Final Project: Forecasting NG Price after Ukraine Crisis

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```
## Warning: package 'readxl' was built under R version 4.1.2

##
## Attaching package: 'lubridate'

## The following objects are masked from 'package:base':
##
##     date, intersect, setdiff, union

## Warning: package 'forecast' was built under R version 4.1.2

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

## Warning: package 'Kendall' was built under R version 4.1.2

## Warning: package 'tseries' was built under R version 4.1.2

## Warning: package 'outliers' was built under R version 4.1.2

## -- Attaching packages --------------------------------------- tidyverse 1.3.1 --

## v tibble  3.1.6     v dplyr   1.0.8
## v tidyr   1.2.0     v stringr 1.4.0
## v readr   2.1.2     v forcats 0.5.1
## v purrr   0.3.4

## Warning: package 'tidyr' was built under R version 4.1.2

## Warning: package 'readr' was built under R version 4.1.2

## Warning: package 'dplyr' was built under R version 4.1.2

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x lubridate::as.difftime() masks base::as.difftime()
## x lubridate::date()        masks base::date()
## x dplyr::filter()          masks stats::filter()
## x lubridate::intersect()   masks base::intersect()
## x dplyr::lag()             masks stats::lag()
## x lubridate::setdiff()     masks base::setdiff()
## x lubridate::union()       masks base::union()
```

```
## Warning: package 'smooth' was built under R version 4.1.2

## Loading required package: greybox

## Warning: package 'greybox' was built under R version 4.1.2

## Package "greybox", v1.0.5 loaded.

##
## Attaching package: 'greybox'

## The following object is masked from 'package:tidyr':
##
##     spread

## The following object is masked from 'package:forecast':
##
##     forecast

## The following object is masked from 'package:lubridate':
##
##     hm

## This is package "smooth", v3.1.5

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric

##
## Attaching package: 'kableExtra'

## The following object is masked from 'package:dplyr':
##
##     group_rows

## Warning: package 'psych' was built under R version 4.1.2

##
## Attaching package: 'psych'

## The following object is masked from 'package:outliers':
##
##     outlier

## The following objects are masked from 'package:ggplot2':
##
##     %+%, alpha
```

```
##          DATE      GDP1      GDP2      GDP3
## 1    1960/3/1  99.66307  99.66307  99.66307
## 2    1960/4/1  99.70633  99.70633  99.70633
## 3    1960/5/1  99.75215  99.75215  99.75215
## 4    1960/6/1  99.79922  99.79922  99.79922
## 5    1960/7/1  99.84206  99.84206  99.84206
## 6    1960/8/1  99.87506  99.87506  99.87506
## 7    1960/9/1  99.89666  99.89666  99.89666
## 8   1960/10/1  99.91446  99.91446  99.91446
## 9   1960/11/1  99.93804  99.93804  99.93804
## 10  1960/12/1  99.97215  99.97215  99.97215
## 11   1961/1/1 100.00929 100.00929 100.00929
## 12   1961/2/1 100.03852 100.03852 100.03852
## 13   1961/3/1 100.05390 100.05390 100.05390
## 14   1961/4/1 100.06343 100.06343 100.06343
## 15   1961/5/1 100.08024 100.08024 100.08024
## 16   1961/6/1 100.11404 100.11404 100.11404
## 17   1961/7/1 100.16198 100.16198 100.16198
## 18   1961/8/1 100.21626 100.21626 100.21626
## 19   1961/9/1 100.27012 100.27012 100.27012
## 20  1961/10/1 100.32304 100.32304 100.32304
## 21  1961/11/1 100.37742 100.37742 100.37742
## 22  1961/12/1 100.43515 100.43515 100.43515
## 23   1962/1/1 100.49369 100.49369 100.49369
## 24   1962/2/1 100.54872 100.54872 100.54872
## 25   1962/3/1 100.59646 100.59646 100.59646
## 26   1962/4/1 100.63605 100.63605 100.63605
## 27   1962/5/1 100.66489 100.66489 100.66489
## 28   1962/6/1 100.67442 100.67442 100.67442
## 29   1962/7/1 100.64673 100.64673 100.64673
## 30   1962/8/1 100.56122 100.56122 100.56122
## 31   1962/9/1 100.40389 100.40389 100.40389
## 32  1962/10/1 100.17480 100.17480 100.17480
## 33  1962/11/1  99.89422  99.89422  99.89422
## 34  1962/12/1  99.60767  99.60767  99.60767
## 35   1963/1/1  99.38782  99.38782  99.38782
## 36   1963/2/1  99.30766  99.30766  99.30766
## 37   1963/3/1  99.40344  99.40344  99.40344
## 38   1963/4/1  99.65265  99.65265  99.65265
## 39   1963/5/1  99.99311  99.99311  99.99311
## 40   1963/6/1 100.35452 100.35452 100.35452
## 41   1963/7/1 100.68078 100.68078 100.68078
## 42   1963/8/1 100.93466 100.93466 100.93466
## 43   1963/9/1 101.10230 101.10230 101.10230
## 44  1963/10/1 101.19297 101.19297 101.19297
## 45  1963/11/1 101.22876 101.22876 101.22876
## 46  1963/12/1 101.23005 101.23005 101.23005
## 47   1964/1/1 101.20476 101.20476 101.20476
## 48   1964/2/1 101.15354 101.15354 101.15354
## 49   1964/3/1 101.07678 101.07678 101.07678
## 50   1964/4/1 100.98077 100.98077 100.98077
## 51   1964/5/1 100.87495 100.87495 100.87495
## 52   1964/6/1 100.76813 100.76813 100.76813
## 53   1964/7/1 100.66567 100.66567 100.66567
```

```
## 54   1964/8/1 100.57118 100.57118 100.57118
## 55   1964/9/1 100.48798 100.48798 100.48798
## 56  1964/10/1 100.42020 100.42020 100.42020
## 57  1964/11/1 100.37219 100.37219 100.37219
## 58  1964/12/1 100.34701 100.34701 100.34701
## 59   1965/1/1 100.34671 100.34671 100.34671
## 60   1965/2/1 100.37029 100.37029 100.37029
## 61   1965/3/1 100.41290 100.41290 100.41290
## 62   1965/4/1 100.46318 100.46318 100.46318
## 63   1965/5/1 100.50852 100.50852 100.50852
## 64   1965/6/1 100.53948 100.53948 100.53948
## 65   1965/7/1 100.55458 100.55458 100.55458
## 66   1965/8/1 100.55629 100.55629 100.55629
## 67   1965/9/1 100.54825 100.54825 100.54825
## 68  1965/10/1 100.53340 100.53340 100.53340
## 69  1965/11/1 100.51441 100.51441 100.51441
## 70  1965/12/1 100.49452 100.49452 100.49452
## 71   1966/1/1 100.47677 100.47677 100.47677
## 72   1966/2/1 100.46334 100.46334 100.46334
## 73   1966/3/1 100.45308 100.45308 100.45308
## 74   1966/4/1 100.44136 100.44136 100.44136
## 75   1966/5/1 100.41913 100.41913 100.41913
## 76   1966/6/1 100.37440 100.37440 100.37440
## 77   1966/7/1 100.29388 100.29388 100.29388
## 78   1966/8/1 100.16765 100.16765 100.16765
## 79   1966/9/1  99.99556  99.99556  99.99556
## 80  1966/10/1  99.79616  99.79616  99.79616
## 81  1966/11/1  99.59481  99.59481  99.59481
## 82  1966/12/1  99.41341  99.41341  99.41341
## 83   1967/1/1  99.26018  99.26018  99.26018
## 84   1967/2/1  99.13678  99.13678  99.13678
## 85   1967/3/1  99.04302  99.04302  99.04302
## 86   1967/4/1  98.97933  98.97933  98.97933
## 87   1967/5/1  98.94610  98.94610  98.94610
## 88   1967/6/1  98.94080  98.94080  98.94080
## 89   1967/7/1  98.95501  98.95501  98.95501
## 90   1967/8/1  98.97683  98.97683  98.97683
## 91   1967/9/1  98.99402  98.99402  98.99402
## 92  1967/10/1  98.99641  98.99641  98.99641
## 93  1967/11/1  98.97442  98.97442  98.97442
## 94  1967/12/1  98.91843  98.91843  98.91843
## 95   1968/1/1  98.82023  98.82023  98.82023
## 96   1968/2/1  98.68405  98.68405  98.68405
## 97   1968/3/1  98.54029  98.54029  98.54029
## 98   1968/4/1  98.44820  98.44820  98.44820
## 99   1968/5/1  98.47149  98.47149  98.47149
## 100  1968/6/1  98.63831  98.63831  98.63831
## 101  1968/7/1  98.92123  98.92123  98.92123
## 102  1968/8/1  99.25652  99.25652  99.25652
## 103  1968/9/1  99.58277  99.58277  99.58277
## 104 1968/10/1  99.86293  99.86293  99.86293
## 105 1968/11/1 100.08536 100.08536 100.08536
## 106 1968/12/1 100.25403 100.25403 100.25403
## 107  1969/1/1 100.38202 100.38202 100.38202
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## 108  1969/2/1 100.48340 100.48340 100.48340
## 109  1969/3/1 100.56781 100.56781 100.56781
## 110  1969/4/1 100.63622 100.63622 100.63622
## 111  1969/5/1 100.68462 100.68462 100.68462
## 112  1969/6/1 100.70791 100.70791 100.70791
## 113  1969/7/1 100.70174 100.70174 100.70174
## 114  1969/8/1 100.66596 100.66596 100.66596
## 115  1969/9/1 100.60693 100.60693 100.60693
## 116 1969/10/1 100.54199 100.54199 100.54199
## 117 1969/11/1 100.49188 100.49188 100.49188
## 118 1969/12/1 100.47373 100.47373 100.47373
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## 120  1970/2/1 100.58036 100.58036 100.58036
## 121  1970/3/1 100.70712 100.70712 100.70712
## 122  1970/4/1 100.85985 100.85985 100.85985
## 123  1970/5/1 101.01215 101.01215 101.01215
## 124  1970/6/1 101.13827 101.13827 101.13827
## 125  1970/7/1 101.21813 101.21813 101.21813
## 126  1970/8/1 101.23536 101.23536 101.23536
## 127  1970/9/1 101.17864 101.17864 101.17864
## 128 1970/10/1 101.04742 101.04742 101.04742
## 129 1970/11/1 100.85041 100.85041 100.85041
## 130 1970/12/1 100.60951 100.60951 100.60951
## 131  1971/1/1 100.36843 100.36843 100.36843
## 132  1971/2/1 100.17389 100.17389 100.17389
## 133  1971/3/1 100.05769 100.05769 100.05769
## 134  1971/4/1 100.01659 100.01659 100.01659
## 135  1971/5/1 100.02903 100.02903 100.02903
## 136  1971/6/1 100.06651 100.06651 100.06651
## 137  1971/7/1 100.10117 100.10117 100.10117
## 138  1971/8/1 100.11126 100.11126 100.11126
## 139  1971/9/1 100.08671 100.08671 100.08671
## 140 1971/10/1 100.03650 100.03650 100.03650
## 141 1971/11/1  99.97741  99.97741  99.97741
## 142 1971/12/1  99.92481  99.92481  99.92481
## 143  1972/1/1  99.88401  99.88401  99.88401
## 144  1972/2/1  99.85615  99.85615  99.85615
## 145  1972/3/1  99.84303  99.84303  99.84303
## 146  1972/4/1  99.85122  99.85122  99.85122
## 147  1972/5/1  99.88903  99.88903  99.88903
## 148  1972/6/1  99.96204  99.96204  99.96204
## 149  1972/7/1 100.06691 100.06691 100.06691
## 150  1972/8/1 100.19667 100.19667 100.19667
## 151  1972/9/1 100.34404 100.34404 100.34404
## 152 1972/10/1 100.50267 100.50267 100.50267
## 153 1972/11/1 100.66746 100.66746 100.66746
## 154 1972/12/1 100.83368 100.83368 100.83368
## 155  1973/1/1 100.99609 100.99609 100.99609
## 156  1973/2/1 101.14940 101.14940 101.14940
## 157  1973/3/1 101.28946 101.28946 101.28946
## 158  1973/4/1 101.41804 101.41804 101.41804
## 159  1973/5/1 101.53819 101.53819 101.53819
## 160  1973/6/1 101.65347 101.65347 101.65347
## 161  1973/7/1 101.76773 101.76773 101.76773
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## 162  1973/8/1 101.88308 101.88308 101.88308
## 163  1973/9/1 101.99788 101.99788 101.99788
## 164 1973/10/1 102.10474 102.10474 102.10474
## 165 1973/11/1 102.19358 102.19358 102.19358
## 166 1973/12/1 102.25521 102.25521 102.25521
## 167  1974/1/1 102.28319 102.28319 102.28319
## 168  1974/2/1 102.27324 102.27324 102.27324
## 169  1974/3/1 102.22201 102.22201 102.22201
## 170  1974/4/1 102.12850 102.12850 102.12850
## 171  1974/5/1 101.98901 101.98901 101.98901
## 172  1974/6/1 101.79525 101.79525 101.79525
## 173  1974/7/1 101.53582 101.53582 101.53582
## 174  1974/8/1 101.20060 101.20060 101.20060
## 175  1974/9/1 100.79002 100.79002 100.79002
## 176 1974/10/1 100.32666 100.32666 100.32666
## 177 1974/11/1  99.84342  99.84342  99.84342
## 178 1974/12/1  99.37312  99.37312  99.37312
## 179  1975/1/1  98.94018  98.94018  98.94018
## 180  1975/2/1  98.56373  98.56373  98.56373
## 181  1975/3/1  98.25831  98.25831  98.25831
## 182  1975/4/1  98.03072  98.03072  98.03072
## 183  1975/5/1  97.88511  97.88511  97.88511
## 184  1975/6/1  97.82249  97.82249  97.82249
## 185  1975/7/1  97.83844  97.83844  97.83844
## 186  1975/8/1  97.92464  97.92464  97.92464
## 187  1975/9/1  98.06888  98.06888  98.06888
## 188 1975/10/1  98.25093  98.25093  98.25093
## 189 1975/11/1  98.44982  98.44982  98.44982
## 190 1975/12/1  98.64940  98.64940  98.64940
## 191  1976/1/1  98.84288  98.84288  98.84288
## 192  1976/2/1  99.02880  99.02880  99.02880
## 193  1976/3/1  99.20741  99.20741  99.20741
## 194  1976/4/1  99.37748  99.37748  99.37748
## 195  1976/5/1  99.53726  99.53726  99.53726
## 196  1976/6/1  99.68594  99.68594  99.68594
## 197  1976/7/1  99.82562  99.82562  99.82562
## 198  1976/8/1  99.95778  99.95778  99.95778
## 199  1976/9/1 100.08047 100.08047 100.08047
## 200 1976/10/1 100.18544 100.18544 100.18544
## 201 1976/11/1 100.26177 100.26177 100.26177
## 202 1976/12/1 100.30010 100.30010 100.30010
## 203  1977/1/1 100.29594 100.29594 100.29594
## 204  1977/2/1 100.24937 100.24937 100.24937
## 205  1977/3/1 100.16464 100.16464 100.16464
## 206  1977/4/1 100.05262 100.05262 100.05262
## 207  1977/5/1  99.92742  99.92742  99.92742
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## 209  1977/7/1  99.70239  99.70239  99.70239
## 210  1977/8/1  99.63470  99.63470  99.63470
## 211  1977/9/1  99.60941  99.60941  99.60941
## 212 1977/10/1  99.62215  99.62215  99.62215
## 213 1977/11/1  99.66253  99.66253  99.66253
## 214 1977/12/1  99.71995  99.71995  99.71995
## 215  1978/1/1  99.78741  99.78741  99.78741
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## 216  1978/2/1  99.86033  99.86033  99.86033
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## 220  1978/6/1 100.11117 100.11117 100.11117
## 221  1978/7/1 100.15283 100.15283 100.15283
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## 223  1978/9/1 100.24658 100.24658 100.24658
## 224 1978/10/1 100.30255 100.30255 100.30255
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## 232  1979/6/1 101.30046 101.30046 101.30046
## 233  1979/7/1 101.45347 101.45347 101.45347
## 234  1979/8/1 101.59324 101.59324 101.59324
## 235  1979/9/1 101.72208 101.72208 101.72208
## 236 1979/10/1 101.83699 101.83699 101.83699
## 237 1979/11/1 101.92983 101.92983 101.92983
## 238 1979/12/1 101.98882 101.98882 101.98882
## 239  1980/1/1 102.00141 102.00141 102.00141
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## 243  1980/5/1 101.52583 101.52583 101.52583
## 244  1980/6/1 101.34392 101.34392 101.34392
## 245  1980/7/1 101.17278 101.17278 101.17278
## 246  1980/8/1 101.02367 101.02367 101.02367
## 247  1980/9/1 100.90228 100.90228 100.90228
## 248 1980/10/1 100.80644 100.80644 100.80644
## 249 1980/11/1 100.73067 100.73067 100.73067
## 250 1980/12/1 100.66895 100.66895 100.66895
## 251  1981/1/1 100.61618 100.61618 100.61618
## 252  1981/2/1 100.56875 100.56875 100.56875
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## 256  1981/6/1 100.40599 100.40599 100.40599
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## 258  1981/8/1 100.35086 100.35086 100.35086
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## 260 1981/10/1 100.32679 100.32679 100.32679
## 261 1981/11/1 100.32136 100.32136 100.32136
## 262 1981/12/1 100.31189 100.31189 100.31189
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## 264  1982/2/1 100.23588 100.23588 100.23588
## 265  1982/3/1 100.15087 100.15087 100.15087
## 266  1982/4/1 100.03588 100.03588 100.03588
## 267  1982/5/1  99.90020  99.90020  99.90020
## 268  1982/6/1  99.75516  99.75516  99.75516
## 269  1982/7/1  99.61212  99.61212  99.61212
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## 270  1982/8/1  99.48172  99.48172  99.48172
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## 272 1982/10/1  99.29198  99.29198  99.29198
## 273 1982/11/1  99.24195  99.24195  99.24195
## 274 1982/12/1  99.22300  99.22300  99.22300
## 275  1983/1/1  99.22828  99.22828  99.22828
## 276  1983/2/1  99.24911  99.24911  99.24911
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## 278  1983/4/1  99.31592  99.31592  99.31592
## 279  1983/5/1  99.36002  99.36002  99.36002
## 280  1983/6/1  99.41429  99.41429  99.41429
## 281  1983/7/1  99.48283  99.48283  99.48283
## 282  1983/8/1  99.56787  99.56787  99.56787
## 283  1983/9/1  99.66648  99.66648  99.66648
## 284 1983/10/1  99.76597  99.76597  99.76597
## 285 1983/11/1  99.84971  99.84971  99.84971
## 286 1983/12/1  99.90270  99.90270  99.90270
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## 288  1984/2/1  99.89684  99.89684  99.89684
## 289  1984/3/1  99.84991  99.84991  99.84991
## 290  1984/4/1  99.80236  99.80236  99.80236
## 291  1984/5/1  99.78043  99.78043  99.78043
## 292  1984/6/1  99.79843  99.79843  99.79843
## 293  1984/7/1  99.84398  99.84398  99.84398
## 294  1984/8/1  99.89299  99.89299  99.89299
## 295  1984/9/1  99.92276  99.92276  99.92276
## 296 1984/10/1  99.92478  99.92478  99.92478
## 297 1984/11/1  99.90060  99.90060  99.90060
## 298 1984/12/1  99.85963  99.85963  99.85963
## 299  1985/1/1  99.81841  99.81841  99.81841
## 300  1985/2/1  99.79423  99.79423  99.79423
## 301  1985/3/1  99.79866  99.79866  99.79866
## 302  1985/4/1  99.82975  99.82975  99.82975
## 303  1985/5/1  99.87856  99.87856  99.87856
## 304  1985/6/1  99.93361  99.93361  99.93361
## 305  1985/7/1  99.98407  99.98407  99.98407
## 306  1985/8/1 100.02048 100.02048 100.02048
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## 309 1985/11/1  99.99832  99.99832  99.99832
## 310 1985/12/1  99.95397  99.95397  99.95397
## 311  1986/1/1  99.90914  99.90914  99.90914
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## 313  1986/3/1  99.87079  99.87079  99.87079
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## 655  2014/9/1  99.62673  99.62673  99.62673
## 656 2014/10/1  99.65608  99.65608  99.65608
## 657 2014/11/1  99.68609  99.68609  99.68609
## 658 2014/12/1  99.71582  99.71582  99.71582
## 659  2015/1/1  99.74479  99.74479  99.74479
## 660  2015/2/1  99.77228  99.77228  99.77228
## 661  2015/3/1  99.79719  99.79719  99.79719
## 662  2015/4/1  99.81862  99.81862  99.81862
## 663  2015/5/1  99.83672  99.83672  99.83672
## 664  2015/6/1  99.85217  99.85217  99.85217
## 665  2015/7/1  99.86559  99.86559  99.86559
## 666  2015/8/1  99.87766  99.87766  99.87766
## 667  2015/9/1  99.88925  99.88925  99.88925
## 668 2015/10/1  99.90143  99.90143  99.90143
## 669 2015/11/1  99.91463  99.91463  99.91463
## 670 2015/12/1  99.92761  99.92761  99.92761
## 671  2016/1/1  99.93614  99.93614  99.93614
## 672  2016/2/1  99.93266  99.93266  99.93266
## 673  2016/3/1  99.91865  99.91865  99.91865
## 674  2016/4/1  99.89814  99.89814  99.89814
## 675  2016/5/1  99.87806  99.87806  99.87806
## 676  2016/6/1  99.86572  99.86572  99.86572
## 677  2016/7/1  99.86617  99.86617  99.86617
## 678  2016/8/1  99.88287  99.88287  99.88287
## 679  2016/9/1  99.91740  99.91740  99.91740
## 680 2016/10/1  99.96884  99.96884  99.96884
## 681 2016/11/1 100.03503 100.03503 100.03503
## 682 2016/12/1 100.11350 100.11350 100.11350
## 683  2017/1/1 100.20051 100.20051 100.20051
## 684  2017/2/1 100.29268 100.29268 100.29268
## 685  2017/3/1 100.38737 100.38737 100.38737
## 686  2017/4/1 100.48250 100.48250 100.48250
## 687  2017/5/1 100.57640 100.57640 100.57640
## 688  2017/6/1 100.66768 100.66768 100.66768
## 689  2017/7/1 100.75546 100.75546 100.75546
## 690  2017/8/1 100.83759 100.83759 100.83759
## 691  2017/9/1 100.90942 100.90942 100.90942
## 692 2017/10/1 100.96294 100.96294 100.96294
## 693 2017/11/1 100.99008 100.99008 100.99008
## 694 2017/12/1 100.98727 100.98727 100.98727
## 695  2018/1/1 100.96188 100.96188 100.96188
## 696  2018/2/1 100.92493 100.92493 100.92493
## 697  2018/3/1 100.88564 100.88564 100.88564
## 698  2018/4/1 100.84677 100.84677 100.84677
## 699  2018/5/1 100.80847 100.80847 100.80847
## 700  2018/6/1 100.77225 100.77225 100.77225
## 701  2018/7/1 100.74489 100.74489 100.74489
```

```
## 702  2018/8/1 100.73484 100.73484 100.73484
## 703  2018/9/1 100.74814 100.74814 100.74814
## 704 2018/10/1 100.78328 100.78328 100.78328
## 705 2018/11/1 100.83431 100.83431 100.83431
## 706 2018/12/1 100.89254 100.89254 100.89254
## 707  2019/1/1 100.94713 100.94713 100.94713
## 708  2019/2/1 100.98754 100.98754 100.98754
## 709  2019/3/1 101.00718 101.00718 101.00718
## 710  2019/4/1 101.00674 101.00674 101.00674
## 711  2019/5/1 100.98980 100.98980 100.98980
## 712  2019/6/1 100.95965 100.95965 100.95965
## 713  2019/7/1 100.91735 100.91735 100.91735
## 714  2019/8/1 100.86284 100.86284 100.86284
## 715  2019/9/1 100.79692 100.79692 100.79692
## 716 2019/10/1 100.72420 100.72420 100.72420
## 717 2019/11/1 100.64996 100.64996 100.64996
## 718 2019/12/1 100.57745 100.57745 100.57745
## 719  2020/1/1 100.50550 100.50550 100.50550
## 720  2020/2/1 100.43086 100.43086 100.43086
## 721  2020/3/1  89.98167  89.98167  89.98167
## 722  2020/4/1  87.78579  87.78579  87.78579
## 723  2020/5/1  86.66534  86.66534  86.66534
## 724  2020/6/1  89.86019  89.86019  89.86019
## 725  2020/7/1  93.03161  93.03161  93.03161
## 726  2020/8/1  96.17070  96.17070  96.17070
## 727  2020/9/1  96.00698  96.00698  96.00698
## 728 2020/10/1  95.85361  95.85361  95.85361
## 729 2020/11/1  95.71599  95.71599  95.71599
## 730 2020/12/1  95.53725  95.53725  95.53725
## 731  2021/1/1  95.37096  95.37096  95.37096
## 732  2021/2/1  95.20871  95.20871  95.20871
## 733  2021/3/1  95.72892  95.72892  95.72892
## 734  2021/4/1  96.24900  96.24900  96.24900
## 735  2021/5/1  96.77051  96.77051  96.77051
## 736  2021/6/1  97.38125  97.38125  97.38125
## 737  2021/7/1  97.99396  97.99396  97.99396
## 738  2021/8/1  98.59528  98.59528  98.59528
## 739  2021/9/1  98.67198  98.67198  98.67198
## 740 2021/10/1  98.72608  98.72608  98.72608
## 741 2021/11/1  98.77543  98.77543  98.77543
## 742 2021/12/1  98.82478  98.82478  98.82478
## 743  2022/1/1  99.07935  99.00337  98.85141
## 744  2022/2/1  99.38328  99.23131  98.92739
## 745  2022/3/1  99.68720  99.45926  99.00337
## 746  2022/4/1  99.99112  99.68720  99.07935
## 747  2022/5/1 100.29505  99.91514  99.15533
## 748  2022/6/1 100.59897 100.14309  99.23131
## 749  2022/7/1 100.90290 100.37103  99.30729
## 750  2022/8/1 101.20682 100.59897  99.38328
## 751  2022/9/1 101.51075 100.82692  99.45926
## 752 2022/10/1 101.81467 101.05486  99.53524
## 753 2022/11/1 102.11860 101.28280  99.61122
## 754 2022/12/1 102.42252 101.51075  99.68720
## 755  2023/1/1 102.72644 101.73869  99.76318
```

```
## New names:
## * `` -> `...3`
## * `` -> `...5`
## * `` -> `...7`
## * `` -> `...9`
## * `` -> `...11`
## * `` -> `...13`
## * `` -> `...15`
## * `` -> `...17`
## * `` -> `...19`
## * `` -> `...21`
## * `` -> `...23`
## * `` -> `...25`
## * `` -> `...27`
## * `` -> `...29`
## * `` -> `...31`
## * `` -> `...33`
## * `` -> `...35`
## * `` -> `...37`
## * `` -> `...39`
## * `` -> `...41`
## * `` -> `...43`
## * `` -> `...45`
## * `` -> `...47`
## * `` -> `...49`
## * `` -> `...51`
## * `` -> `...53`
## * `` -> `...55`
## * `` -> `...57`
## * `` -> `...59`
## * `` -> `...61`
## * `` -> `...63`
## * `` -> `...65`
## * `` -> `...67`
## * `` -> `...69`
## * `` -> `...71`
## * `` -> `...73`
## * `` -> `...75`
## * `` -> `...77`
## * `` -> `...79`
## * `` -> `...81`
```

Introduction, Motivation, Relevance, and Objectives Since the start of the Russian invasion of Ukraine, the volume of Russian gas delivered to the EU through Ukraine did not actually decrease, but natural gas spot prices and futures prices rose considerably (Reuters, 2022). For example, "in the UK market, the March price was up 58.6% at 321.97 pence per therm and the winter 2022 price had risen 37.85% to 105 p/therm." One reason is that Russia's overall natural gas supply decreased compared to previous years (Reuters, 2022). Another reason is that the demand for natural gas in the EU is rising due to the economic recovery from the pandemic. Arguably, the most important reason that EU natural gas price increases is due to market speculation in response to the political uncertainties. This gives us the motivation for our project: to forecast the EU natural gas price after the Ukraine crisis.

First, let's take a step back and provide some background on the global natural gas market. The global natural gas market is composed of regional markets that are grouped based on either transoceanic shipping (i.e. the Atlantic and Pacific Basins). "In recent years, roughly 70% of natural gas flows across the globe are

transported to market destinations within the country of production, while an additional 20% flows cross international borders through pipelines, and nearly 10% is moved to market destinations as liquefied natural gas (LNG)." The limitation in transporting natural gas creates different prices among the major regions globally. For example, East Asia countries usually have high natural gas prices, followed by EU countries; the US tends to have a lower natural gas price.

In a 2010 study, "Russia is the world's largest exporter of pipeline gas, accounting for 26% of global exports". Many EU countries are among the top 10 gas importers, including Germany, Italy, France, Spain, and the UK (formal EU member). According to IEA, the EU imported 155 bcm of natural gas from Russia in 2021, accounting for around 45% of the EU's total gas imports and 40% of its total gas consumption. Considering the EU countries plan to reduce or even embargo the natural gas imports from Russia after the Russian invasion of Ukraine, the natural gas price in Europe is expected to experience the most direct impact.

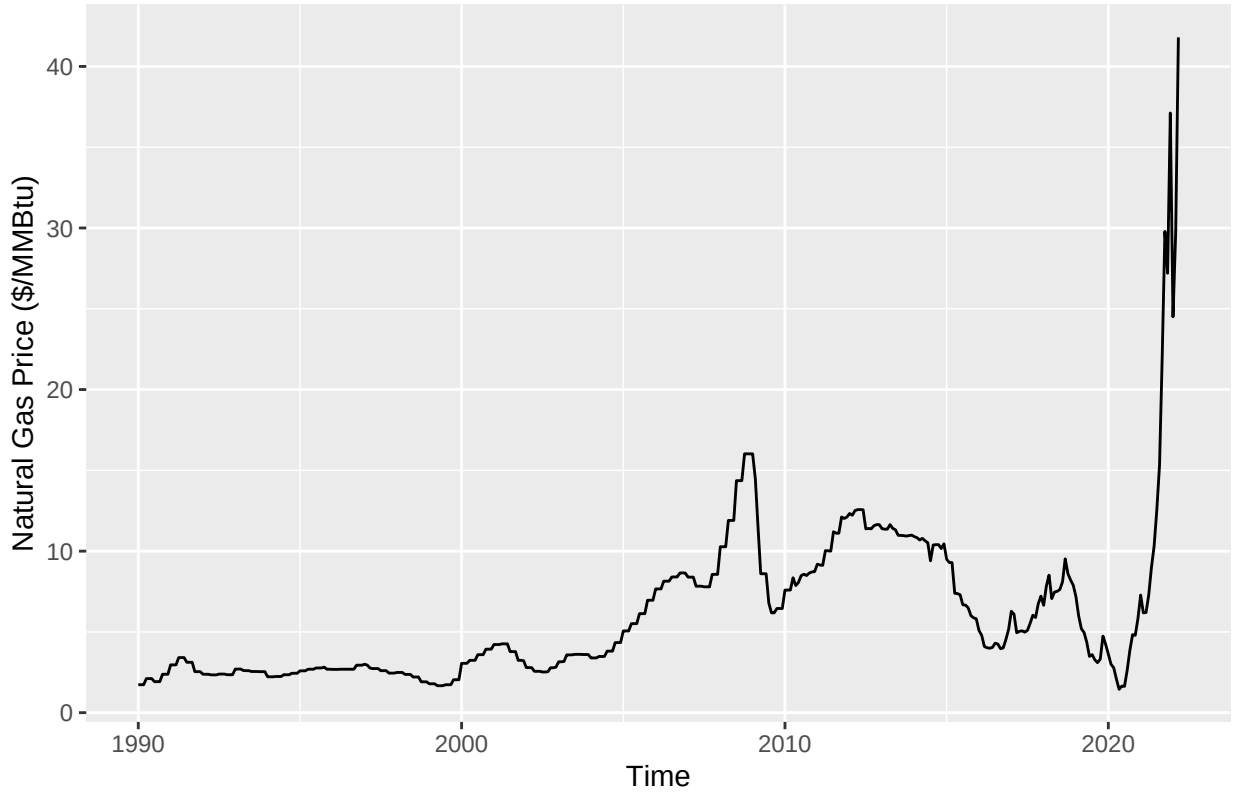
The objective of this project is to forecast the EU natural gas price after the Ukraine crisis. The motivation is to see which model (if any), can predict natural gas prices in a period of high volatility caused by political events. We want to explore whether the following exogenous variables can capture some of the impacts of the Russia-Ukraine war, thus improving our model performance.

Specifically, we think these exogenous variables could have a close relationship with NG price: Consumption: it reflects the seasonal variations with NG price (higher in the winter when heating need is higher) GDP: it is a proxy of economic activities (high economic activities will need more energy inputs and more NG). Imports: Due to EU's high dependence on imported NG from Russia.

We also came up with four hypotheses to better understand how models work under disruptions in general: 1)Forecasting in a period of high uncertainty is difficult, as the historical observations are not very applicable to the testing period 2)Because we observe a non-linear increase in NG price from 2021, we hypothesize that a feed-forward neural networks model can better capture this trend and give a relatively accurate forecast result. 3)Adding exogenous variables can improve the model performance as they can explain some of the variations in NG price. 4) Because we observed a stronger correlation between NG price and import than with GDP, we hypothesized that adding import data can improve the model performance more than adding GDP data.

Dataset Information

Figure 1. Historical EU Natural Gas Price




```
##
##  Pettitt's test for single change-point detection
##
## data:  ts_EU_price
## U* = 34916, p-value < 2.2e-16
## alternative hypothesis: two.sided
## sample estimates:
## probable change point at time K
##                             177
```

```
##
##  Pettitt's test for single change-point detection
##
## data:  ts_EU_price_shorten_200409_202203
## U* = 6404, p-value = 9.52e-12
## alternative hypothesis: two.sided
## sample estimates:
## probable change point at time K
##                             127
```

By using the pettitt.test function, we detected two points of inflection in our historical NG price data ($p<0.05$), one in September 2004 and the other one in July 2014, so we trim the data before July 2014, and take NG historical data from JUly 2014 to March 2022 to forecast the NG price until December 2022. Because Russia started mobilizing its troops near Ukraine at the beginning of 2022, we assume NG price since Januray 2022 are impacted by this event.

```
## Warning in cbind(EU_price$Price[295:372], EU_GDP$GDP, Consumption$Consumption, :
## number of rows of result is not a multiple of vector length (arg 1)
```

```
## Warning in cbind(EU_price$Price[295:387], Import$Import1): number of rows of
## result is not a multiple of vector length (arg 1)
```

```
##             [,1]        [,2]
## [1,]  1.00000000 -0.04584427
## [2,] -0.04584427  1.00000000
```

Table 1: Table1. Correlation Coefficient Matrice

	Price	GDP	Consumption	Import
Price	1.0000000	0.0314424	-0.0051395	-0.0420958
GDP	0.0314424	1.0000000	-0.0545164	0.0517559
Consumption	-0.0051395	-0.0545164	1.0000000	0.1633462
Import	-0.0420958	0.0517559	0.1633462	1.0000000

To better perform the forecast, we introduce three exogenous variables: consumption, import, and GDP(as a proxy of economic status) in the EU. Historical monthly natural gas price and the monthly normalized GDP in Europe are from the Federal Reserve Banks of St.Louis' website, and the monthly natural gas consumption and import in the EU are from the Eurostat data browser. Through exploring the correlations between natural gas price and the other factors, we found that all variables have relatively weak correlations, in which GDP shows a positive correlation to NG price and import shows a negative correlation, and consumption with a really weak correlation (Table 1). Therefore, we decided to include GDP and natural gas imports as exogenous variables in our forecast. As GDP and import show the strongest positive correlation of 0.05, we also analyze models that include both variables to explore how their interaction can impact the forecast result.

```
## Warning in cbind(EU_price$Price[295:372], EU_GDP$GDP, Consumption$Consumption, :
## number of rows of result is not a multiple of vector length (arg 1)
```

Table 2: Table 2. First ten rows of data

Price ($/MMBtu)	GDP(Normalized)	Consumption(Million Cubic Metres)	Import(Million Cubic Metres)
9.40	99.66307	43998	53575
10.38	99.70633	36881	44978
10.40	99.75215	32070	48792
10.40	99.79922	23731	47342
10.16	99.84206	23110	50724
10.45	99.87506	19391	46070
9.50	99.89666	20871	47634
9.29	99.91446	18581	42248
9.29	99.93804	21662	43615
7.39	99.97215	26536	47023

Table 3: Table 3. Data Descriptions

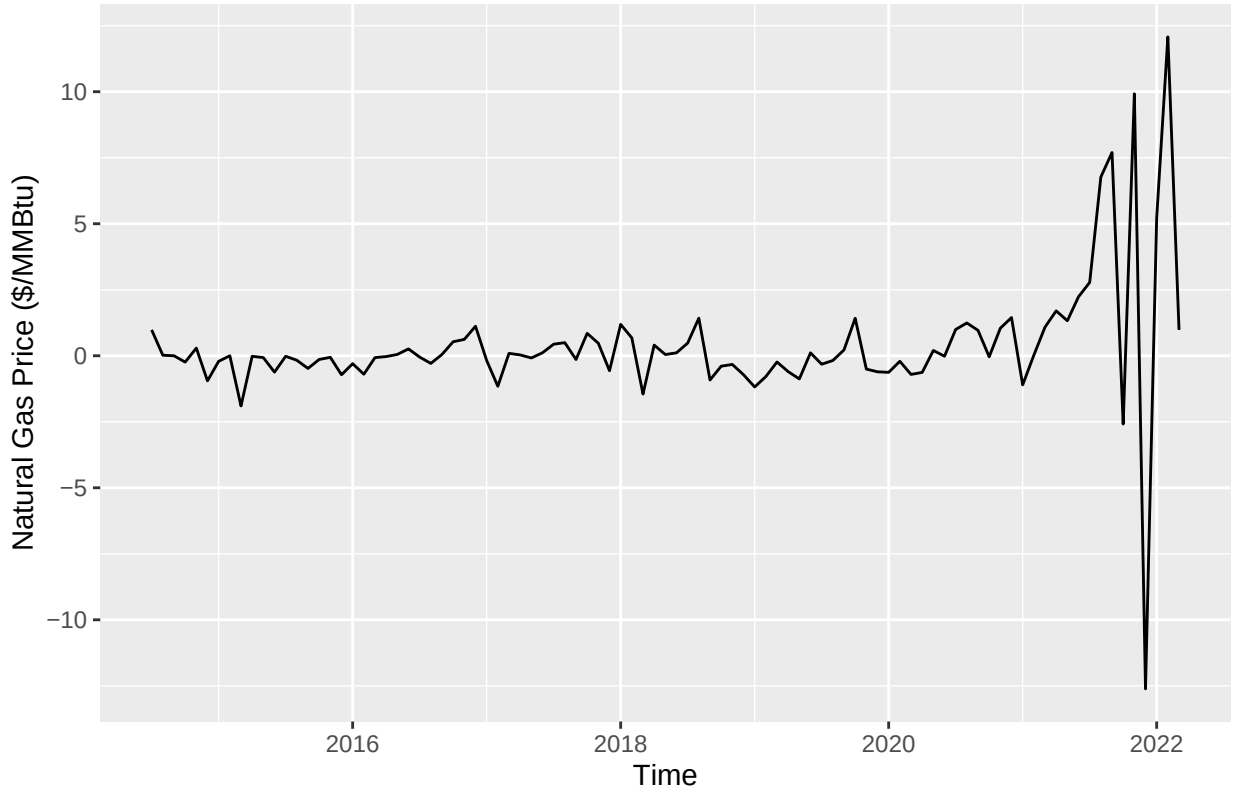
	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se	source
Price ($/MMBtu)	755	5.92	2.26	5.81	5.84	2.34e+00	1.045	10.4	9.0	0.268	-0.628	0.0823	FRED
GDP(Normalized)	755	100.00	1.37	100.00	100.00	8.78e-01	86.70	103.0	16.2	-3.680	28.800	0.0498	FRED
Consumption(Million Cubic Metres)	755	32200.0	10600.0	30200.0	31400.0	1.27e+04	18400.0	57600.0	39200.0	0.464	-1.080	385.000	Eurostat
Import(Million Cubic Metres)	755	51500.0	6460.0	51700.0	51700.0	6.24e+03	33600.0	68100.0	27500.0	-0.314	-0.110	199.000	Eurostat

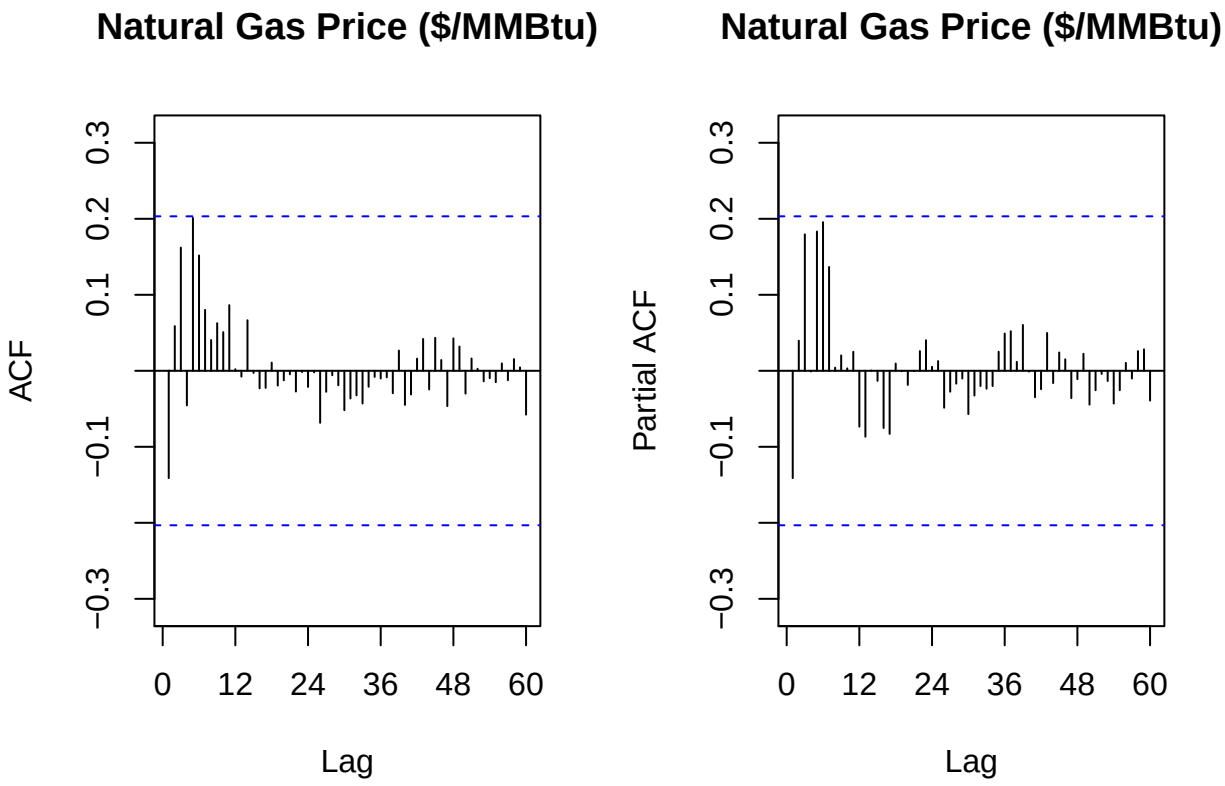
```
## [1] "Results for ADF test on EU NG Price data"
```

```
## Warning in adf.test(ts_EU_price_shorten_201407_202203, alternative =
## "stationary"): p-value greater than printed p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  ts_EU_price_shorten_201407_202203
## Dickey-Fuller = 2.6572, Lag order = 4, p-value = 0.99
## alternative hypothesis: stationary
```

Figure 2.Differenced EU Natural Gas Price





The ADF test indicates that the original series contains a unit root (i.e. there is a stochastic trend)($p>0.99$). After removing the trend by differencing, the detrended series doesn't show a constant pattern within each year. Instead, it looks like white noise with a mean around zero and fluctuating up and down randomly over time. This situation indicates that the original time series doesn't contain a seasonality component. Neither ACF nor PACF of the differenced series show significant values, which could be caused by the superimposing of autoregression and moving average terms.

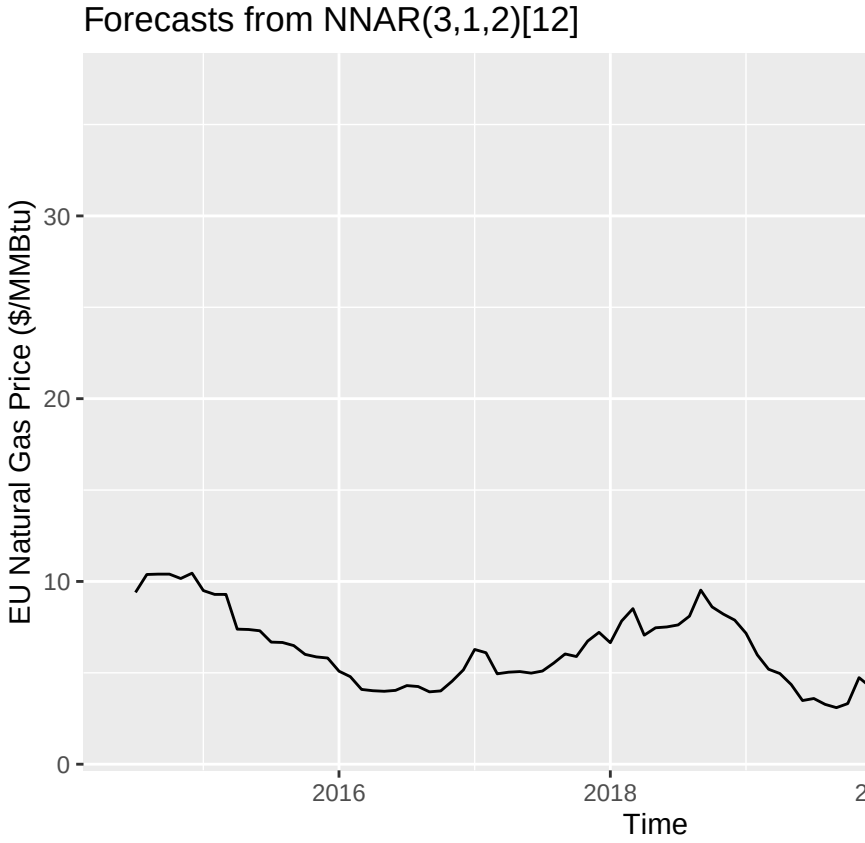
From the historical NG price data, we observed a huge increase starting from January 2021. Because we want to compare models' performance under disruptions, we purposely include this increasing trend in the training set. Thus, our training set includes data from July 2014 to December 2021, while our test set includes data from January 2022 to March 2022. The same time frame is used to split exogenous variables so that they will have the same length as NG price data when fitting the models and forecasting.

In order to accurately forecast the natural gas price in 2022, we created three scenarios for each of the two exogenous variables. For GDP growth in the EU in 2022, the EU Economic and Social committee estimated growth of 4% (GDP_scenario_1) before the Russian invasion of Ukraine, and dropped its estimation to 3% (GDP_scenario_2) after the invasion. Yet, some investment banks like Credit Suisse predicted annual GDP growth of only 1% (GDP_scenario_3) due to this invasion. While the level of sanctions on natural gas imports from Russia is still under debate in different countries in the EU, we expect the total natural gas import in the EU would decrease by about 20% (Import_scenario_2) if there is a complete embargo on Russian imports. If the EU countries failed to embargo Russia, a 10% decrease (Import_scenario_2) in natural gas imports is expected with some sanctions on Russia, and only a 5% decrease (Import_scenario_3) if the sanctions are not strictly implemented.

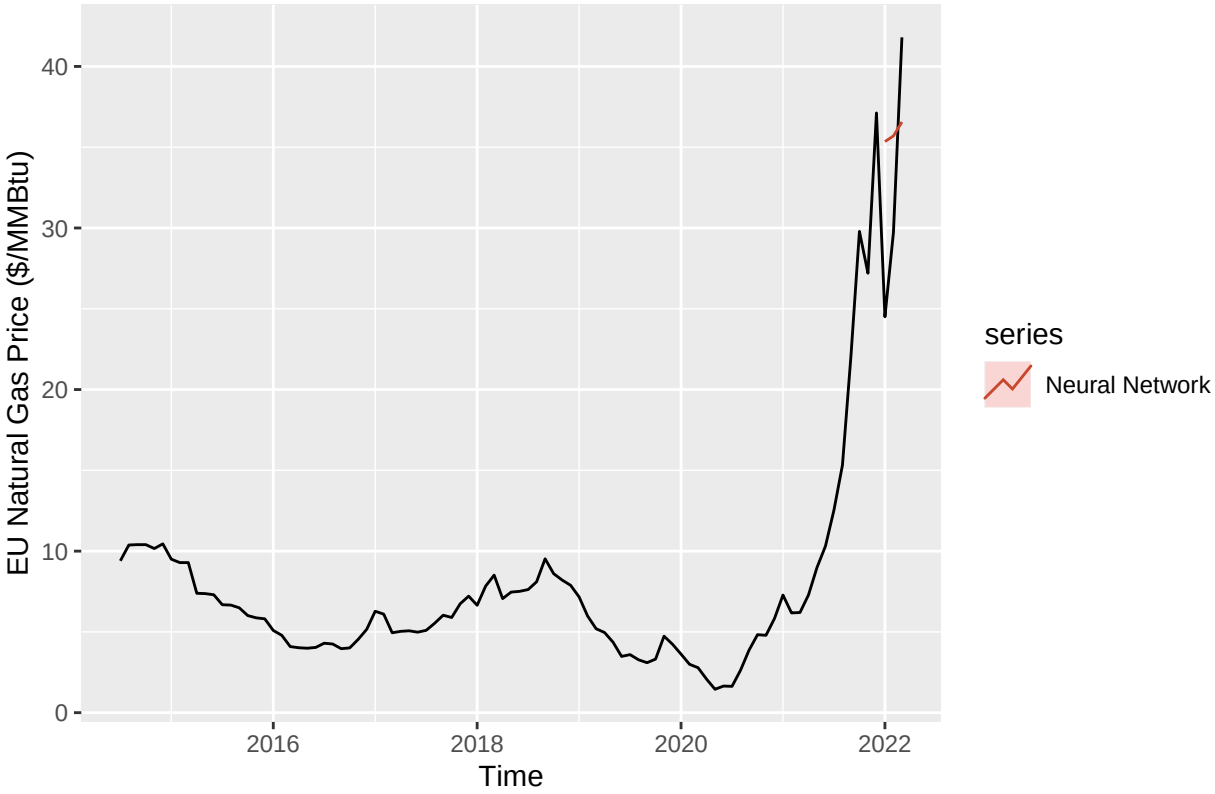
Method Our method is to fit ARIMA, Neural Network (NN), STL+ETS, and TBATS models on the NG price training set (including models with exogenous variables), and use the fitted models to forecast NG price from January 2022 to March 2022. Then the forecasted results are compared to the observed data and the accuracies of different models are compared. Then, the best model with the lowest RMSE score

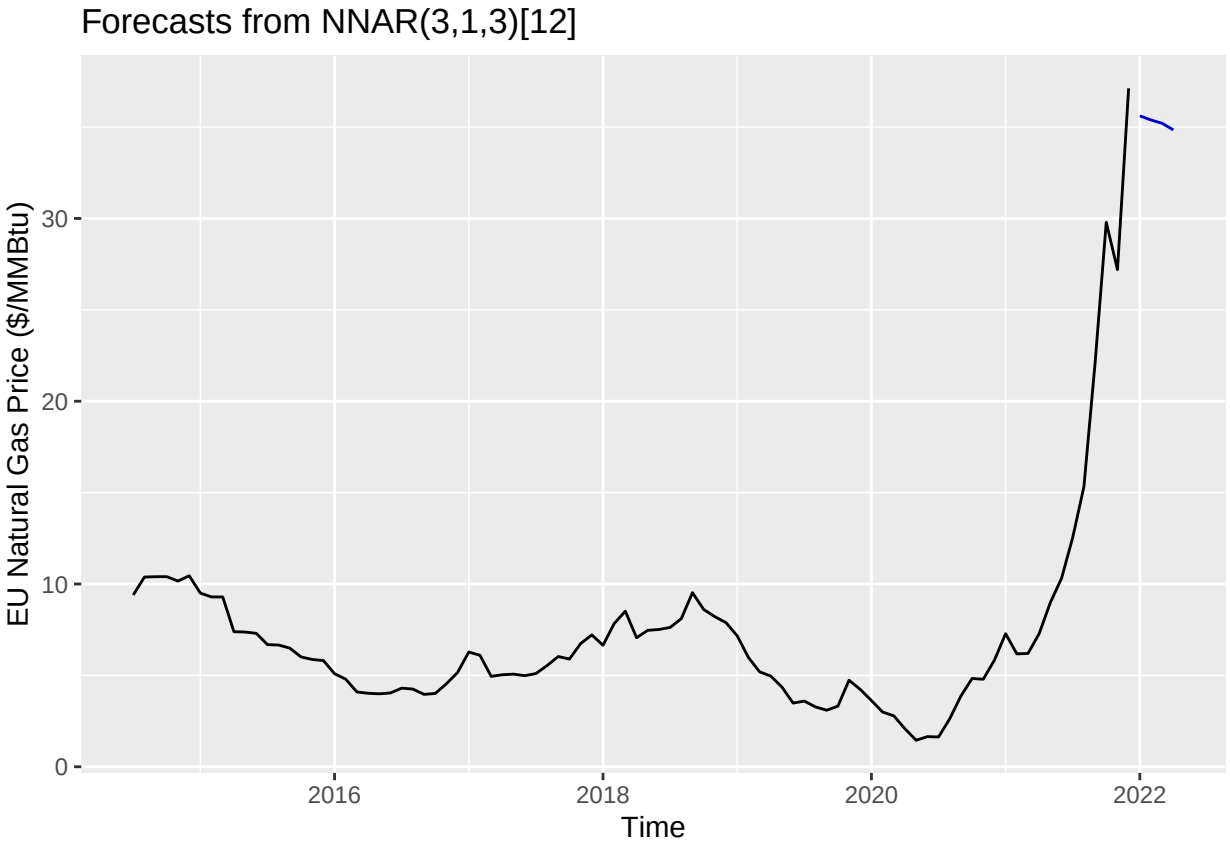
will be selected to forecast the NG price from April 2022 to December 2022. If the model allows us to add in exogenous variables, we would add in proposed scenarios for GDP and import to generate corresponding forecast results.

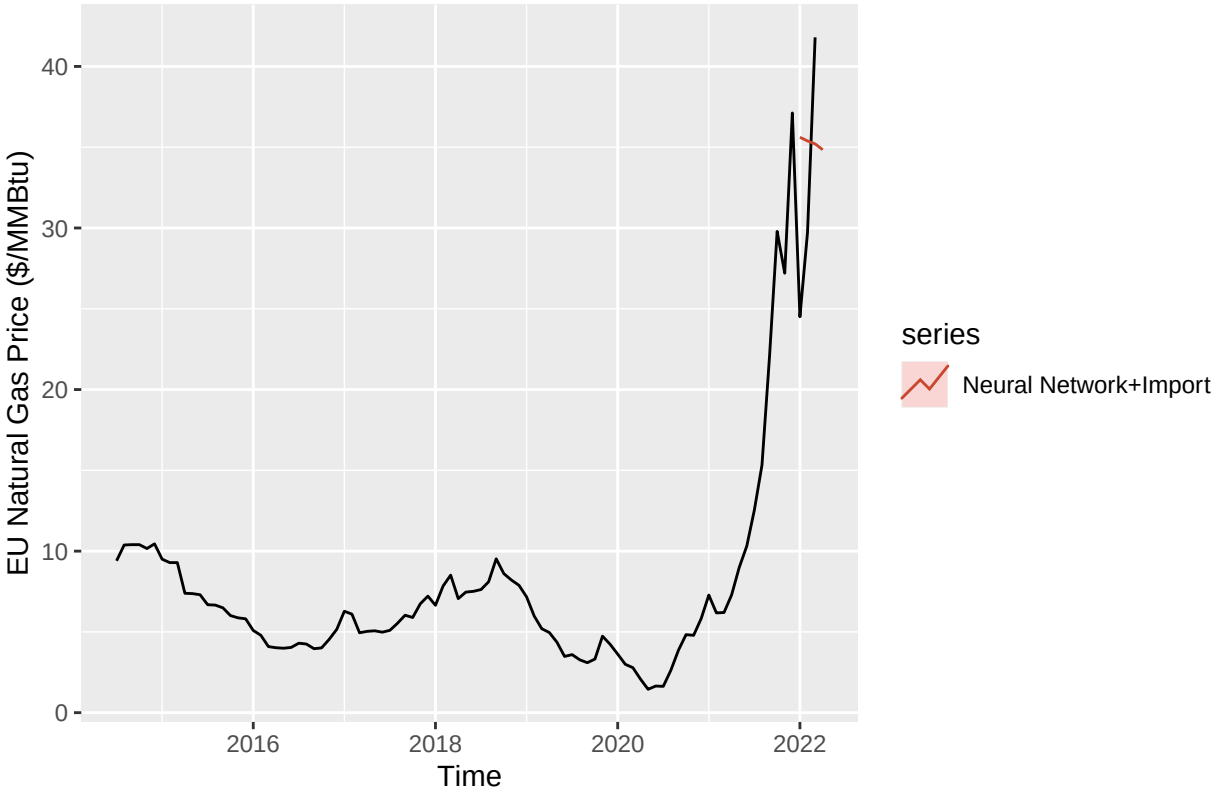
Result Graphs below show the comparison between forecasted prices from 2022/1 to 2022/3 using models

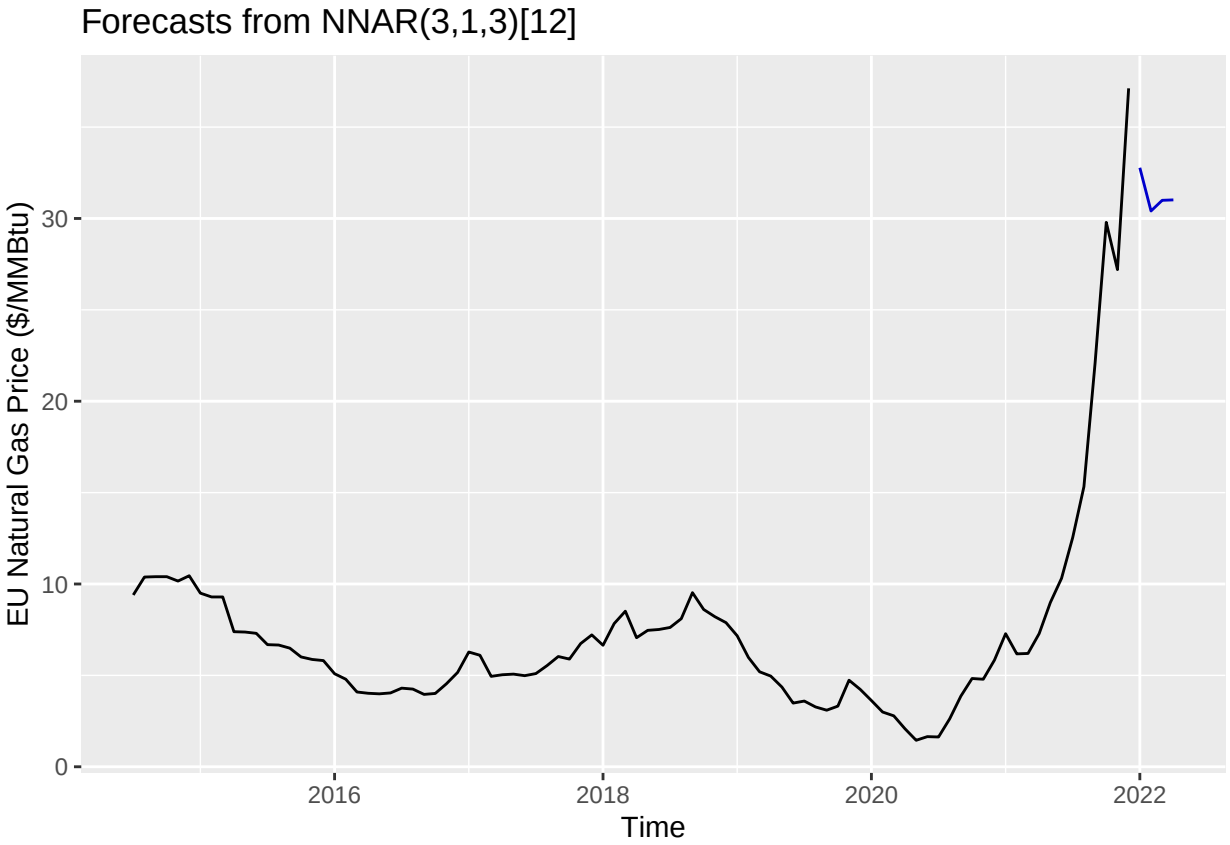


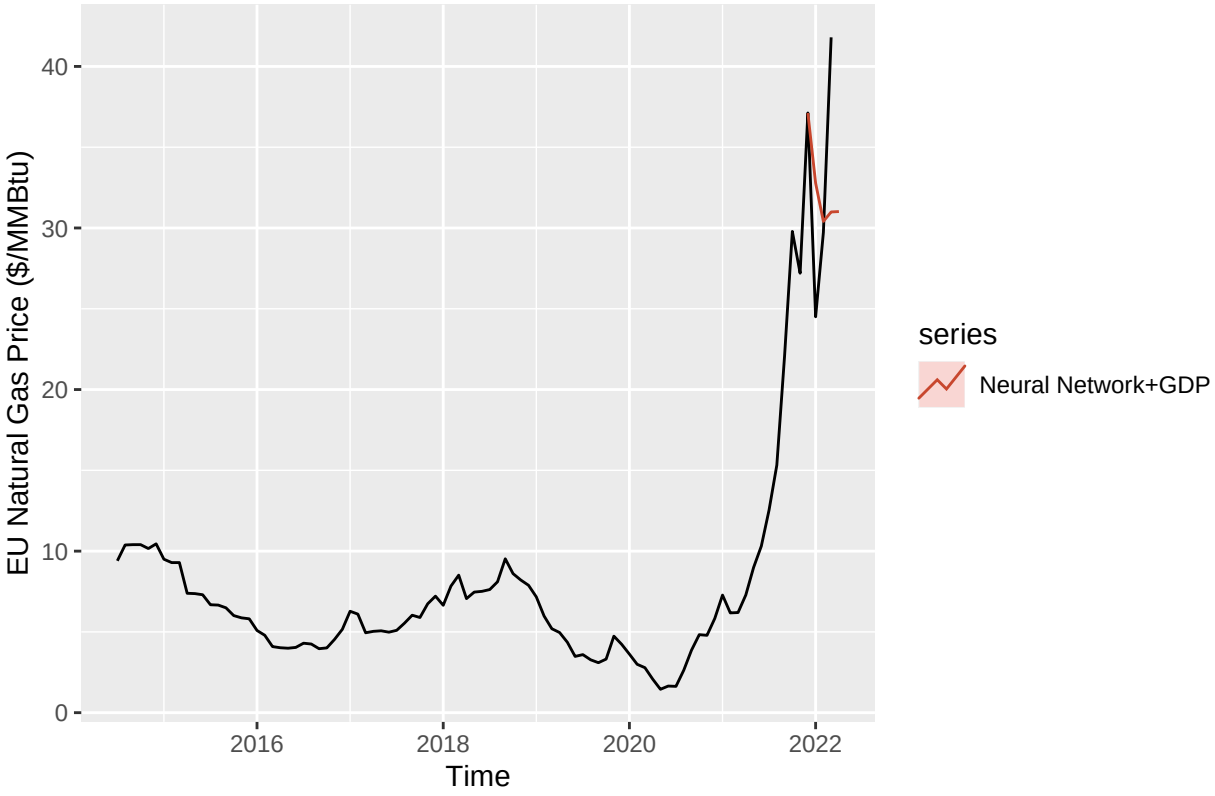
that fitted the training set and the observed data.


EU Natural Gas Price ($/MMBtu)
40
30
20
10
0
2016
2018
2020
2022
Time
series
Neural Network

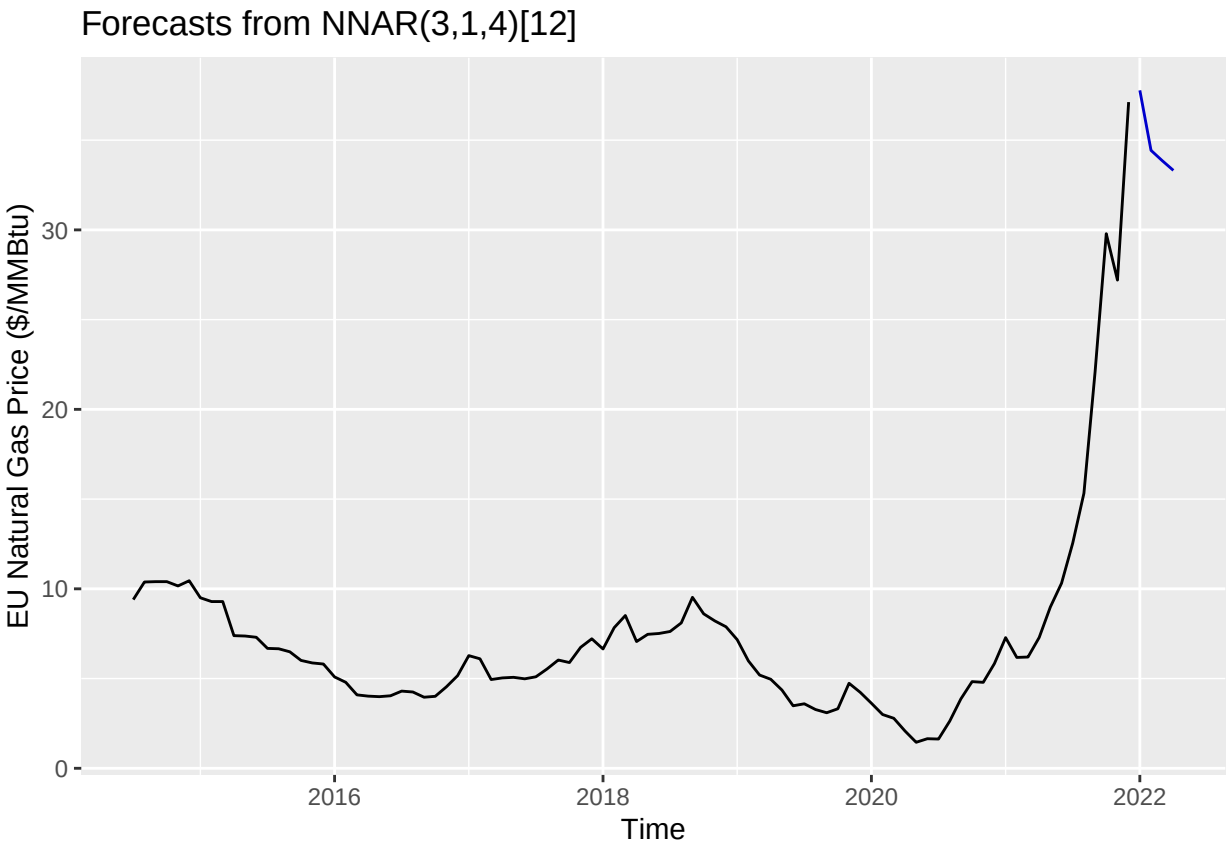

Forecasts from NNAR(3,1,3)[12]
EU Natural Gas Price ($/MMBtu)
0
10
20
30
2016
2018
2020
2022
Time

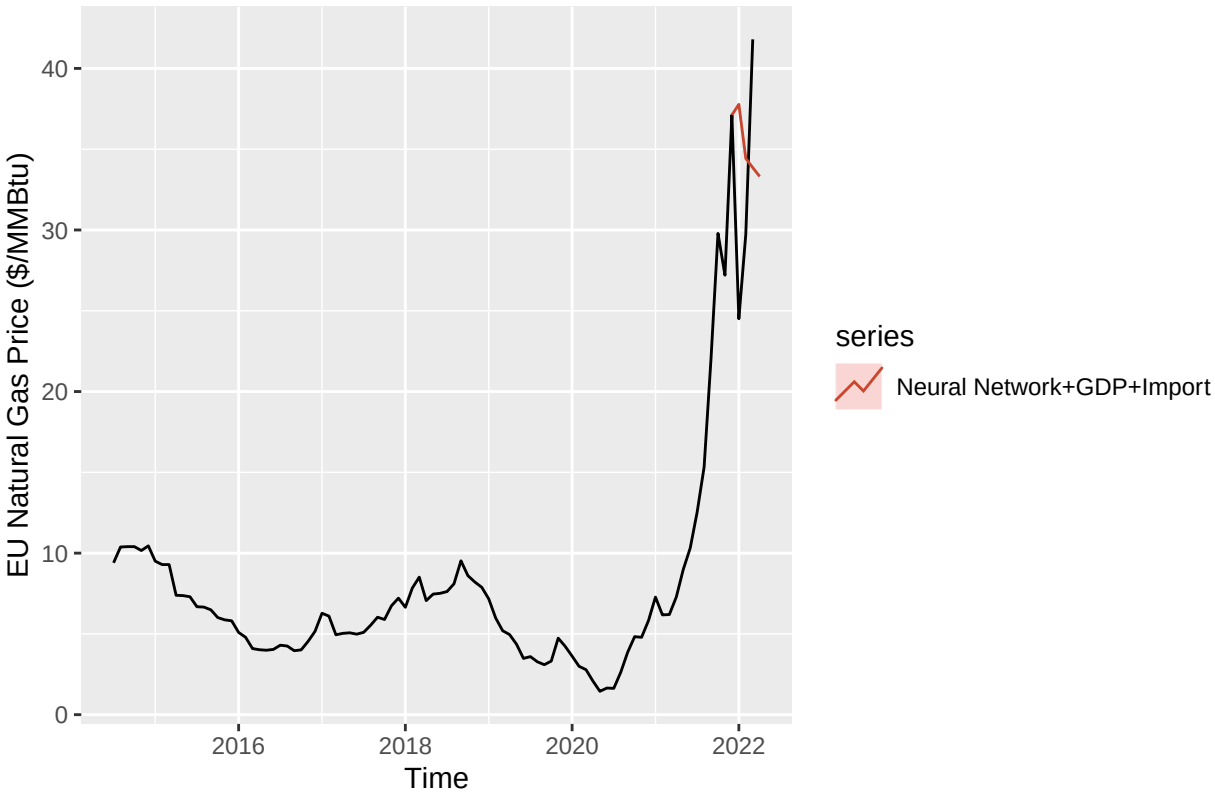

EU Natural Gas Price ($/MMBtu)
40
30
20
10
0
2016
2018
2020
2022
Time
series
Neural Network+Import

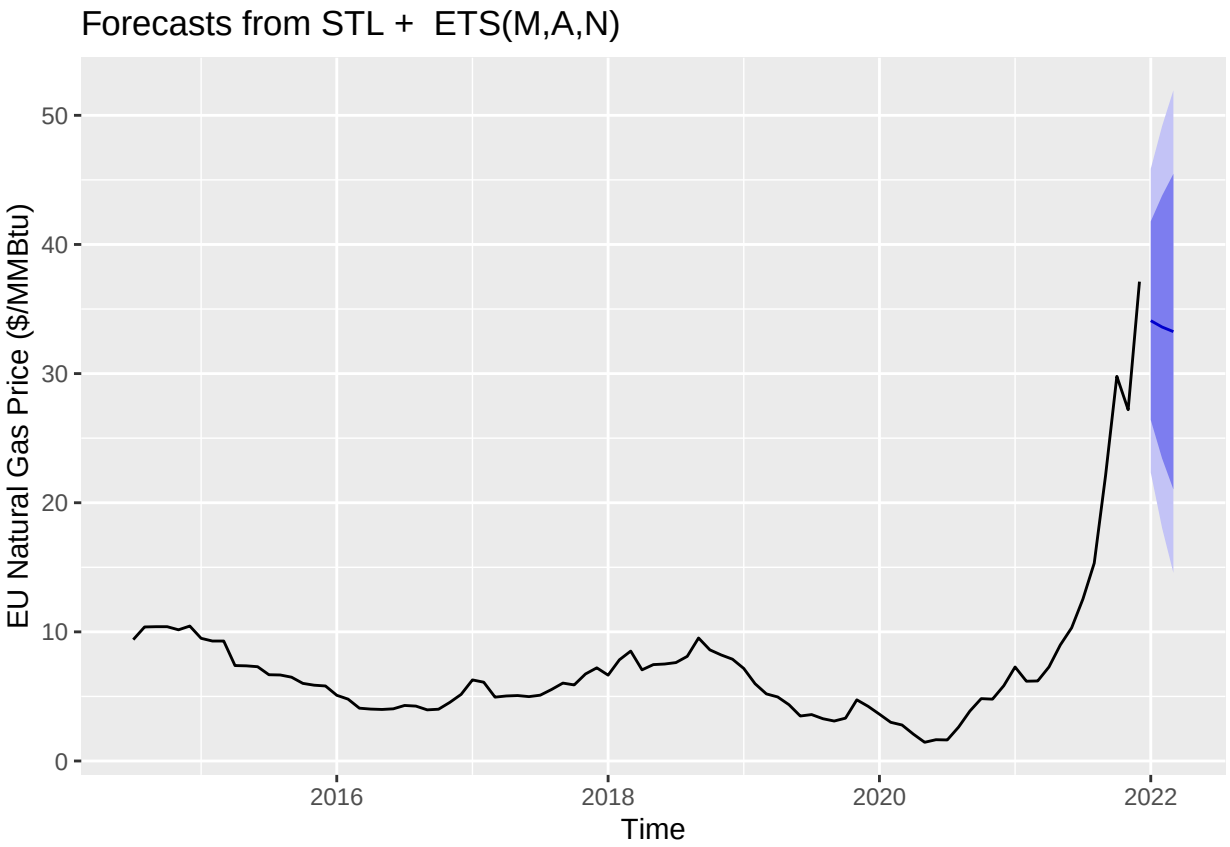

Forecasts from NNAR(3,1,3)[12]
EU Natural Gas Price ($/MMBtu)
0
10
20
30
2016
2018
2020
2022
Time

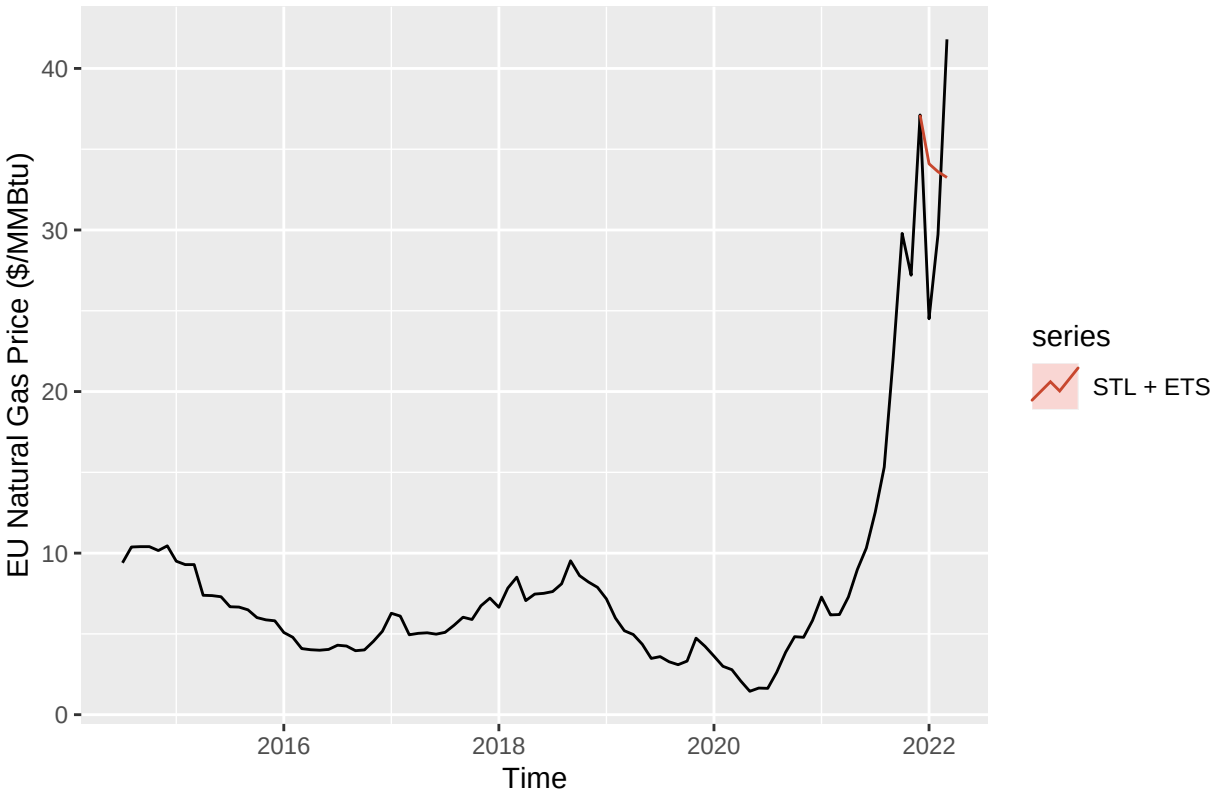


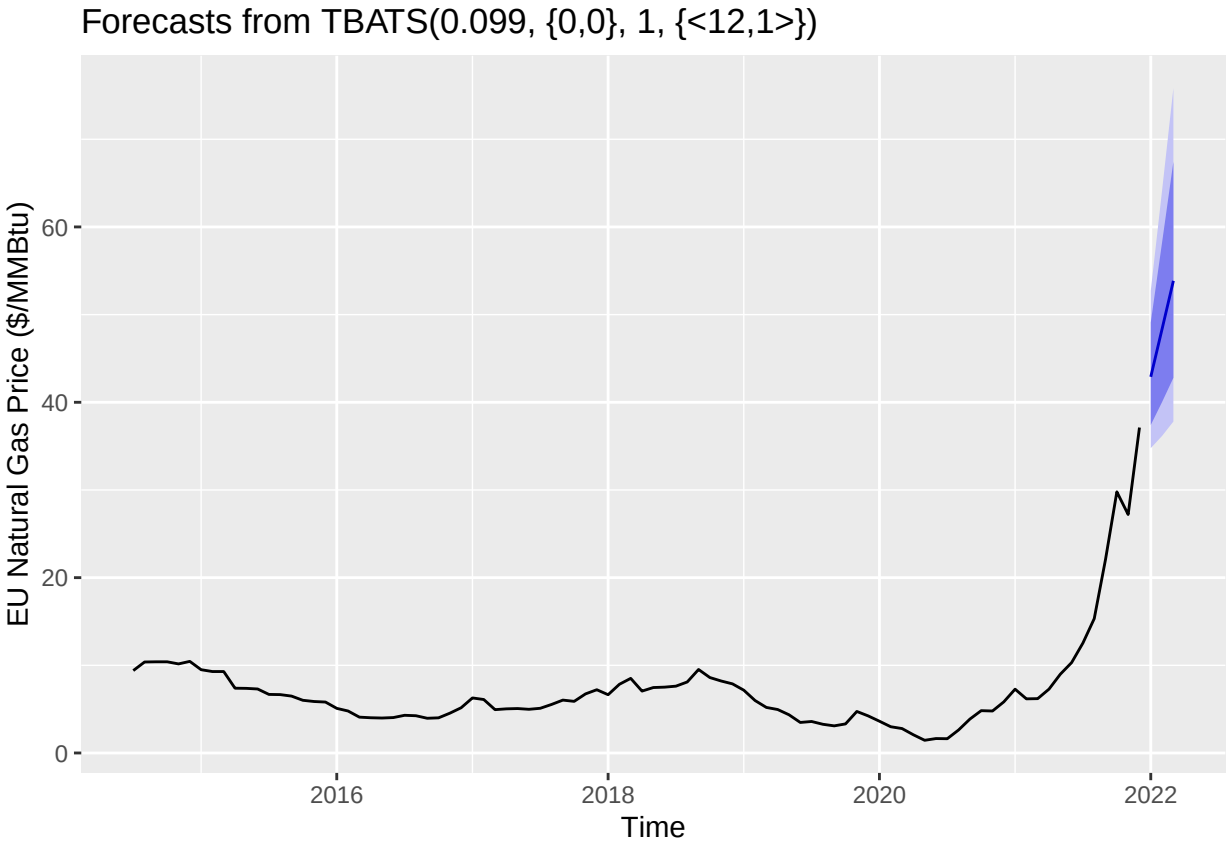

```
## Warning in forecast.nnetar(NN_fit_withGDPandImport, xreg =
## cbind(ts_EU_GDP_test, : xreg contains different column names from the xreg used
## in training. Please check that the regressors are in the same order.
```

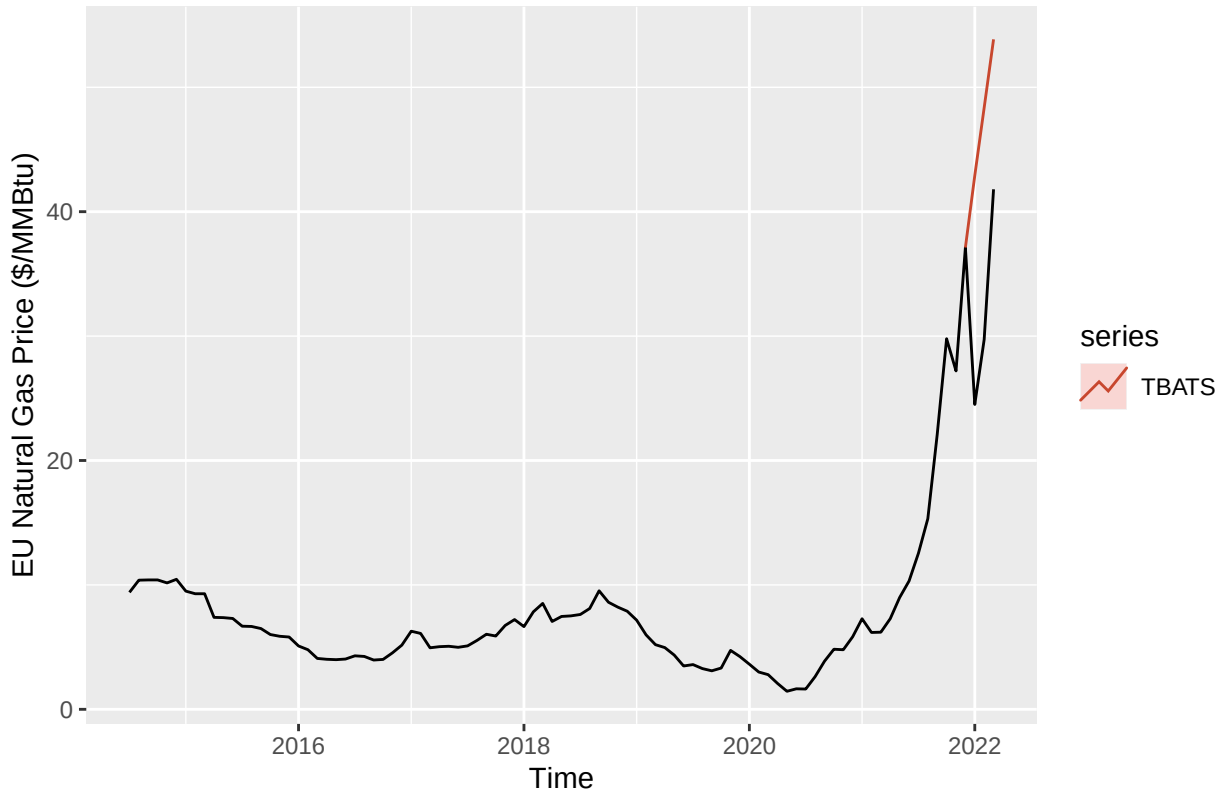

Forecasts from NNAR(3,1,4)[12]
EU Natural Gas Price ($/MMBtu)
0
10
20
30
2016
2018
2020
2022
Time

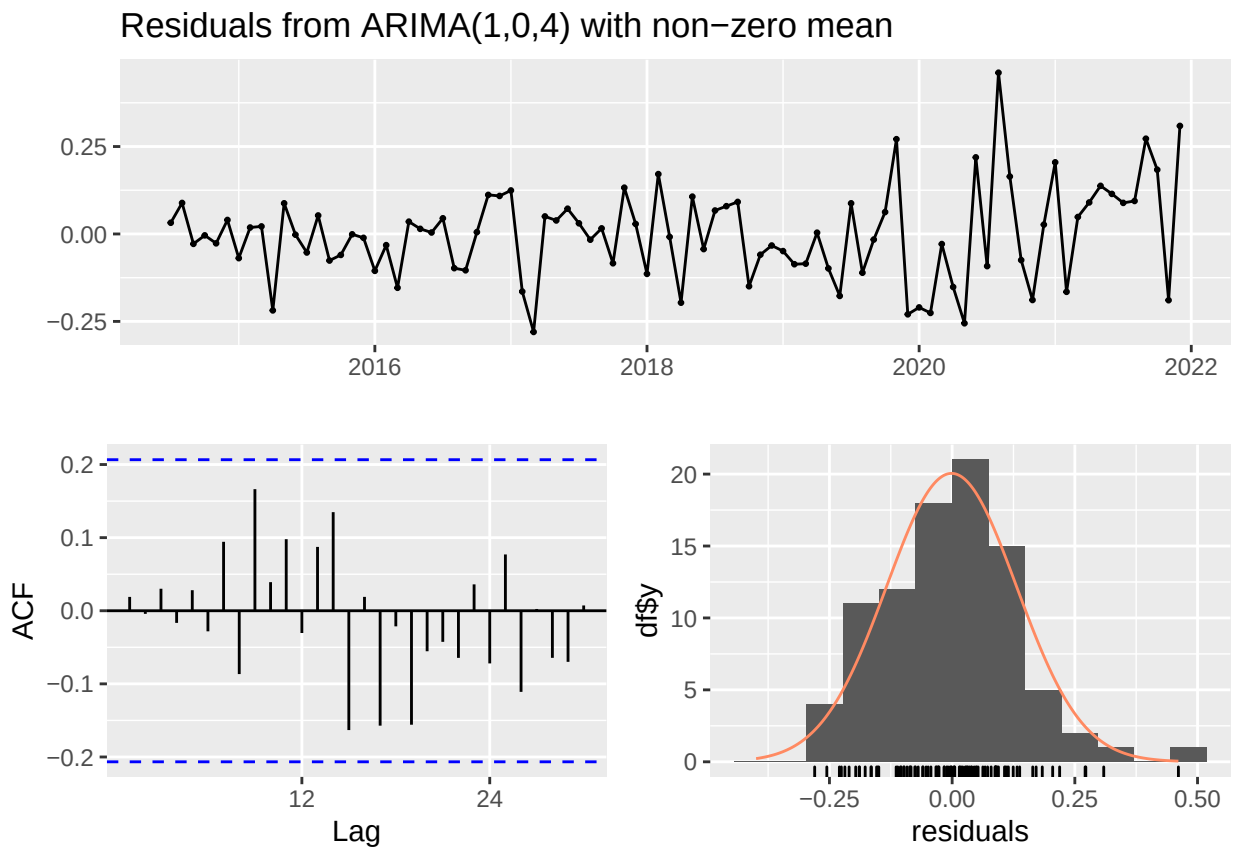

EU Natural Gas Price ($/MMBtu)
40
30
20
10
0
2016
2018
2020
2022
Time
series
Neural Network+GDP+Import


Forecasts from STL + ETS(M,A,N)
EU Natural Gas Price ($/MMBtu)
50
40
30
20
10
0
2016
2018
2020
2022
Time

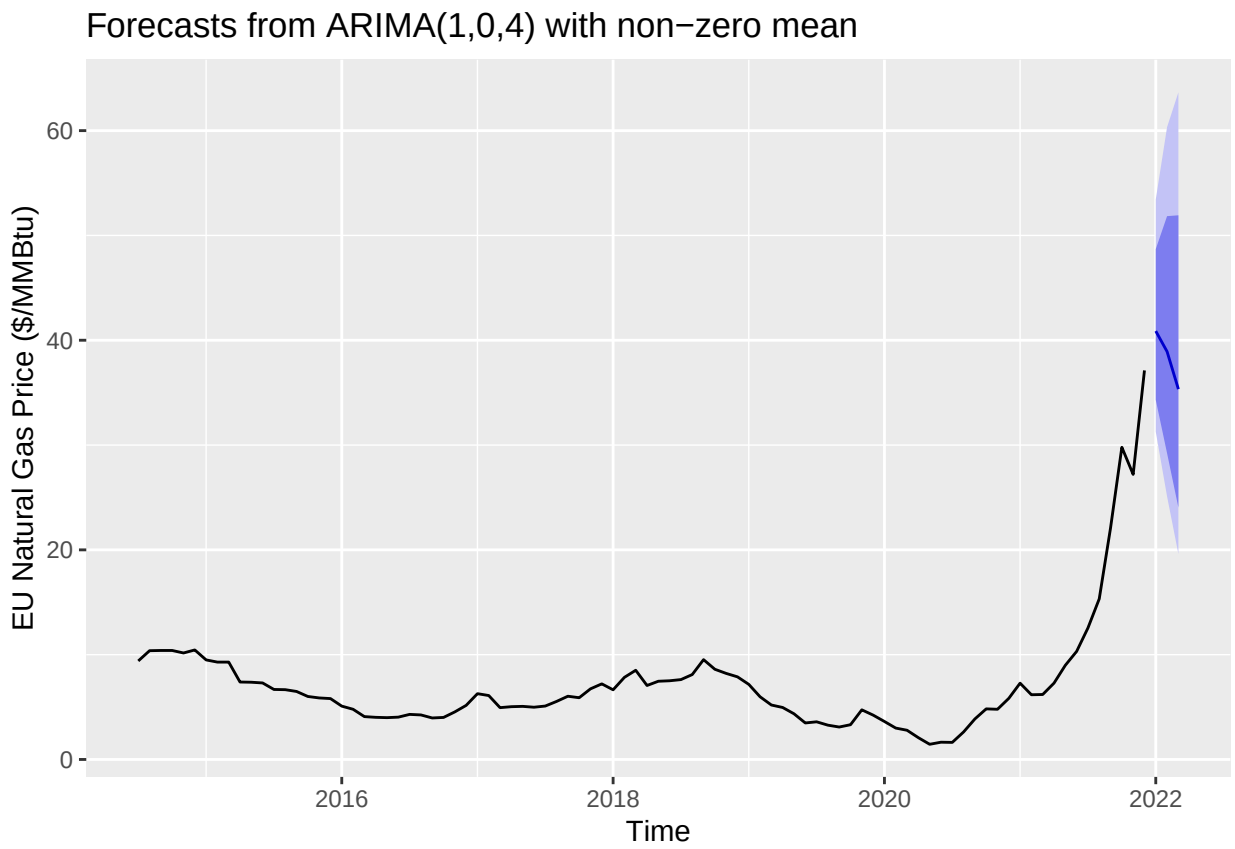

EU Natural Gas Price ($/MMBtu)
40
30
20
10
0
2016
2018
2020
2022
Time
series
STL + ETS

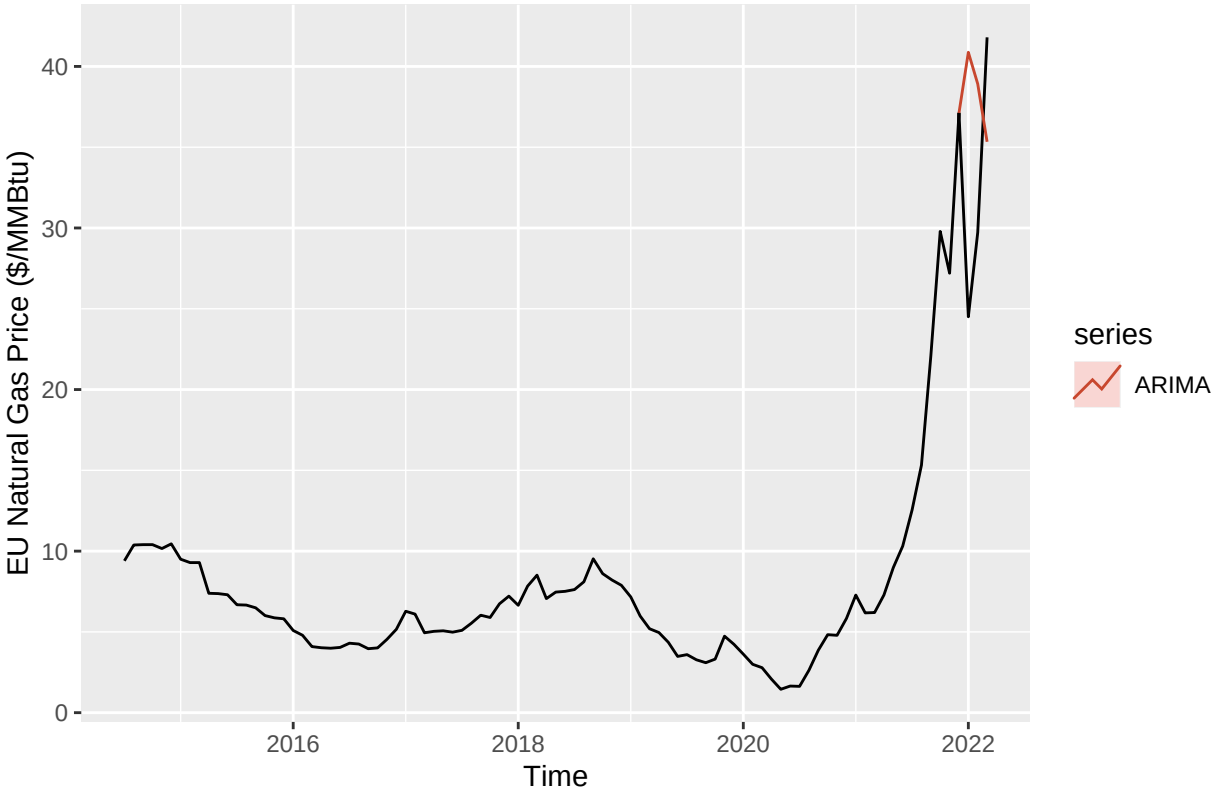

Forecasts from TBATS(0.099, {0,0}, 1, {<12,1>})
EU Natural Gas Price ($/MMBtu)
0
20
40
60
2016
2018
2020
2022
Time


EU Natural Gas Price ($/MMBtu)
40
20
0
2016
2018
2020
2022
Time
series
TBATS

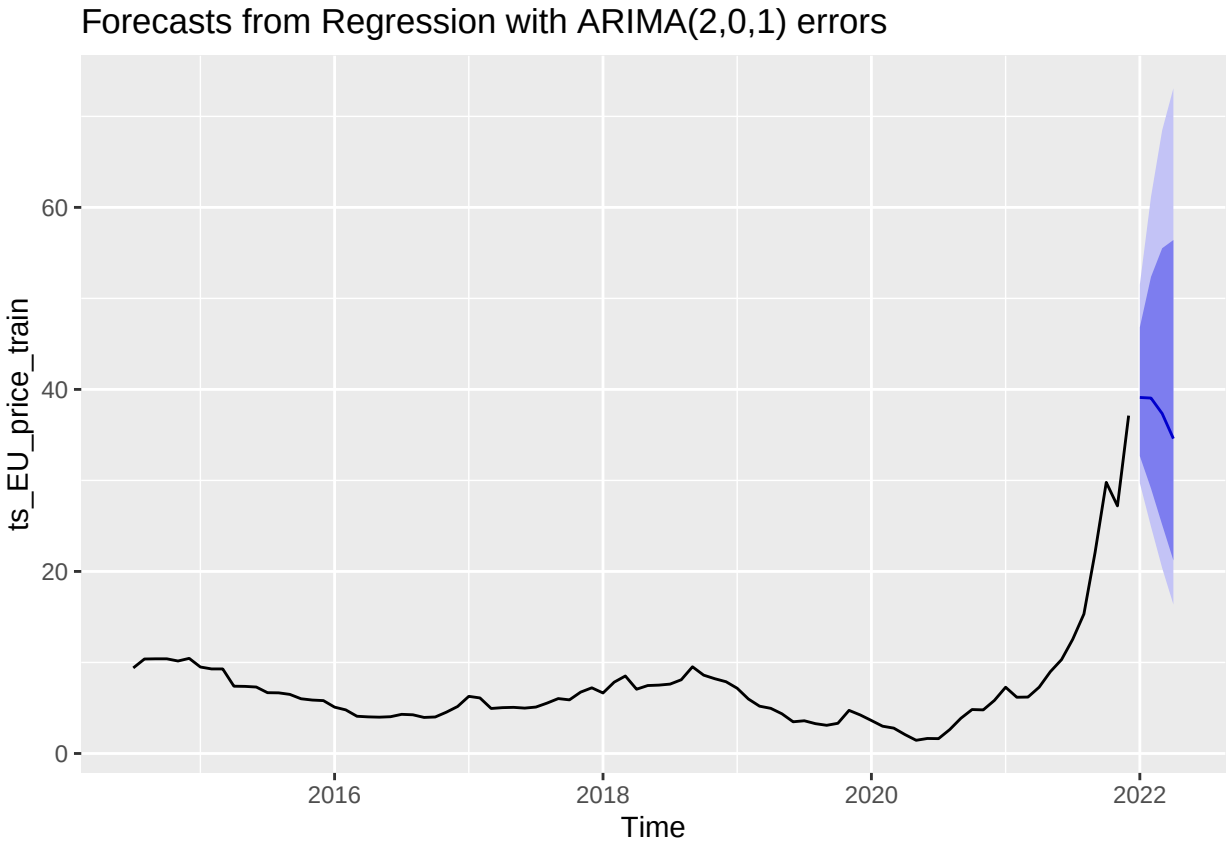


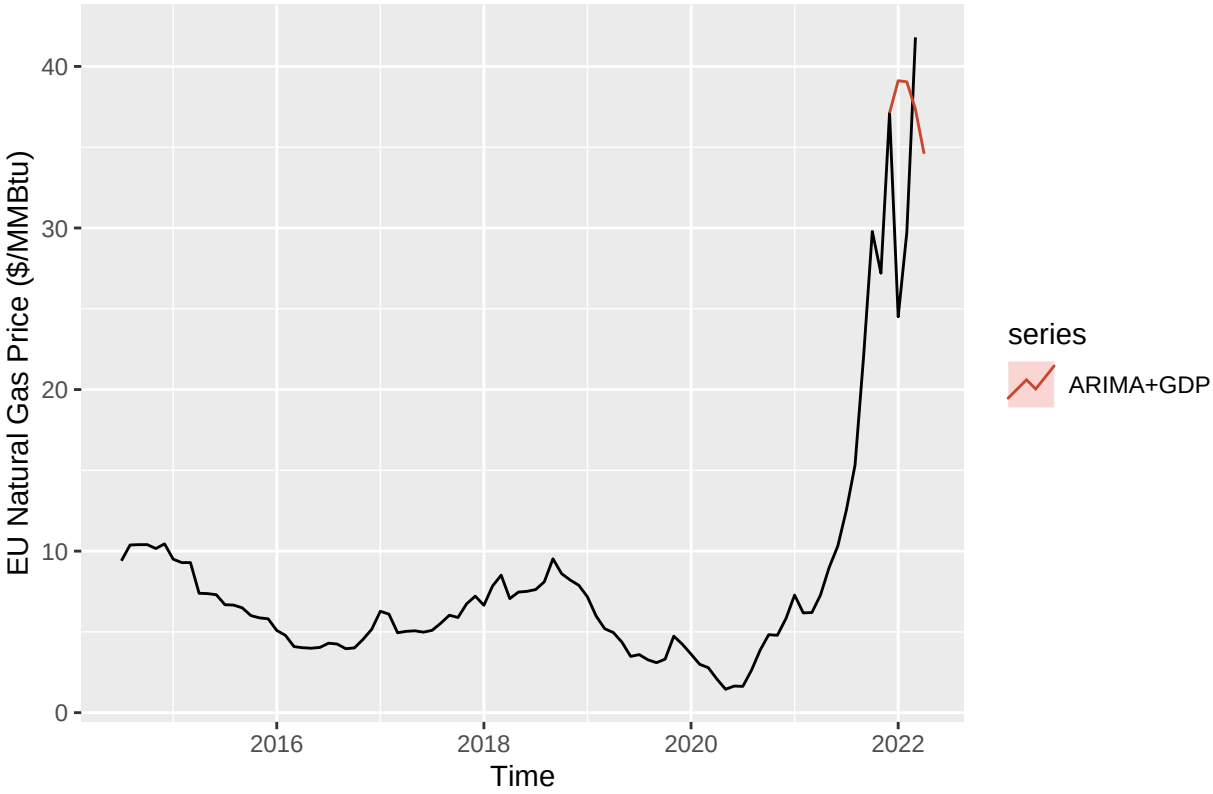

```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(1,0,4) with non-zero mean
## Q* = 14.671, df = 12, p-value = 0.2599
##
## Model df: 6.   Total lags used: 18
```

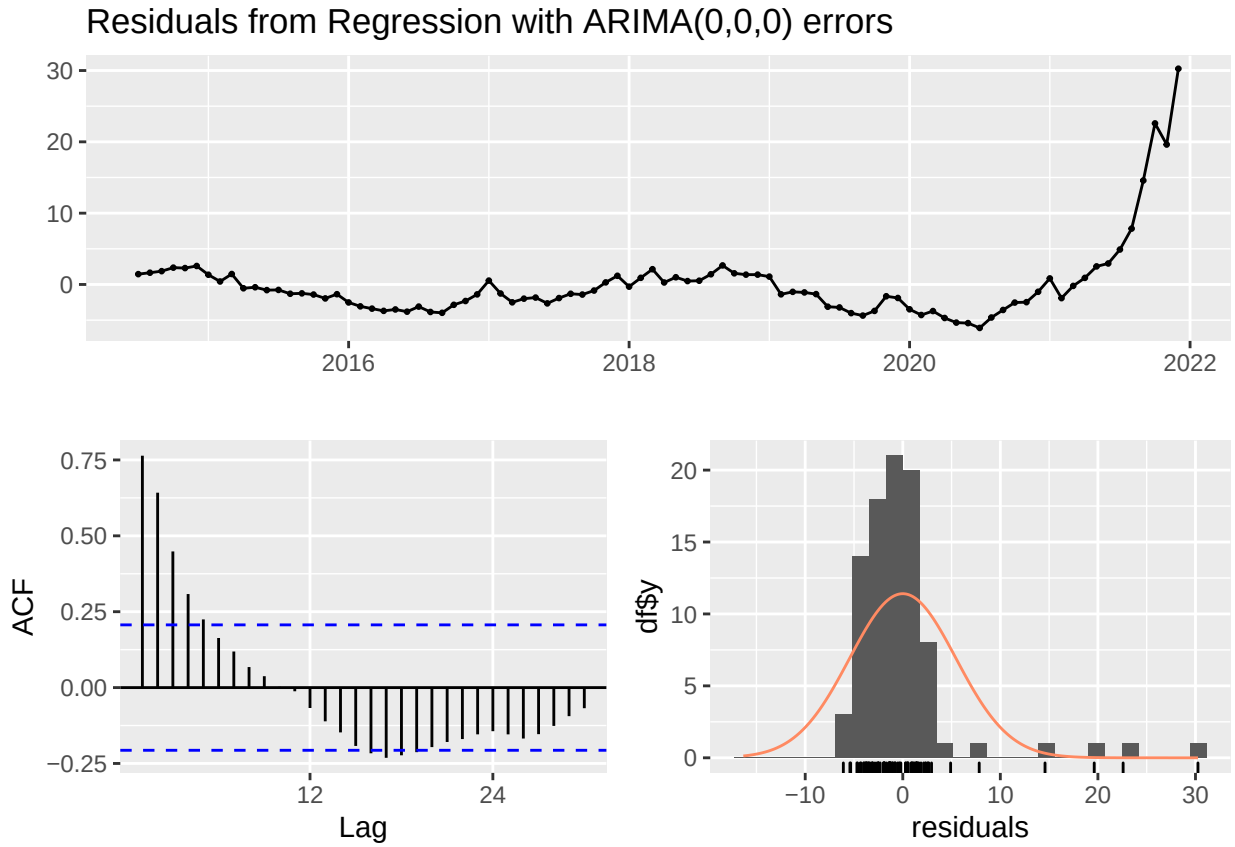

Forecasts from ARIMA(1,0,4) with non−zero mean
EU Natural Gas Price ($/MMBtu)
60
40
20
0
2016
2018
2020
2022
Time



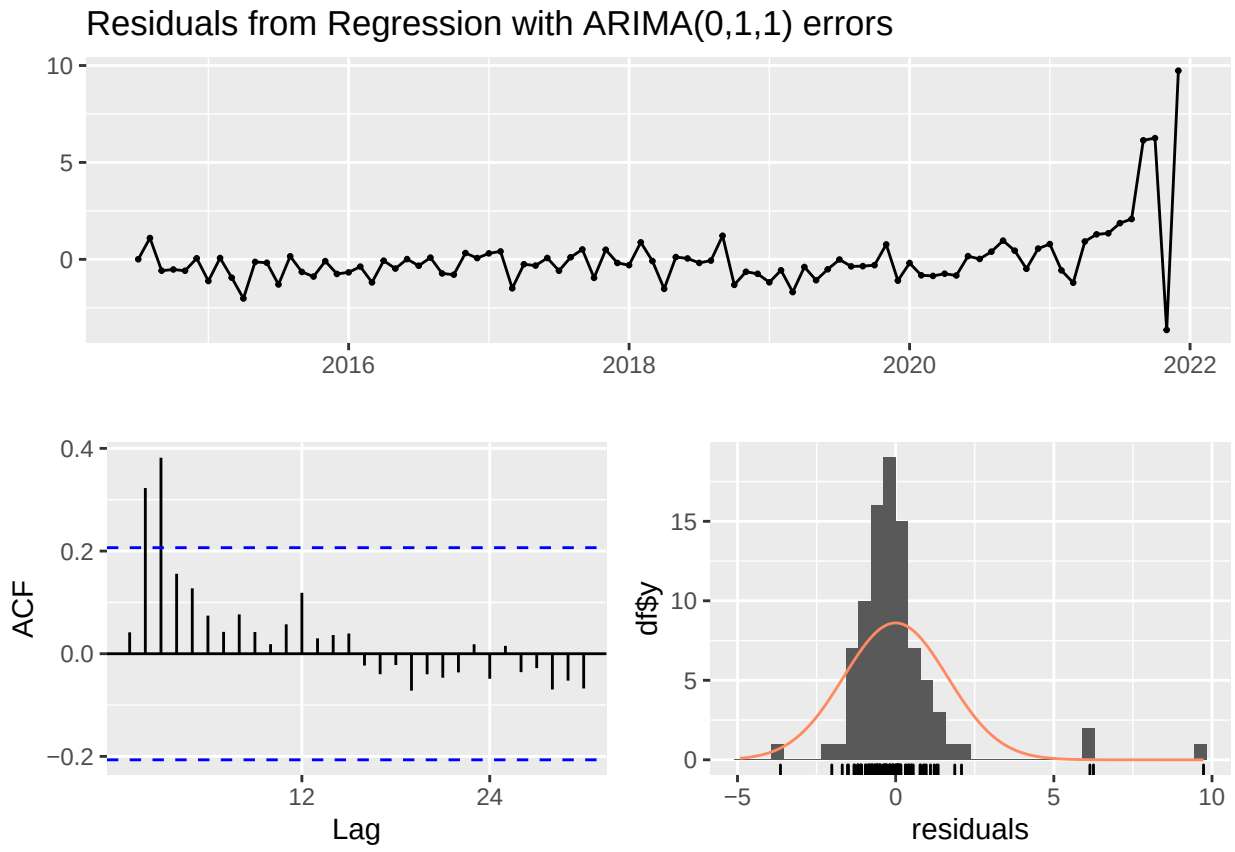
The residual from the ARIMA(1,0,4) appears to be white noise with a mean around zero and no clear trend observed. The residuals are normally distributed, and all ACF values are within the intervals (i.e. insignificant).


Forecasts from Regression with ARIMA(2,0,1) errors
ts_EU_price_train
60
40
20
0
2016
2018
2020
2022
Time

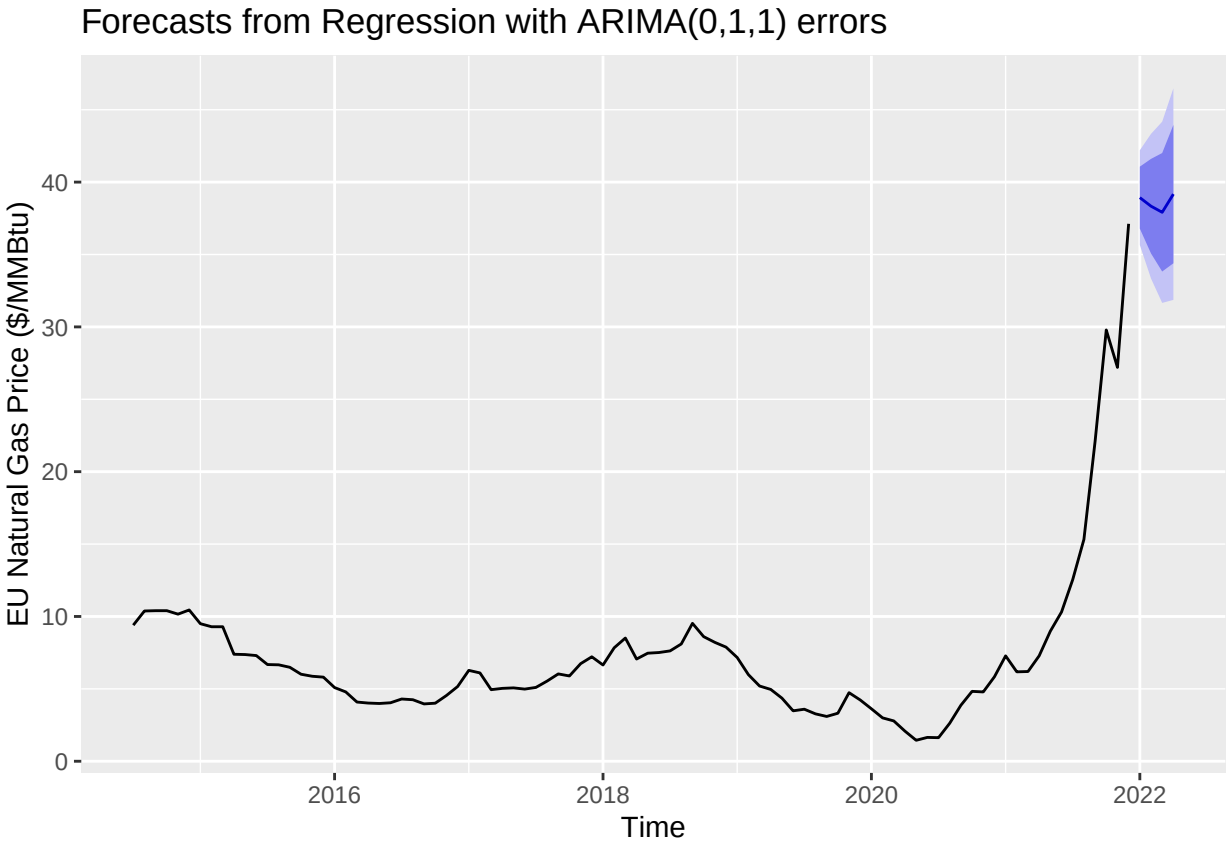

EU Natural Gas Price ($/MMBtu)
40
30
20
10
0
2016
2018
2020
2022
Time
series
ARIMA+GDP

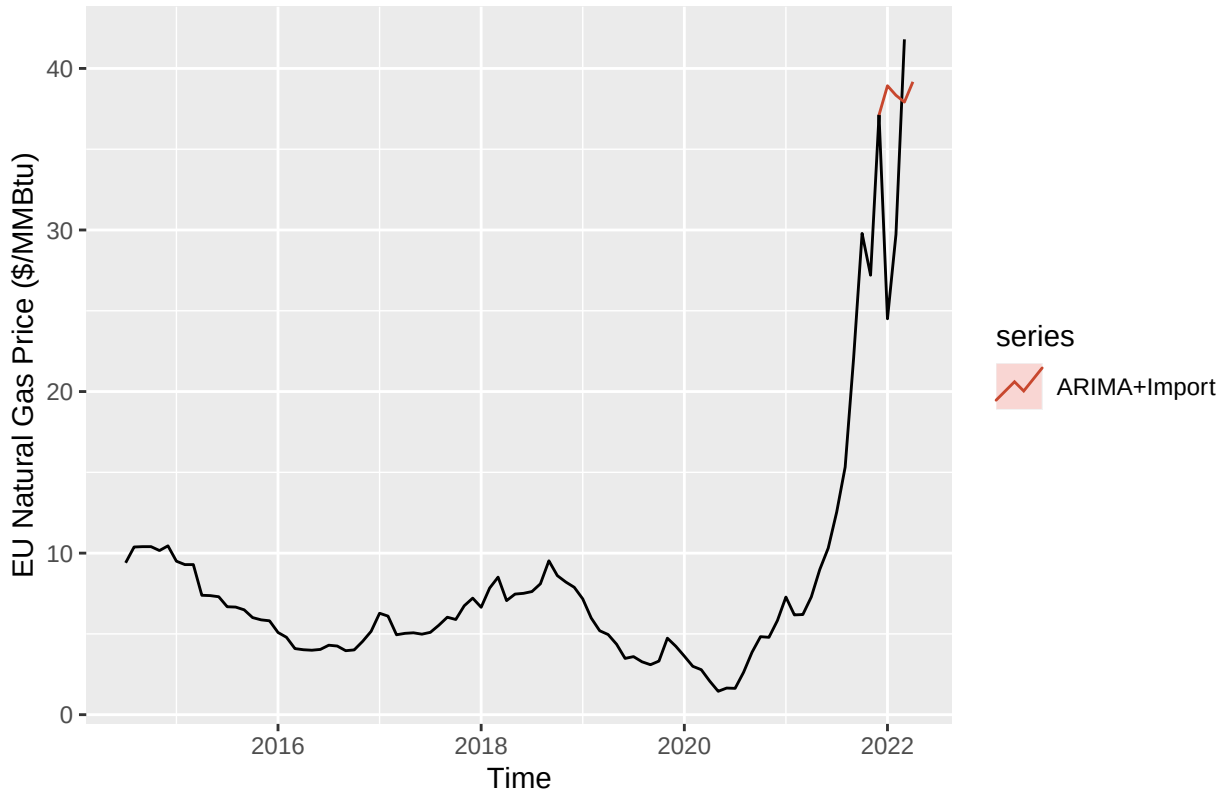



```
##
##  Ljung-Box test
##
## data:  Residuals from Regression with ARIMA(0,0,0) errors
## Q* = 156.27, df = 16, p-value < 2.2e-16
##
## Model df: 2.   Total lags used: 18
```

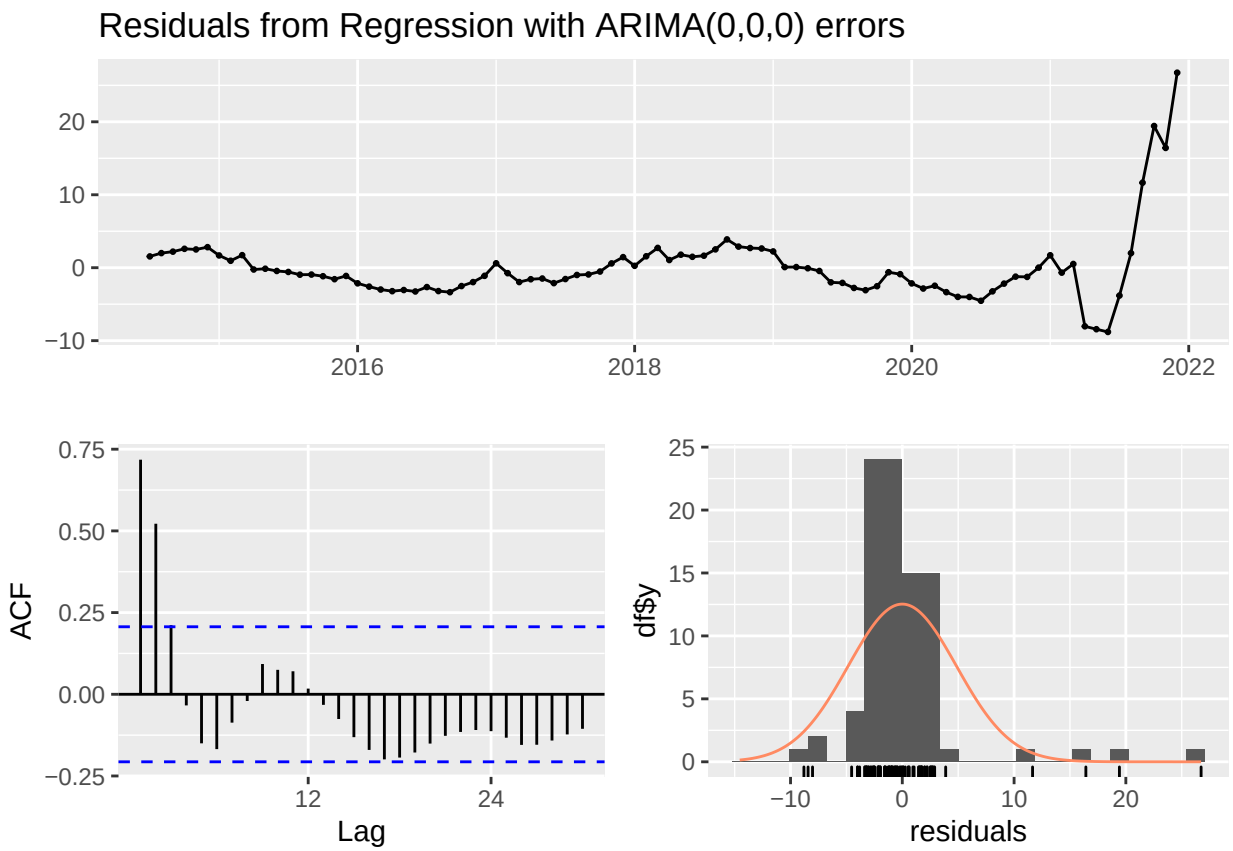



```
##
##  Ljung-Box test
##
## data:  Residuals from Regression with ARIMA(0,1,1) errors
## Q* = 31.831, df = 15, p-value = 0.006789
##
## Model df: 3.   Total lags used: 18
```


Forecasts from Regression with ARIMA(0,1,1) errors
EU Natural Gas Price ($/MMBtu)
0
10
20
30
40
2016
2018
2020
2022
Time

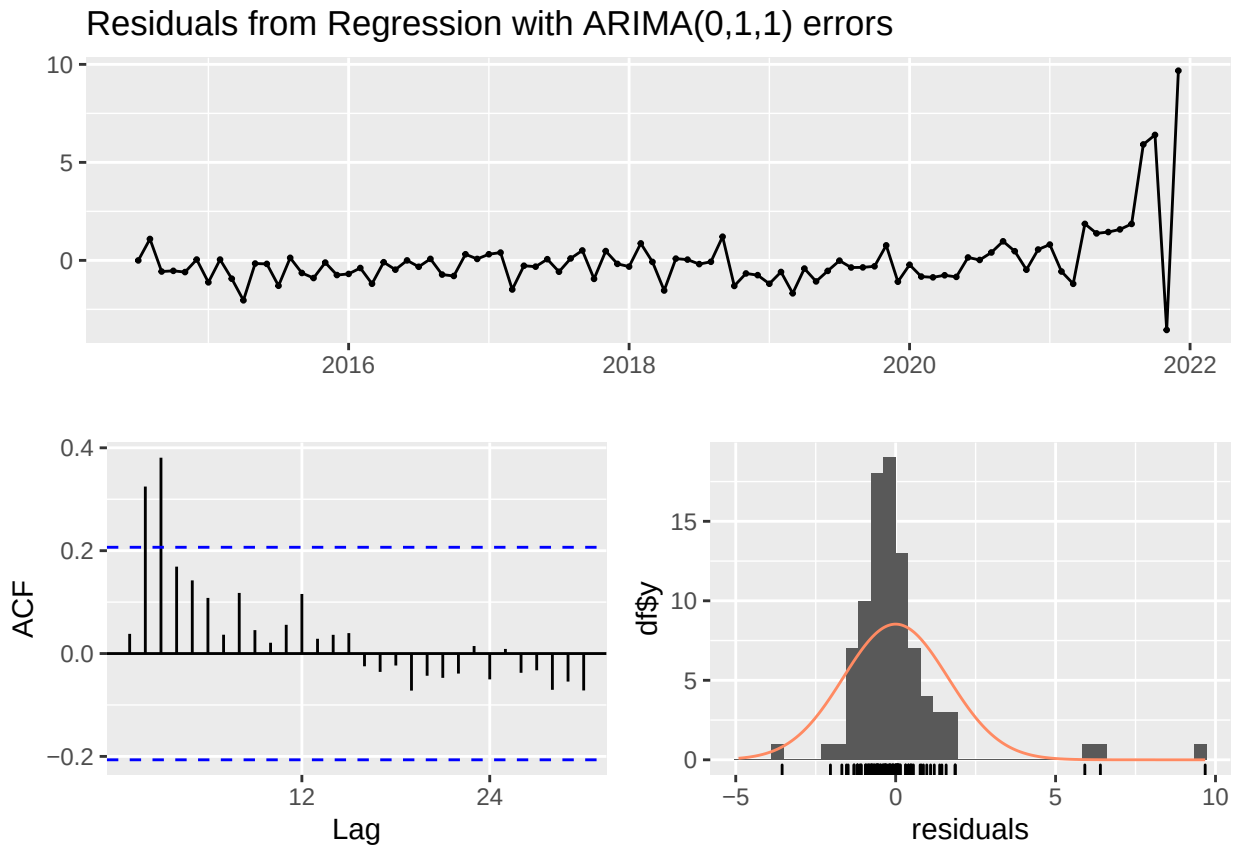


When fitting the training set with import as a regressor, the result is ARIMA (0,0,0), which means the series is white noise. However, when checking the residuals, a clear pattern in ACF is observed, and residuals are not normally distributed. An ARIMA (0,1,1) was manually fitted and gave a better residual result (residuals around zero and show no clear trend). Thus, ARIMA (0,1,1) was used to forecast NG price from 2022/01 to



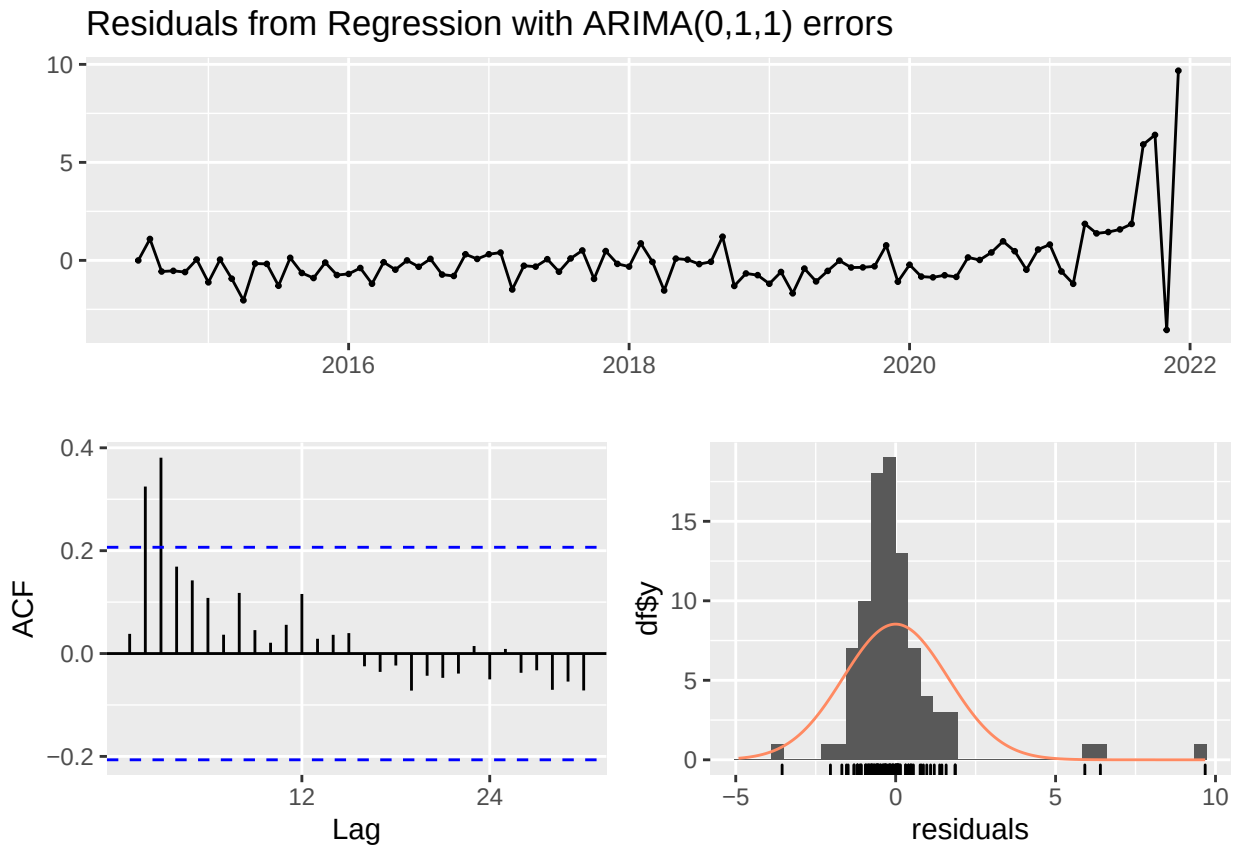
2022/03.

```
##
##  Ljung-Box test
##
## data:  Residuals from Regression with ARIMA(0,0,0) errors
## Q* = 100.41, df = 15, p-value = 1.088e-14
##
## Model df: 3.   Total lags used: 18
```

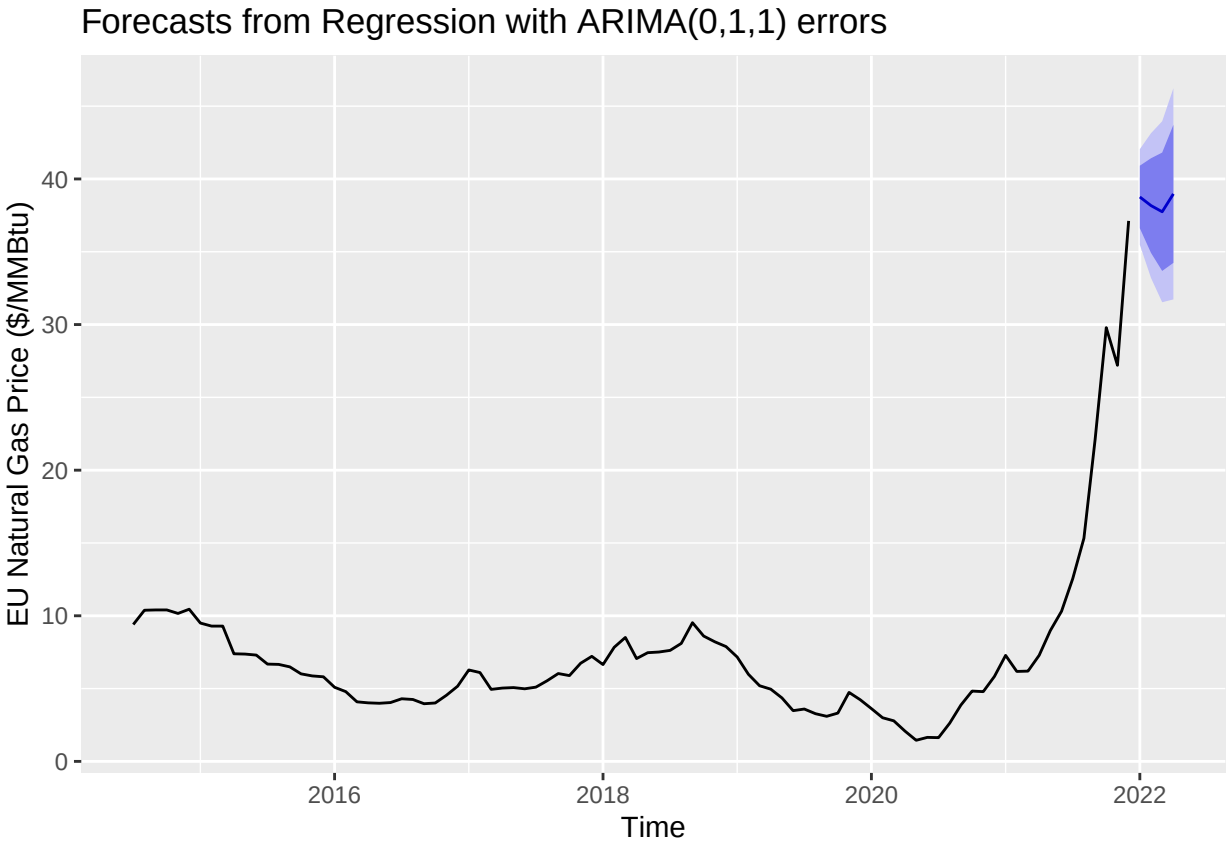


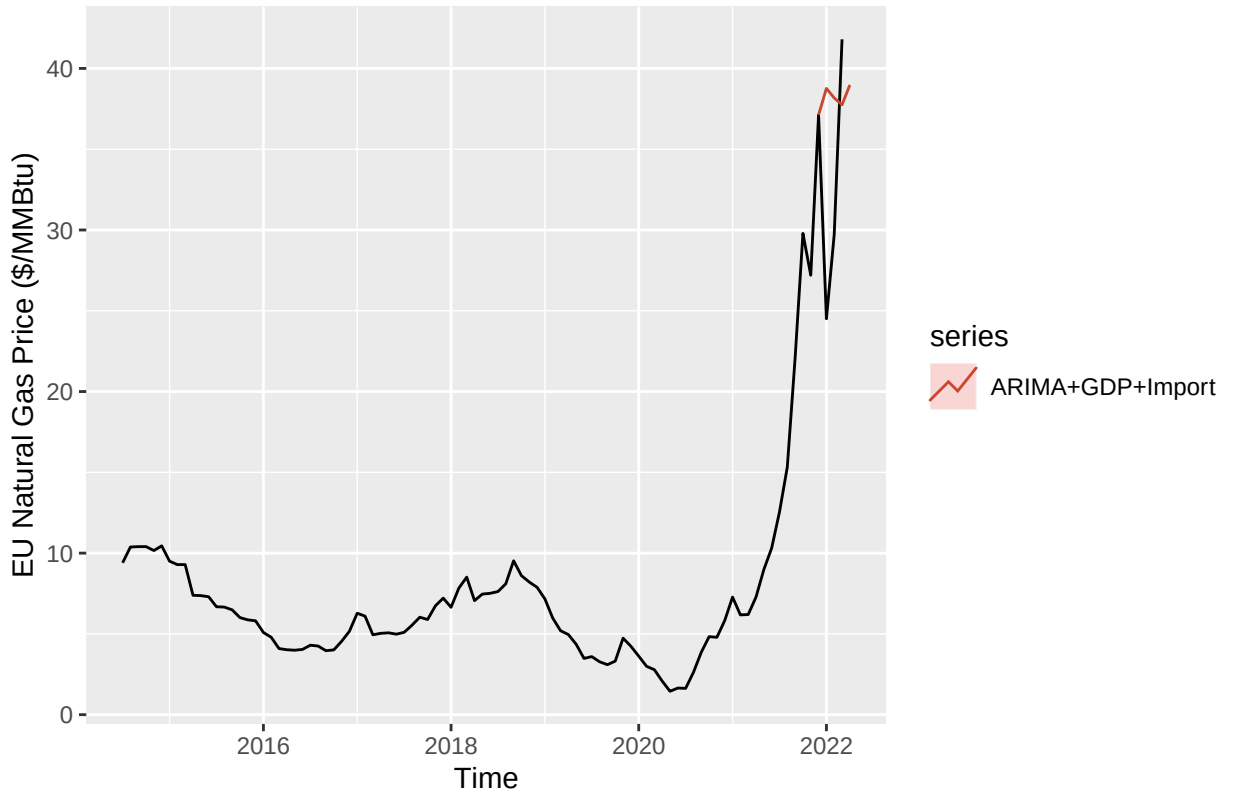

```
##
##  Ljung-Box test
##
## data:  Residuals from Regression with ARIMA(0,1,1) errors
## Q* = 33.952, df = 14, p-value = 0.002096
##
## Model df: 4.   Total lags used: 18

## Warning in forecast.forecast_ARIMA(ARIMA_fit_withImportandGDP, xreg =
## cbind(ts_EU_import_test, : xreg contains different column names from the xreg
## used in training. Please check that the regressors are in the same order.
```




```
##
##  Ljung-Box test
##
## data:  Residuals from Regression with ARIMA(0,1,1) errors
## Q* = 33.952, df = 14, p-value = 0.002096
##
## Model df: 4.   Total lags used: 18
```


Forecasts from Regression with ARIMA(0,1,1) errors
EU Natural Gas Price ($/MMBtu)
0
10
20
30
40
2016
2018
2020
2022
Time



A similar situation happened when we autofit NG price training set with both import and GDP as regressors. Thus, we also manually fit an ARIMA (0,1,1) and used it to forecast NG price from 2022/01 to 2022/03.

```
## The best model by RMSE is: STL+ETS
```

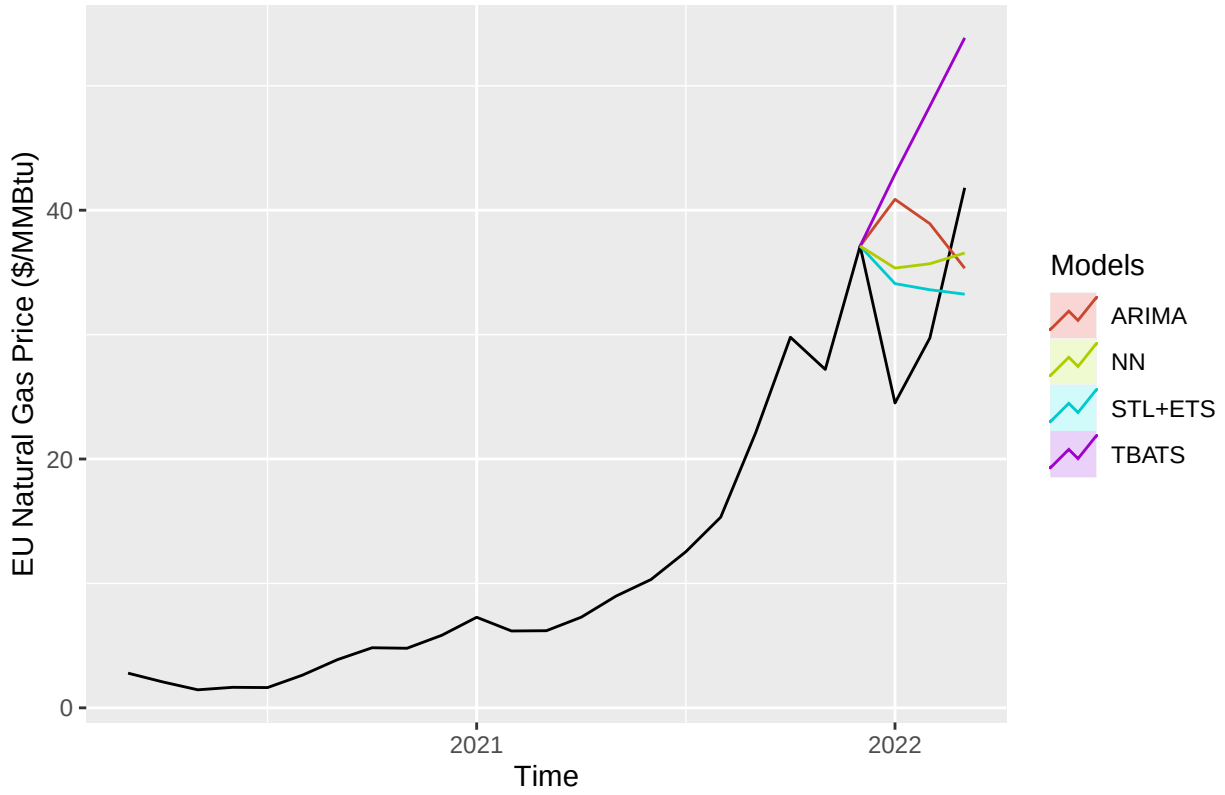
Table 4: Forecast Accuracy for EU NG Price

	ME	RMSE	MAE	MPE	MAPE	ACF1	Theil's U
STL+ETS	-1.64152	7.75066	7.34184	-10.58410	24.22103	-0.02914	0.71586
ARIMA	-6.36534	11.46380	10.67543	-27.41896	37.73004	-0.02928	0.94519
TBATS	-16.36282	16.64441	16.36282	-55.53750	55.53750	-0.18540	1.87892
NN	-3.85824	7.76115	7.35176	-17.26777	25.62537	-0.03281	0.65565
ARIMA+GDP	-6.49303	10.33134	9.46206	-26.77667	33.87950	-0.04130	0.89128
ARIMA+Import	-6.38398	9.95491	8.97348	-26.18050	32.37539	-0.02838	0.81747
ARIMA+Import+GDP	-6.21720	9.85005	8.91934	-25.63472	32.09908	-0.02838	0.80810
NN+Import	-3.39198	8.14347	7.78853	-16.20111	26.71901	-0.03135	0.69836
NN+GDP	0.61816	7.86677	6.58699	-3.39698	20.63393	-0.00919	0.79498
NN+GDP+Import	-3.34505	9.33338	8.63943	-16.99620	29.66200	-0.00813	0.71727

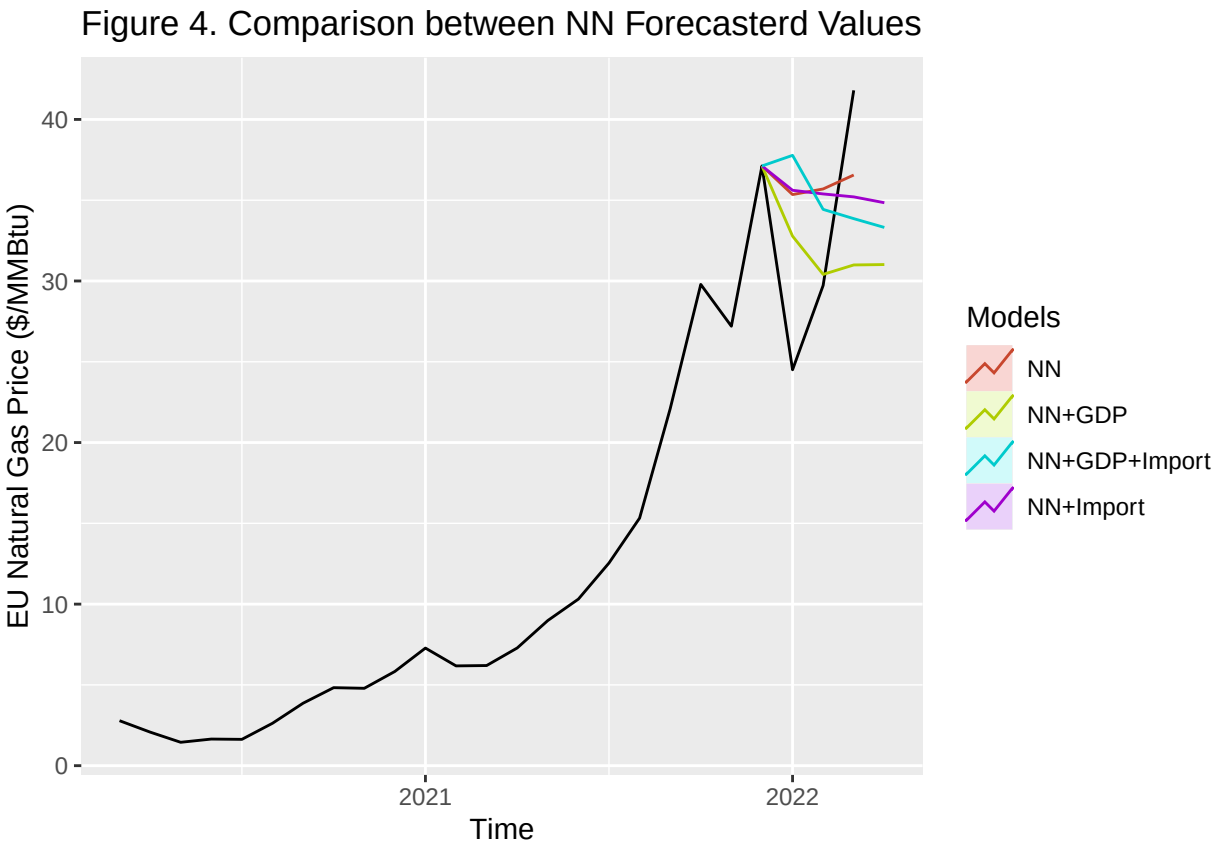
According to the table, the model with the lowest RMSE score is NN purely dependent on historical NG price, the second-best model is STL+ETS, followed by ARIMA+Import+GDP. Thus, we choose NN as the model to fit the forecast for 2022. It is noteworthy that our choice of the test set is uncommon, because we expect NG prices to follow different trends after the Ukraine crisis. Thus, this result only applies to our data set which undergoes a huge increase and lots of fluctuations. The effect of exogenous variables depends

on different models. For example, among all ARIMA models, the best one is ARIMA with both GDP and Import, but among all NN models, the NN without any exogenous variable gives the lowest RMSE score.

Figure 3. Comparison between Observed Data and Forecasted Values

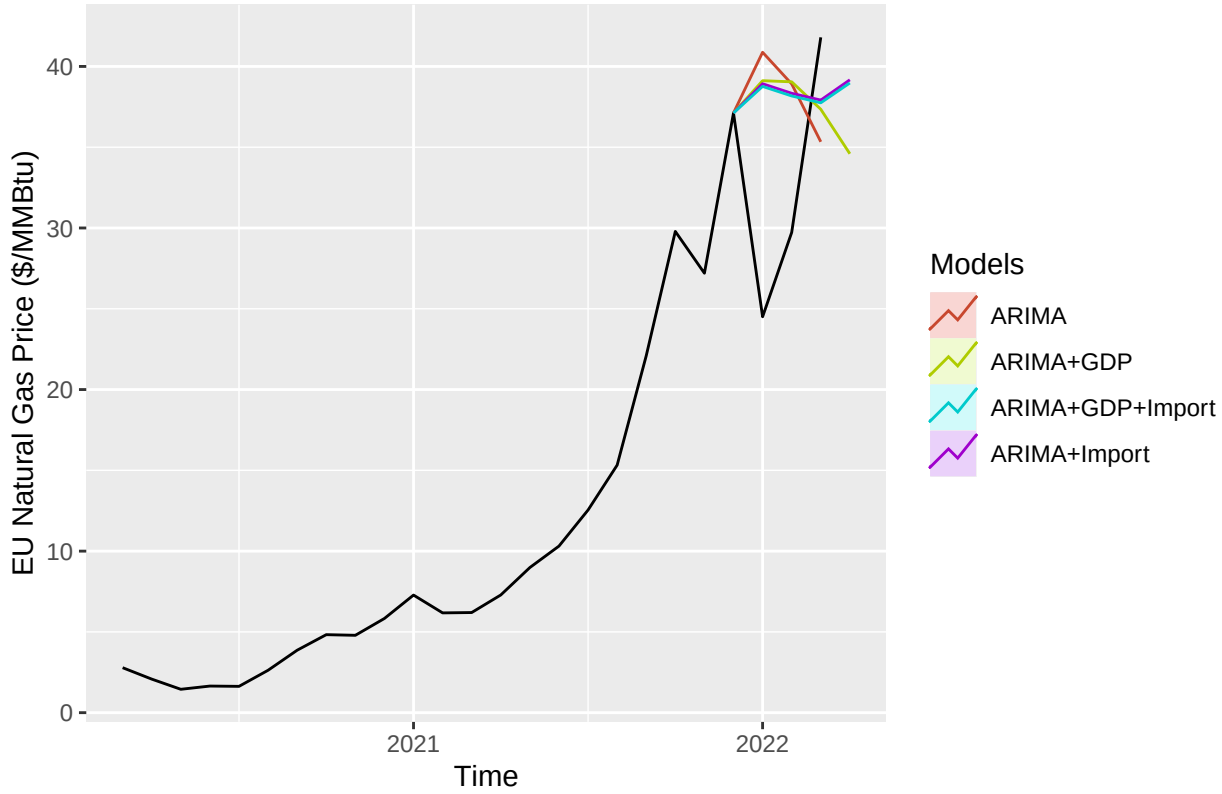


To better analyze the differences between different models, forecasts without exogenous variables are plotted and analyzed separately below. This graph only shows a comparison between observed data and the forecasts based on the NG historical price training set. TBATS performed well in following the trend observed recently, but it failed to integrate the fluctuations, thus receiving the highest RMSE score. NN and STL+ETS forecasted the same price in January, while NN and ARIMA forecasted the same price in March.



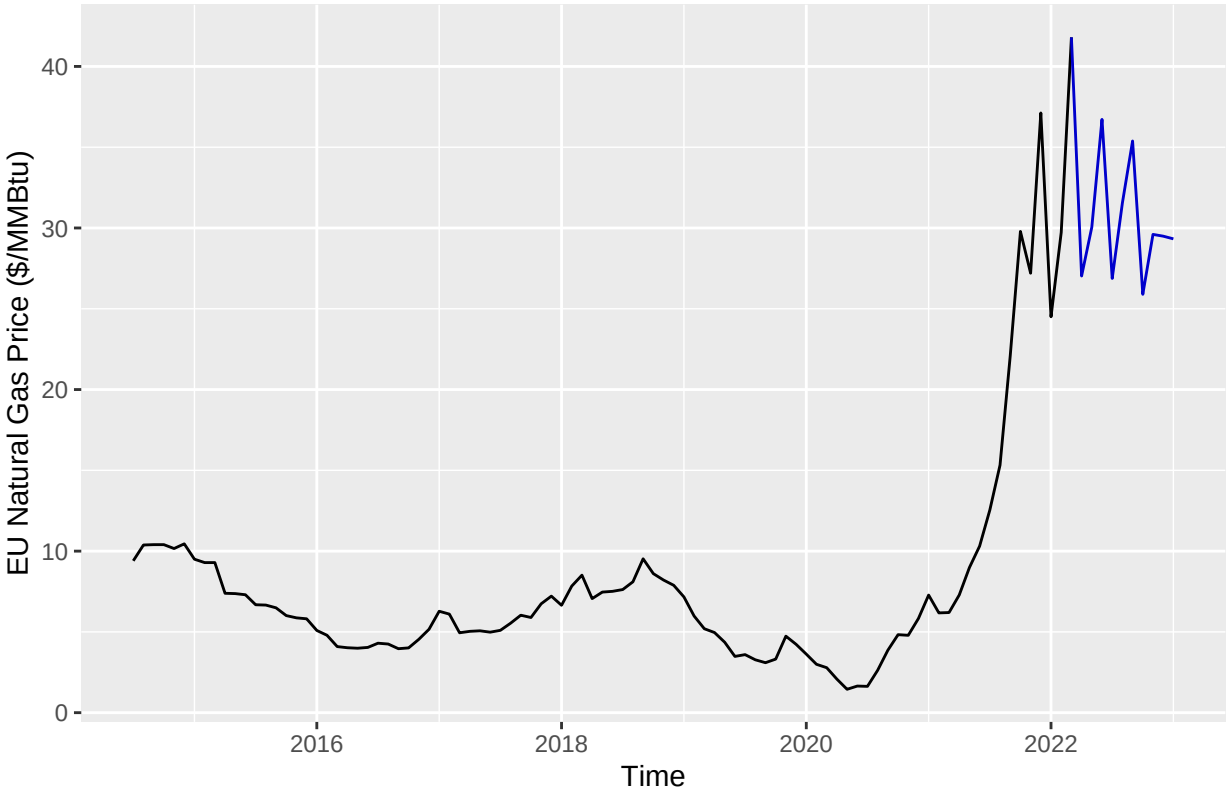
Among NN models results, both NN with import as a regressor and NN with both import and GDP forecast an increase in natural gas price in January 2022 and then a significant decrease in February 2022, while NN and NN with GDP forecast a decrease in January. Overall, there is a significant overlap between NN+GDP+Import and NN+import forecasts, which indicates that import has a greater impact on the forecast results. Compared to the original NN, the integration of import data increases the fluctuation of the forecast results, while GDP only brings up the level of forecast slightly and keeps the fluctuation similar as before (Figure 4).

Figure 5. Comparison between ARIMA Forecasterd Values



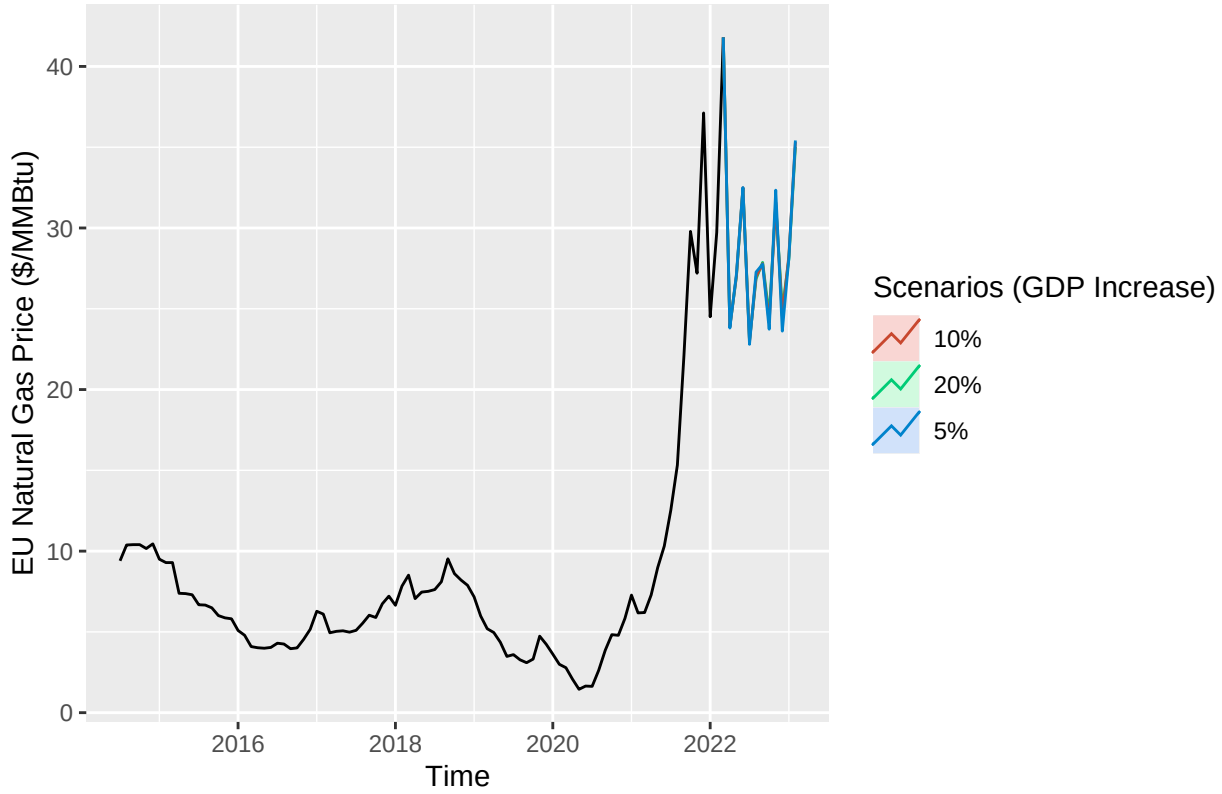
Among ARIMA models results, all four models show an increase trend in January, and then a decrease trend in February. Compared to the ARIMA model without exogenous variables, GDP as a regressor doesn't change the overall trend of the forecast, while import shows a larger impact on the forecast result When both GDP and import data are added into the ARIMA model, the forecast almost overlaps with the one from ARIMA+import, which indicates that import has a greater impact onto the forecast result compared to GDP (Figure 5).

Figure 6. Forecasted EU NG Price with NN Model



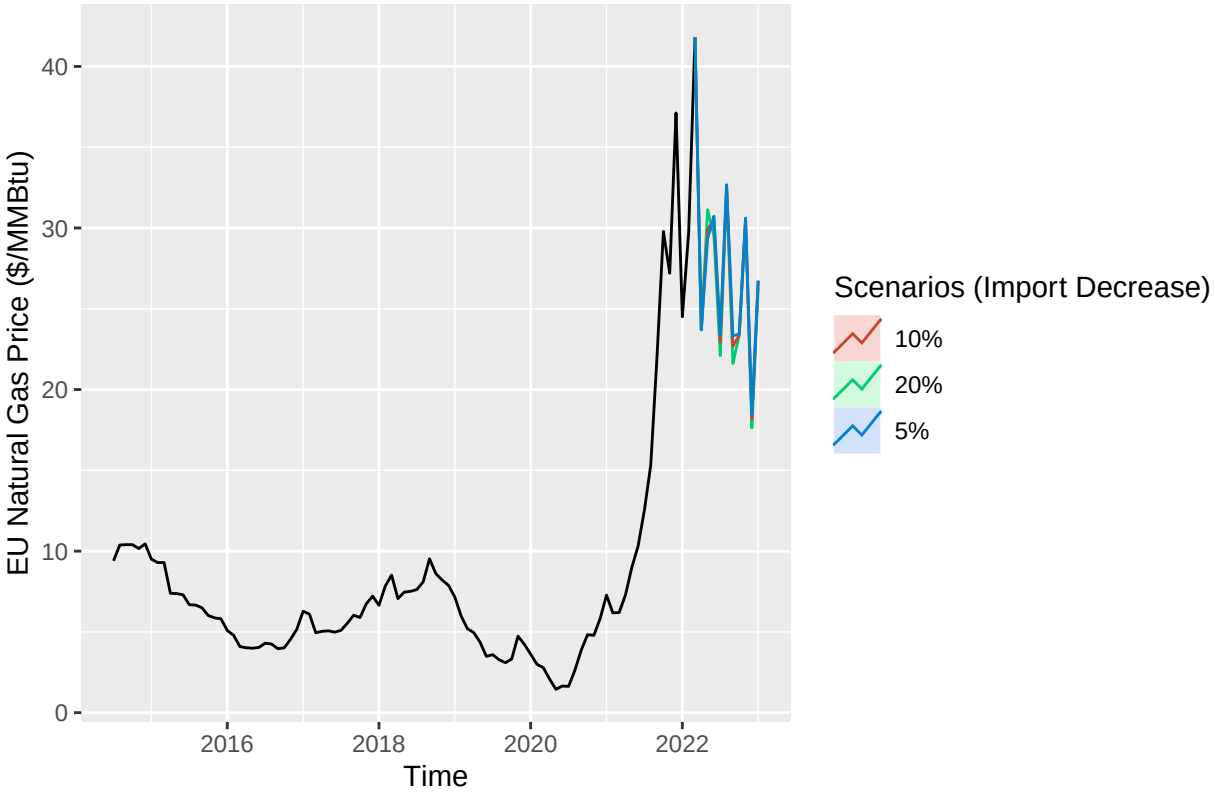
According to the best-performed model, which is NN purely dependent on NG historical price, the forecast results show that EU NG price will fluctuate a lot throughout the year with an overall decreasing trend. The peak is forecasted to be in March 2022, and the price will fall back to 28 $/MMBtu at the end of the year (Figure 6).

Figure 7. EU NG Price Forecast with NN under GDP scenarios



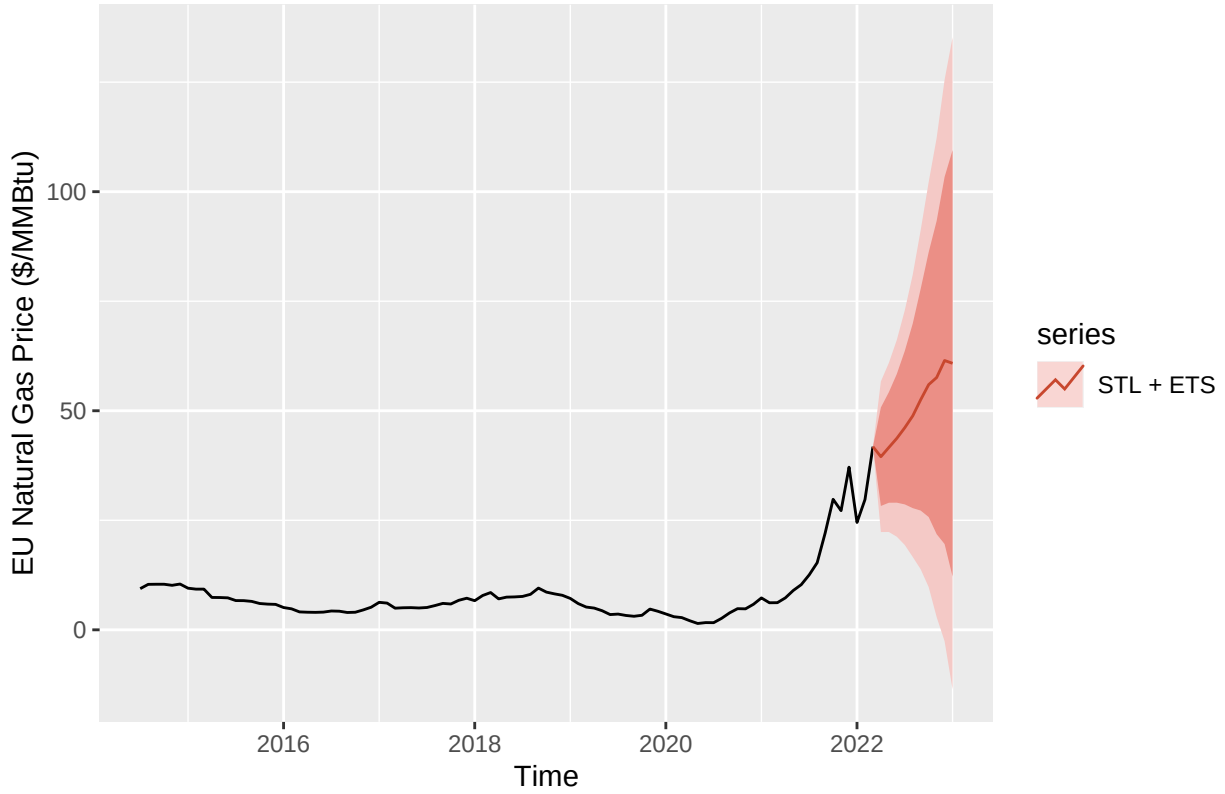
NN with GDP as a regressor shows a similar pattern compared to the original NN model, the peak is still forecasted to happen in March 2022, but overall the integration of GDP drives up the level of the price forecast to 35 $/MMBtu at the end of the year. Three GDP scenarios don't lead to any significant effect on the forecast results (Figure 7).

Figure 8. EU NG Price Forecast with NN under Import Scenarios



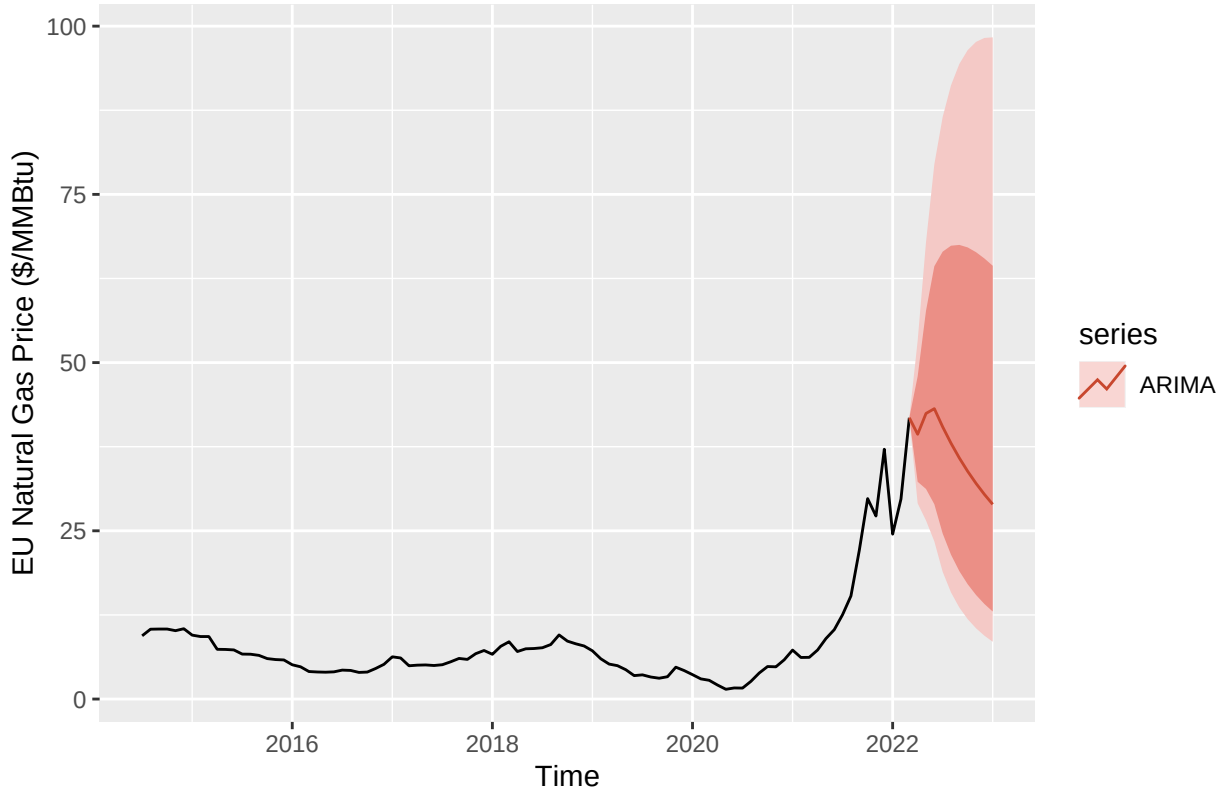
NN with import as a regressor forecasts a more significant decreasing trend of NG price over 2022, even though at the end of the year, the price is forecasted to be 30 $/MMBtu (similar to previous NN models). The lowest price forecast reaches almost 20 $/MMBtu. There is no significant difference between the three proposed import scenarios (Figure 8).

Figure 9. EU NG Price Forecast Result Using STL+ETS



Because our historical data shows a significant increase since 2021, we expect the forecast in 2022 to have a high uncertainty. This is proved by our second-best model: STL_ETS. The forecast results show an overall increasing trend reaching an NG price of around 60 $/MMBtu until the end of the year. There is also a wide confidence interval ranging from negative NG price value to higher than 150 $/MMBtu (Figure 9).

Figure 10. EU NG Price Forecast Result Using ARIMA

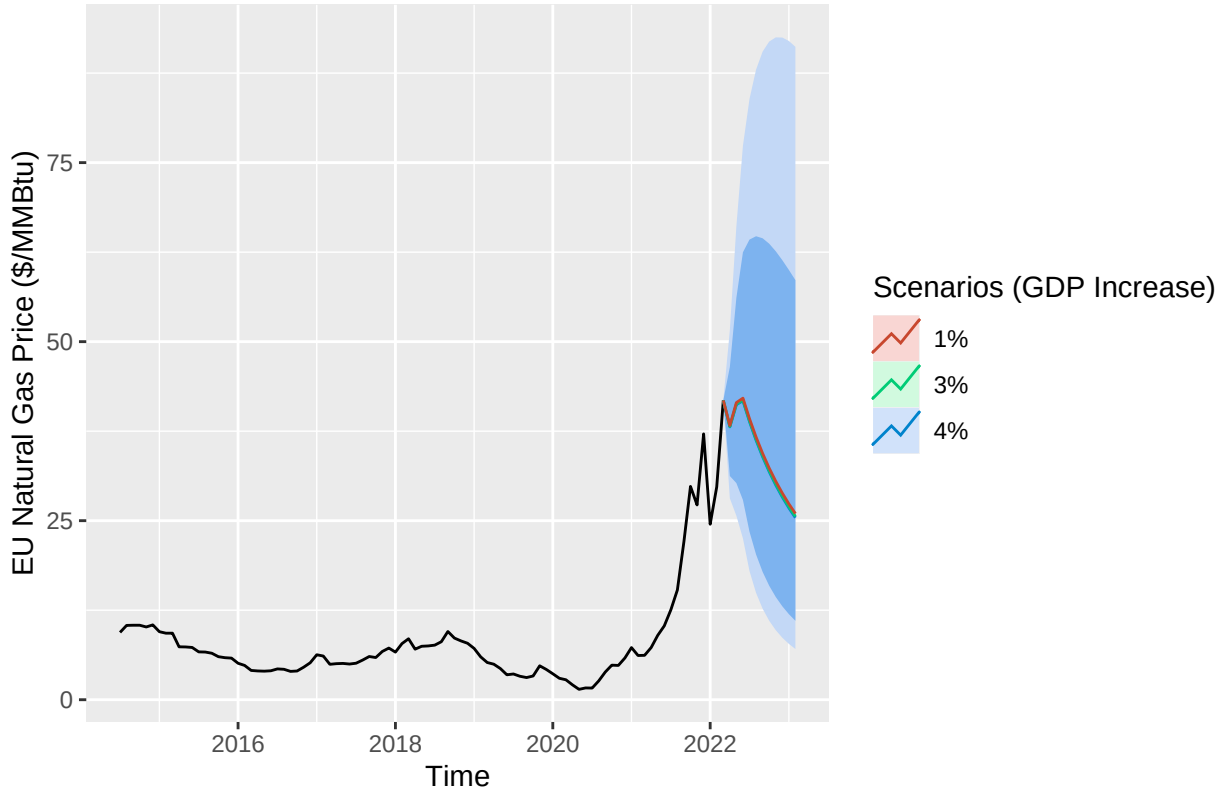


To have a sense of how the integration of exogenous variables affects the confidence interval change, we conducted a forecast using ARIMA models, even though their RMSE score is not as good as NN or STL+ETS.In contrast to the STL+ETS result, the ARIM forecast shows a peak in NG price around mid 2022, and a drop to around 30 $/MMBtu at the end of the year. However, the confidence interval is still wide with a range from 10 to almost 100 $/MMBtu (Figure 10).

```
ARIMA_Four_fit_withGDP_202212 <- auto.arima(ts_EU_price_shorten_201407_202203,
                              seasonal=FALSE,
                              lambda=0,
                              xreg=ts_EU_GDP_201407_202203
                              )
ARIMA_Four_for_withGDP1_202212 <- forecast::forecast(ARIMA_Four_fit_withGDP_202212,
                            xreg=ts_EU_GDP1_202203_202301,
                            h=9
                            )
ARIMA_Four_for_withGDP2_202212 <- forecast::forecast(ARIMA_Four_fit_withGDP_202212,
                            xreg=ts_EU_GDP2_202203_202301,
                            h=9
                            )
ARIMA_Four_for_withGDP3_202212 <- forecast::forecast(ARIMA_Four_fit_withGDP_202212,
                            xreg=ts_EU_GDP3_202203_202301,
                            h=9
                            )
autoplot(ts_EU_price_shorten_201407_202203, main="Figure 11. EU NG Price Forecast Results
↪  under 3 GDP Scenarios") +
  autolayer(ARIMA_Four_for_withGDP1_202212, series="4%",showgap=F) +
  autolayer(ARIMA_Four_for_withGDP2_202212, series="3% ",PI=FALSE,showgap=F) +
```

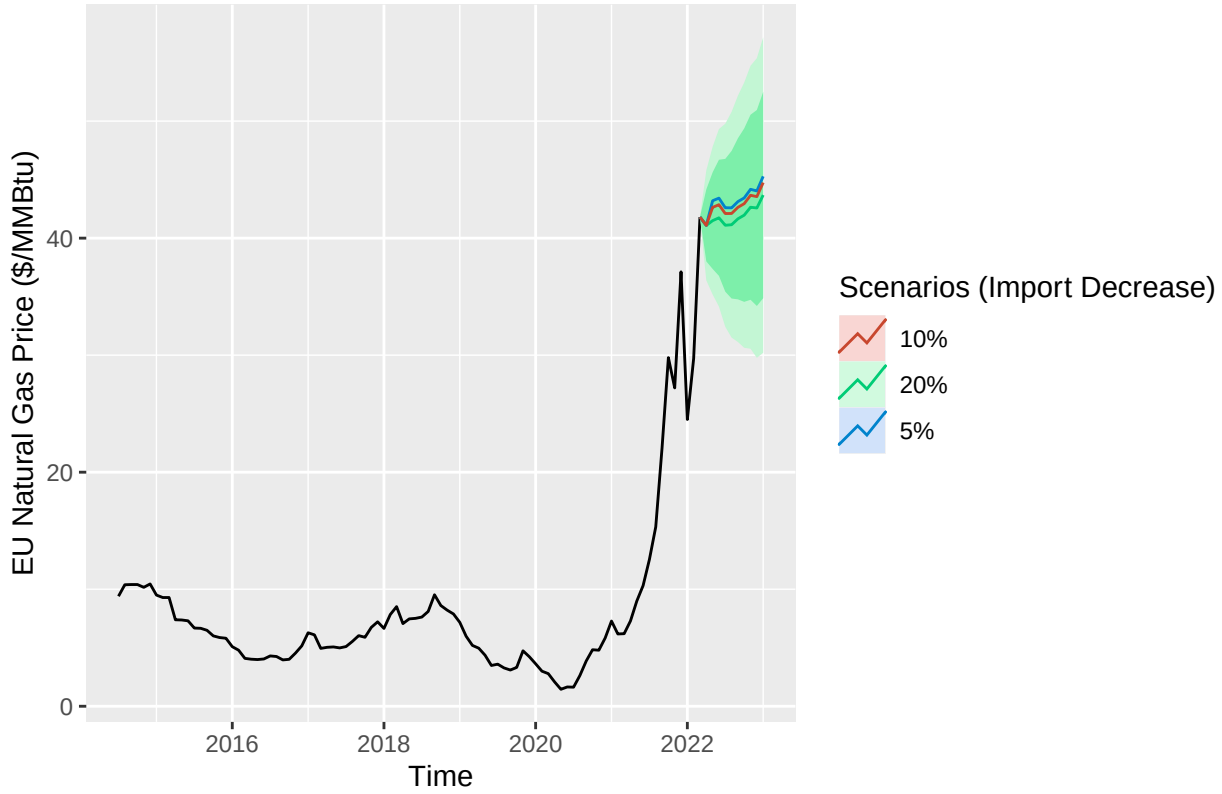
```
autolayer(ARIMA_Four_for_withGDP3_202212, series="1%",PI=FALSE,showgap=F)+
guides(colour=guide_legend(title="Scenarios (GDP Increase)"))+
ylab("EU Natural Gas Price ($/MMBtu)")
```

Figure 11. EU NG Price Forecast Results under 3 GDP Scenarios



The ARIMA model with GDP as a regressor shows a similar trend, leading to a slightly lower price forecast at the end of the year ($25/MMbtu) than the original ARIMA model ($30/MMBtu), and the forecast is still with high uncertainty (i.e. wide confidence interval). There are no significant forecast differences under the three scenarios we proposed, and neither of the three scenarios causes a significant change in the forecast result compared to the original ARIMA model (Figure 11).

Figure 12. EU NG Price Forecast Results under 3 Import Scenarios



ARIMA models with import as a regressor show completely different results than the previous models. There are much smaller fluctuations and the overall trend is going upward, leading to an NG price forecast at around 45 $/MMBtu at the end of 2022. The much narrower confidence interval indicates that the integration of import data improves the uncertainty of the price forecast. Three import scenarios lead to similar trends but slightly off level of forecasts. Import decrease by 5% returns the highest NG price forecast, while import decreased by 20% returns the lowest NG price forecast (Figure 12). Even though historical import and NG price data are negatively correlated, we found that the scenario with the lowest import decrease (5%) leads to the lowest NG price forecast, and the highest import decrease (20%) leads to the highest NG price forecast (Figure x). This indicates that in highly fluctuated time series, the already weak correlation between two variables might be polluted, thus the forecast results might not show the same correlation relationship shown in the historical data.

Conclusion Our project allows us to test the hypothesis at the beginning of our project: 1) Indeed, forecasting in a period of high uncertainty is a difficult exercise, even just forecasting 3 data points. In the test data, compared to Dec 2021, NG price decreased significantly in Jan 2022, increased in Feb 2022, and continued to increase in march 2022. Only two models predicted this general fluctuation correctly: NN and STL+ETS. However, even these two models misrepresented the magnitude of this fluctuation. The models' RMSE ranges from 7 to 16, confirming that predicting in a period with high volatility is difficult. 2) As expected, the Neural network with the lowest RMSE score at 7.54, turned out to be the best-performed model among all models in capturing the nonlinear trend in our time series. 3) Adding exogenous variables doesn't necessarily lead to an improvement in model performance. From our results, ARIMA models performed better with exogenous variables, while NN models performed worse with exogenous variables. Interestingly, we found that some exogenous variables can improve the certainty of the forecast while others cannot. For example, adding import data into the ARIMA model greatly narrowed the confidence level while adding GDP led to a slight shift in confidence interval but the width keeps the same. In conclusion, adding exogenous variables does not necessarily decreases the RMSE score, but may improve the certainty of the forecast. 4) The variable has a stronger correlation with NG price indeed affects the forecast results more,

but it doesn't necessarily improve the forecast performance. In both NN and ARIMA models, import has a greater impact on NG price forecast results. Import data also leads to greater change in RMSE compared to the ARIMA and NN without any exogenous variables but does not necessarily lower the RMSE score.