appendix2

February 3, 2026

[5]:

```python
import pandas as pd
from pandas.tseries.offsets import QuarterEnd
import numpy as np
import statsmodels.api as sm
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
import seaborn as sns
import statsmodels.api as sm
from statsmodels.tsa.vector_ar.vecm import VECM, select_order, select_coint_rank
from statsmodels.tsa.api import VAR
from statsmodels.tsa.stattools import adfuller
from statsmodels.tsa.ardl import ARDL
from sklearn.metrics import mean_squared_error
from sklearn.linear_model import Ridge
import statsmodels.formula.api as smf
from statsmodels.tsa.ardl import ardl_select_order
from datetime import datetime
import re
import io
import os
pd.options.display.max_seq_items = 4000 ## This is only for cosmetics.
```

0.1 Introduction

This is the notebook file to replicate our macroeconometrics approach. This notebook does not contain the `blackmarblepy` application. Source data is from `blackmarblepy` for nightlight, and BPS. If you happens to find any issues, you can find Tim via timothy.ginting@dewanekonomi.go.id

You will see the following sections in this notebook:

1. Real GDP and quarterly night light index (NTL) graph;
2. OLS and residuals;
3. ADF test and Johansen Cointegration test;
4. VECM graph;
5. VAR graph; and
6. ARDL graph.

We do those steps for both quarterly dataset and growth dataset.

0.2 Quarterly Real GDP vs Quarterly NTL.

0.2.1 Dataset

turn on the last line to see the dataframe.

[6]:

```
## Data prep
### Creating data
ntl=pd.read_excel('data/ntl_monthly_avg_2012-2025.xlsx')
gdp=pd.read_excel('data/GDP_YoY_Quarterly_12_25.xlsx')

### Make time index
ntl.Date=pd.to_datetime(ntl['Date'])
ntl['qtr']=ntl['Date'].dt.quarter
ntl['year']=ntl['Date'].dt.year
### Averaging the radiance into quarterly, make it yoy quarterly growth
ntl=ntl.groupby(['year','qtr'])['NTL_Radiance'].mean().reset_index()
ntl['Date']=pd.date_range(start='2012-01-01', periods=len(ntl), freq='QE')
ntl=ntl[['Date','NTL_Radiance']]
ntl['g']=np.log(gdp['GDP'])
ntl['ntlg']=np.log(ntl['NTL_Radiance'])
#ntl['NTL_Radiancelag'] = ntl['NTL_Radiance'].shift(4)
#ntl['ntlg'] = ((ntl['NTL_Radiance'] - ntl['NTL_Radiancelag']) /␣
 ↪ntl['NTL_Radiancelag']) * 100
### Creating dummy quarterly and dummy covid
ntl['q1']=np.where(ntl['Date'].dt.quarter==1,1,0)
ntl['q2']=np.where(ntl['Date'].dt.quarter==2,1,0)
ntl['q3']=np.where(ntl['Date'].dt.quarter==3,1,0)
ntl['q4']=np.where(ntl['Date'].dt.quarter==4,1,0)
ntl['covid']=np.where((ntl['Date'].dt.year>=2020) & (ntl['Date'].dt.
 ↪year<=2022),1,0)
ntl['scar']=np.where((ntl['Date'].dt.year>=2020) ,1,0)
### Back to making time index
ntl=ntl.dropna().reset_index(drop=True)
ntl=ntl.set_index('Date')
ntl=ntl.asfreq('QE-DEC')
#ntlm=ntlm[['g','ntlg']]
ntlm = ntl.copy()


### Creating dummy quarterly and dummy covid

## OLS-ing
mod=sm.OLS(ntl['g'], sm.add_constant(ntl['ntlg'])).fit()
ntl['resid']=mod.resid
ntl['ols']=mod.predict()
#ntl
```

[7]:

```
ntl
```

[7]:

```
            NTL_Radiance          g      ntlg  q1  q2  q3  q4  covid  scar  \
Date
2012-03-31      0.100662  14.433708 -2.295983   1   0   0   0      0     0
2012-06-30      0.189770  14.472522 -1.661945   0   1   0   0      0     0
2012-09-30      0.201600  14.505469 -1.601472   0   0   1   0      0     0
2012-12-31      0.181741  14.482751 -1.705174   0   0   0   1      0     0
2013-03-31      0.181099  14.487636 -1.708710   1   0   0   0      0     0
2013-06-30      0.234966  14.526899 -1.448315   0   1   0   0      0     0
2013-09-30      0.214179  14.559160 -1.540944   0   0   1   0      0     0
2013-12-31      0.177394  14.537093 -1.729384   0   0   0   1      0     0
2014-03-31      0.198539  14.537529 -1.616770   1   0   0   0      0     0
2014-06-30      0.228889  14.575094 -1.474518   0   1   0   0      0     0
2014-09-30      0.208971  14.607300 -1.565561   0   0   1   0      0     0
2014-12-31      0.227192  14.586337 -1.481961   0   0   0   1      0     0
2015-03-31      0.208106  14.584711 -1.569706   1   0   0   0      0     0
2015-06-30      0.253962  14.621408 -1.370569   0   1   0   0      0     0
2015-09-30      0.278351  14.653988 -1.278874   0   0   1   0      0     0
2015-12-31      0.242006  14.636580 -1.418793   0   0   0   1      0     0
2016-03-31      0.227219  14.632962 -1.481841   1   0   0   0      0     0
2016-06-30      0.238701  14.672240 -1.432542   0   1   0   0      0     0
2016-09-30      0.224804  14.703097 -1.492527   0   0   1   0      0     0
2016-12-31      0.177672  14.684788 -1.727814   0   0   0   1      0     0
2017-03-31      0.213267  14.681832 -1.545210   1   0   0   0      0     0
2017-06-30      0.250814  14.721150 -1.383044   0   1   0   0      0     0
2017-09-30      0.234657  14.752504 -1.449632   0   0   1   0      0     0
2017-12-31      0.228167  14.735384 -1.477678   0   0   0   1      0     0
2018-03-31      0.212880  14.731280 -1.547028   1   0   0   0      0     0
2018-06-30      0.275492  14.772503 -1.289198   0   1   0   0      0     0
2018-09-30      0.278985  14.802943 -1.276597   0   0   1   0      0     0
2018-12-31      0.240019  14.785899 -1.427035   0   0   0   1      0     0
2019-03-31      0.268528  14.780660 -1.314800   1   0   0   0      0     0
2019-06-30      0.281646  14.821793 -1.267105   0   1   0   0      0     0
2019-09-30      0.287257  14.851826 -1.247379   0   0   1   0      0     0
2019-12-31      0.287051  14.834267 -1.248097   0   0   0   1      0     0
2020-03-31      0.267930  14.809883 -1.317030   1   0   0   0      1     1
2020-06-30      0.249277  14.767079 -1.389190   0   1   0   0      1     1
2020-09-30      0.244379  14.816319 -1.409034   0   0   1   0      1     1
2020-12-31      0.240803  14.812356 -1.423776   0   0   0   1      1     1
2021-03-31      0.211271  14.802985 -1.554615   1   0   0   0      1     1
2021-06-30      0.277040  14.835464 -1.283592   0   1   0   0      1     1
2021-09-30      0.278676  14.851003 -1.277704   0   0   1   0      1     1
2021-12-31      0.290040  14.861445 -1.237736   0   0   0   1      1     1
2022-03-31      0.308280  14.852010 -1.176748   1   0   0   0      1     1
2022-06-30      0.320683  14.888615 -1.137302   0   1   0   0      1     1
2022-09-30      0.354965  14.906736 -1.035735   0   0   1   0      1     1
```

```
2022-12-31      0.273342  14.910291 -1.297033   0   0   0   1      1     1
2023-03-31      0.376730  14.901228 -0.976227   1   0   0   0      0     1
2023-06-30      0.382103  14.939070 -0.962065   0   1   0   0      0     1
2023-09-30      0.396137  14.954935 -0.925995   0   0   1   0      0     1
2023-12-31      0.389863  14.959466 -0.941960   0   0   0   1      0     1
2024-03-31      0.396779  14.951110 -0.924377   1   0   0   0      0     1
2024-06-30      0.381805  14.988299 -0.962845   0   1   0   0      0     1
2024-09-30      0.326604  15.003205 -1.119007   0   0   1   0      0     1
2024-12-31      0.346432  15.008445 -1.060069   0   0   0   1      0     1
2025-03-31      0.332004  14.998627 -1.102609   1   0   0   0      0     1
2025-06-30      0.427293  15.038198 -0.850284   0   1   0   0      0     1
2025-09-30      0.408545  15.052376 -0.895152   0   0   1   0      0     1

               resid        ols
Date
2012-03-31  0.185897  14.247811
2012-06-30 -0.117716  14.590238
2012-09-30 -0.117429  14.622898
2012-12-31 -0.084139  14.566891
2013-03-31 -0.077345  14.564981
2013-06-30 -0.178714  14.705613
2013-09-30 -0.096427  14.655587
2013-12-31 -0.016722  14.553816
2014-03-31 -0.077106  14.614635
2014-06-30 -0.116367  14.691461
2014-09-30 -0.034992  14.642292
2014-12-31 -0.101105  14.687442
2015-03-31 -0.055342  14.640053
2015-06-30 -0.126194  14.747601
2015-09-30 -0.143135  14.797123
2015-12-31 -0.084977  14.721557
2016-03-31 -0.054545  14.687507
2016-06-30 -0.041891  14.714132
2016-09-30  0.021362  14.681735
2016-12-31  0.130124  14.554664
2017-03-31  0.028549  14.653283
2017-06-30 -0.019714  14.740864
2017-09-30  0.047602  14.704902
2017-12-31  0.045629  14.689755
2018-03-31  0.078979  14.652301
2018-06-30 -0.019045  14.791548
2018-09-30  0.004589  14.798353
2018-12-31  0.068793  14.717106
2019-03-31  0.002939  14.777721
2019-06-30  0.018314  14.803479
2019-09-30  0.037693  14.814133
2019-12-31  0.020522  14.813745
```

```
2020-03-31  0.033366  14.776517
2020-06-30  0.029534  14.737545
2020-09-30  0.089492  14.726827
2020-12-31  0.093491  14.718866
2021-03-31  0.154781  14.648204
2021-06-30  0.040889  14.794575
2021-09-30  0.053247  14.797755
2021-12-31  0.042104  14.819341
2022-03-31 -0.000268  14.852279
2022-06-30  0.015033  14.873582
2022-09-30 -0.021700  14.928436
2022-12-31  0.122975  14.787316
2023-03-31 -0.059346  14.960574
2023-06-30 -0.029153  14.968223
2023-09-30 -0.032769  14.987703
2023-12-31 -0.019615  14.979081
2024-03-31 -0.037467  14.988577
2024-06-30  0.020497  14.967802
2024-09-30  0.119742  14.883463
2024-12-31  0.093151  14.915294
2025-03-31  0.106309  14.892319
2025-06-30  0.009605  15.028593
2025-09-30  0.048016  15.004361
```

[8]:

```
gdp
```

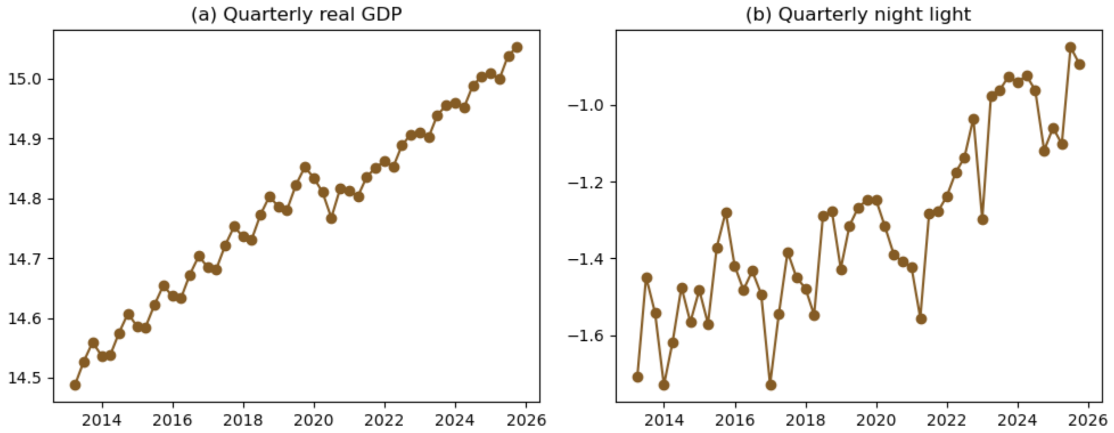
[8]:

```
         Date        GDP  Real GDP YoY Growth Indonesia
0  2012-03-01  1855580.2                       6.110087
1  2012-06-01  1929018.7                       6.207811
2  2012-09-01  1993632.3                       5.940039
3  2012-12-01  1948852.2                       5.870644
4  2013-03-01  1958395.5                       5.540871
5  2013-06-01  2036816.6                       5.588225
6  2013-09-01  2103598.1                       5.515852
7  2013-12-01  2057687.6                       5.584590
8  2014-03-01  2058584.9                       5.115892
9  2014-06-01  2137385.6                       4.937558
10 2014-09-01  2207343.6                       4.931812
11 2014-12-01  2161552.5                       5.047652
12 2015-03-01  2158040.0                       4.831236
13 2015-06-01  2238704.4                       4.740315
14 2015-09-01  2312843.5                       4.779496
15 2015-12-01  2272929.2                       5.152625
16 2016-03-01  2264721.0                       4.943421
17 2016-06-01  2355445.0                       5.214650
18 2016-09-01  2429260.6                       5.033505
19 2016-12-01  2385186.8                       4.938896
```

```
20 2017-03-01  2378146.4                       5.008361
21 2017-06-01  2473512.9                       5.012552
22 2017-09-01  2552296.9                       5.064763
23 2017-12-01  2508971.9                       5.189744
24 2018-03-01  2498697.5                       5.069120
25 2018-06-01  2603852.6                       5.269417
26 2018-09-01  2684332.2                       5.173195
27 2018-12-01  2638969.6                       5.181314
28 2019-03-01  2625180.5                       5.061957
29 2019-06-01  2735414.1                       5.052571
30 2019-09-01  2818812.7                       5.009831
31 2019-12-01  2769748.1                       4.955665
32 2020-03-01  2703027.1                       2.965381
33 2020-06-01  2589769.2                      -5.324419
34 2020-09-01  2720481.3                      -3.488398
35 2020-12-01  2709721.7                      -2.167215
36 2021-03-01  2684445.5                      -0.687437
37 2021-06-01  2773065.2                       7.077696
38 2021-09-01  2816492.1                       3.529184
39 2021-12-01  2846056.9                       5.031336
40 2022-03-01  2819331.8                       5.024736
41 2022-06-01  2924444.0                       5.458898
42 2022-09-01  2977920.0                       5.731523
43 2022-12-01  2988527.4                       5.005891
44 2023-03-01  2961564.4                       5.044905
45 2023-06-01  3075781.9                       5.174929
46 2023-09-01  3124968.2                       4.937950
47 2023-12-01  3139160.6                       5.040382
48 2024-03-01  3113039.9                       5.114712
49 2024-06-01  3230990.3                       5.046145
50 2024-09-01  3279509.8                       4.945382
51 2024-12-01  3296741.7                       5.019848
52 2025-03-01  3264533.7                       4.866427
53 2025-06-01  3396302.6                       5.116459
54 2025-09-01  3444800.0                       5.040000
```

[9]:

```python
# Plotting GDP Growth and Night light growth side by side

fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2, figsize=(10, 4))
ntlm=ntl[4:]
ax1.plot(ntlm['g'],color='#845B24',marker='o', linestyle='-')
ax1.set_title('(a) Quarterly real GDP')

ax2.plot(ntlm['ntlg'], linestyle='-', color='#845B24',marker='o')
ax2.set_title('(b) Quarterly night light')

plt.tight_layout()
plt.savefig("fig/figQ.png") # Turn off to not save, or change file name to save␣
 ↪in your preferred location
plt.show()
```

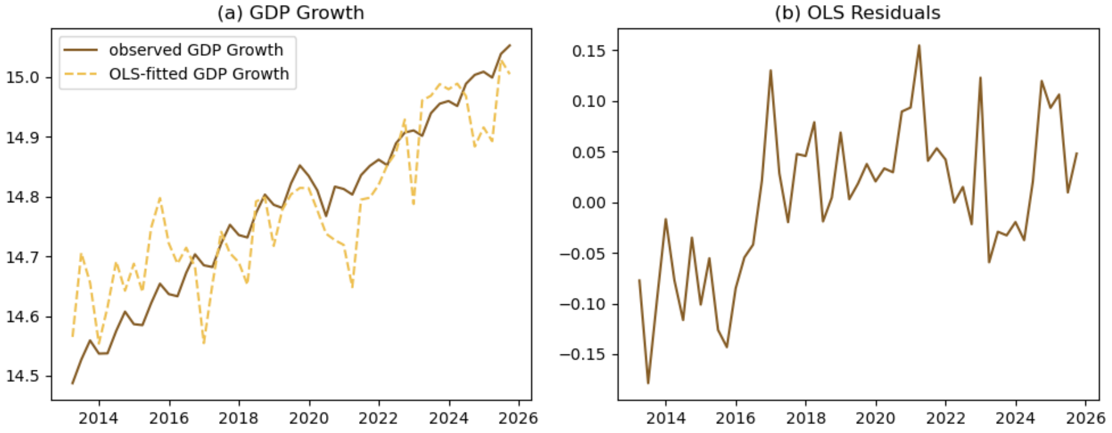


0.2.2 OLS and residuals

[10]:
```
## OLS results and plotting residuals
ntl=ntlm
print(mod.summary())
fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2, figsize=(10, 4))

ax1.plot(ntlm['g'],color='#845B24',linestyle="-",label="observed GDP Growth")
ax1.plot(ntlm['ols'],color='#EEC051',linestyle="--",label="OLS-fitted GDP␣
 ↪Growth")
ax1.set_title('(a) GDP Growth')
ax1.legend()

ax2.plot(ntlm['resid'], linestyle='-', color='#845B24')
ax2.set_title('(b) OLS Residuals')

plt.tight_layout()
plt.savefig("fig/Qols.png") # Turn off to not save, or change file name to save␣
 ↪in your preferred location
plt.show()
```

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                      g   R-squared:                       0.768
Model:                            OLS   Adj. R-squared:                  0.764
Method:                 Least Squares   F-statistic:                     175.8
Date:                Tue, 03 Feb 2026   Prob (F-statistic):           1.83e-18
Time:                        16:48:02   Log-Likelihood:                 61.443
```

```
No. Observations:                  55   AIC:                            -118.9
Df Residuals:                      53   BIC:                            -114.9
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         15.4878      0.056    275.961      0.000      15.375      15.600
ntlg           0.5401      0.041     13.257      0.000       0.458       0.622
==============================================================================
Omnibus:                        0.196   Durbin-Watson:                   0.879
Prob(Omnibus):                  0.907   Jarque-Bera (JB):                0.397
Skew:                           0.026   Prob(JB):                        0.820
Kurtosis:                       2.587   Cond. No.                         10.8
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
```



0.2.3 ADF test of the series and residuals.

We don't first diff in this step cuz we do another ADF test on the growth dataset.

[11]:
```python
## ADF Test for g, ntlg and OLS residuals
def adf_test(series, name=""):
    """
    Perform ADF test and print results
    """
    result = adfuller(series.dropna(), autolag="BIC")
    print(f"ADF Test for {name}")
    print(f"  Test Statistic : {result[0]:.4f}")
    print(f"  p-value        : {result[1]:.4f}")
    print(f"  #Lags Used     : {result[2]}")
    print(f"  #Observations  : {result[3]}")
    for key, value in result[4].items():
        print(f"   Critical Value {key} : {value:.4f}")
    if result[1] <= 0.05:
        print(f"  ==> {name} is stationary\n (reject H0 of unit root)\n")
    else:
        print(f"  ==> {name} is non-stationary\n (fail to reject H0)\n")

# Run ADF tests for both series
adf_test(ntlm["g"], "GDP YoY Growth")
adf_test(ntlm["ntlg"], "NTL YoY Growth")
adf_test(ntlm["resid"], "OLS Residuals")
```

```
ADF Test for GDP YoY Growth
  Test Statistic : -0.3748
  p-value        : 0.9142
  #Lags Used     : 4
  #Observations  : 46
   Critical Value 1% : -3.5813
   Critical Value 5% : -2.9268
   Critical Value 10% : -2.6015
  ==> GDP YoY Growth is non-stationary
 (fail to reject H0)

ADF Test for NTL YoY Growth
  Test Statistic : -2.0542
  p-value        : 0.2633
  #Lags Used     : 0
  #Observations  : 50
   Critical Value 1% : -3.5685
   Critical Value 5% : -2.9214
   Critical Value 10% : -2.5987
  ==> NTL YoY Growth is non-stationary
 (fail to reject H0)

ADF Test for OLS Residuals
  Test Statistic : -3.4638
  p-value        : 0.0090
  #Lags Used     : 0
  #Observations  : 50
   Critical Value 1% : -3.5685
   Critical Value 5% : -2.9214
   Critical Value 10% : -2.5987
  ==> OLS Residuals is stationary
 (reject H0 of unit root)
```

0.2.4 Johansen cointegration test

[12]:

```
# Select optimal lag order
ntlm=ntl[['g','ntlg']]
lag_order = select_order(ntlm), maxlags=12, deterministic="ci")
print(lag_order.summary())

# Select cointegration rank
coint_rank = select_coint_rank(ntlm, det_order=0, k_ar_diff=lag_order.bic)
print(coint_rank.summary())
```

```
  Cell In[12], line 3
    lag_order = select_order(ntlm), maxlags=12, deterministic="ci")
                                                                  ^
SyntaxError: unmatched ')'
```

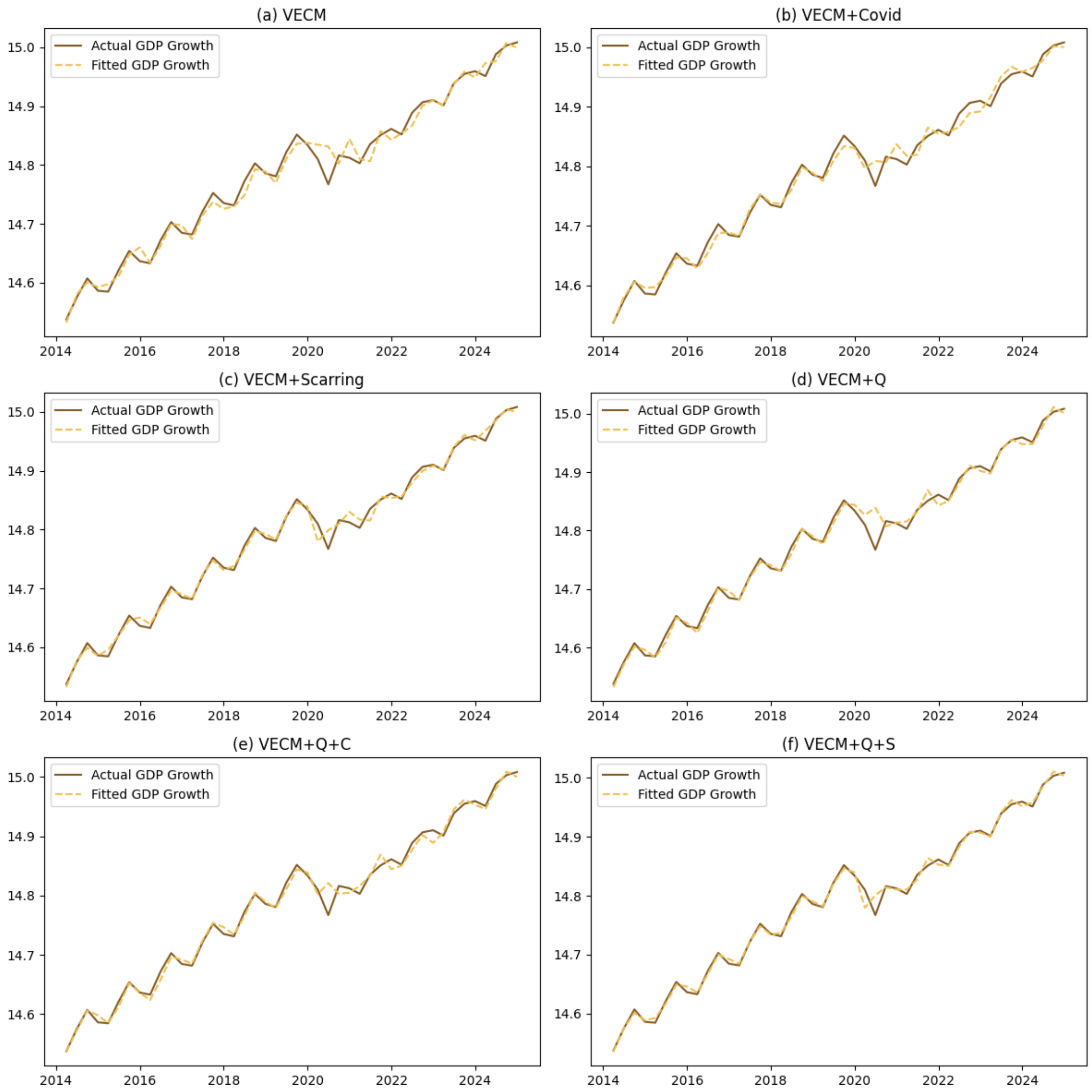
0.2.5 VECM with quarterly dataset

[ ]:

```
en=ntl[['g','ntlg']]
exc=ntl[['covid']]
exs=ntl[['scar']]
exq=ntl[['q1','q2','q3']]
exqc=ntl[['q1','q2','q3','covid']]
exqs=ntl[['q1','q2','q3','scar']]

lag=lag_order.aic

ve = VECM(en,k_ar_diff=lag, coint_rank=1, deterministic="cili").fit()
vec = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exc,deterministic="cili").fit()
ves = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exs,deterministic="cili").fit()
veq = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exq,deterministic="cili").fit()
veqc = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exqc,deterministic="cili").
 ↪fit()
veqs = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exqs,deterministic="cili").
 ↪fit()

models = {'fve': ve, 'fvec': vec,'fves': ves, 'fveq': veq,'fveqc': veqc,␣
 ↪'fveqs': veqs}
results = {}

for name, model in models.items():
    fitted = pd.DataFrame(model.fittedvalues, columns=en.columns)
    fitted.index = pd.date_range(end='2024-12-31', periods=44, freq='QE')
    merged = pd.merge(en, fitted, left_index=True, right_index=True,␣
 ↪suffixes=('', f'_fitted'))
```

```
    results[name] = merged


fig, ax = plt.subplots(3,2,figsize=(12, 12))

ax[0,0].plot(results['fve']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[0,0].plot(results['fve']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[0,0].set_title('(a) VECM')
ax[0,0].legend()

ax[0,1].plot(results['fvec']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[0,1].plot(results['fvec']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[0,1].set_title('(b) VECM+Covid')
ax[0,1].legend()

ax[1,0].plot(results['fves']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[1,0].plot(results['fves']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[1,0].set_title('(c) VECM+Scarring')
ax[1,0].legend()

ax[1,1].plot(results['fveq']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[1,1].plot(results['fveq']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[1,1].set_title('(d) VECM+Q')
ax[1,1].legend()

ax[2,0].plot(results['fveqc']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[2,0].plot(results['fveqc']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[2,0].set_title('(e) VECM+Q+C')
ax[2,0].legend()

ax[2,1].plot(results['fveqs']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[2,1].plot(results['fveqs']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[2,1].set_title('(f) VECM+Q+S')
ax[2,1].legend()
```

```
plt.tight_layout()
plt.savefig("fig/VECMQ.png")
plt.show()
```



0.3 ARDL with quarterly dataset

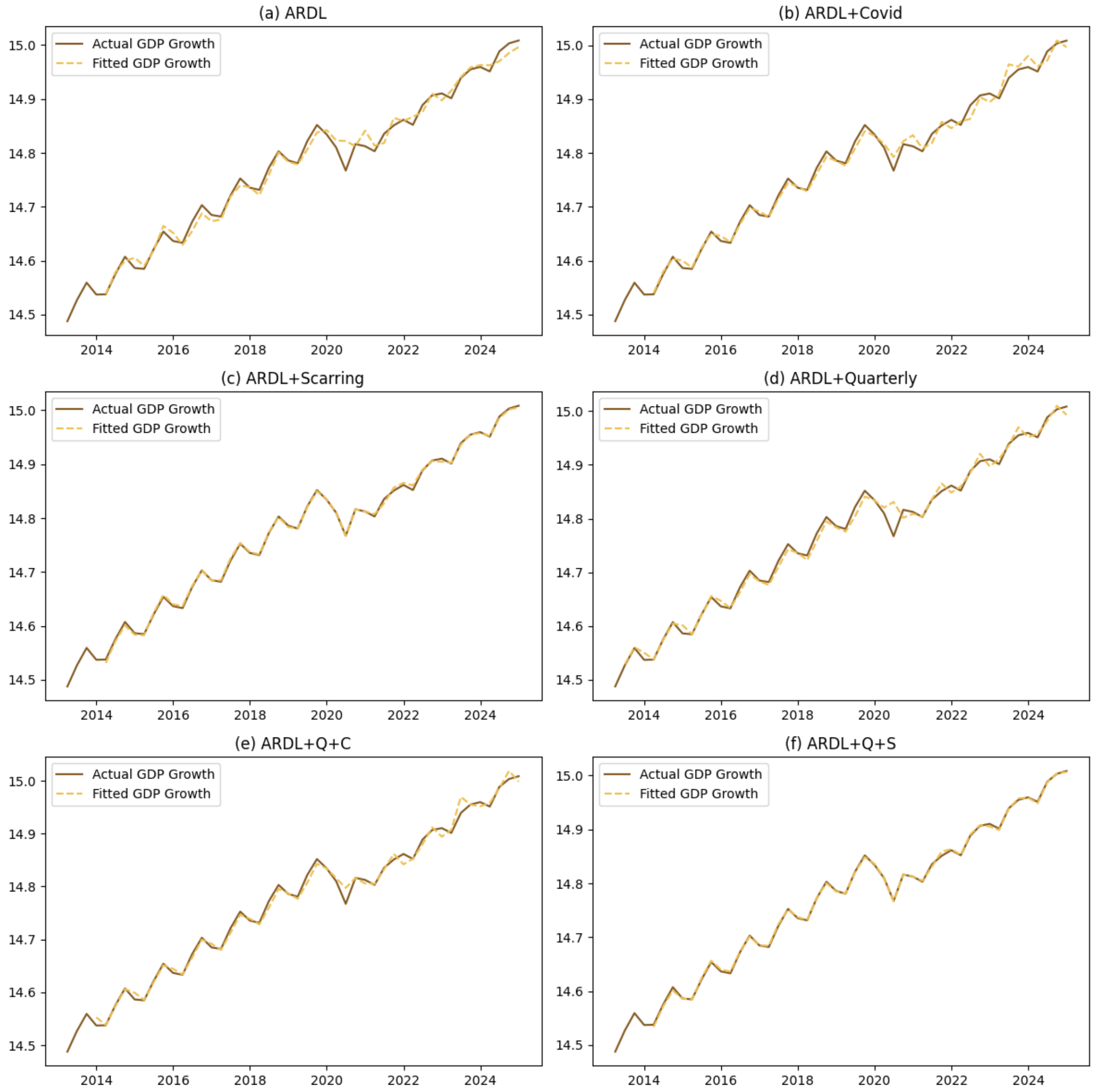
[ ]:
```
en=ntl[['g']]
ex=ntl[['ntlg']]
exc=ntl[['ntlg','covid']]
exs=ntl[['ntlg','scar']]
exq=ntl[['ntlg','q1','q2','q3']]
exqc=ntl[['ntlg','q1','q2','q3','covid']]
```

```
exqs=ntl[['ntlg','q1','q2','q3','scar']]

lags = ardl_select_order(endog=en, exog=ex, maxlag=4,maxorder=4,␣
 ↪ic='aic',seasonal=False)
ve = ARDL(endog=en,lags=lags.ar_lags,exog=ex,order=lags.dl_lags,trend='ct').
 ↪fit()
lags = ardl_select_order(endog=en, exog=exc, maxlag=4,maxorder=4,␣
 ↪ic='aic',seasonal=False)
vec= ARDL(endog=en,lags=lags.ar_lags,exog=exc,order=lags.dl_lags,trend='ct').
 ↪fit()
lags = ardl_select_order(endog=en, exog=exs, maxlag=4,maxorder=4,␣
 ↪ic='aic',seasonal=False)
ves= ARDL(endog=en,lags=lags.ar_lags,exog=exs,order=lags.dl_lags,trend='ct').
 ↪fit()
lags = ardl_select_order(endog=en, exog=exq, maxlag=4,maxorder=4,␣
 ↪ic='aic',seasonal=False)
veq= ARDL(endog=en,lags=lags.ar_lags,exog=exq,order=lags.dl_lags,trend='ct').
 ↪fit()
lags = ardl_select_order(endog=en, exog=exqc, maxlag=4,maxorder=4,␣
 ↪ic='aic',seasonal=False)
veqc= ARDL(endog=en,lags=lags.ar_lags,exog=exqc,order=lags.dl_lags,trend='ct').
 ↪fit()
lags = ardl_select_order(endog=en, exog=exqs, maxlag=4,maxorder=4,␣
 ↪ic='aic',seasonal=False)
veqs= ARDL(endog=en,lags=lags.ar_lags,exog=exqs,order=lags.dl_lags,trend='ct').
 ↪fit() # This looks too good to be true

models = {'fve': ve, 'fvec': vec,'fves': ves, 'fveq': veq,'fveqc': veqc,␣
 ↪'fveqs': veqs}
results = {}

for name, model in models.items():
    fitted = pd.DataFrame(model.predict(), columns=en.columns)
    fitted.index = pd.date_range(end='2024-12-31', periods=48, freq='QE')
    merged = pd.merge(en, fitted, left_index=True, right_index=True,␣
 ↪suffixes=('', f'_fitted'))
    results[name] = merged


fig, ax = plt.subplots(3,2,figsize=(12, 12))

ax[0,0].plot(results['fve']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[0,0].plot(results['fve']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[0,0].set_title('(a) ARDL')
```

```
ax[0,0].legend()

ax[0,1].plot(results['fvec']['g'],color='#845B24',linestyle='-',label="Actual␣
  ↪GDP Growth")
ax[0,1].plot(results['fvec']['g_fitted'], linestyle='--', color='#EEC051',␣
  ↪label="Fitted GDP Growth")
ax[0,1].set_title('(b) ARDL+Covid')
ax[0,1].legend()

ax[1,0].plot(results['fves']['g'],color='#845B24',linestyle='-',label="Actual␣
  ↪GDP Growth")
ax[1,0].plot(results['fves']['g_fitted'], linestyle='--', color='#EEC051',␣
  ↪label="Fitted GDP Growth")
ax[1,0].set_title('(c) ARDL+Scarring')
ax[1,0].legend()

ax[1,1].plot(results['fveq']['g'],color='#845B24',linestyle='-',label="Actual␣
  ↪GDP Growth")
ax[1,1].plot(results['fveq']['g_fitted'], linestyle='--', color='#EEC051',␣
  ↪label="Fitted GDP Growth")
ax[1,1].set_title('(d) ARDL+Quarterly')
ax[1,1].legend()

ax[2,0].plot(results['fveqc']['g'],color='#845B24',linestyle='-',label="Actual␣
  ↪GDP Growth")
ax[2,0].plot(results['fveqc']['g_fitted'], linestyle='--', color='#EEC051',␣
  ↪label="Fitted GDP Growth")
ax[2,0].set_title('(e) ARDL+Q+C')
ax[2,0].legend()

ax[2,1].plot(results['fveqs']['g'],color='#845B24',linestyle='-',label="Actual␣
  ↪GDP Growth")
ax[2,1].plot(results['fveqs']['g_fitted'], linestyle='--', color='#EEC051',␣
  ↪label="Fitted GDP Growth")
ax[2,1].set_title('(f) ARDL+Q+S')
ax[2,1].legend()
plt.tight_layout()
plt.savefig("fig/ARDLQ.png") # Turn off to not save, or change file name to␣
  ↪save in your preferred location
plt.show()
```

```
C:\Users\imed\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.13_qbz5n2
kfra8p0\LocalCache\local-packages\Python313\site-
packages\statsmodels\tsa\ardl\model.py:455: SpecificationWarning: exog contains
variables that are missing from the order dictionary.  Missing keys: ntlg.
  return _format_order(self.data.orig_exog, order, self._causal)
C:\Users\imed\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.13_qbz5n2
```

```
kfra8p0\LocalCache\local-packages\Python313\site-
packages\statsmodels\tsa\ardl\model.py:455: SpecificationWarning: exog contains
variables that are missing from the order dictionary.  Missing keys: q1.
  return _format_order(self.data.orig_exog, order, self._causal)
C:\Users\imed\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.13_qbz5n2
kfra8p0\LocalCache\local-packages\Python313\site-
packages\statsmodels\tsa\ardl\model.py:455: SpecificationWarning: exog contains
variables that are missing from the order dictionary.  Missing keys: ntlg, q1.
  return _format_order(self.data.orig_exog, order, self._causal)
C:\Users\imed\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.13_qbz5n2
kfra8p0\LocalCache\local-packages\Python313\site-
packages\statsmodels\tsa\ardl\model.py:455: SpecificationWarning: exog contains
variables that are missing from the order dictionary.  Missing keys: q2.
  return _format_order(self.data.orig_exog, order, self._causal)
```



(a) ARDL

(b) ARDL+Covid

(c) ARDL+Scarring

(d) ARDL+Quarterly

(e) ARDL+Q+C

(f) ARDL+Q+S

0.4 Growth Regression

0.4.1 The GDP and night light growth dataset

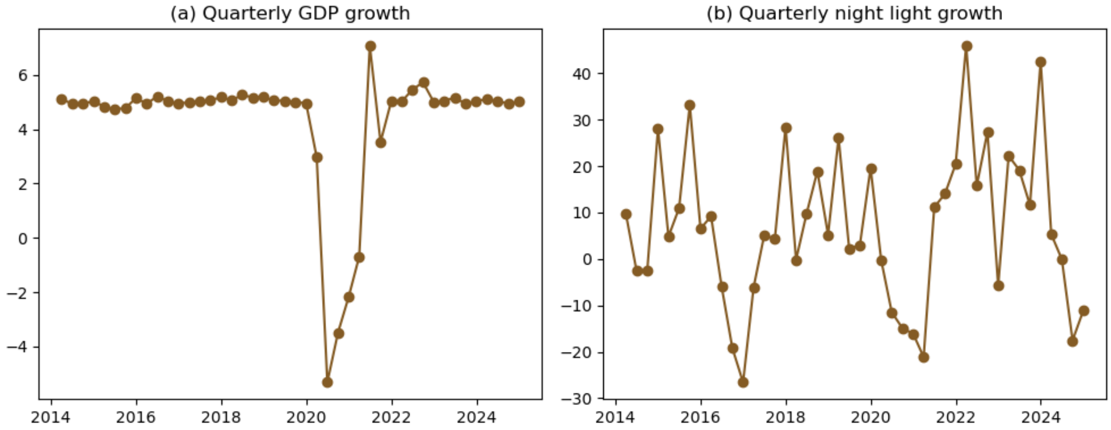
Turn on the last line of the first codeblock to see the dataframe

[ ]:

```
## Data prep
### Creating data
ntl=pd.read_csv('ntl_monthly_avg_2012-2024.csv')
gdp=pd.read_excel('GDP_YoY_Quarterly_12_24.xlsx')

### Make time index
ntl.Date=pd.to_datetime(ntl['Date'])
ntl['qtr']=ntl['Date'].dt.quarter
ntl['year']=ntl['Date'].dt.year
### Averaging the radiance into quarterly, make it yoy quarterly growth
ntl=ntl.groupby(['year','qtr'])['NTL_Radiance'].mean().reset_index()
ntl['Date']=pd.date_range(start='2012-01-01', periods=len(ntl), freq='QE')
ntl=ntl[['Date','NTL_Radiance']]
ntl['g']=(gdp['Real GDP YoY Growth Indonesia'])
ntl['ntlg']=(ntl['NTL_Radiance'])
ntl['NTL_Radiancelag'] = ntl['NTL_Radiance'].shift(4)
ntl['ntlg'] = ((ntl['NTL_Radiance'] - ntl['NTL_Radiancelag']) /␣
  ↪ntl['NTL_Radiancelag']) * 100
### Creating dummy quarterly and dummy covid
ntl['q1']=np.where(ntl['Date'].dt.quarter==1,1,0)
ntl['q2']=np.where(ntl['Date'].dt.quarter==2,1,0)
ntl['q3']=np.where(ntl['Date'].dt.quarter==3,1,0)
ntl['q4']=np.where(ntl['Date'].dt.quarter==4,1,0)
ntl['covid']=np.where((ntl['Date'].dt.year>=2020) & (ntl['Date'].dt.
  ↪year<=2022),1,0)
ntl['scar']=np.where((ntl['Date'].dt.year>=2020) ,1,0)
### Back to making time index
ntl=ntl.dropna().reset_index(drop=True)
ntl=ntl.set_index('Date')
ntl=ntl.asfreq('QE-DEC')
#ntlm=ntlm[['g','ntlg']]

### Creating dummy quarterly and dummy covid

## OLS-ing
mod=sm.OLS(ntl['g'], sm.add_constant(ntl['ntlg'])).fit()
ntl['resid']=mod.resid
ntl['ols']=mod.predict()
#ntl
```

[ ]:

```python
# Plotting GDP Growth and Night light growth side by side
fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2, figsize=(10, 4))
ntlm=ntl[4:]
ax1.plot(ntlm['g'],color='#845B24',marker='o', linestyle='-')
ax1.set_title('(a) Quarterly GDP growth')

ax2.plot(ntlm['ntlg'], linestyle='-', color='#845B24',marker='o')
ax2.set_title('(b) Quarterly night light growth')

plt.tight_layout()
plt.savefig("fig/fig.png")
plt.show()
```

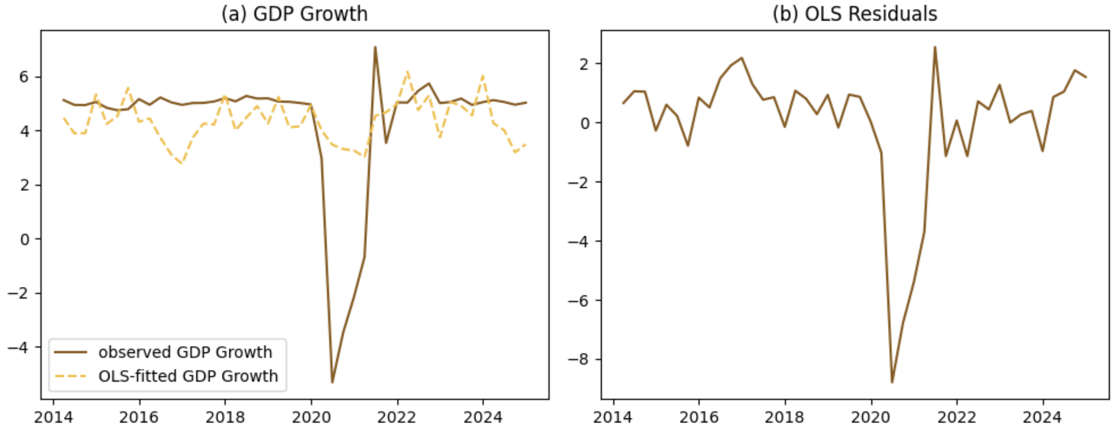


0.4.2 OLS Regression

[ ]:

```python
## OLS results and plotting residuals
ntl=ntlm
print(mod.summary())
fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2, figsize=(10, 4))

ax1.plot(ntlm['g'],color='#845B24',linestyle="-",label="observed GDP Growth")
ax1.plot(ntlm['ols'],color='#EEC051',linestyle="--",label="OLS-fitted GDP␣
  ↪Growth")
ax1.set_title('(a) GDP Growth')
ax1.legend()

ax2.plot(ntlm['resid'], linestyle='-', color='#845B24')
ax2.set_title('(b) OLS Residuals')

plt.tight_layout()
plt.savefig("fig/ols.png") # Turn off to not save, or change file name to save in your preferred location
plt.show()
```

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                      g   R-squared:                       0.150
Model:                            OLS   Adj. R-squared:                  0.132
Method:                 Least Squares   F-statistic:                     8.126
Date:                Tue, 30 Sep 2025   Prob (F-statistic):            0.00651
Time:                        09:40:10   Log-Likelihood:                -104.61
No. Observations:                  48   AIC:                             213.2
Df Residuals:                      46   BIC:                             217.0
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          4.0069      0.345     11.617      0.000       3.313       4.701
ntlg           0.0470      0.016      2.851      0.007       0.014       0.080
==============================================================================
Omnibus:                       42.129   Durbin-Watson:                   0.736
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              126.380
Skew:                          -2.449   Prob(JB):                     3.61e-28
Kurtosis:                       9.260   Cond. No.                         22.9
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
```



0.4.3 ADF Test

[ ]:

```python
## ADF Test for g, ntlg and OLS residuals
def adf_test(series, name=""):
    """
    Perform ADF test and print results
    """
    result = adfuller(series.dropna(), autolag="BIC")
    print(f"ADF Test for {name}")
    print(f"  Test Statistic : {result[0]:.4f}")
    print(f"  p-value        : {result[1]:.4f}")
    print(f"  #Lags Used     : {result[2]}")
    print(f"  #Observations  : {result[3]}")
    for key, value in result[4].items():
        print(f"   Critical Value {key} : {value:.4f}")
    if result[1] <= 0.05:
        print(f"  ==> {name} is stationary\n (reject H0 of unit root)\n")
    else:
        print(f"  ==> {name} is non-stationary\n (fail to reject H0)\n")

# Run ADF tests for both series
adf_test(ntlm["g"], "GDP YoY Growth")
adf_test(ntlm["ntlg"], "NTL YoY Growth")
adf_test(ntlm["resid"], "OLS Residuals")
```

```
ADF Test for GDP YoY Growth
  Test Statistic : -2.7478
  p-value        : 0.0661
  #Lags Used     : 0
  #Observations  : 43
   Critical Value 1% : -3.5925
   Critical Value 5% : -2.9315
   Critical Value 10% : -2.6041
  ==> GDP YoY Growth is non-stationary
 (fail to reject H0)

ADF Test for NTL YoY Growth
  Test Statistic : -4.2533
  p-value        : 0.0005
  #Lags Used     : 0
  #Observations  : 43
   Critical Value 1% : -3.5925
   Critical Value 5% : -2.9315
   Critical Value 10% : -2.6041
  ==> NTL YoY Growth is stationary
 (reject H0 of unit root)

ADF Test for OLS Residuals
```

```
 Test Statistic : -2.9893
 p-value        : 0.0359
 #Lags Used     : 0
 #Observations  : 43
  Critical Value 1% : -3.5925
  Critical Value 5% : -2.9315
  Critical Value 10% : -2.6041
 ==> OLS Residuals is stationary
(reject H0 of unit root)
```

0.4.4 Johansen Cointegration test

[ ]:

```
# Select optimal lag order
ntlm=ntl[['g','ntlg']]
lag_order = select_order(ntlm.asfreq('QE-DEC'), maxlags=12, deterministic="ci")
print(lag_order.summary())

# Select cointegration rank
coint_rank = select_coint_rank(ntlm.asfreq('QE-DEC'), det_order=0,␣
 ↪k_ar_diff=lag_order.bic)
print(coint_rank.summary())
```

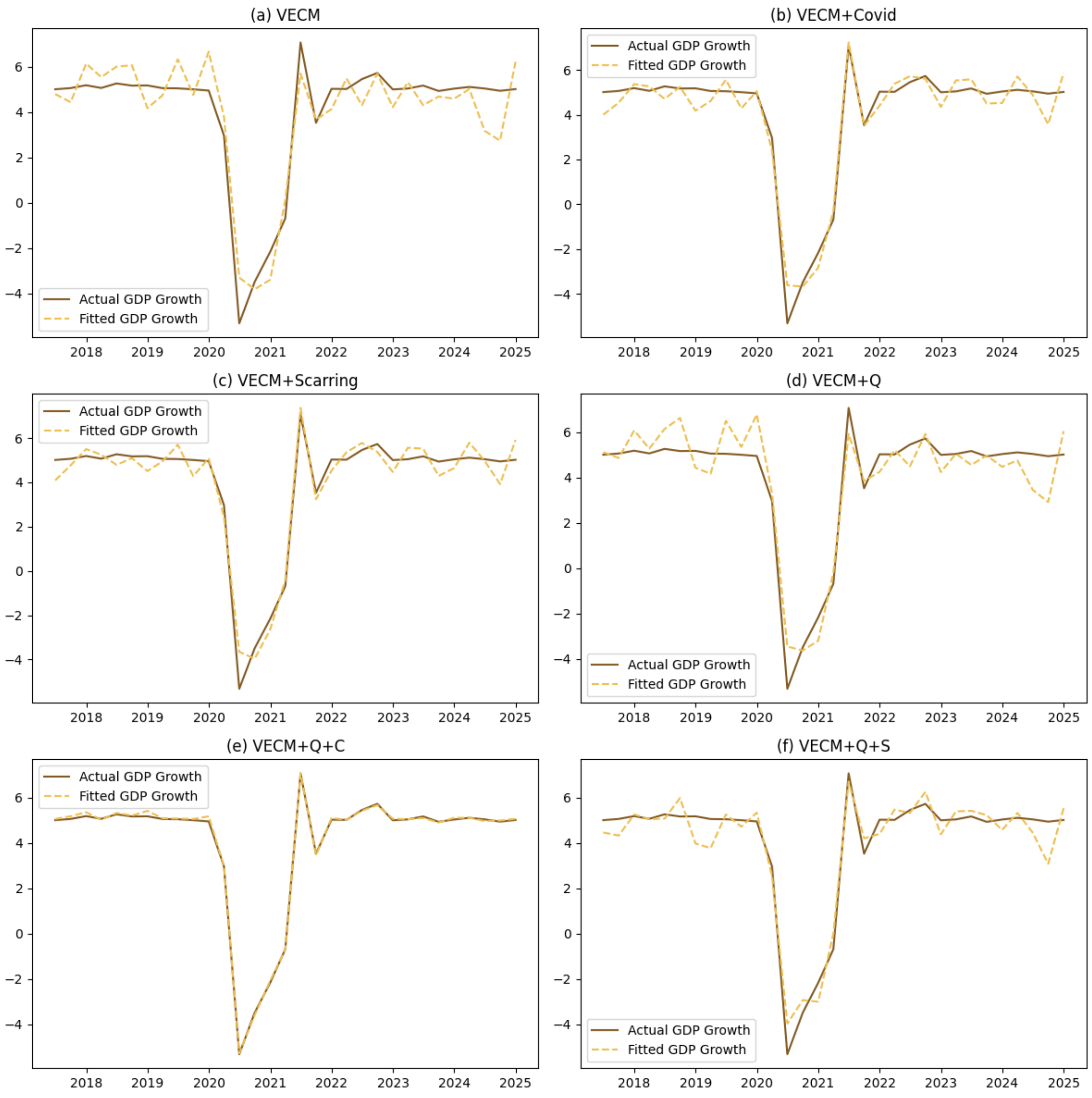
```
 VECM Order Selection (* highlights the minimums)
==================================================
       AIC         BIC         FPE         HQIC
--------------------------------------------------
0        7.167      7.537*      1300.*       7.288
1        7.384       7.939       1627.       7.565
2        7.552       8.292       1950.       7.793
3        7.303       8.228       1557.       7.604
4        7.103       8.214       1324.       7.465
5        7.182       8.477       1513.       7.604
6        7.367       8.847       1972.       7.849
7        7.216       8.882       1896.       7.759
8        7.469       9.320       2854.       8.072
9        7.035       9.070       2303.       7.698
10       6.595       8.815       2040.       7.318
11       6.339       8.745       2570.       7.123
12      5.159*       7.750       1815.      6.004*
--------------------------------------------------
Johansen cointegration test using trace test statistic with 5% significance
level
=====================================
r_0 r_1 test statistic critical value
-------------------------------------
  0   2          27.82          15.49
  1   2          7.259          3.841
```

0.4.5 VECM with growth

[ ]:

```
en=ntl[['g','ntlg']]
exc=ntl[['covid']]
exs=ntl[['scar']]
exq=ntl[['q1','q2','q3']]
exqc=ntl[['q1','q2','q3','covid']]
exqs=ntl[['q1','q2','q3','scar']]

lag=lag_order.aic

ve = VECM(en,k_ar_diff=lag, coint_rank=1, deterministic="ci").fit()
vec = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exc,deterministic="ci").fit()
ves = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exs,deterministic="ci").fit()
veq = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exq,deterministic="ci").fit()
veqc = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exqc,deterministic="ci").fit()
veqs = VECM(en,k_ar_diff=lag, coint_rank=1, exog=exqs,deterministic="ci").fit()

models = {'fve': ve, 'fvec': vec,'fves': ves, 'fveq': veq,'fveqc': veqc,␣
 ↪'fveqs': veqs}
results = {}

for name, model in models.items():
    fitted = pd.DataFrame(model.fittedvalues, columns=en.columns)
    fitted.index = pd.date_range(end='2024-12-31', periods=31, freq='QE')
    merged = pd.merge(en, fitted, left_index=True, right_index=True,␣
 ↪suffixes=('', f'_fitted'))
    results[name] = merged


fig, ax = plt.subplots(3,2,figsize=(12, 12))

ax[0,0].plot(results['fve']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[0,0].plot(results['fve']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[0,0].set_title('(a) VECM')
ax[0,0].legend()

ax[0,1].plot(results['fvec']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[0,1].plot(results['fvec']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[0,1].set_title('(b) VECM+Covid')
ax[0,1].legend()
```

```
ax[1,0].plot(results['fves']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[1,0].plot(results['fves']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[1,0].set_title('(c) VECM+Scarring')
ax[1,0].legend()

ax[1,1].plot(results['fveq']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[1,1].plot(results['fveq']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[1,1].set_title('(d) VECM+Q')
ax[1,1].legend()

ax[2,0].plot(results['fveqc']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[2,0].plot(results['fveqc']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[2,0].set_title('(e) VECM+Q+C')
ax[2,0].legend()

ax[2,1].plot(results['fveqs']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[2,1].plot(results['fveqs']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[2,1].set_title('(f) VECM+Q+S')
ax[2,1].legend()
plt.tight_layout()
plt.savefig("fig/VECM.png")
plt.show()
```



0.4.6 VAR with growth

[ ]:

```
en=ntl[['g','ntlg']]
exc=ntl[['covid']]
exs=ntl[['scar']]
exq=ntl[['q1','q2','q3']]
exqc=ntl[['q1','q2','q3','covid']]
exqs=ntl[['q1','q2','q3','scar']]

#lag=lag_order.aic

ve = sm.tsa.VARMAX(en, order=(4,0), trend='n').fit(maxiter=1000, disp=False)
```

```
vec = sm.tsa.VARMAX(en, order=(4,0), trend='n',exog=exc).fit(maxiter=1000, disp=False)
ves = sm.tsa.VARMAX(en, order=(4,0), trend='n',exog=exs).fit(maxiter=1000, disp=False)
veq = sm.tsa.VARMAX(en, order=(4,0), trend='n',exog=exq).fit(maxiter=1000, disp=False)
veqc = sm.tsa.VARMAX(en, order=(4,0), trend='n',exog=exqc).fit(maxiter=1000, disp=False)
veqs = sm.tsa.VARMAX(en, order=(4,0), trend='n',exog=exqs).fit(maxiter=1000, disp=False)


models = {'fve': ve, 'fvec': vec,'fves': ves, 'fveq': veq,'fveqc': veqc, 'fveqs': veqs}
results = {}

for name, model in models.items():
    fitted = pd.DataFrame(model.fittedvalues, columns=en.columns)
    fitted.index = pd.date_range(end='2024-12-31', periods=48, freq='QE')
    merged = pd.merge(en, fitted, left_index=True, right_index=True, suffixes=('', f'_fitted'))
    results[name] = merged

fig, ax = plt.subplots(3,2,figsize=(12, 12))

ax[0,0].plot(results['fve']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[0,0].plot(results['fve']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[0,0].set_title('(a) VAR')
ax[0,0].legend()

ax[0,1].plot(results['fvec']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[0,1].plot(results['fvec']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[0,1].set_title('(b) VAR+Covid')
ax[0,1].legend()

ax[1,0].plot(results['fves']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[1,0].plot(results['fves']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[1,0].set_title('(c) VAR+Scarring')
ax[1,0].legend()
```

```
ax[1,1].plot(results['fveq']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[1,1].plot(results['fveq']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[1,1].set_title('(d) VAR+Q')
ax[1,1].legend()

ax[2,0].plot(results['fveqc']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[2,0].plot(results['fveqc']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[2,0].set_title('(e) VAR+Q+C')
ax[2,0].legend()

ax[2,1].plot(results['fveqs']['g'],color='#845B24',linestyle='-',label="Actual␣
 ↪GDP Growth")
ax[2,1].plot(results['fveqs']['g_fitted'], linestyle='--', color='#EEC051',␣
 ↪label="Fitted GDP Growth")
ax[2,1].set_title('(f) VAR+Q+S')
ax[2,1].legend()
plt.tight_layout()
plt.savefig("fig/VAR.png")
plt.show()
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
Cell In[18], line 23
     21 for name, model in models.items():
     22     fitted = pd.DataFrame(model.fittedvalues, columns=en.columns)
---> 23     fitted.index = pd.date_range(end='2024-12-31', periods=48, freq='QE')
     24     merged = pd.merge(en, fitted, left_index=True, right_index=True,␣
 ↪suffixes=('', f'_fitted'))
     25     results[name] = merged

File ~\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.
 ↪13_qbz5n2kfra8p0\LocalCache\local-packages\Python313\site-packages\pandas\core\generic.
 ↪py:6332, in NDFrame.__setattr__(self, name, value)
   6330 try:
   6331     object.__getattribute__(self, name)
-> 6332     return object.__setattr__(self, name, value)
   6333 except AttributeError:
   6334     pass

File pandas/_libs/properties.pyx:69, in pandas._libs.properties.AxisProperty.
 ↪__set__()
```

```
File ~\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.
 ↪13_qbz5n2kfra8p0\LocalCache\local-packages\Python313\site-packages\pandas\core\generic.
 ↪py:814, in NDFrame._set_axis(self, axis, labels)
    809 """
    810 This is called from the cython code when we set the `index` attribute
    811 directly, e.g. `series.index = [1, 2, 3]`.
    812 """
    813 labels = ensure_index(labels)
--> 814 self._mgr.set_axis(axis, labels)
    815 self._clear_item_cache()

File ~\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.
 ↪13_qbz5n2kfra8p0\LocalCache\local-packages\Python313\site-packages\pandas\core\internals\ma
 ↪py:238, in BaseBlockManager.set_axis(self, axis, new_labels)
    236 def set_axis(self, axis: AxisInt, new_labels: Index) -> None:
    237     # Caller is responsible for ensuring we have an Index object.
--> 238     self._validate_set_axis(axis, new_labels)
    239     self.axes[axis] = new_labels

File ~\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.
 ↪13_qbz5n2kfra8p0\LocalCache\local-packages\Python313\site-packages\pandas\core\internals\ba
 ↪py:98, in DataManager._validate_set_axis(self, axis, new_labels)
     95     pass
     97 elif new_len != old_len:
---> 98     raise ValueError(
     99         f"Length mismatch: Expected axis has {old_len} elements, new "
    100         f"values have {new_len} elements"
    101     )

ValueError: Length mismatch: Expected axis has 44 elements, new values have 48␣
 ↪elements
```

0.4.7 ARDL with growth

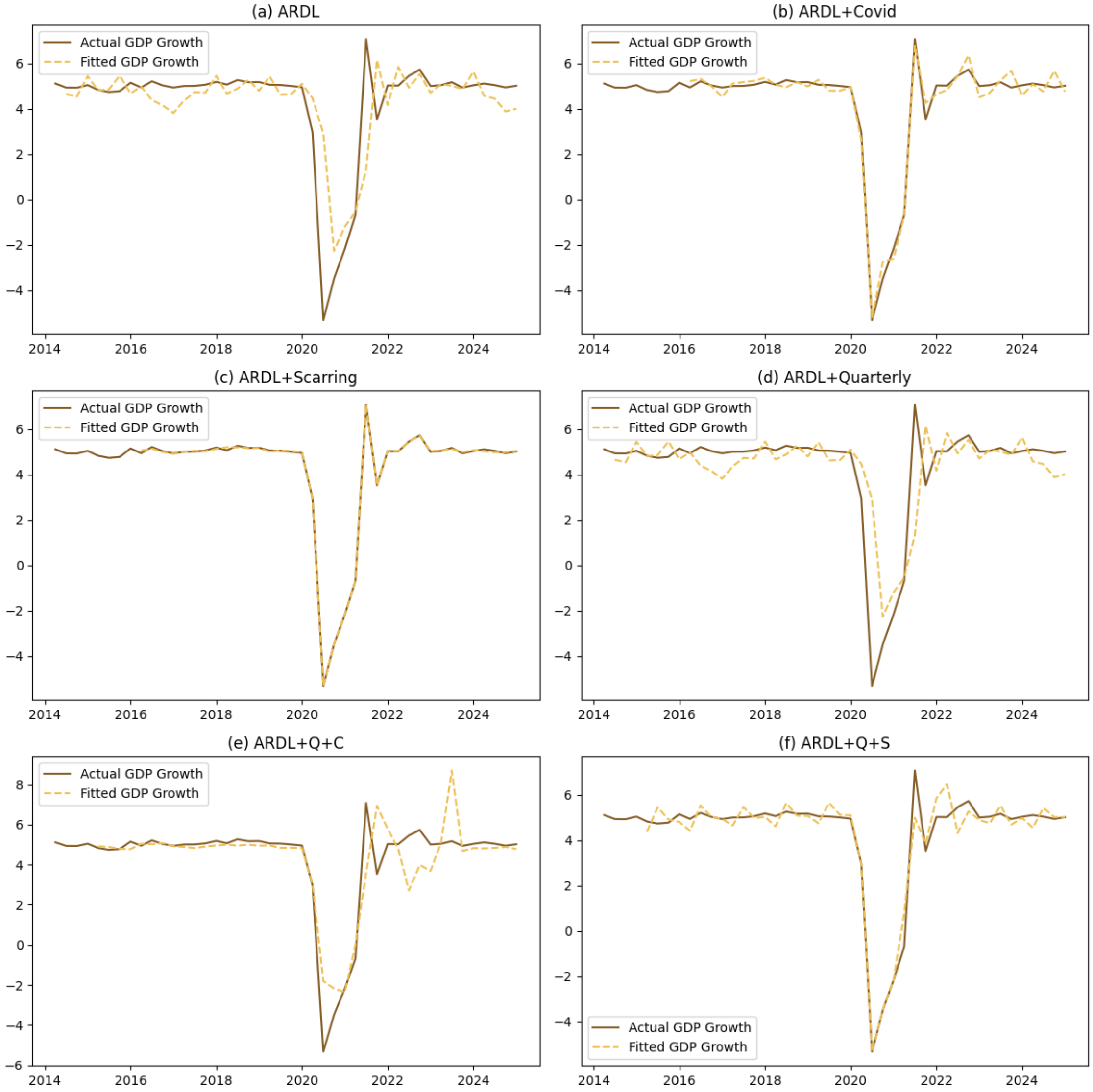
[ ]:
```
en=ntl[['g']]
ex=ntl[['ntlg']]
exc=ntl[['ntlg','covid']]
exs=ntl[['ntlg','scar']]
exq=ntl[['ntlg','q1','q2','q3']]
exqc=ntl[['ntlg','q1','q2','q3','covid']]
exqs=ntl[['ntlg','q1','q2','q3','scar']]

lags = ardl_select_order(endog=en, exog=ex, maxlag=8,maxorder=8,␣
 ↪ic='aic',seasonal=False)
ve = ARDL(endog=en,lags=lags.ar_lags,exog=ex,order=lags.dl_lags,trend='ct').
 ↪fit()
```

```
lags = ardl_select_order(endog=en, exog=exc, maxlag=8,maxorder=8,␣
 ↪ic='aic',seasonal=False)
vec= ARDL(endog=en,lags=lags.ar_lags,exog=exc,order=lags.dl_lags,trend='ct').
 ↪fit()
lags = ardl_select_order(endog=en, exog=exs, maxlag=8,maxorder=8,␣
 ↪ic='aic',seasonal=False)
ves= ARDL(endog=en,lags=lags.ar_lags,exog=exs,order=lags.dl_lags,trend='ct').
 ↪fit()
lags = ardl_select_order(endog=en, exog=exq, maxlag=4,maxorder=4,␣
 ↪ic='aic',seasonal=False)
veq= ARDL(endog=en,lags=lags.ar_lags,exog=exq,order=lags.dl_lags,trend='ct').
 ↪fit()
lags = ardl_select_order(endog=en, exog=exqc, maxlag=4,maxorder=4,␣
 ↪ic='aic',seasonal=False)
veqc= ARDL(endog=en,lags=lags.ar_lags,exog=exqc,order=lags.dl_lags,trend='ct').
 ↪fit()
lags = ardl_select_order(endog=en, exog=exqs, maxlag=4,maxorder=4,␣
 ↪ic='aic',seasonal=False)
veqs= ARDL(endog=en,lags=lags.ar_lags,exog=exqs,order=lags.dl_lags,trend='ct').
 ↪fit()

models = {'fve': ve, 'fvec': vec,'fves': ves}
results = {}

for name, model in models.items():
    fitted = pd.DataFrame(model.predict(), columns=en.columns)
    fitted.index = pd.date_range(end='2024-12-31', periods=44, freq='QE')
    merged = pd.merge(en, fitted, left_index=True, right_index=True,␣
 ↪suffixes=('', f'_fitted'))
    results[name] = merged

models = {'fveq': veq,'fveqc': veqc, 'fveqs': veqs}
result = {}

for name, model in models.items():
    fitted = pd.DataFrame(model.predict(), columns=en.columns)
    fitted.index = pd.date_range(end='2024-12-31', periods=44, freq='QE')
    merged = pd.merge(en, fitted, left_index=True, right_index=True,␣
 ↪suffixes=('', f'_fitted'))
    result[name] = merged



fig, ax = plt.subplots(3,2,figsize=(12, 12))
```

```python
ax[0,0].plot(results['fve']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[0,0].plot(results['fve']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[0,0].set_title('(a) ARDL')
ax[0,0].legend()

ax[0,1].plot(results['fvec']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[0,1].plot(results['fvec']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[0,1].set_title('(b) ARDL+Covid')
ax[0,1].legend()

ax[1,0].plot(results['fves']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[1,0].plot(results['fves']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[1,0].set_title('(c) ARDL+Scarring')
ax[1,0].legend()

ax[1,1].plot(result['fveq']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[1,1].plot(result['fveq']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[1,1].set_title('(d) ARDL+Quarterly')
ax[1,1].legend()

ax[2,0].plot(result['fveqc']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[2,0].plot(result['fveqc']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[2,0].set_title('(e) ARDL+Q+C')
ax[2,0].legend()

ax[2,1].plot(result['fveqs']['g'],color='#845B24',linestyle='-',label="Actual GDP Growth")
ax[2,1].plot(result['fveqs']['g_fitted'], linestyle='--', color='#EEC051', label="Fitted GDP Growth")
ax[2,1].set_title('(f) ARDL+Q+S')
ax[2,1].legend()
plt.tight_layout()
plt.savefig("fig/ARDL.png")
plt.show()
```

```
C:\Users\imed\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.13_qbz5n2
kfra8p0\LocalCache\local-packages\Python313\site-
```

```
packages\statsmodels\tsa\ardl\model.py:455: SpecificationWarning: exog contains
variables that are missing from the order dictionary.  Missing keys: q3, q2, q1.
  return _format_order(self.data.orig_exog, order, self._causal)
C:\Users\imed\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.13_qbz5n2
kfra8p0\LocalCache\local-packages\Python313\site-
packages\statsmodels\tsa\ardl\model.py:455: SpecificationWarning: exog contains
variables that are missing from the order dictionary.  Missing keys: ntlg, q3,
q2, q1.
  return _format_order(self.data.orig_exog, order, self._causal)
C:\Users\imed\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.13_qbz5n2
kfra8p0\LocalCache\local-packages\Python313\site-
packages\statsmodels\tsa\ardl\model.py:455: SpecificationWarning: exog contains
variables that are missing from the order dictionary.  Missing keys: ntlg, q3.
  return _format_order(self.data.orig_exog, order, self._causal)
```



(a) ARDL

(b) ARDL+Covid

(c) ARDL+Scarring

(d) ARDL+Quarterly

(e) ARDL+Q+C

(f) ARDL+Q+S

[ ]:

```python
# Model Functions

def run_vecm(en_train, exog_train, rank=1, det="ci", maxlags=8):
    """VECM with exogenous terms and valid det_type ('ci' or 'co')."""
    if det not in ["ci", "co"]:
        raise ValueError("det_type must be 'ci' or 'co' for VECM.")
    try:
        sel = select_order(en_train, maxlags=maxlags, deterministic=det)
        lag = sel.aic if (sel.aic is not None and sel.aic >= 1) else 1
    except Exception as e:
        print(f"select_order failed ({e}); fallback lag=1")
        lag = 1
    print(f"VECM | lag={lag}, rank={rank}, det={det}")
    model = VECM(en_train, k_ar_diff=lag, coint_rank=rank,
                 deterministic=det, exog=exog_train).fit()
    fitted = pd.DataFrame(model.fittedvalues, columns=en_train.columns,
                          index=en_train.index[-len(model.fittedvalues):])
    return model, fitted

def run_var(en_train, exog_train=None, maxlags=8):
    df = en_train.copy()
    if exog_train is not None:
        df = pd.concat([df, exog_train], axis=1)
    var_model = VAR(df)
    sel = var_model.select_order(maxlags=maxlags)
    p = max(sel.aic, 1) if sel.aic else 1
    print(f"VAR | lag={p}")
    res = var_model.fit(p)
    fitted = res.fittedvalues
    return res, fitted, p

def run_bvar_ridge(en_train, exog_train=None, p=2, lam=0.1):
    Y, X = [], []
    base = en_train.copy()
    if exog_train is not None:
        base = pd.concat([base, exog_train], axis=1)
    for t in range(p, len(base)):
        Y.append(base.values[t, :2])  # first 2 columns (g, ntlg)
        X.append(base.values[t-p:t].flatten())
    Y, X = np.array(Y), np.array(X)
    coefs = []
    for j in range(Y.shape[1]):
        ridge = Ridge(alpha=lam, fit_intercept=True)
        ridge.fit(X, Y[:, j])
        coefs.append(ridge)
    fitted_vals = np.array([r.predict(X) for r in coefs]).T
    fitted = pd.DataFrame(fitted_vals, index=base.index[p:],␣
↪columns=['g','ntlg'])
    return coefs, fitted, p

def run_ardl(en_ardl, ex_ardl, maxlags=8):
    try:
        lag_sel = ardl_select_order(endog=en_ardl, exog=ex_ardl,
                                    maxlag=maxlags, maxorder=maxlags,
                                    ic="aic", seasonal=False)
        print(f"ARDL | AR lags={lag_sel.ar_lags}, exog lags={lag_sel.dl_lags}")
        model = ARDL(endog=en_ardl, lags=lag_sel.ar_lags,
                     exog=ex_ardl, order=lag_sel.dl_lags, trend="ct").fit()
    except Exception as e:
        print(f"ARDL selection failed ({e}); fallback (1,0)")
        model = ARDL(endog=en_ardl, lags=1, exog=ex_ardl, order=0, trend="ct").
↪fit()
    fitted = model.fittedvalues.to_frame(name="g")
    return model, fitted
```

```
[ ]: def parse_ardl_summary(model_res):
         """Cleanly extract ARDL coefficients as a proper DataFrame."""
         try:
             summary_table = model_res.summary().tables[1]
             df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
             df.reset_index(inplace=True)
             df.rename(columns={"index": "variable"}, inplace=True)
             return df
         except Exception:
             if hasattr(model_res, "params"):
                 return pd.DataFrame({
                     "variable": model_res.params.index,
                     "coef": model_res.params.values,
                     "std_err": getattr(model_res, "bse", np.nan),
                     "z": getattr(model_res, "tvalues", np.nan),
                     "P>|z|": getattr(model_res, "pvalues", np.nan)
                 })
             else:
                 return pd.DataFrame({"info": ["Could not parse ARDL coefficients.
     ↪"]})


     def parse_text_summary(summary_text, start_pattern=None, end_pattern=None):
         """Generic parser for fixed-width text tables in statsmodels summaries."""
         lines = summary_text.splitlines()
         start, end = None, None
         if start_pattern:
```

```python
        for i, line in enumerate(lines):
            if re.search(start_pattern, line):
                start = i + 2
            elif end_pattern and start is not None and re.search(end_pattern, line):
                end = i - 1
                break
    if start is None:
        start, end = 0, len(lines)
    block_lines = lines[start:end]
    data_lines = [ln for ln in block_lines if re.match(r"^[A-Za-zL0-9]", ln.strip())]
    if not data_lines:
        return None
    table_str = "\n".join(data_lines)
    df = pd.read_fwf(
        io.StringIO(table_str),
        names=["variable", "coef", "std_err", "z", "P>|z|", "CI_low", "CI_high"],
        infer_nrows=100
    )
    for col in ["coef", "std_err", "z", "P>|z|", "CI_low", "CI_high"]:
        if col in df.columns:
            df[col] = pd.to_numeric(df[col], errors="coerce")
    return df.dropna(subset=["coef"], how="all")


def parse_var_summary_tables(model_res):
    """Extract both merged and detailed coefficient tables from VAR summary."""
    summary_text = str(model_res.summary())
    lines = summary_text.splitlines()
    results = []
    eq_name = None
    capture = False
    block_lines = []

    for line in lines:
        match_eq = re.match(r"Results for equation (.+)", line)
        if match_eq:
            if eq_name and block_lines:
                results.append((eq_name, "\n".join(block_lines)))
                block_lines = []
            eq_name = match_eq.group(1).strip()
            capture = True
            continue
        if capture and re.match(r"Correlation matrix", line):
            if eq_name and block_lines:
                results.append((eq_name, "\n".join(block_lines)))
            break
        elif capture and re.match(r"^[A-Za-zL0-9]", line.strip()):
            block_lines.append(line.strip())

    all_tables = []
    for eq_name, block in results:
        df = pd.read_fwf(
            io.StringIO(block),
            names=["variable", "coef", "std_err", "t_stat", "p_value"],
            infer_nrows=100
        )
        for c in ["coef", "std_err", "t_stat", "p_value"]:
            df[c] = pd.to_numeric(df[c], errors="coerce")
        df["equation"] = eq_name
        all_tables.append(df)

    if not all_tables:
        return (pd.DataFrame({"info": ["No coefficients parsed from VAR summary.
 ↪"]}), None)

    # Compact merged table
    merged = None
    for df in all_tables:
        eq_name = df["equation"].iloc[0]
        sub = df[["variable", "coef"]].copy()
        sub.rename(columns={"coef": eq_name}, inplace=True)
        merged = sub if merged is None else pd.merge(merged, sub,␣
 ↪on="variable", how="outer")

    detailed = pd.concat(all_tables, ignore_index=True)
    return merged, detailed
```

[ ]:

```
# Settings
model_type   = "VAR"        # "VECM", "VAR", "VAR_diff", "BVAR", "ARDL"
spec_type    = "covid"    # "baseline", "covid", "scar", "q", "q_covid",␣
 ↪"q_scar"
chosen_rank  = 1             # for VECM
det_type     = "ci"          # for VECM
steps_ahead  = 4             # 4=2024Q3-2025Q2, 8=2023Q3-2025Q2
ridge_lambda = 0.1           # for BVAR
max_lags     = 8

# Forecast horizon
if steps_ahead == 4:
    future_idx = pd.date_range("2024-09-30", periods=steps_ahead, freq="QE")
    train_end  = pd.Timestamp("2024-06-30")
```

```
elif steps_ahead == 8:
    future_idx = pd.date_range("2023-09-30", periods=steps_ahead, freq="QE")
    train_end  = pd.Timestamp("2023-06-30")
else:
    raise ValueError("steps_ahead must be 4 or 8.")

# Base data prep
en    = ntlm[['g','ntlg']]
exc   = ntlm[['covid']]
exs   = ntlm[['scar']]
exq   = ntlm[['q1','q2','q3']]
exqc = ntlm[['q1','q2','q3','covid']]
exqs = ntlm[['q1','q2','q3','scar']]

ntlm_train = ntlm.loc[:train_end].copy()
en_train   = en.loc[:train_end]

# unified exog map for all models
exog_map = {
    "baseline": None,
    "covid":   exc.loc[:train_end],
    "scar":    exs.loc[:train_end],
    "q":       exq.loc[:train_end],
    "q_covid": exqc.loc[:train_end],
    "q_scar":  exqs.loc[:train_end],
}
exog_train = exog_map.get(spec_type, None)

# Define endog/exog for ARDL specifically
en_ardl   = ntlm[['g']].loc[:train_end]
ex_ardl   = {
    "baseline": ntlm[['ntlg']],
    "covid":   ntlm[['ntlg','covid']],
    "scar":    ntlm[['ntlg','scar']],
    "q":       ntlm[['ntlg','q1','q2','q3']],
    "q_covid": ntlm[['ntlg','q1','q2','q3','covid']],
    "q_scar":  ntlm[['ntlg','q1','q2','q3','scar']],
}[spec_type].loc[:train_end]


# Execution
if model_type == "VECM":
    model_res, fitted_df = run_vecm(en_train, exog_train, rank=chosen_rank,␣
  ↪det=det_type)
    last_exog = exog_train.iloc[-1].values if exog_train is not None else None
    exog_future = np.tile(last_exog, (steps_ahead, 1)) if last_exog is not None␣
  ↪else None
```

```
    fcst_array = model_res.predict(steps=steps_ahead, exog_fc=exog_future)

elif model_type == "VAR":
    model_res, fitted_df, p = run_var(en_train, exog_train)
    fcst_array = model_res.forecast(y=en_train.values[-p:], steps=steps_ahead)

elif model_type == "BVAR":
    coefs, fitted_df, p = run_bvar_ridge(en_train, exog_train, lam=ridge_lambda)
    history = en_train.values.copy()
    for _ in range(steps_ahead):
        x_new = history[-p:].flatten().reshape(1, -1)
        y_new = [ridge.predict(x_new)[0] for ridge in coefs]
        history = np.vstack([history, y_new])
    fcst_array = history[-steps_ahead:]

elif model_type == "ARDL":

    # ==========================
    # 1. Fit ARDL model
    # ==========================
    model_res, fitted_df = run_ardl(en_ardl, ex_ardl)

    # ==========================
    # 2. Forecast target quarter (2025Q3)
    # ==========================
    train_end   = pd.Timestamp("2025-06-30")        # last known GDP/NTL
    steps_ahead = 1                                 # only 1-quarter ahead
    future_idx  = pd.date_range("2025-09-30", periods=1, freq="QE")   # 2025Q3

    # ==========================
    # 3. Exogenous values for 2025Q3
    #    Use last available (2025Q2)
    # ==========================
    x_future = pd.DataFrame(
        np.tile(ex_ardl.iloc[-1].values, (steps_ahead, 1)),
        columns=ex_ardl.columns,
        index=future_idx
    )

    # ==========================
    # 4. Proper ARDL prediction
    #    MUST use integer index, NOT timestamp
    # ==========================
    fcst_series = model_res.predict(
        start=len(en_ardl),
        end=len(en_ardl),
        exog_oos=x_future
    )

    # ==========================
    # 5. Match expected output shape
    # ==========================
    fcst_array = np.column_stack([
        fcst_series.values,
        np.tile(en_ardl["g"].iloc[-1], steps_ahead)
    ])


# Actuals

# Ensure Date is datetime and quarterly
if 'Date' in gdp.columns:
    gdp['Date'] = pd.to_datetime(gdp['Date']) + QuarterEnd(0)
    gdp = gdp.set_index('Date')
else:
    # already indexed by date
    gdp.index = pd.to_datetime(gdp.index) + QuarterEnd(0)

# Align to quarterly frequency
gdp = gdp.asfreq('QE-DEC')

# Compute log of GDP levels
if 'GDP' not in gdp.columns:
    raise ValueError("No 'GDP' column found in gdp DataFrame.")
gdp['log_gdp'] = np.log(gdp['GDP'])

# Extract actuals aligned to future_idx
actual_gdp = gdp['log_gdp'].reindex(future_idx).rename("g_actual")


# Compare
compare = pd.DataFrame({
    "g_forecast": fcst_df["g"],
    "g_actual": actual_gdp
}, index=future_idx)
compare["error"] = compare["g_forecast"] - compare["g_actual"]

mae = compare["error"].abs().mean()
rmse = np.sqrt((compare["error"]**2).mean())

# Print for all models/specs
print(f"{model_type}-{spec_type} → Forecast {future_idx.min().date()}-
{future_idx.max().date()}")
display(compare.round(3))
```

```
print(f"MAE: {mae:.3f}, RMSE: {rmse:.3f}")

# Plot
plt.figure(figsize=(12,6))
plt.plot(en.index, en["g"], label="Actual log(GDP) in-sample", color="#7f6000")
plt.plot(fitted_df.index, fitted_df["g"], "--", label=f"Fitted {model_type}-{spec_type}", color="#FFBF00")
plt.plot(fcst_df.index, fcst_df["g"], "o--", label=f"Forecast log(GDP) ({model_type}-{spec_type})",
         color="#FFBF00", markerfacecolor="none")
plt.plot(compare.index, compare["g_actual"], "x-", label="Actual log(GDP) OOS", color="black", linewidth=2)

plt.axvspan(fcst_df.index[0], fcst_df.index[-1], color="gray", alpha=0.15)
plt.axhline(0, color="gray", linestyle=":")
plt.legend()

# Title with model + spec type
plt.title(f"{model_type}-{spec_type} - In-sample fit & Out-of-sample forecast")

plt.ylabel("log(GDP)")
plt.xlabel("Date")

# Y-axis limits
plt.ylim(14.25, 15.25)

# X-axis ticks: show every year
import matplotlib.dates as mdates
plt.gca().xaxis.set_major_locator(mdates.YearLocator(1))
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))
plt.xticks(rotation=45)

plt.show()

# === Prepare Excel output path ===
timestamp = datetime.now().strftime("%Y%m%d_%H%M")
output_file = f"model_results_{model_type}_{spec_type}_{timestamp}.xlsx"

# === 1. Forecast Comparison Sheet ===
compare_out = compare.copy()
compare_out.index.name = "Date"

# === 2. Fit Statistics Sheet ===
fit_stats = pd.DataFrame({
    "Model": [model_type],
    "Specification": [spec_type],
    "Steps_ahead": [steps_ahead],
    "MAE": [mae],
    "RMSE": [rmse],
    "Rank (VECM only)": [chosen_rank if model_type == "VECM" else None],
    "Deterministic type": [det_type if model_type == "VECM" else None],
    "Train_end": [train_end.strftime("%Y-%m-%d")]
})


# === 3. Coefficient Table Extraction (unified for all models) ===
coef_table = None
coef_table_detailed = None  # for VAR detailed output


# === Apply model-specific parsing ===
try:
    if model_type == "VECM":
        coef_table = parse_text_summary(
            model_res.summary().as_text(),
            start_pattern=r"equation g",
            end_pattern=r"equation ntlg"
        )

    elif model_type in ["VAR", "VAR_diff"]:
        coef_table, coef_table_detailed = parse_var_summary_tables(model_res)

    elif model_type == "ARDL":
        coef_table = parse_ardl_summary(model_res)

    elif model_type == "BVAR":
        coef_data = []
        for i, ridge in enumerate(coefs):
            row = {"equation": f"eq{i+1}"}
            if hasattr(ridge, "coef_"):
                row.update({f"beta_{j}": b for j, b in enumerate(ridge.coef_.
 ↪flatten(), 1)})
            coef_data.append(row)
        coef_table = pd.DataFrame(coef_data)

    else:
        coef_table = pd.DataFrame({"info": ["No coefficient table extracted."]})

except Exception as e:
    coef_table = pd.DataFrame({"error": [f"Could not extract coefficients:␣
 ↪{e}"]})
    coef_table_detailed = None
```

```
# === Write all results to Excel ===
with pd.ExcelWriter(output_file, engine="openpyxl") as writer:
    compare_out.to_excel(writer, sheet_name="Forecast_vs_Actual")
    fit_stats.to_excel(writer, sheet_name="Fit_Stats", index=False)

    if model_type in ["VAR", "VAR_diff"]:
        if coef_table is not None:
            coef_table.to_excel(writer, sheet_name="VAR_Merged", index=False)
        if coef_table_detailed is not None:
            coef_table_detailed.to_excel(writer, sheet_name="VAR_Detailed",␣
 ↪index=False)
    elif coef_table is not None:
        coef_table.to_excel(writer, sheet_name="Model_Coefficients",␣
 ↪index=False)

print(f"  Results saved to {output_file}")
```

```
VAR | lag=4
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
Cell In[9], line 63
     61 elif model_type == "VAR":
     62     model_res, fitted_df, p = run_var(en_train, exog_train)
---> 63     fcst_array = model_res.forecast(y=en_train.values[-p:],␣
 ↪steps=steps_ahead)
     65 elif model_type == "BVAR":
     66     coefs, fitted_df, p = run_bvar_ridge(en_train, exog_train,␣
 ↪lam=ridge_lambda)

File ~\anaconda3\Lib\site-packages\statsmodels\tsa\vector_ar\var_model.py:1176,␣
 ↪in VARProcess.forecast(self, y, steps, exog_future)
   1174 else:
   1175     exog_future = np.column_stack(exogs)
-> 1176 return forecast(y, self.coefs, trend_coefs, steps, exog_future)

File ~\anaconda3\Lib\site-packages\statsmodels\tsa\vector_ar\var_model.py:261,␣
 ↪in forecast(y, coefs, trend_coefs, steps, exog)
    258             prior_y = forcs[h - i - 1]
    260         # i=1 is coefs[0]
--> 261         f = f + np.dot(coefs[i - 1], prior_y)
    263     forcs[h - 1] = f
    265 return forcs

ValueError: shapes (3,3) and (2,) not aligned: 3 (dim 1) != 2 (dim 0)
```

[ ]:

```python
# === SETTINGS ===
model_types = ["VECM", "VAR", "VAR_diff", "BVAR", "ARDL"]
spec_types  = ["baseline", "covid", "scar", "q", "q_covid", "q_scar"]
steps_ahead = 4
ridge_lambda = 0.1
chosen_rank = 1
det_type = "ci"
max_lags = 8

# === OUTPUT FOLDER ===
timestamp = datetime.now().strftime("%Y%m%d_%H%M")
base_dir = f"forecast_results_{timestamp}"
os.makedirs(base_dir, exist_ok=True)

# === FORECAST HORIZON ===
if steps_ahead == 4:
    future_idx = pd.date_range("2024-09-30", periods=steps_ahead, freq="QE")
    train_end  = pd.Timestamp("2024-06-30")
elif steps_ahead == 8:
    future_idx = pd.date_range("2023-09-30", periods=steps_ahead, freq="QE")
    train_end  = pd.Timestamp("2023-06-30")
else:
    raise ValueError("steps_ahead must be 4 or 8.")

# === DATA PREPARATION ===
# assumes `ntlm` and `gdp` already defined in memory
en   = ntlm[['g','ntlg']]
exc  = ntlm[['covid']]
exs  = ntlm[['scar']]
exq  = ntlm[['q1','q2','q3']]
exqc = ntlm[['q1','q2','q3','covid']]
exqs = ntlm[['q1','q2','q3','scar']]
ntlm_train = ntlm.loc[:train_end].copy()
en_train   = en.loc[:train_end]

# align gdp
if 'Date' in gdp.columns:
    gdp['Date'] = pd.to_datetime(gdp['Date']) + QuarterEnd(0)
    gdp = gdp.set_index('Date')
else:
    gdp.index = pd.to_datetime(gdp.index) + QuarterEnd(0)
gdp = gdp.asfreq('QE-DEC')
gdp['log_gdp'] = np.log(gdp['GDP'])

# === HELPER FUNCTIONS ===
def parse_var_summary_tables(model_res):
    summary_text = str(model_res.summary())
    lines = summary_text.splitlines()
    results = []
    eq_name, capture, block_lines = None, False, []

    for line in lines:
        match_eq = re.match(r"Results for equation (.+)", line)
        if match_eq:
            if eq_name and block_lines:
                results.append((eq_name, "\n".join(block_lines)))
                block_lines = []
            eq_name = match_eq.group(1).strip()
            capture = True
            continue
        if capture and re.match(r"Correlation matrix", line):
            if eq_name and block_lines:
                results.append((eq_name, "\n".join(block_lines)))
            break
        elif capture and re.match(r"^[A-Za-zL0-9]", line.strip()):
            block_lines.append(line.strip())

    all_tables = []
    for eq_name, block in results:
        df = pd.read_fwf(
            io.StringIO(block),
            names=["variable", "coef", "std_err", "t_stat", "p_value"],
            infer_nrows=100
        )
        for c in ["coef", "std_err", "t_stat", "p_value"]:
            df[c] = pd.to_numeric(df[c], errors="coerce")
        df["equation"] = eq_name
        all_tables.append(df)

    if not all_tables:
        return pd.DataFrame({"info": ["No coefficients parsed from VAR summary."]}), None

    merged = None
    for df in all_tables:
        eq = df["equation"].iloc[0]
        sub = df[["variable", "coef"]].copy()
        sub.rename(columns={"coef": eq}, inplace=True)
        merged = sub if merged is None else pd.merge(merged, sub, on="variable", how="outer")

    detailed = pd.concat(all_tables, ignore_index=True)
    return merged, detailed
```

```python
def parse_ardl_summary(model_res):
    try:
        summary_table = model_res.summary().tables[1]
        df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
        df.reset_index(inplace=True)
        df.rename(columns={"index": "variable"}, inplace=True)
        return df
    except Exception:
        if hasattr(model_res, "params"):
            return pd.DataFrame({
                "variable": model_res.params.index,
                "coef": model_res.params.values,
                "std_err": getattr(model_res, "bse", np.nan),
                "z": getattr(model_res, "tvalues", np.nan),
                "P>|z|": getattr(model_res, "pvalues", np.nan)
            })
        else:
            return pd.DataFrame({"info": ["Could not parse ARDL coefficients.
↪"]})


# === STORAGE FOR SUMMARY RESULTS ===
summary_rows = []

# === MAIN LOOP ===
for model_type in model_types:
    for spec_type in spec_types:

        # Select exog
        exog_map = {
            "baseline": None,
            "covid":   exc.loc[:train_end],
            "scar":    exs.loc[:train_end],
            "q":       exq.loc[:train_end],
            "q_covid": exqc.loc[:train_end],
            "q_scar":  exqs.loc[:train_end],
        }
        exog_train = exog_map.get(spec_type, None)

        # Prepare ARDL vars
        en_ardl    = ntlm[['g']].loc[:train_end]
        ex_ardl    = {
            "baseline": ntlm[['ntlg']],
            "covid":   ntlm[['ntlg','covid']],
            "scar":    ntlm[['ntlg','scar']],
            "q":       ntlm[['ntlg','q1','q2','q3']],
            "q_covid": ntlm[['ntlg','q1','q2','q3','covid']],
            "q_scar":  ntlm[['ntlg','q1','q2','q3','scar']],
        }[spec_type].loc[:train_end]

        # === Run model ===
        if model_type == "VECM":
            model_res, fitted_df = run_vecm(en_train, exog_train,␣
↪rank=chosen_rank, det=det_type)
            last_exog = exog_train.iloc[-1].values if exog_train is not None␣
↪else None
            exog_future = np.tile(last_exog, (steps_ahead, 1)) if last_exog is␣
↪not None else None
            fcst_array = model_res.predict(steps=steps_ahead,␣
↪exog_fc=exog_future)

        # elif model_type == "VAR":
        #     model_res, fitted_df, p = run_var(en_train, exog_train)

        #     try:
        #         # Try forecast with or without exog
        #         if getattr(model_res, "k_exog", 0) > 0 and exog_train is not␣
↪None:
        #             last_exog = exog_train.iloc[-1].values
        #             exog_future = np.tile(last_exog, (steps_ahead, 1))
        #             fcst_array = model_res.forecast(
        #                 y=en_train.values[-p:],
        #                 steps=steps_ahead,
        #                 exog_future=exog_future
        #             )
        #         else:
        #             fcst_array = model_res.forecast(
        #                 y=en_train.values[-p:],
        #                 steps=steps_ahead
        #             )

        #         except ValueError as e:
        #             # Detect the specific exog alignment error and skip␣
↪gracefully
        #             if "No exog in model" in str(e) and "exog_future" in␣
↪str(e):
        #                 print(f" Skipping {model_type}-{spec_type}: {e}")
        #                 continue  # move to next spec/model combo
        #             else:
        #                 raise  # re-raise any other unexpected error
        # elif model_type == "VAR_diff":
        #     model_res, fitted_df, p = run_var(en_train.diff().dropna(),␣
↪exog_train)
        #     y_input = en_train.diff().dropna().values[-p:]

        #     if getattr(model_res, "k_exog", 0) > 0 and exog_train is not None:
        #         last_exog = exog_train.iloc[-1].values
        #         exog_future = np.tile(last_exog, (steps_ahead, 1))
        #         fcst_array = model_res.forecast(y=y_input, steps=steps_ahead,␣
↪exog_future=exog_future)
        #     else:
        #         fcst_array = model_res.forecast(y=y_input, steps=steps_ahead)



        # elif model_type == "BVAR":
        #     coefs, fitted_df, p = run_bvar_ridge(en_train, exog_train,␣
↪lam=ridge_lambda)
        #     history = en_train.values.copy()
        #     for _ in range(steps_ahead):
        #         x_new = history[-p:].flatten().reshape(1, -1)
        #         y_new = [ridge.predict(x_new)[0] for ridge in coefs]
        #         history = np.vstack([history, y_new])
        #     fcst_array = history[-steps_ahead:]

        elif model_type == "ARDL":
            model_res, fitted_df = run_ardl(en_ardl, ex_ardl)
            x_future = pd.DataFrame(
                np.tile(ex_ardl.iloc[-1].values, (steps_ahead, 1)),
                columns=ex_ardl.columns,
                index=future_idx
            )
            fcst_series = model_res.predict(
                start=len(en_ardl),
                end=len(en_ardl) + steps_ahead - 1,
                exog_oos=x_future
            )
            fcst_array = np.column_stack([
                fcst_series.values,
                np.tile(en_ardl["g"].iloc[-1], steps_ahead)
            ])
        else:
            continue

        # === Forecast results ===
        fcst_df = pd.DataFrame(fcst_array, columns=en_train.columns, index=future_idx)
        actual_gdp = gdp['log_gdp'].reindex(future_idx).rename("g_actual")
        compare = pd.DataFrame({
            "g_forecast": fcst_df["g"],
            "g_actual": actual_gdp
        }, index=future_idx)
        compare["error"] = compare["g_forecast"] - compare["g_actual"]
        mae = compare["error"].abs().mean()
        rmse = np.sqrt((compare["error"]**2).mean())

        # === Plot ===
        plt.figure(figsize=(12,6))
        plt.plot(en.index, en["g"], label="Actual log(GDP) in-sample", color="#7f6000")
        plt.plot(fitted_df.index, fitted_df["g"], "--", label=f"Fitted {model_type}-{spec_type}", color="#FFBF00")
        plt.plot(fcst_df.index, fcst_df["g"], "o--", label=f"Forecast log(GDP) ({model_type}-{spec_type})",
                 color="#FFBF00", markerfacecolor="none")
        plt.plot(compare.index, compare["g_actual"], "x-", label="Actual log(GDP) OOS", color="black", linewidth=2)
        plt.axvspan(fcst_df.index[0], fcst_df.index[-1], color="gray", alpha=0.15)
        plt.axhline(0, color="gray", linestyle=":")
        plt.legend()
        plt.title(f"{model_type}-{spec_type} - In-sample fit & Out-of-sample forecast")
        plt.ylabel("log(GDP)")
        plt.xlabel("Date")
        plt.ylim(14.25, 15.25)
        plt.gca().xaxis.set_major_locator(mdates.YearLocator(1))
        plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))
        plt.xticks(rotation=45)

        plot_path = os.path.join(base_dir, f"{model_type}_{spec_type}_forecast.png")
        plt.tight_layout()
        plt.savefig(plot_path, dpi=200)
        plt.close()

        # === Coefficients extraction ===
        coef_table = None
        coef_table_detailed = None
        if model_type == "VAR":
            coef_table, coef_table_detailed =␣
↪parse_var_summary_tables(model_res)
        elif model_type == "ARDL":
            coef_table = parse_ardl_summary(model_res)
        elif model_type == "BVAR":
            coef_data = []
            for i, ridge in enumerate(coefs):
                row = {"equation": f"eq{i+1}"}
                if hasattr(ridge, "coef_"):
                    row.update({f"beta_{j}": b for j, b in enumerate(ridge.
↪coef_.flatten(), 1)})
                coef_data.append(row)
            coef_table = pd.DataFrame(coef_data)

        # === Save to Excel ===
        excel_path = os.path.join(base_dir, f"{model_type}_{spec_type}.xlsx")
        with pd.ExcelWriter(excel_path, engine="openpyxl") as writer:
            compare.to_excel(writer, sheet_name="Forecast_vs_Actual")
            pd.DataFrame({
                "Model": [model_type],
                "Specification": [spec_type],
                "Steps_ahead": [steps_ahead],
                "MAE": [mae],
                "RMSE": [rmse],
                "Rank (VECM only)": [chosen_rank if model_type == "VECM" else␣
↪None],
                "Deterministic type": [det_type if model_type == "VECM" else␣
↪None],
                "Train_end": [train_end.strftime("%Y-%m-%d")]
            }).to_excel(writer, sheet_name="Fit_Stats", index=False)
            if model_type == "VAR":
                if coef_table is not None:
                    coef_table.to_excel(writer, sheet_name="VAR_Merged",␣
↪index=False)
                if coef_table_detailed is not None:
                    coef_table_detailed.to_excel(writer,␣
↪sheet_name="VAR_Detailed", index=False)
            elif coef_table is not None:
                coef_table.to_excel(writer, sheet_name="Model_Coefficients",␣
↪index=False)

        # record to summary
        summary_rows.append({
            "Model": model_type,
            "Specification": spec_type,
            "MAE": mae,
            "RMSE": rmse
        })

# === Final Summary Table ===
summary_df = pd.DataFrame(summary_rows)
summary_df.to_excel(os.path.join(base_dir, "model_summary.xlsx"), index=False)

print(f"\n  All models completed. Results saved in: {base_dir}")
```

```
VECM | lag=3, rank=1, det=ci
VECM | lag=3, rank=1, det=ci
VECM | lag=3, rank=1, det=ci
VECM | lag=3, rank=1, det=ci
VECM | lag=3, rank=1, det=ci
VECM | lag=3, rank=1, det=ci
ARDL | AR lags=[1, 2, 3, 4, 5], exog lags={'ntlg': [0, 1, 2]}
```

```
C:\Users\timot\AppData\Local\Temp\ipykernel_27584\4133505496.py:107:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
C:\Users\timot\anaconda3\Lib\site-packages\statsmodels\tsa\ardl\model.py:455:
SpecificationWarning: exog contains variables that are missing from the order
dictionary.  Missing keys: ntlg.
  return _format_order(self.data.orig_exog, order, self._causal)
```

```
ARDL | AR lags=[1, 2, 3, 4, 5, 6, 7, 8], exog lags={'covid': [0, 1, 2, 3, 4, 5,
6, 7, 8]}
```

```
C:\Users\timot\AppData\Local\Temp\ipykernel_27584\4133505496.py:107:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
```

```
ARDL | AR lags=[1, 2, 3, 4, 5, 6, 7, 8], exog lags={'ntlg': [0, 1, 2, 3, 4, 5,
6, 7, 8], 'scar': [0, 1, 2, 3, 4, 5, 6, 7]}
```

```
C:\Users\timot\AppData\Local\Temp\ipykernel_27584\4133505496.py:107:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
```

```
ARDL selection failed (The number of regressors (45) including deterministics,
lags of the endog, lags of the exogenous, and fixed regressors is larger than
the sample available for estimation (42).); fallback (1,0)
```

```
C:\Users\timot\AppData\Local\Temp\ipykernel_27584\4133505496.py:107:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
```

```
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
```

```
ARDL selection failed (The number of regressors (54) including deterministics,
lags of the endog, lags of the exogenous, and fixed regressors is larger than
the sample available for estimation (42).); fallback (1,0)
```

```
C:\Users\timot\AppData\Local\Temp\ipykernel_27584\4133505496.py:107:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
```

```
ARDL selection failed (The number of regressors (54) including deterministics,
lags of the endog, lags of the exogenous, and fixed regressors is larger than
the sample available for estimation (42).); fallback (1,0)

  All models completed. Results saved in: forecast_results_20251017_2119
```

```
C:\Users\timot\AppData\Local\Temp\ipykernel_27584\4133505496.py:107:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
```

[ ]:

```python
# === SETTINGS ===
model_types = ["VECM", "VAR", "VAR_diff", "BVAR", "ARDL"]
spec_types  = ["baseline", "covid", "scar", "q", "q_covid", "q_scar"]
ridge_lambda = 0.1
chosen_rank = 1
det_type = "ci"
max_lags = 8

# === OUTPUT FOLDER ===
timestamp = datetime.now().strftime("%Y%m%d_%H%M")
base_dir = f"forecast_results_{timestamp}"
os.makedirs(base_dir, exist_ok=True)

# === DATA PREPARATION ===
en   = ntlm[['g','ntlg']]
exc  = ntlm[['covid']]
exs  = ntlm[['scar']]
exq  = ntlm[['q1','q2','q3']]
exqc = ntlm[['q1','q2','q3','covid']]
exqs = ntlm[['q1','q2','q3','scar']]

# --- Align GDP ---
if 'Date' in gdp.columns:
    gdp['Date'] = pd.to_datetime(gdp['Date']) + QuarterEnd(0)
    gdp = gdp.set_index('Date')
else:
    gdp.index = pd.to_datetime(gdp.index) + QuarterEnd(0)
gdp = gdp.asfreq('QE-DEC')
gdp['log_gdp'] = np.log(gdp['GDP'])

# === HELPERS ===
def parse_vecm_summary(model_res):
    try:
        summary_text = str(model_res.summary())
        lines = summary_text.splitlines()
        data_lines = [ln for ln in lines if re.match(r"^[A-Za-z]", ln.strip())]
        df = pd.read_fwf(io.StringIO("\n".join(data_lines)),
                         names=["variable", "coef", "std_err", "t_stat",␣
 ↪"p_value"],
                         infer_nrows=100)
        for c in ["coef", "std_err", "t_stat", "p_value"]:
            df[c] = pd.to_numeric(df[c], errors="coerce")
        return df.dropna(subset=["coef"], how="all")
    except Exception as e:
        return pd.DataFrame({"error":[f"Could not parse VECM coefficients:␣
 ↪{e}"]})

def parse_text_summary(summary_text, start_pattern=None, end_pattern=None):
    lines = summary_text.splitlines()
    start, end = None, None

    if start_pattern:
        for i, line in enumerate(lines):
            if re.search(start_pattern, line):
                start = i + 2
            elif end_pattern and start is not None and re.
 ↪search(end_pattern,line):
                end = i - 1
                break
    if start is None:
        start, end = 0, len(lines)

    block_lines = lines[start:end]
    data_lines  = [ln for ln in block_lines if re.match(r"^[A-Za-zL0-9]", ln.
 ↪strip())]

    if not data_lines:
        return None

    df = pd.read_fwf(
        io.StringIO("\n".join(data_lines)),
        names=["variable","coef","std_err","z","P>|z|","CI_low","CI_high"],
        infer_nrows=100
    )
    for col in ["coef","std_err","z","P>|z|","CI_low","CI_high"]:
        if col in df.columns:
            df[col] = pd.to_numeric(df[col], errors="coerce")
    return df.dropna(subset=["coef"], how="all")


summary_rows = []

# === MAIN LOOP ===
for model_type in model_types:
    for spec_type in spec_types:

        print(f"\n=== Running {model_type}-{spec_type} ===")

        # ============================================================
        # 1. TRAINING WINDOW & FORECAST HORIZON
        # ============================================================
        if model_type == "VECM":
            train_end   = pd.Timestamp("2023-12-31")
            steps_ahead = 8  # 2024Q1-2025Q3 (for example)

        elif model_type == "ARDL":
            # Train up to 2025Q2 and forecast 1 step = 2025Q3
            train_end   = pd.Timestamp("2025-06-30")   # last observed quarter
            steps_ahead = 1                            # only predict 2025Q3

        else:
            train_end   = pd.Timestamp("2024-09-30")
            steps_ahead = 4

        # === Common forecast index (for whatever we forecast) ===
        future_idx = pd.date_range(train_end + QuarterEnd(0),
                                   periods=steps_ahead,
                                   freq="QE")

        # ============================================================
        # 2. PREPARE DATA
        # ============================================================
        ntlm_train = ntlm.loc[:train_end].copy()
        en_train   = en.loc[:train_end]

        exog_map = {
            "baseline": None,
            "covid":   exc.loc[:train_end],
            "scar":    exs.loc[:train_end],
            "q":       exq.loc[:train_end],
            "q_covid": exqc.loc[:train_end],
            "q_scar":  exqs.loc[:train_end],
        }
        exog_train = exog_map.get(spec_type, None)

        # ARDL-specific endog/exog
        en_ardl = ntlm[['g']].loc[:train_end]
        ex_ardl = {
            "baseline": ntlm[['ntlg']],
            "covid":   ntlm[['ntlg','covid']],
            "scar":    ntlm[['ntlg','scar']],
            "q":       ntlm[['ntlg','q1','q2','q3']],
            "q_covid": ntlm[['ntlg','q1','q2','q3','covid']],
            "q_scar":  ntlm[['ntlg','q1','q2','q3','scar']],
        }[spec_type].loc[:train_end]

        # ============================================================
        # 3. RUN MODEL
        # ============================================================
        if model_type == "VECM":
            model_res, fitted_df = run_vecm(en_train, exog_train,
                                            rank=chosen_rank, det=det_type)
            last_exog = exog_train.iloc[-1].values if exog_train is not None␣
↪else None
            exog_future = np.tile(last_exog, (steps_ahead, 1)) if last_exog is␣
↪not None else None
            fcst_array = model_res.predict(steps=steps_ahead,␣
↪exog_fc=exog_future)

        elif model_type == "ARDL":
            # ---- Fit ARDL on data up to 2025Q2 ----
            model_res, fitted_df = run_ardl(en_ardl, ex_ardl)

            # Some quick diagnostics so we see what the model "thinks"
            print("ARDL | last training index:", en_ardl.index[-1])
            print("ARDL | len(en_ardl):", len(en_ardl))

            # ---- Forecast 1 step ahead (index = len(en_ardl)) ----
            # Target quarter is 2025Q3 = 2025-09-30
            future_idx = pd.DatetimeIndex([pd.Timestamp("2025-09-30")])

            # Exogenous for 2025Q3: use latest available (2025Q2) values
            exog_oos = ex_ardl.iloc[[-1]].copy()
            exog_oos.index = future_idx
            # Important: use integer positions for ARDL .predict
            # We have observations indexed 0..len(en_ardl)-1 internally,
            # so next forecast is at position len(en_ardl)
            fcst_series = model_res.predict(
                start=len(en_ardl),      # first out-of-sample obs
                end=len(en_ardl),        # same, since 1-step ahead
                exog_oos=exog_oos
            )

            print("ARDL | forecast index (future_idx):", future_idx)
            print("ARDL | fcst_series:", fcst_series)

            # Match 2-column convention (g + placeholder ntlg)
            fcst_array = np.column_stack([
                fcst_series.values,
                np.tile(en_ardl["g"].iloc[-1], 1)
            ])

        else:
            # Skip other models for now if you want, or keep your VAR/BVAR logic
            continue

        # ==============================================================
        # 4. FORECAST RESULTS & COMPARISON
        # ==============================================================
        fcst_df = pd.DataFrame(fcst_array, columns=en_train.columns, index=future_idx)
        actual_gdp = gdp['log_gdp'].reindex(future_idx).rename("g_actual")

        compare = pd.DataFrame({
            "g_forecast": fcst_df["g"],
            "g_actual": actual_gdp
        }, index=future_idx)

        compare["error"] = compare["g_forecast"] - compare["g_actual"]
        mae  = compare["error"].abs().mean()
        rmse = np.sqrt((compare["error"]**2).mean())

        # ==============================================================
        # 5. EXPORT EXCEL + COEFFICIENTS
        # ==============================================================
        coef_table = None
        if model_type == "ARDL":
            coef_table = parse_ardl_summary(model_res)
        elif model_type == "VECM":
            coef_table = parse_text_summary(
                model_res.summary().as_text(),
                start_pattern=r"equation g",
                end_pattern=r"equation ntlg"
            )

        excel_path = os.path.join(base_dir, f"{model_type}_{spec_type}.xlsx")
        with pd.ExcelWriter(excel_path, engine="openpyxl") as writer:
            compare.to_excel(writer, sheet_name="Forecast_vs_Actual")
            pd.DataFrame({
                "Model": [model_type],
                "Specification": [spec_type],
                "Steps_ahead": [steps_ahead],
                "MAE": [mae],
                "RMSE": [rmse],
                "Train_end": [train_end.strftime("%Y-%m-%d")]
            }).to_excel(writer, sheet_name="Fit_Stats", index=False)
            if coef_table is not None:
                coef_table.to_excel(writer, sheet_name="Model_Coefficients",␣
 ↪index=False)

        summary_rows.append({
            "Model": model_type,
            "Specification": spec_type,
            "MAE": mae,
            "RMSE": rmse
        })

# === FINAL SUMMARY ===
summary_df = pd.DataFrame(summary_rows)
summary_df.to_excel(os.path.join(base_dir, "model_summary.xlsx"), index=False)
print("\n All models completed.")
```

```
=== Running VECM-baseline ===
VECM | lag=3, rank=1, det=ci

=== Running VECM-covid ===
VECM | lag=3, rank=1, det=ci

=== Running VECM-scar ===
VECM | lag=3, rank=1, det=ci

=== Running VECM-q ===
VECM | lag=3, rank=1, det=ci

=== Running VECM-q_covid ===
VECM | lag=3, rank=1, det=ci
```

```
=== Running VECM-q_scar ===
VECM | lag=3, rank=1, det=ci

=== Running VAR-baseline ===

=== Running VAR-covid ===

=== Running VAR-scar ===

=== Running VAR-q ===

=== Running VAR-q_covid ===

=== Running VAR-q_scar ===

=== Running VAR_diff-baseline ===

=== Running VAR_diff-covid ===

=== Running VAR_diff-scar ===

=== Running VAR_diff-q ===

=== Running VAR_diff-q_covid ===

=== Running VAR_diff-q_scar ===

=== Running BVAR-baseline ===

=== Running BVAR-covid ===

=== Running BVAR-scar ===

=== Running BVAR-q ===

=== Running BVAR-q_covid ===

=== Running BVAR-q_scar ===

=== Running ARDL-baseline ===
ARDL | AR lags=[1, 2, 3, 4, 5], exog lags={'ntlg': [0, 1, 2]}
ARDL | last training index: 2025-06-30 00:00:00
ARDL | len(en_ardl): 54
ARDL | forecast index (future_idx): DatetimeIndex(['2025-09-30'],
dtype='datetime64[ns]', freq=None)
ARDL | fcst_series: 2025-09-30    15.056096
Freq: QE-DEC, dtype: float64
```

```
=== Running ARDL-covid ===
```

```
C:\Users\timot\AppData\Local\Temp\ipykernel_20052\4048580729.py:5:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
C:\Users\timot\AppData\Local\Temp\ipykernel_20052\4048580729.py:5:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
```

```
ARDL | AR lags=[1, 2, 3, 4, 5, 6, 7], exog lags={'ntlg': [0, 1], 'covid': [0, 1,
2]}
ARDL | last training index: 2025-06-30 00:00:00
ARDL | len(en_ardl): 54
ARDL | forecast index (future_idx): DatetimeIndex(['2025-09-30'],
dtype='datetime64[ns]', freq=None)
ARDL | fcst_series: 2025-09-30    15.055996
Freq: QE-DEC, dtype: float64

=== Running ARDL-scar ===
ARDL | AR lags=[1, 2, 3, 4, 5, 6, 7], exog lags={'ntlg': [0, 1], 'scar': [0, 1,
2, 3, 4, 5, 6, 7]}
ARDL | last training index: 2025-06-30 00:00:00
ARDL | len(en_ardl): 54
ARDL | forecast index (future_idx): DatetimeIndex(['2025-09-30'],
dtype='datetime64[ns]', freq=None)
ARDL | fcst_series: 2025-09-30    15.053384
Freq: QE-DEC, dtype: float64

=== Running ARDL-q ===
```

```
C:\Users\timot\AppData\Local\Temp\ipykernel_20052\4048580729.py:5:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
```

```
ARDL | AR lags=[1, 2, 3, 4], exog lags={'ntlg': [0], 'q2': [0], 'q3': [0]}
ARDL | last training index: 2025-06-30 00:00:00
ARDL | len(en_ardl): 54
ARDL | forecast index (future_idx): DatetimeIndex(['2025-09-30'],
dtype='datetime64[ns]', freq=None)
ARDL | fcst_series: 2025-09-30    15.0617
Freq: QE-DEC, dtype: float64

=== Running ARDL-q_covid ===
ARDL selection failed (The number of regressors (54) including deterministics,
lags of the endog, lags of the exogenous, and fixed regressors is larger than
the sample available for estimation (46).); fallback (1,0)
ARDL | last training index: 2025-06-30 00:00:00
ARDL | len(en_ardl): 54
ARDL | forecast index (future_idx): DatetimeIndex(['2025-09-30'],
dtype='datetime64[ns]', freq=None)
ARDL | fcst_series: 2025-09-30    15.065373
Freq: QE-DEC, dtype: float64

=== Running ARDL-q_scar ===
ARDL selection failed (The number of regressors (54) including deterministics,
lags of the endog, lags of the exogenous, and fixed regressors is larger than
the sample available for estimation (46).); fallback (1,0)
ARDL | last training index: 2025-06-30 00:00:00
ARDL | len(en_ardl): 54
ARDL | forecast index (future_idx): DatetimeIndex(['2025-09-30'],
dtype='datetime64[ns]', freq=None)
ARDL | fcst_series: 2025-09-30    15.053884
Freq: QE-DEC, dtype: float64

  All models completed.
```

```
C:\Users\timot\anaconda3\Lib\site-packages\statsmodels\tsa\ardl\model.py:455:
SpecificationWarning: exog contains variables that are missing from the order
dictionary.  Missing keys: q1.
  return _format_order(self.data.orig_exog, order, self._causal)
C:\Users\timot\AppData\Local\Temp\ipykernel_20052\4048580729.py:5:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
C:\Users\timot\AppData\Local\Temp\ipykernel_20052\4048580729.py:5:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
C:\Users\timot\AppData\Local\Temp\ipykernel_20052\4048580729.py:5:
FutureWarning: Passing literal html to 'read_html' is deprecated and will be
removed in a future version. To read from a literal string, wrap it in a
'StringIO' object.
  df = pd.read_html(summary_table.as_html(), header=0, index_col=0)[0]
```

[ ]: