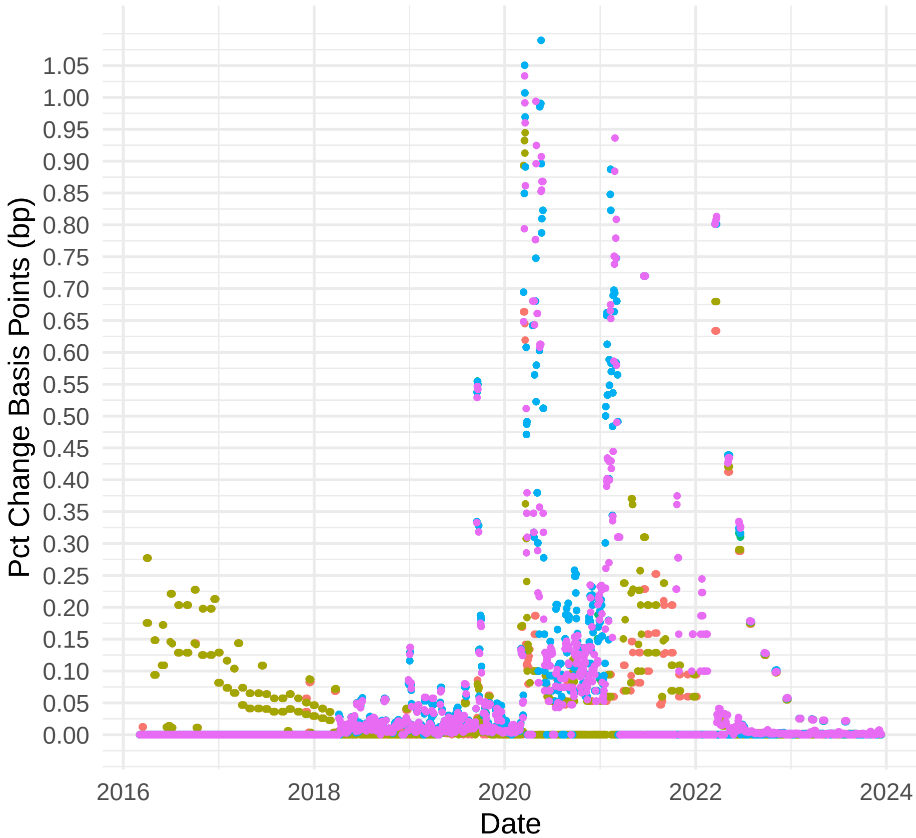


Figure 1: Daily rates 2016-2023

Volatility in the sample, the standard deviation of log percent change 2 plots: log percent change, and stadard deviation of log percent change over arbitrary periods, i.e number of days.

(see Figure @ref(fig:volatility log percent change)

This measure of volatility needs work since str(sdrates) 1956 observations five day rolling average. But Rolling every five days so maybe ok



(see Figure @ref(fig:stdev volatility 5day)

Episodes that suggest different policy regimes

#Discuss plots and statistics of episodes daily epoch rates

Episodes

The pattern in rate data from 2016 t0 2023 suggests the following episodes that may correspond with differing policy regimes or external shocks (Figure @ref(fig:EFFR, FOMC targets 2016-2023-plot):

normalcy adjust covid zlb inflation

```
## [1] "2016-03-04" "2019-08-01" "2019-11-01" "2020-03-17" "2022-03-17"
## [6] "2016-03-04"
```

```
## [1] "2019-07-31" "2019-10-31" "2020-03-16" "2022-03-16" "2023-12-14"
## [6] "2023-12-14"
```

```
## [1] "2016-03-04"
```

```
## [1] "2019-08-01"
```

```
## [1] "2016-03-04" "2019-08-01" "2019-11-01" "2020-03-17" "2022-03-17"
## [6] "2016-03-04"
```

```
## [1] "2019-07-31" "2019-10-31" "2020-03-16" "2022-03-16" "2023-12-14"
## [6] "2023-12-14"
```

episode characteristics

Table @ref(tab:normtable_characteristics) provides a summary of the data. [1] 1 [1] 858 'data.frame': 858 obs. of 6 variables: $ sdate: Date, format: "2016-03-04" "2016-03-07" ... $ EFFR : num 36 36 36 36 36 36 36 37 37 37 ... $ OBFR : num 37 37 37 37 37 37 37 37 37 37 ... $ TGCR : num 0 0 0 0 0 0 0 0 0 0 ... $ BGCR : num 0 0 0 0 0 0 0 0 0 0 ... $ SOFR : num 0 0 0 0 0 0 0 0 0 0 ... [,1] [,2] [,3] [,4] [1,] 133.78904 83.82984 83.83566 84.78438 [2,] 75.86364 158.52564 166.42075 350.22028 [3,] 143.09441 NA NA NA [4,] 118.09441 NA NA NA [5,] 129.37646 79.88345 79.96620 81.43706 [6,] 133.32634 83.43823 83.45221 83.54779 [7,] 134.54662 83.65618 83.68298 86.84848 [8,] 147.02331 85.50350 88.44172 89.96853 EFFR TGCR BGCR SOFR Rate 133.78904 83.82984 83.83566 84.78438 Volume 75.86364 158.52564 166.42075 350.22028 Upper target 143.09441 NA NA NA Lower target 118.09441 NA NA NA Percentile_01 129.37646 79.88345 79.96620 81.43706 Percentile_25 133.32634 83.43823 83.45221 83.54779 Percentile_75 134.54662 83.65618 83.68298 86.84848 Percentile_99 147.02331 85.50350 88.44172 89.96853

Table @ref(tab:normtable_metrics) provides a summary of the data. % latex table generated in R 4.3.2 by xtable 1.8-4 package % Tue Mar 19 22:28:01 2024

	Category	Median	IQR	RANGE
EFFR	EFFR	133.79	1.22	
TGCR	TGCR	83.83	0.22	
BGCR	BGCR	83.84	0.23	
SOFR	SOFR	84.78	3.30	

The average weighted median for the EFFR during the nomrmalcy period is 124 basis points (pb). The average weighted medians of other money market rates cluster around the median EFFR - TGCR,BGCR and SOFR 84-85 bp. Daily transaction volume in SOFR (billions of dollars) is around 350 billion. The money market volumes in TGCR and BGCR around 158-166 billion. Daily trade volume in EFFR is a low 76 billion. The percentiles of rates reflect the same clustering around the EFFR and SOFR as do their medians.

The interquartile range for the money market rates TGCR and BGCR are 0.22-0,23 bp, smaller than the 1.22 bp of the policy rate, EFFR. The SOFR has the largest IQR, some 3.3 bp. The OBFR,designed to track the policy rate. is similar to the EFFR.

The range of the data, the 9th ,minus the first percentile, is more sensitive to outliers/ Some 17.65 basis points for the EFFR and 5.62-8.53the money market rates, TGCR, BGCR, and SOFR.

IS THE ABOVE OLD CODE?

Table @ref(tab:adjust_characteristics) provides a summary of the data. [1] 859 [1] 922 [,1] [,2] [,3] [,4] [1,] NaN NaN NaN NaN [2,] NaN NaN NaN NaN [3,] NaN NA NA NA [4,] NaN NA NA NA [5,] NaN NaN NaN NaN [6,] NaN NaN NaN NaN [7,] NaN NaN NaN NaN [8,] NaN NaN NaN NaN EFFR TGCR BGCR SOFR Rate NaN NaN NaN NaN Volume NaN NaN NaN NaN Upper target NaN NA NA NA Lower target NaN NA NA NA Percentile_01 NaN NaN NaN NaN Percentile_25 NaN NaN NaN NaN Percentile_75 NaN NaN NaN NaN Percentile_99 NaN NaN NaN NaN

Table @ref(tab:adjusttable_metrics) provides a summary of the data. % latex table generated in R 4.3.2 by xtable 1.8-4 package % Tue Mar 19 22:28:01 2024

	Category	Median	IQR	RANGE
EFFR	EFFR			
TGCR	TGCR			
BGCR	BGCR			
SOFR	SOFR			

COVID ——————- Table @ref(tab:covid_characteristics) provides a summary of the data. [1] 923 [1] 1013 [,1] [,2] [,3] [,4] [1,] NaN NaN NaN NaN [2,] NaN NaN NaN NaN [3,] NaN NA NA NA [4,] NaN NA

NA NA [5,] NaN NaN NaN NaN [6,] NaN NaN NaN NaN [7,] NaN NaN NaN NaN [8,] NaN NaN NaN NaN EFFR TGCR BGCR SOFR Rate NaN NaN NaN NaN Volume NaN NaN NaN NaN Upper target NaN NA NA NA Lower target NaN NA NA NA Percentile_01 NaN NaN NaN NaN Percentile_25 NaN NaN NaN NaN Percentile_75 NaN NaN NaN NaN Percentile_99 NaN NaN NaN NaN

Table @ref(tab:covidtable_metrics) provides a summary of the data. % latex table generated in R 4.3.2 by xtable 1.8-4 package % Tue Mar 19 22:28:01 2024

	Category	Median	IQR	RANGE
EFFR	EFFR			
TGCR	TGCR			
BGCR	BGCR			
SOFR	SOFR			

ZLB ———————————————— Table @ref(tab:zlbtable_characteristics) provides a summary of the data. [1] 1014 [1] 1518 [,1] [,2] [,3] [,4] [1,] NaN NaN NaN NaN [2,] NaN NaN NaN NaN [3,] NaN NA NA NA [4,] NaN NA NA NA [5,] NaN NaN NaN NaN [6,] NaN NaN NaN NaN [7,] NaN NaN NaN NaN [8,] NaN NaN NaN NaN EFFR TGCR BGCR SOFR Rate NaN NaN NaN NaN Volume NaN NaN NaN NaN Upper target NaN NA NA NA Lower target NaN NA NA NA Percentile_01 NaN NaN NaN NaN Percentile_25 NaN NaN NaN NaN Percentile_75 NaN NaN NaN NaN Percentile_99 NaN NaN NaN NaN

–> Table @ref(tab:zlbtable_metrics) provides a summary of the data. % latex table generated in R 4.3.2 by xtable 1.8-4 package % Tue Mar 19 22:28:02 2024

	Category	Median	IQR	RANGE
EFFR	EFFR			
TGCR	TGCR			
BGCR	BGCR			
SOFR	SOFR			

INFLATION ————————————- Table @ref(tab:inflationtable_characteristics) provides a summary of the data.

[1] 1519 [1] 1957 [,1] [,2] [,3] [,4] [1,] NaN NaN NaN NaN [2,] NaN NaN NaN NaN [3,] NaN NA NA NA [4,] NaN NA NA NA [5,] NaN NaN NaN NaN [6,] NaN NaN NaN NaN [7,] NaN NaN NaN NaN [8,] NaN NaN NaN NaN EFFR TGCR BGCR SOFR Rate NaN NaN NaN NaN Volume NaN NaN NaN NaN Upper target NaN NA NA NA Lower target NaN NA NA NA Percentile_01 NaN NaN NaN NaN Percentile_25 NaN NaN NaN NaN Percentile_75 NaN NaN NaN NaN Percentile_99 NaN NaN NaN NaN

Table @ref(tab:inflationtable_metrics) provides a summary of the data. % latex table generated in R 4.3.2 by xtable 1.8-4 package % Tue Mar 19 22:28:02 2024

	Category	Median	IQR	RANGE
EFFR	EFFR			
TGCR	TGCR			
BGCR	BGCR			
SOFR	SOFR			

Episode plots:———————————————

(see Figure @ref(fig:EFFR during normalcy period 3/4/2016-7/31/2019-plot)

```
## Warning: attributes are not identical across measure variables; they will be
## dropped

## Warning: Removed 858 rows containing missing values (`geom_line()`).

## [1] 89
```

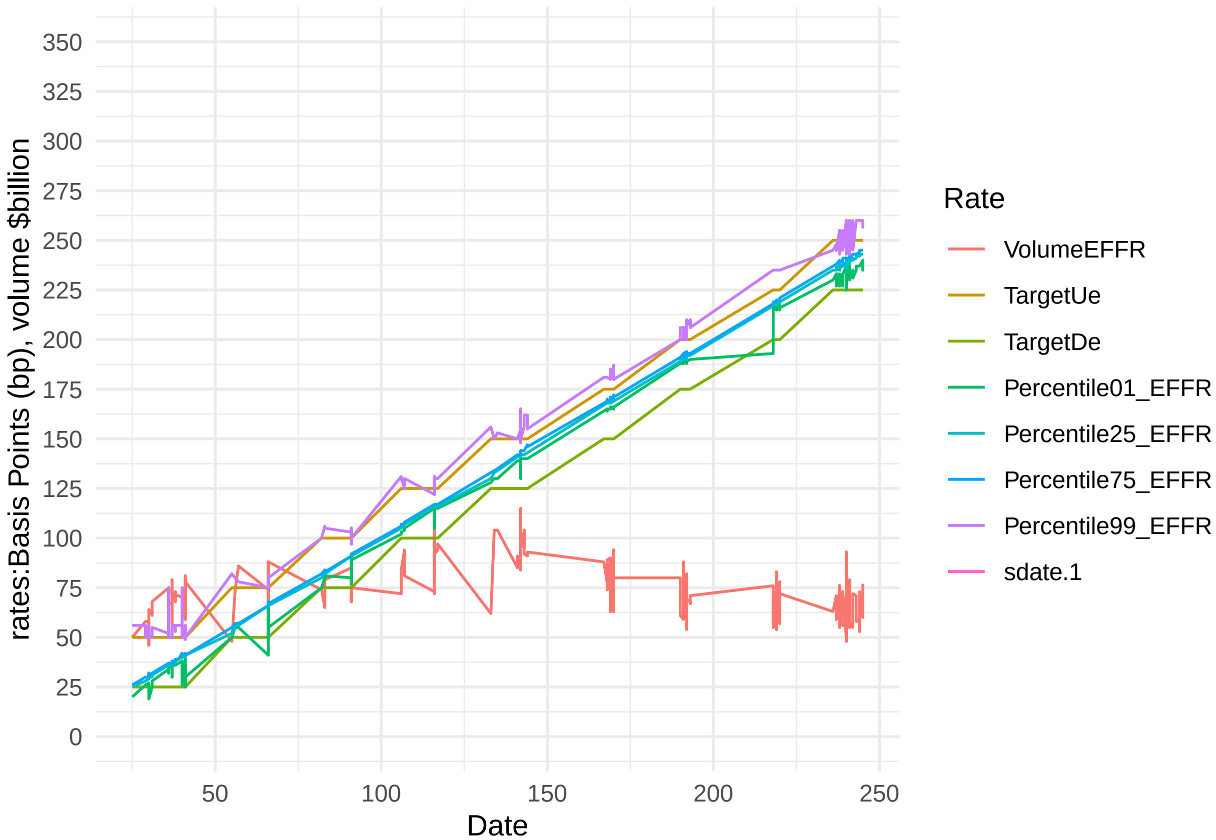


Figure 2: EFFR during normalcy period 3/4/2016-7/31/2019

```
## [1] 46
```

#(see Figure @ref(fig:EFFR during adjustment period 8/1/2019 - 10/31/2019-plot)

```
## Warning: attributes are not identical across measure variables; they will be
## dropped
```

```
## Warning: Removed 129 rows containing missing values (`geom_line()`).
```

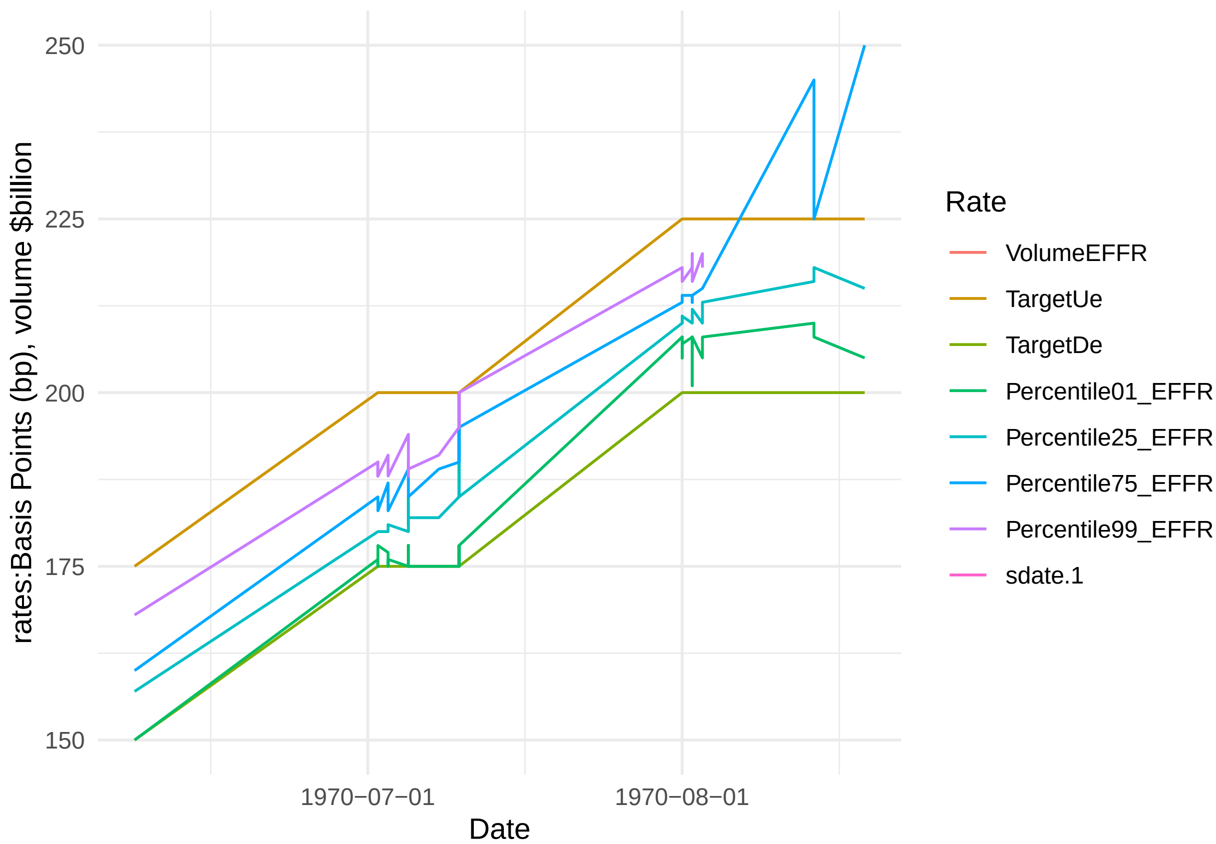


Figure 3: EFFR during adjustment period 8/1/2019 - 10/31/2019

```
## [1] 85
```

```
## [1] 51
```

(see Figure @ref(fig:EFFR during covid period 11/1/2019-3/16/2020-plot)

```
## Warning: attributes are not identical across measure variables; they will be
## dropped
```

```
## Warning: Removed 91 rows containing missing values (`geom_line()`).
```

(see Figure @ref(fig:EFFR during zero lower bound (Zlb) period 3/17/2020-3/16/2022

```
## Warning: attributes are not identical across measure variables; they will be
## dropped
```

```
## Warning: Removed 1541 rows containing missing values (`geom_line()`).
```

(see Figure @ref(fig:EFFR during inflation period 3/17/2022-12/14/2023-plot)

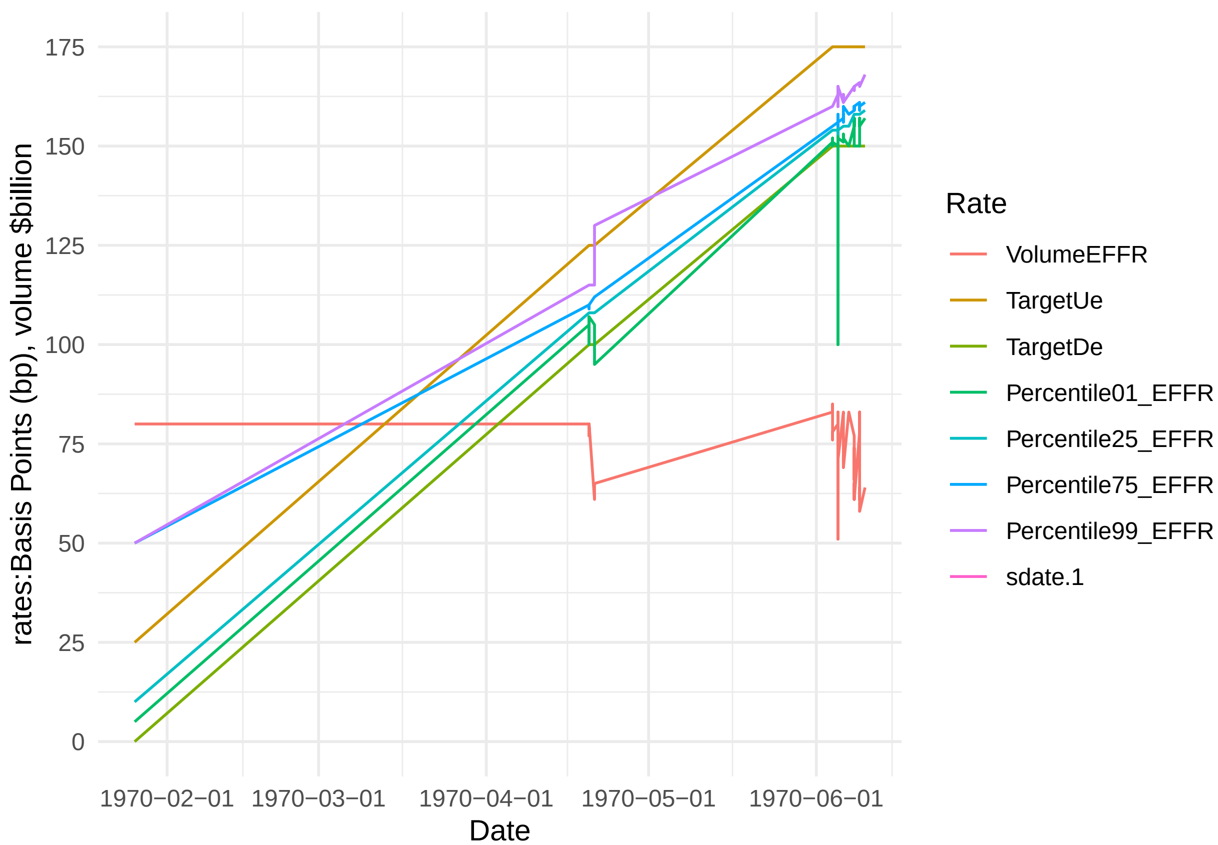


Figure 4: EFFR during covid period 11/1/2019-3/16/2020

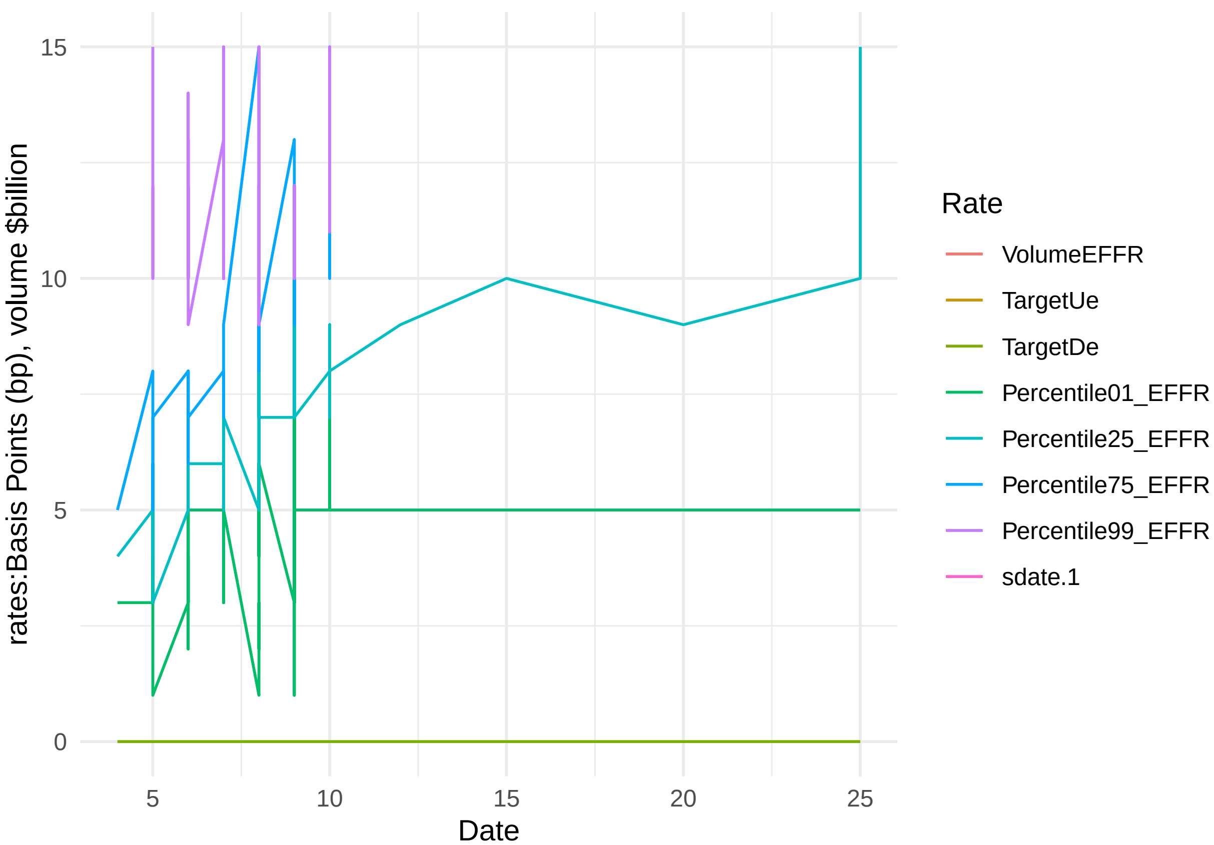


Figure 5: EFFR during zero lower bound (zlb) period 3/17/2020-3/16/2022

```
## Warning: attributes are not identical across measure variables; they will be
## dropped
```

```
## Warning: Removed 1342 rows containing missing values (`geom_line()`).
```

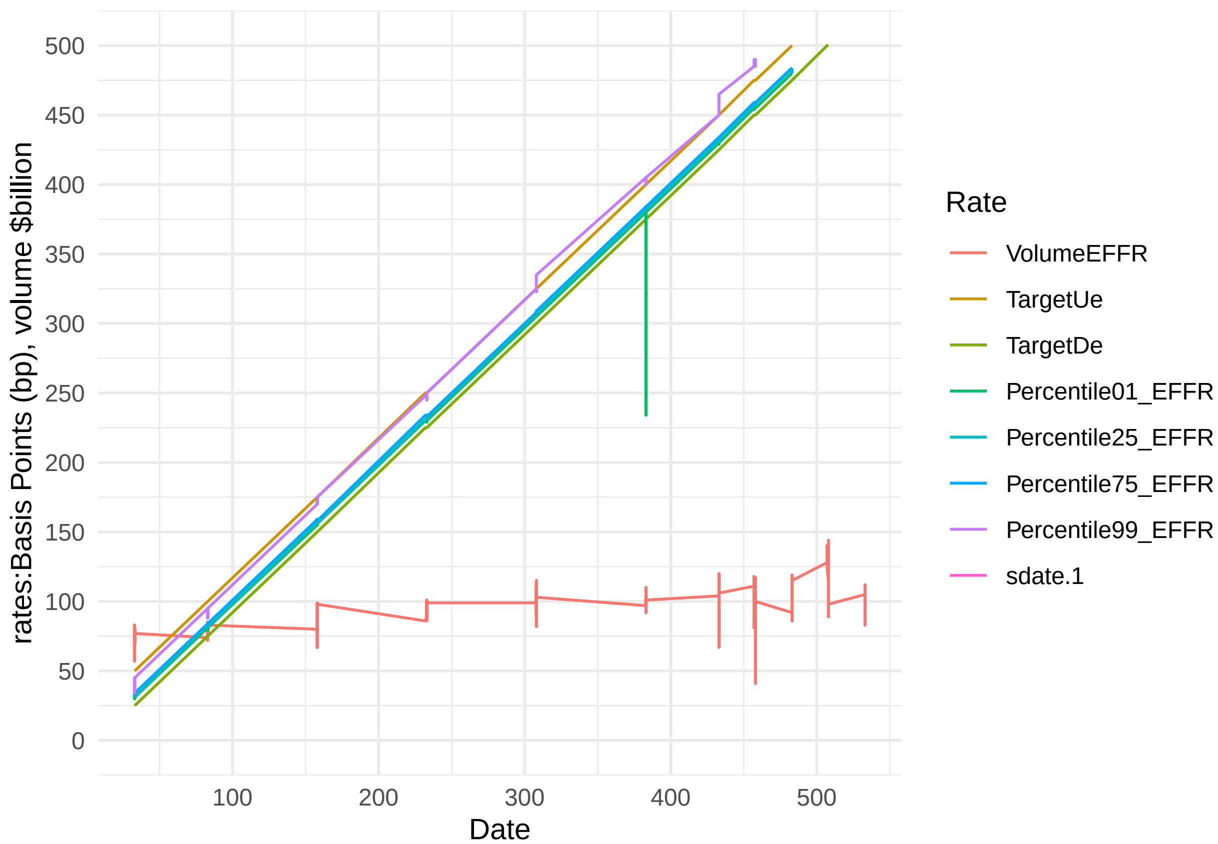
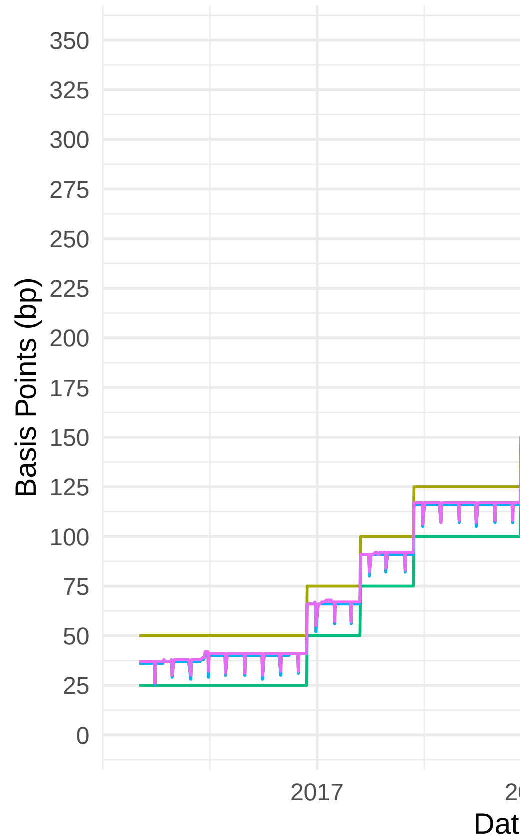


Figure 6: EFFR during inflation period 03/17/2022-12/14/2023



Quantiles, are these necessary or can be included in plots above ————————-

```
## Warning: Removed 515 rows containing missing values (`geom_line()`).
```

```
## Warning: Removed 1395 rows containing missing values (`geom_line()`).
```

Volatile rates during episodes

```
## Warning: Removed 2090 rows containing missing values (`geom_point()`).
```

Figure 7: Overnight rates EFFR percentiles adjustment period

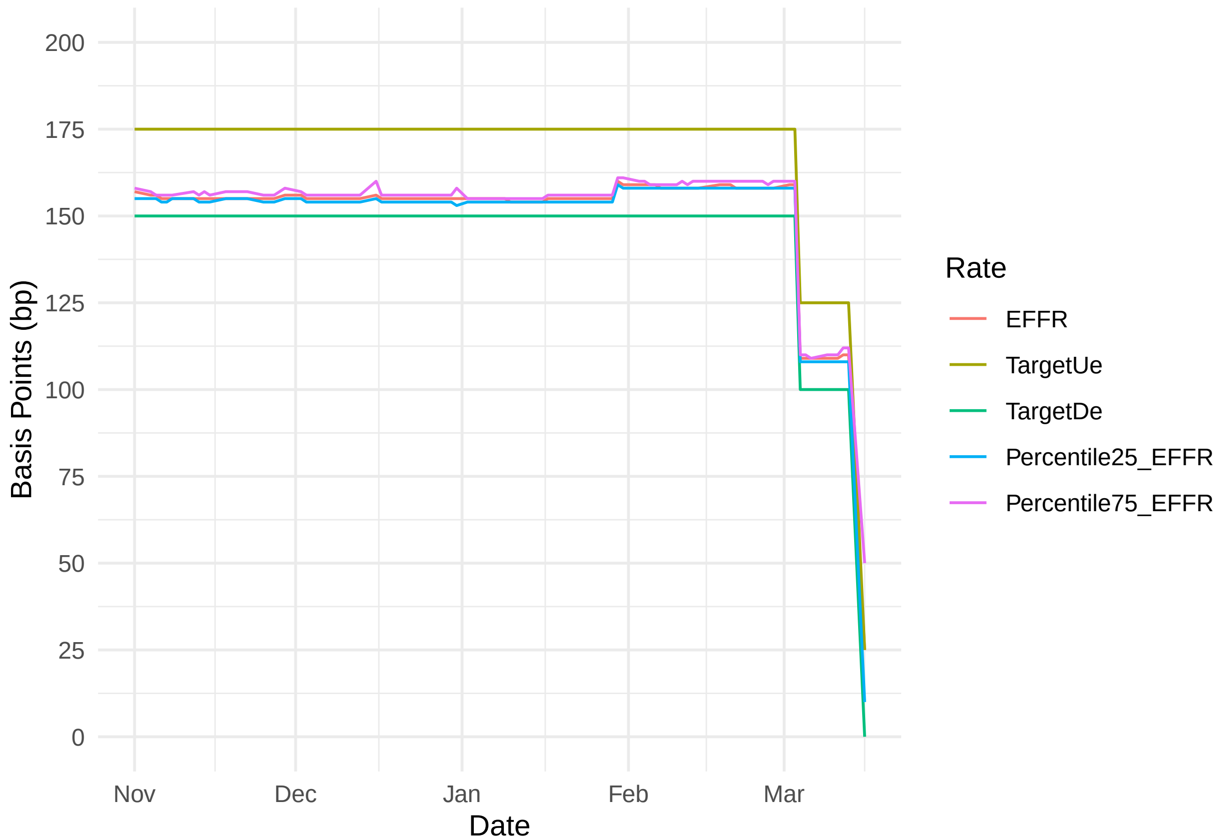


Figure 8: Overnight rates EFFR percentiles during covid

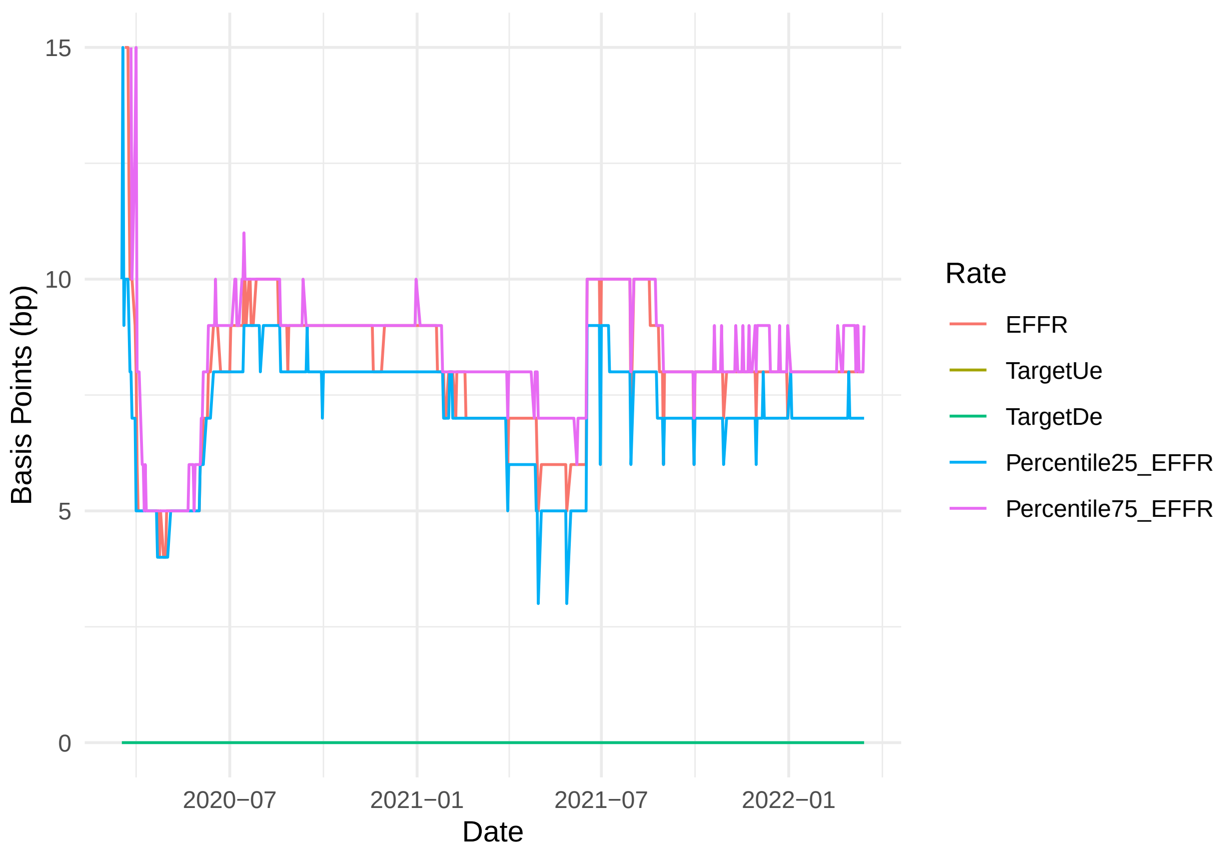


Figure 9: Overnight rates EFFR percentiles zero lower bound

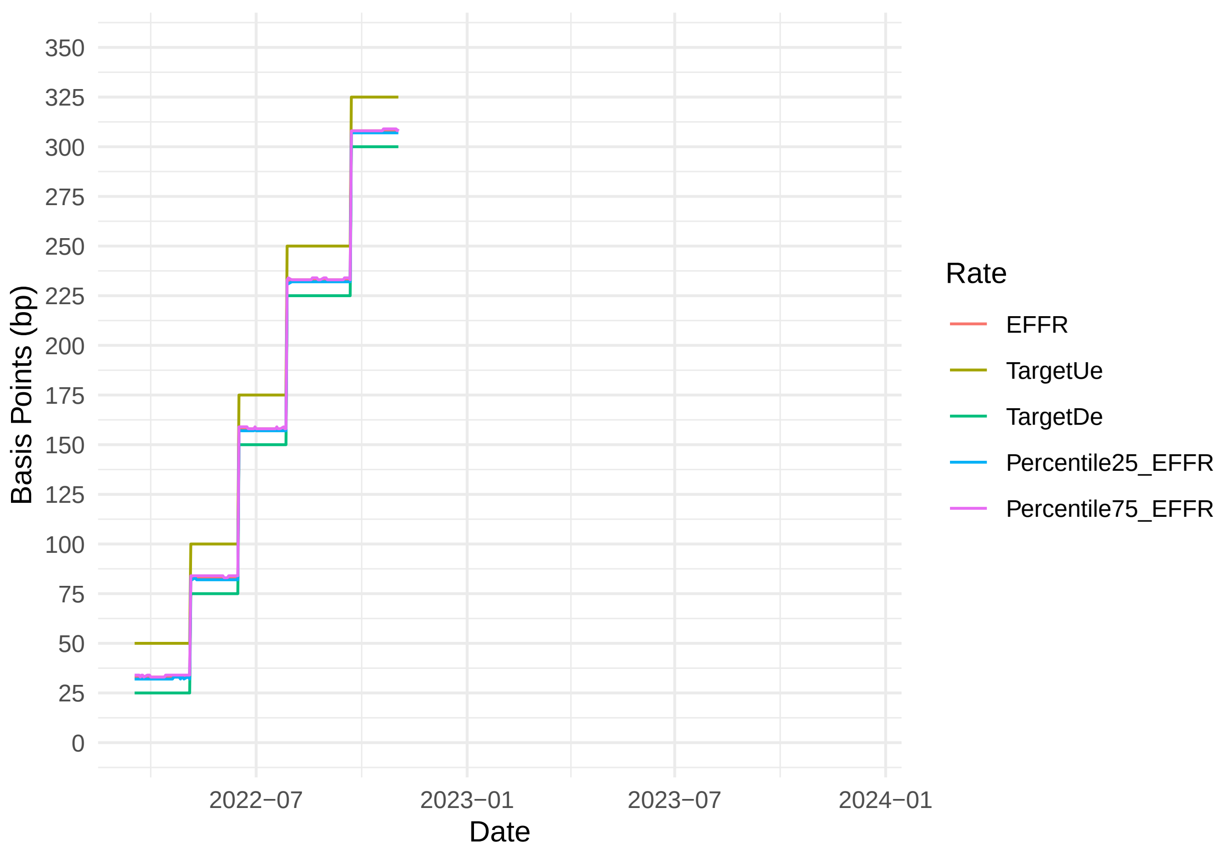
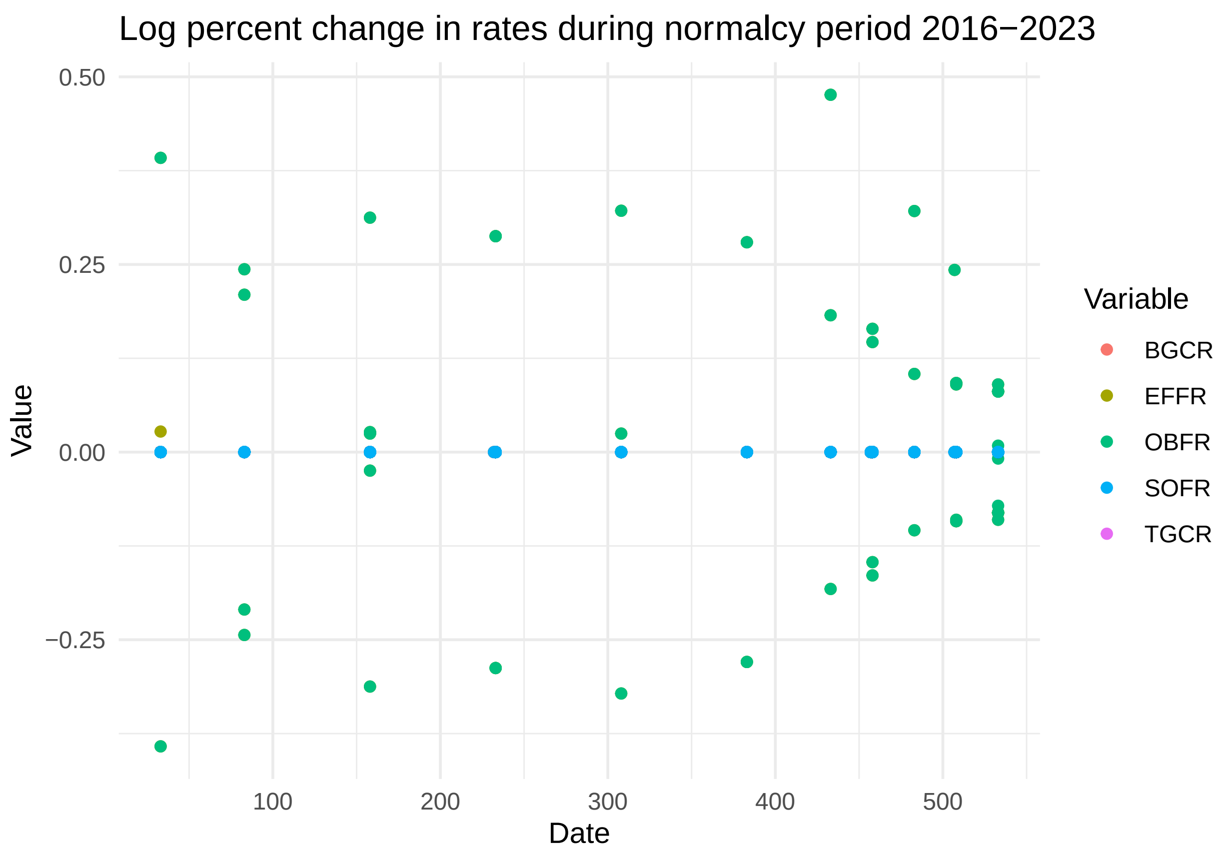


Figure 10: Overnight rates EFFR percentiles inflation



[FINISH OR DELETE]

Dispersion, clustering

Dispersion measures hypothesis 2 Bertolini et al () note the tendency of all rates to respond revert quickly to the policy rate FFR after to shocks from pilicy changes in the FFR, IOR, (and events?). For the objective of this paper, to understand Fed tolerance for volatility of the FFR, I examine relation between volatility, disperion among key overnight tates. and any deviations of the FFR within its target range. A related question to address with the Fed's preference for offsetting volatility when managing the FFR within FOMC targets.

Duffie and Krishnamurthy () and Alonso provide evidence that there exists significant dispersion of the money market rates from the policy rate that suggest problems for transmission of FONC to the broader economy. The effectiveness of monetary policy to transmit the desired stance of monetary policy to financial markets and the real economy economy depends on efficient transmission of rate changes to other short rates in wholesale and consumer funding market.

Duffie and Krishnamurthy () and Gara Afonso, Kyungmin Kim, Antoine Martin, Ed Nosal, Simon Potter, and Sam Schulhofer-Wohl () provide direct evidence of of dispersion among overnight policy and wholesale money market rates from the policy rate and deviationof the FFR from the FOMC target range.

Duffie and Krishnamurthy warn dispersion in rates hampers the transmission of FONC policy to the broader economy. Dispersion across money market interest rates is a primary indicator of the level of efficiency in how other key short-term interest rates reflect Fed policy changes. They argue that the current setting of U.S.-dollar money markets limits the transmission of Fed policy to the economy.

The Duffie Krishnamurthy dispersion index

The Duffie Krishnamurthy () index of dispersion of overnight rate, the weighted mean absolute deviation of the cross-sectional adjusted rates. The measure of dispersion of overnight rates is the absolute deviation of the cross rates of overnight reference and money market rates. This index indicates the level of passthrough inefficiency, the passthrough effectiveness of the Federal Reserve's monetary policy, the transmission of policy to the economy through other short term rates. [**?**]

Their index of rate dispersion DK_t for day t in U.S. short-term money markets is the weighted mean absolute deviation of the cross-sectional distribution of overnight-equivalent rates on that day. DK_t is constructed from overnight equivalent rates $\hat{r}_{i,t}$. Rates are adjusted for term and credit spreads after adjusting for premia associated with credit risk and term structure.frictions associated with imperfect #competition, regulation, infrastructure, and other forms of institutional segmentation within money markets.

Duffie Krishnamurthy dispersion index D_t at day t is the weighted mean absolute deviation of the cross-sectional adjusted rates distribution on day t (Figure ~**??**) (Table %~**??**)). Rates $y_{i,t(m)}$ denote the rate at time t on instrument i, maturing in m days. Since our rate data are daily, I drop the maturity m, so that rates are $y_{t,i}$. First adjust the rate to remove term-structure effects, obtaining the associated "overnight-equivalent" rate as $\widehat{y_{i,t}} = y_{i,t(m)} - (OISt(m) - OISt(1)), (4.1)$ is the volume-weighted mean rate. $v_{i,t} is the estimated outstanding amount of this instrument on day t (dollars).The Duffie and Krishnamurthy index of dispersion of overnight rate is the weighted mean absolute deviation of the cross-sectional adjusted rates.Dispersion of rates imply rates follow different distributions.

[CORRECT EQUATION]

$$nrates < -ncol(rrbp) D_t = \frac{1}{v_{i,t}} \left(\sum_{i=1}^{nrates} \times abs \hat{y}_{i,t} - \bar{y}_t \right) (4.2) \bar{y}_t = \left(\frac{\sum_i^n v_{i,t} \times \cdot \hat{y}_{i,t}}{\sum_i^n v_{i,t}} \right)$$

–>

Their results show dispersion ranged between 4 and 7 basis points between the end of 2012 and December 17, 2015. Dispersion increased by over 10 basis points, immediately after the first passthrough event in the current Fed monetary policy setting, when the interest rate paid by the Fed on excess reserves (IOER) was increased from 25 to 50 basis basis points on December 17, 2015.

In our sample from 2016 through 2022, the Duffie Krishnamurthy diversity index registers low dispersion, under 4 basis points, among the five overnight rates EFFR, OBFR, TGCR, BGCR, and SOHR during 2016 and the first quarter of 2017 before jumping to around 5 during the last 2 weeks of March 2017 %(Figure **??**.

Their measure of dispersion rises to over 50 basis points during December 2018 to mid April 2019. The index triples to 151.14 basis on April 19, 2019 and remains at this high level, reaching a high 254.83 points during the spike in repo rates September 19, 2019. The index tapers off after of the dash for cash on March 17, 2020 after spiking 27.5 basis points. Throughout 2020 and 2021, the index was under 1 point. The level of dispersion rose steadily during March 2022, reaching over 200 basis points during the last part of December 2022 as the FOMC raised the target range for the Federal Funds rate to fight inflation. The index rose from 14.57 April 15, 2022 to 209.25 on December 29, 2022.

[add Dispersion 2023]

1. ?? The dispersion index of the five daily rates from 2016 to 2023 #(Figure **??**)

Gara Afonso, Kyungmin Kim, Antoine Martin, Ed Nosal, Simon Potter, and Sam Schulhofer-Wohl () measure istance of the Federal Funds rates from FOMC targets

Gara Afonso, Kyungmin Kim, Antoine Martin, Ed Nosal, Simon Potter, and Sam Schulhofer-Wohl () propose dispersion index D_t as a measure of the difference of value weighted daily EFFR from the actual policy target, the upper and lower target rates specified by the FOMC (the EFFR, the effective fed funds rate published by the Federal Reserve Bank of New York). (Figure).

The daily value of D_t ,the deviations between the value weighted daily fed funds rate and weighted fed funds rate, the actual policy target (the EFFR, the effective fed funds rate published by the Federal Reserve Bank of New York) FOMC (Figure), During 2016-2022 managing the policy rate remained within its target range (**??**). ADD OBSERVATIONS

They Calculate D_t based on the conditions that - the actual rate is not higher than the upper FOMC target If FFR > upper target TU, $D_t = rho_b ar_t - rho_m ax_t$

- the actual rate is not lower than the lower FOMC target FFR < lower target TD $D_t < -rho_b ar_t - rho_m in_t$

Otherwise $D_t = 0$.

$$T < -nrow(rrbp) rho_b ar_t < -0 rho_m ax_t < -0 rho_m in_t < -0 D < -0 if (rho_m ax_t < rho_b ar_t) D_t < -rho_b ar_t - rho_m ax_t elseif($$

(Figure ~**??**) (Table %~**??**))

The daily value of D_t, the deviations between the value weighted daily fed funds rate (FFR) and the FOMC target, show the EFFR remained within the target ranges from 2017-2023. FOMC targets were not established until [2018?]

The EFFR stays within the bounds of the FOMC target rates (left panel of Figure ~**??**) and 50 percent of the data, the data within the 25th and 75th percentile (right panel)

The SOFR stays within the bounds of the FOMC target rates (left panel of Figure ~**??**) and the 25th and 75th percentile (right panel)

Target rates and quintiles EFFR, SOFR

The behavior of the EFFR and SOFR offer another view of dispersion. Boxplots here? Box plots, quintile plots?

```
## 'data.frame':    4 obs. of  6 variables:
##  $ Group: Factor w/ 4 levels "EFFR","TGCR",..: 1 2 3 4
##  $ y0   : num  129.4 79.9 80 81.4
##  $ y25  : num  133.3 83.4 83.5 83.5
##  $ y50  : num  133.8 83.8 83.8 84.8
##  $ y75  : num  134.5 83.7 83.7 86.8
##  $ y100 : num  147 85.5 88.4 90
```

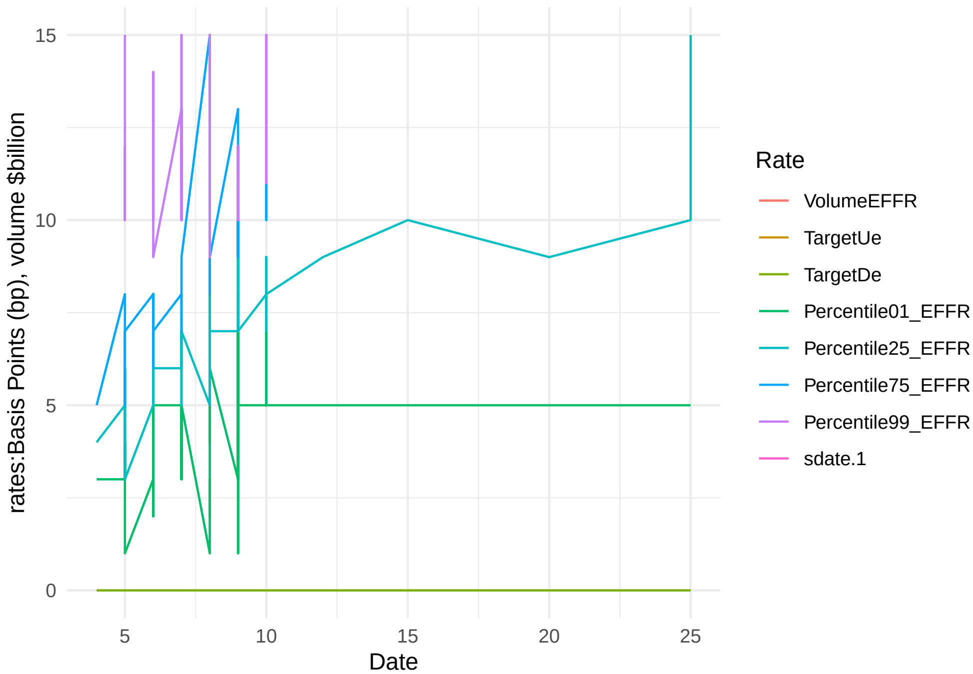


Figure 11: Daily rates normalcy 2016-2019

```
## 'data.frame':    4 obs. of  6 variables:
##  $ Group: Factor w/ 4 levels "EFFR","TGCR",..: 1 2 3 4
##  $ y0   : num  192 192 192 196
##  $ y25  : num  197 206 206 206
##  $ y50  : num  200 206 206 208
##  $ y75  : num  202 207 207 217
##  $ y100 : num  210 214 226 238
```

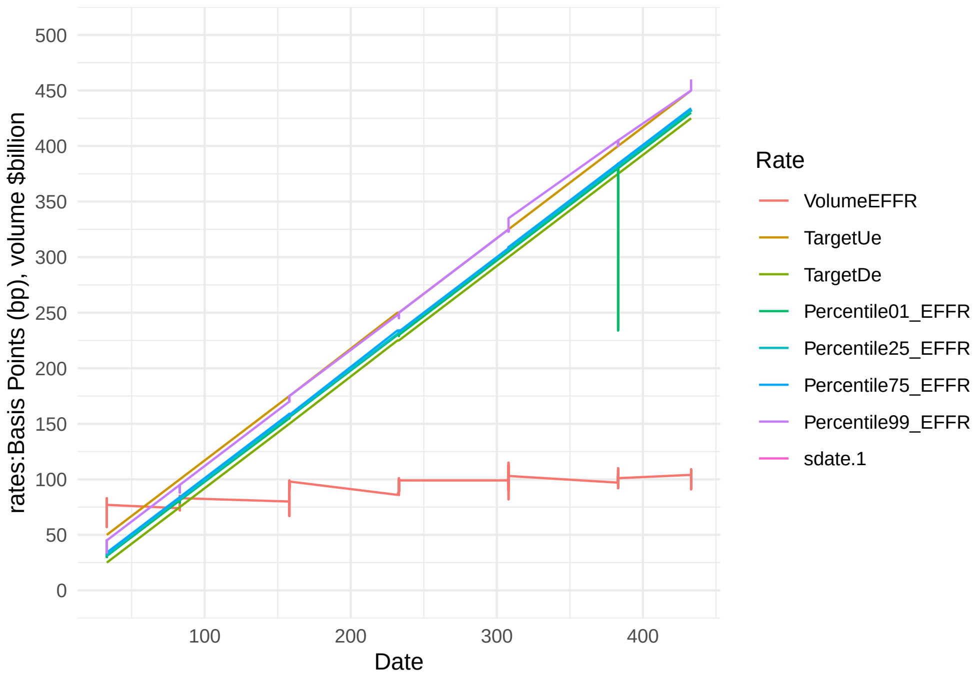


Figure 12: Daily rates adjust 2019

```
## 'data.frame':    4 obs. of  6 variables:
##  $ Group: Factor w/ 4 levels "EFFR","TGCR",..: 1 2 3 4
##  $ y0   : num  146 142 142 146
##  $ y25  : num  150 148 148 149
##  $ y50  : num  150 149 149 151
##  $ y75  : num  152 149 149 156
##  $ y100 : num  158 153 158 165
```

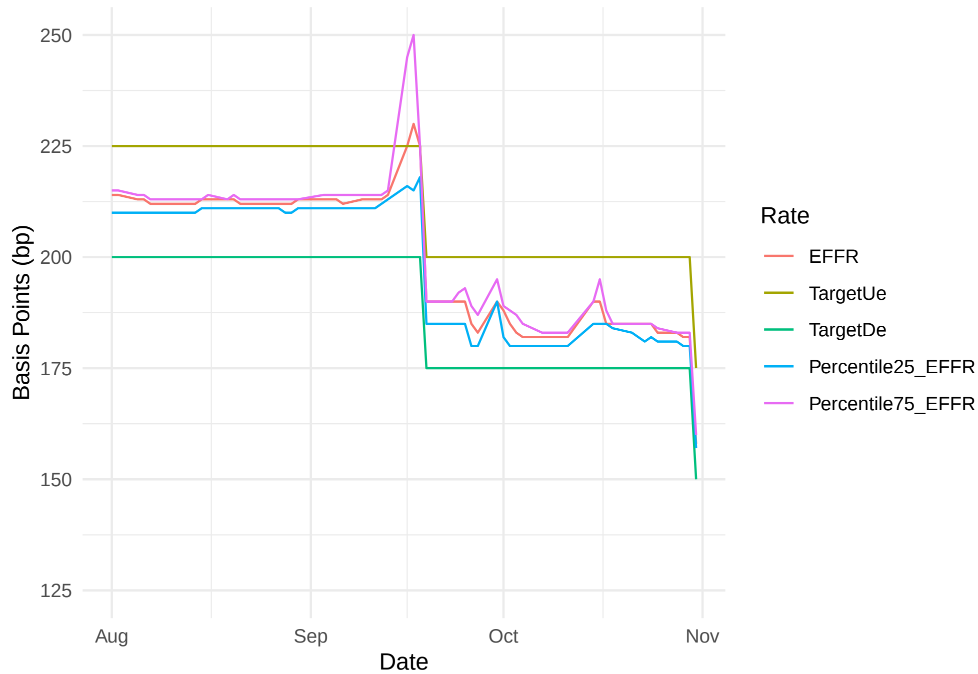


Figure 13: Daily rates covid 2016-2019

```
## 'data.frame':    4 obs. of  6 variables:
##  $ Group: Factor w/ 4 levels "EFFR","TGCR",..: 1 2 3 4
##  $ y0   : num  5.07 2.08 2.05 1.57
##  $ y25  : num  7.13 4.52 4.53 3.92
##  $ y50  : num  8.09 4.59 4.59 5.41
##  $ y75  : num  8.67 4.65 4.67 6.97
##  $ y100 : num  12.4 13.3 13.9 16
```

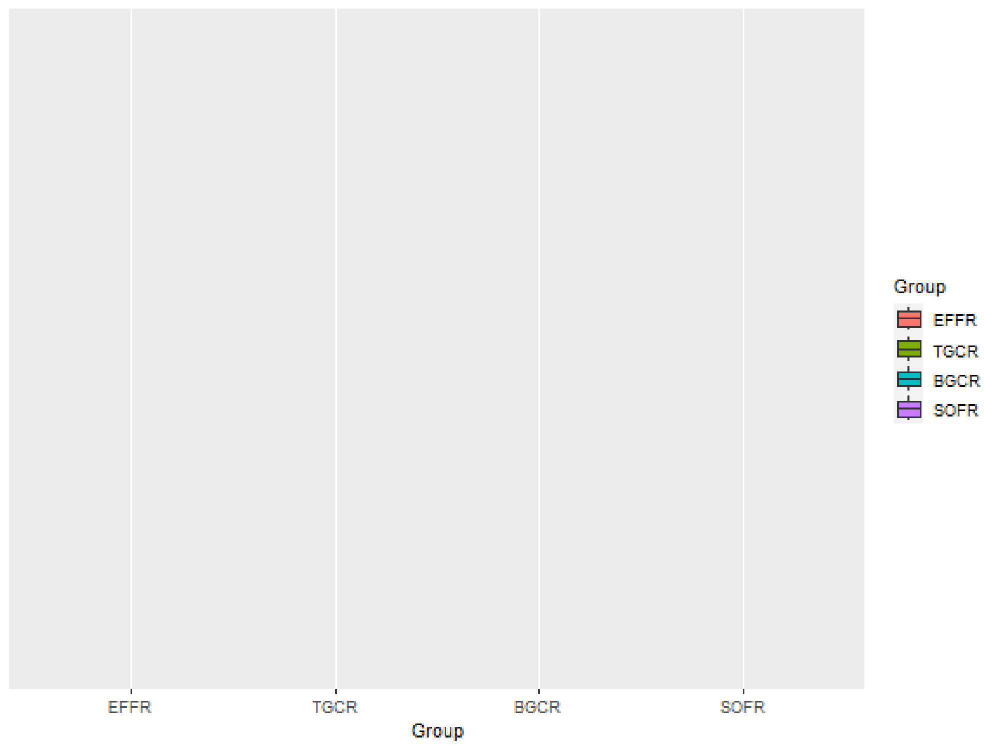


Figure 14: Daily rates zlb 2016-2019

```
## 'data.frame':    4 obs. of  6 variables:
##  $ Group: Factor w/ 4 levels "EFFR","TGCR",..: 1 2 3 4
##  $ y0   : num  365 341 341 355
##  $ y25  : num  368 361 361 362
##  $ y50  : num  369 362 362 364
##  $ y75  : num  369 364 364 368
##  $ y100 : num  389 373 375 377
```

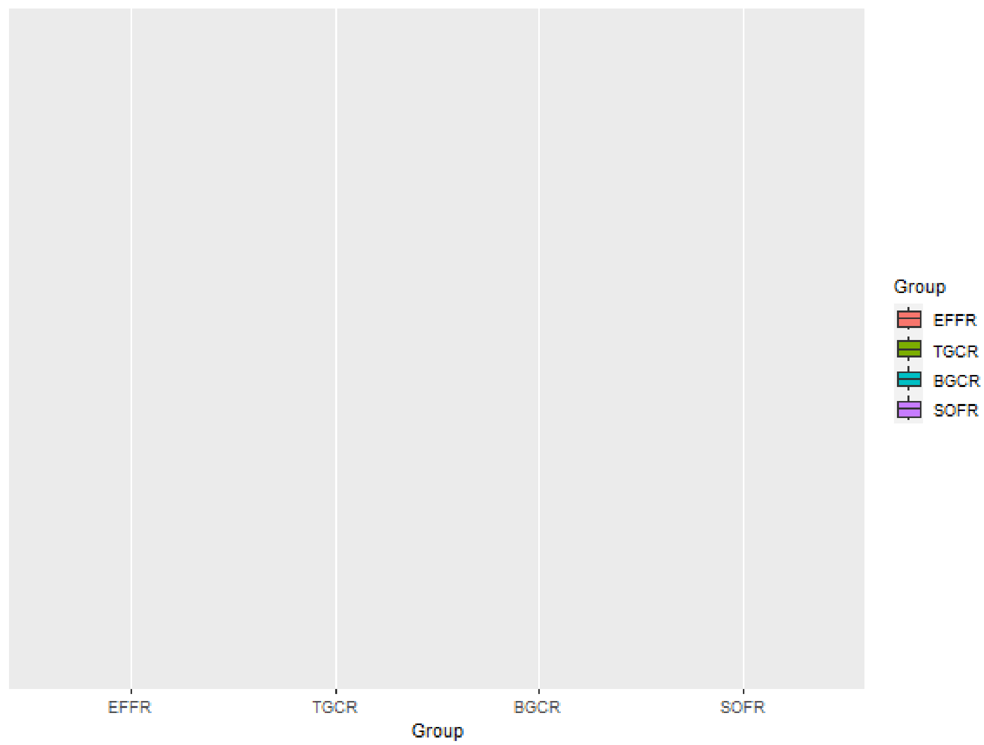


Figure 15: Daily rates nflation 2022-2023

Transaction volumes

Reserves

Total reserves in the U. S. banking system now exceed $$$3.081237 trillion (Totresns). At the beginning of 2009, reserves were $$$800 billion, compared to approximately $$$10 billion pre-crisis. Reserves continued to increase until late 2014. Fed's quantitative easing programs raised reserves to a peak of $$$2.8 trillion in September 2014, reaching $$$4.275 at then end of 2021 In November 2022 through late 2017, reserves started to decline, reaching a low of $$$1.4 trillion in early September 2019 (Table **??**, Figure **??**) under the Federal Open Market Committee policy of "balance sheet normalization" aggregate reserves,

During the initial years of the sample from 3/02/2016 until 2023 reserves were around $$$200 million until 9/28/2016 when reserves fell to $$$180 million. Then returned to $$$200 million on 2/15/2017 until6/24/2018, reaching a low of $$$160 million on 1/4/2017 (Table ~**??**).

The reasons for changes in the level of reserves in the banking system include: 1) the Federal Reserve trades securities with banks in order to manage the Federal Funds rate (FFR) within the FOMC target range. These temporaty operations are the focus of this paper. Purchases through repurchase agreements increase the size of the Federal Reserve balance sheet. Sales through reverse repurchase agreements decrease reserves. Through temporary open market operations (TOMO),The Federal Reserve changes the level of aggregate reserves short-term through repurchase and reverse repurchase agreements iThe trading desk at the NY Fed conducts all repo and reverse repo operations, including small value exercises. https://www.newyorkfed.org/markets/desk-operations/.

2)The US Treasury transfers funds between reserves and non-reserve accounts at the FederalReserve example https://www.moneyandbanking.com/commentary/2020/11/8/the-case-of-the-treasury-account-at-the-federal-reserve **??** Figure @ref(fig:FedLiabilties).

These repo operations temporarily add or drain reserves available to the banking system and influence day-to-day trading in the Federal Funds market. The Federal Reserve responds to volatility in the federal funds market by adjusting the reserve supply to keep the federal funds rate within its target range through repo and reverse repo operations each day In a repurchase or repo transaction, the Federal Reserve purchases securities to banks. Aggregate reserves increase when the Fed credits the Federal Reserve accounts of the selling banks.

In a repo transaction, the Desk purchases securities from a counterparty subject to an agreement to resell the securities at a later date. Each repo transaction is economically similar to a loan collateralized by securities, and temporarily increases the supply of reserve balances in the banking system. The repo rate. interest" paid on that loan, is the difference between the original price and the second, higher price. In a reverse repo transaction, the Desk sells securities to a counterparty subject to an agreement to repurchase the securities at a later date. Reverse repo transactions temporarily reduce the supply of reserve balances in the banking system.

When the Federal Reserve lends to counter parties in a reverse repo transaction, the Fed sale of securities lower aggregate reserves as funds are debited from depositor accounts. These operations are quick and are put in place within a matter of days. For example, in September 2019, the federal funds rate spiked up on September 16 and 17. On September 18-21 ... and dash for cash March 2020. Counterparties that lend to the Fed include primary dealers, hedge funds, insurance firms, money markets and financial firms with large pools of cash . CHECK

Reserves also can change when the US Treasurytransfers funds between reserves and non-reserve accounts at the Federal Reserve. The Treasury keeps an account at the Fed or deposits in Treasury Tax and Loan (TT&L) accounts at commercial banks to provide a buffer to avoid payment issues. A Treasury deposit reduces reserves in the banking system. A decrease in government deposits adds reserves.Prior to 2008, when reserve levels were very low, a change of $1 billion could move interbank lending rates substantially. To avoid unpleasant surprises, the Treasury and the Fed agreed to target an account level of $5 billion at the end of every business day. If the government thought they would miss, officials would alert the Fed staff in the morning so that they could use open-market operations to adjust.

When the target was $5 billion and the Fed's liabilities were a relatively modest $750 billion, Treasury deposits accounted for less than 1 percent of the total. In the decade starting in 2008, Treasury balances rose to around $400 billion, accounting for an average of 5% of Fed liabilities. Since June 2020, Treasury deposits at the Fed now account 23 percent of total liabilities.

In the recently established repo facility n July 2021, the Standing Repo Facility (SRF), the Desk purchases securities from a counterparty subject to an agreement to repurchase the securities at a later date, temporarily increases the supply of reserve balances in the banking system and lowers the FFR. The repo rate. . Each repo transaction is economically similar to a loan collateralized by securities,interest" paid on that loan, is the difference between the original price and the second, higher price. In a reverse repo transaction, the Desk sells securities to a counterparty subject to an agreement to repurchase the securities at a later date. temporarily decreases the supply of reserve balances in the banking system and raising the FFR.

[Reverse repo facility] Counterparties that lend to the Fed include money markets and dealers.

The FOMC planned reduction of holdings of securities,'balance sheet normalization', began October 2017, by holding them to maturity, rather than by selling them back in financial markets. This reduction of reserves engendered a disruption in repurchase (repo) markets in September 2019. To resolve this crisis, In October 2019, the Fed resumed purchasing massive amounts of debt securities.

The quantitative easing asset purchases, QE1, QE2, and QE3, challenged the Federal Reserve bank's ability to control short-term interest rates. As a result, the Fed and other central banks changed their overall frameworks for controlling short-term interest rates. Pre-crisis, these frameworks were typically based on adjusting the scarcity value of a limited supply of central bank deposits (reserves), but the substantial increase in liquidity resulting from asset purchases in response to the crisis made other techniques necessary.

The increases in SOFR volumes dwarf the EFFR increased 068 %268 in 2019 and 878 in 2022. SOFR volumes fell 682 in 2020 and 292 in 2021. Daily SOFR trading volumes, $1.1 trillion dwarf the Federal funds market, $62.5 billion. (2020? Gibbs CME webinar on repo).