m-assignment-1-jupyter-python-code

April 4, 2024

[ ]:
```
# Load the dataset
import pandas as pd
import numpy as np

df = pd.read_csv('/content/current.csv')

# Clean the DataFrame by removing the row with transformation codes
df_cleaned = df.drop(index=0)
df_cleaned.reset_index(drop=True, inplace=True)
df_cleaned['sasdate'] = pd.to_datetime(df_cleaned['sasdate'], format='%m/%d/%Y')
df_cleaned
```

[ ]:

	sasdate	RPI	W875RX1	DPCERA3M086SBEA	CMRMTSPLx	\
0	1959-01-01	2583.560	2426.0	15.188	2.766768e+05	
1	1959-02-01	2593.596	2434.8	15.346	2.787140e+05	
2	1959-03-01	2610.396	2452.7	15.491	2.777753e+05	
3	1959-04-01	2627.446	2470.0	15.435	2.833627e+05	
4	1959-05-01	2642.720	2486.4	15.622	2.853072e+05	
..	…	…	…	…	…	
776	2023-09-01	19111.748	15741.9	116.594	1.507530e+06	
777	2023-10-01	19145.402	15784.6	116.663	1.505477e+06	
778	2023-11-01	19213.108	15859.9	117.127	1.514733e+06	
779	2023-12-01	19251.946	15899.0	117.773	1.530296e+06	
780	2024-01-01	19377.558	15948.8	117.639	NaN	

	RETAILx	INDPRO	IPFPNSS	IPFINAL	IPCONGD	…	\
0	18235.77392	21.9665	23.3891	22.2688	31.7011	…	
1	18369.56308	22.3966	23.7048	22.4617	31.9337	…	
2	18523.05762	22.7193	23.8483	22.5719	31.9337	…	
3	18534.46600	23.2032	24.1927	22.9026	32.4374	…	
4	18679.66354	23.5528	24.3936	23.1231	32.5925	…	
..	…	…	…	…	…	…	
776	705304.00000	103.2096	101.0935	101.3665	102.1034	…	
777	703528.00000	102.3722	100.5292	100.5527	101.1664	…	
778	703336.00000	102.6710	100.9362	101.2159	101.8557	…	
779	706180.00000	102.6715	100.8332	101.2843	101.9884	…	
780	700291.00000	102.5739	100.9984	101.7258	102.6235	…	

```
     DNDGRG3M086SBEA  DSERRG3M086SBEA  CES0600000008  CES2000000008  \
0             18.294           10.152           2.13           2.45
1             18.302           10.167           2.14           2.46
2             18.289           10.185           2.15           2.45
3             18.300           10.221           2.16           2.47
4             18.280           10.238           2.17           2.48
..               …                …              …              …
776          120.395          123.976          29.90          34.55
777          120.040          124.228          29.97          34.67
778          119.325          124.551          30.26          34.96
779          119.193          124.917          30.45          35.01
780          118.745          125.662          30.56          35.21

     CES3000000008  UMCSENTx  DTCOLNVHFNM   DTCTHFNM     INVEST  VIXCLSx
0             2.04       NaN      6476.00   12298.00    84.2043      NaN
1             2.05       NaN      6476.00   12298.00    83.5280      NaN
2             2.07       NaN      6508.00   12349.00    81.6405      NaN
3             2.08       NaN      6620.00   12484.00    81.8099      NaN
4             2.08      95.3      6753.00   12646.00    80.7315      NaN
..             …         …            …          …         …       …
776          26.62      67.9    508808.61  913938.95  5074.6108  15.0424
777          26.65      63.8    513229.64  918210.64  5015.5456  19.0462
778          26.89      61.3    517434.30  922552.40  4999.7208  13.8563
779          27.14      69.7    522366.13  928336.14  5077.4222  12.6960
780          27.22       NaN          NaN        NaN  5105.3504  13.3453

[781 rows x 128 columns]
```

[ ]:
```python
# Extract transformation codes
transformation_codes = df.iloc[0, 1:].to_frame().reset_index()
transformation_codes.columns = ['Series', 'Transformation_Code']

# Function to apply transformations based on the transformation code
import numpy as np
def apply_transformation(series, code):
    if code == 1:
        # No transformation
        return series
    elif code == 2:
        # First difference
        return series.diff()
    elif code == 3:
        # Second difference
        return series.diff().diff()
    elif code == 4:
        # Log
```

```
        return np.log(series)
    elif code == 5:
        # First difference of log
        return np.log(series).diff()
    elif code == 6:
        # Second difference of log
        return np.log(series).diff().diff()
    elif code == 7:
        # Delta (x_t/x_{t-1} - 1)
        return series.pct_change()
    else:
        raise ValueError("Invalid transformation code")

# Applying the transformations to each column in df_cleaned based on␣
 ↪transformation_codes
for series_name, code in transformation_codes.values:
    df_cleaned[series_name] = apply_transformation(df_cleaned[series_name].
 ↪astype(float), float(code))

df_cleaned = df_cleaned[2:]
df_cleaned.reset_index(drop=True, inplace=True)
df_cleaned.head()
```

[ ]:

	sasdate	RPI	W875RX1	DPCERA3M086SBEA	CMRMTSPLx	RETAILx	\
0	1959-03-01	0.006457	0.007325	0.009404	-0.003374	0.008321	
1	1959-04-01	0.006510	0.007029	-0.003622	0.019915	0.000616	
2	1959-05-01	0.005796	0.006618	0.012043	0.006839	0.007803	
3	1959-06-01	0.003068	0.003012	0.003642	-0.000097	0.009064	
4	1959-07-01	-0.000580	-0.000762	-0.003386	0.012155	-0.000330	

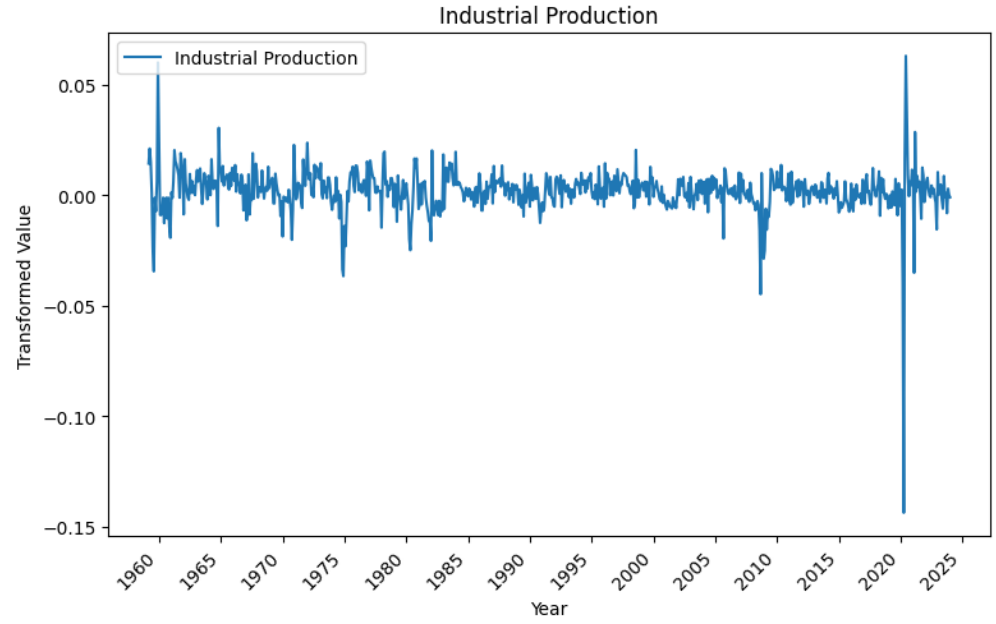
	INDPRO	IPFPNSS	IPFINAL	IPCONGD	…	DNDGRG3M086SBEA	\
0	0.014306	0.006035	0.004894	0.000000	…	-0.001148	
1	0.021075	0.014338	0.014545	0.015650	…	0.001312	
2	0.014955	0.008270	0.009582	0.004770	…	-0.001695	
3	0.001141	0.007034	0.007128	-0.004767	…	0.003334	
4	-0.024240	0.001168	0.008249	0.013054	…	-0.001204	

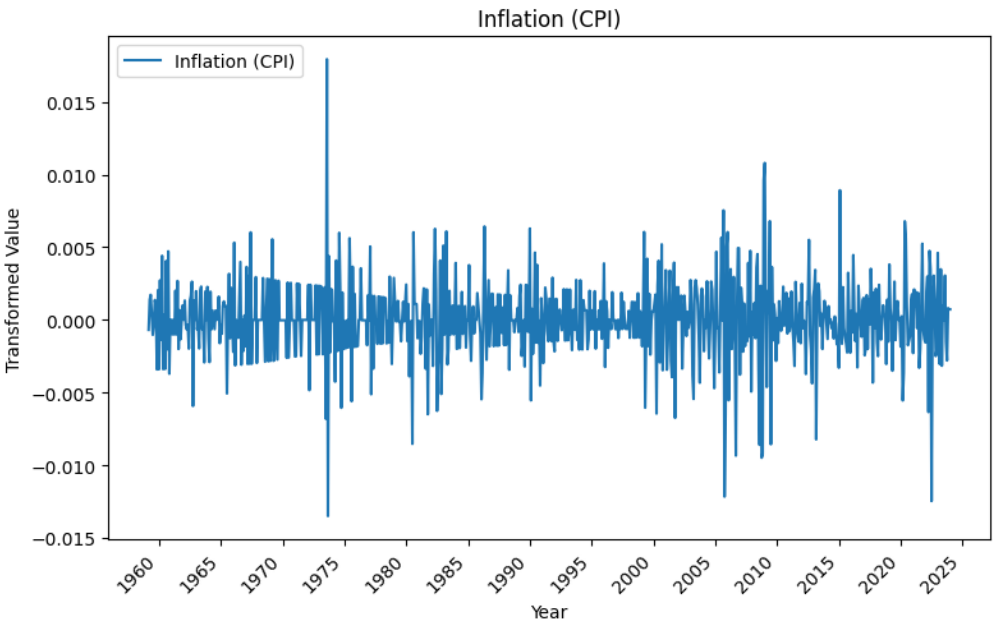
	DSERRG3M086SBEA	CES0600000008	CES2000000008	CES3000000008	UMCSENTx	\
0	0.000292	-0.000022	-0.008147	0.004819	NaN	
1	0.001760	-0.000022	0.012203	-0.004890	NaN	
2	-0.001867	-0.000021	-0.004090	-0.004819	NaN	
3	0.001946	-0.004619	0.003992	0.004796	NaN	
4	-0.000013	0.000000	-0.004040	-0.004796	NaN	

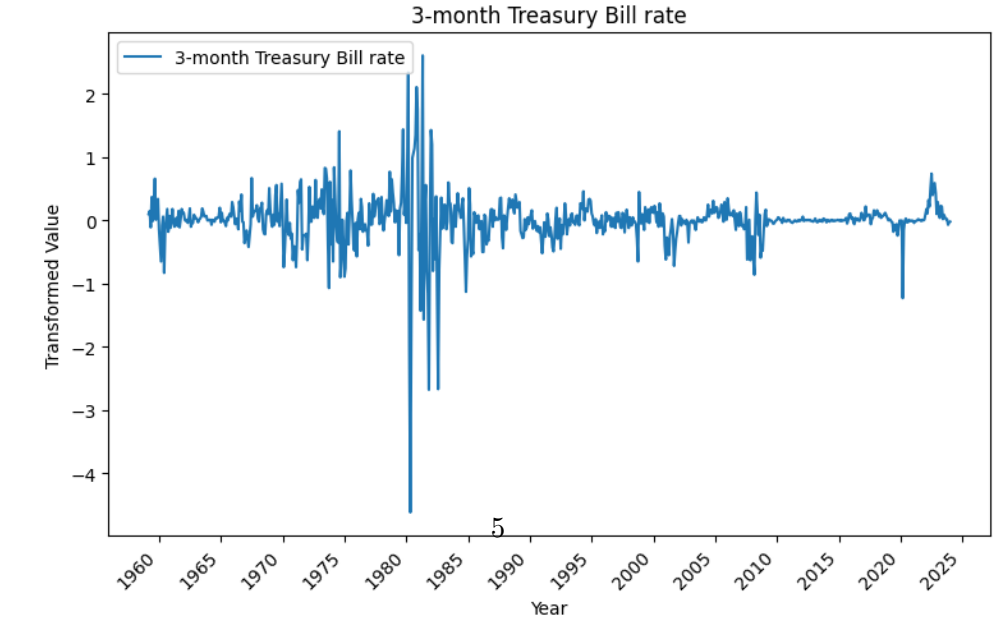
	DTCOLNVHFNM	DTCTHFNM	INVEST	VIXCLSx
0	0.004929	0.004138	-0.014792	NaN
1	0.012134	0.006734	0.024929	NaN

```
2     0.002828  0.002020 -0.015342      NaN
3     0.009726  0.009007 -0.012252      NaN
4    -0.004631 -0.001000  0.029341      NaN

[5 rows x 128 columns]
```

[ ]:
```python
# Plotting
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
series_to_plot = ['INDPRO', 'CPIAUCSL', 'TB3MS']
series_names = ['Industrial Production', 'Inflation (CPI)', '3-month Treasury␣
 ↪Bill rate']
fig, axs = plt.subplots(len(series_to_plot), 1, figsize=(8, 15))
for ax, series_name, plot_title in zip(axs, series_to_plot, series_names):
    if series_name in df_cleaned.columns:
        dates = pd.to_datetime(df_cleaned['sasdate'], format='%m/%d/%Y')
        ax.plot(dates, df_cleaned[series_name], label=plot_title)
        ax.xaxis.set_major_locator(mdates.YearLocator(base=5))
        ax.xaxis.set_major_formatter(mdates.DateFormatter('%Y'))
        ax.set_title(plot_title)
        ax.set_xlabel('Year')
        ax.set_ylabel('Transformed Value')
        ax.legend(loc='upper left')
        plt.setp(ax.xaxis.get_majorticklabels(), rotation=45, ha='right')
    else:
        ax.set_visible(False)  # Hide plots for which the data is not available
plt.tight_layout()
plt.show()
```


Industrial Production
Industrial Production
Transformed Value
0.05
0.00
−0.05
−0.10
−0.15
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year


Inflation (CPI)
Inflation (CPI)
Transformed Value
0.015
0.010
0.005
0.000
−0.005
−0.010
−0.015
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year


3-month Treasury Bill rate
3-month Treasury Bill rate
Transformed Value
2
1
0
−1
−2
−3
−4
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year

[22]:
```
# Prepare the data for ARX model
Y = df_cleaned['INDPRO'].dropna()
X = df_cleaned[['CPIAUCSL', 'FEDFUNDS']].dropna()

# Set the number of lags for Y and X
h = 1 # One-step ahead
p = 4
r = 4

# Prepare the target variable, lagged variables, and exogenous variables
Y_target = Y.shift(-h).dropna()
Y_lagged = pd.concat([Y.shift(i) for i in range(p+1)], axis=1).dropna()
X_lagged = pd.concat([X.shift(i) for i in range(r+1)], axis=1).dropna()

#Forecasting with ARX

Yraw = df_cleaned['INDPRO']
Xraw = df_cleaned[['CPIAUCSL', 'TB3MS']]
num_lags = 4 ## this is p
num_leads = 1 ## this is h
X = pd.DataFrame()

## Add the lagged values of Y
col = 'INDPRO'
for lag in range(0,num_lags+1):
  # Shift each column in the DataFrame and name it with a lag suffix
    X[f'{col}_lag{lag}'] = Yraw.shift(lag)
for col in Xraw.columns:
  for lag in range(0,num_lags+1):
    # Shift each column in the DataFrame and name it with a lag suffix
    X[f'{col}_lag{lag}'] = Xraw[col].shift(lag)

## Add a column on ones (for the intercept)
X.insert(0, 'Ones', np.ones(len(X)))
## X is now a DataFrame
X.head()
```

[22]:

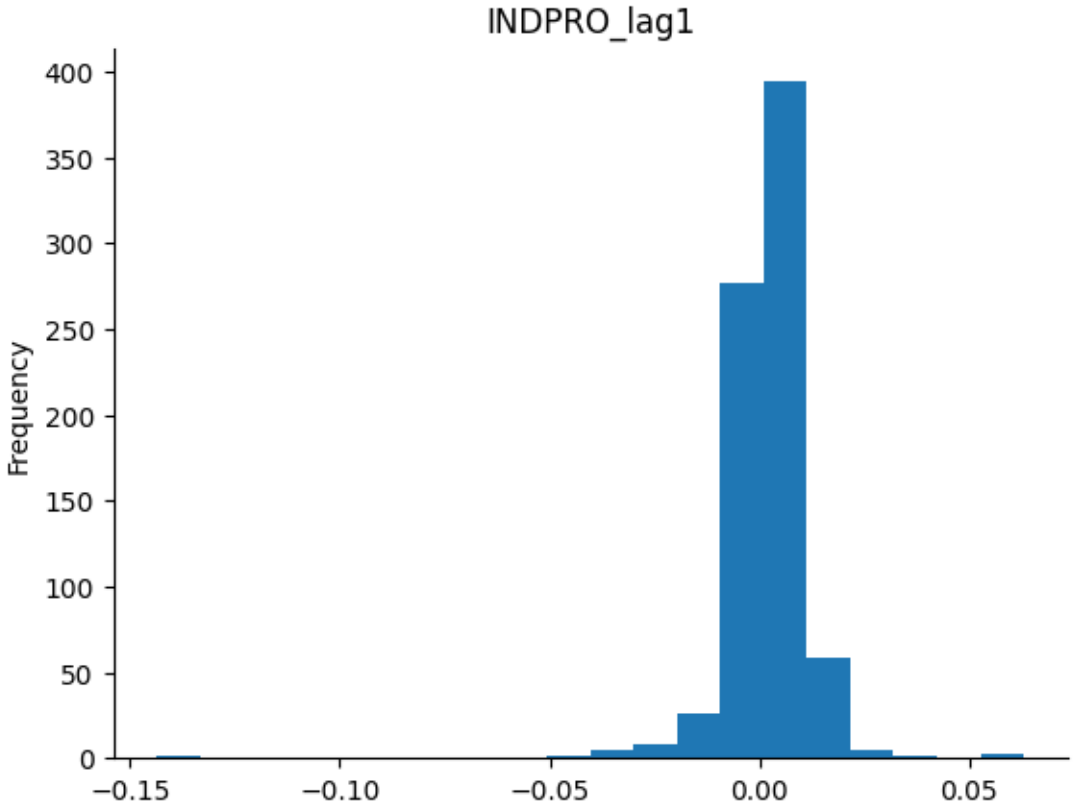
	Ones	INDPRO_lag0	INDPRO_lag1	INDPRO_lag2	INDPRO_lag3	INDPRO_lag4	\
0	1.0	0.014306	NaN	NaN	NaN	NaN	
1	1.0	0.021075	0.014306	NaN	NaN	NaN	
2	1.0	0.014955	0.021075	0.014306	NaN	NaN	
3	1.0	0.001141	0.014955	0.021075	0.014306	NaN	
4	1.0	-0.024240	0.001141	0.014955	0.021075	0.014306	

CPIAUCSL_lag0	CPIAUCSL_lag1	CPIAUCSL_lag2	CPIAUCSL_lag3	CPIAUCSL_lag4	\

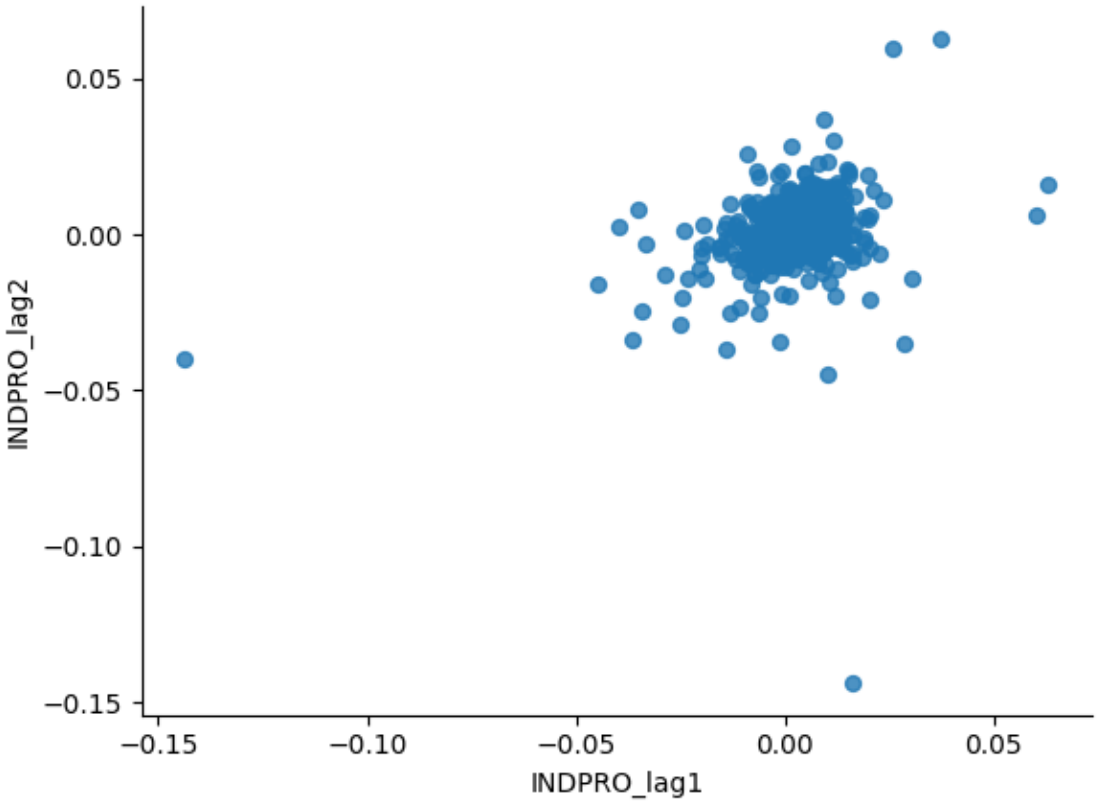
0	-0.000690	NaN	NaN	NaN	NaN
1	0.001380	-0.000690	NaN	NaN	NaN
2	0.001723	0.001380	-0.000690	NaN	NaN
3	0.000339	0.001723	0.001380	-0.00069	NaN
4	-0.001034	0.000339	0.001723	0.00138	-0.00069

	TB3MS_lag0	TB3MS_lag1	TB3MS_lag2	TB3MS_lag3	TB3MS_lag4
0	0.10	NaN	NaN	NaN	NaN
1	0.15	0.10	NaN	NaN	NaN
2	-0.11	0.15	0.10	NaN	NaN
3	0.37	-0.11	0.15	0.10	NaN
4	-0.01	0.37	-0.11	0.15	0.1

[ ]:
```
# @title INDPRO_lag1

from matplotlib import pyplot as plt
X['INDPRO_lag1'].plot(kind='hist', bins=20, title='INDPRO_lag1')
plt.gca().spines[['top', 'right',]].set_visible(False)
```

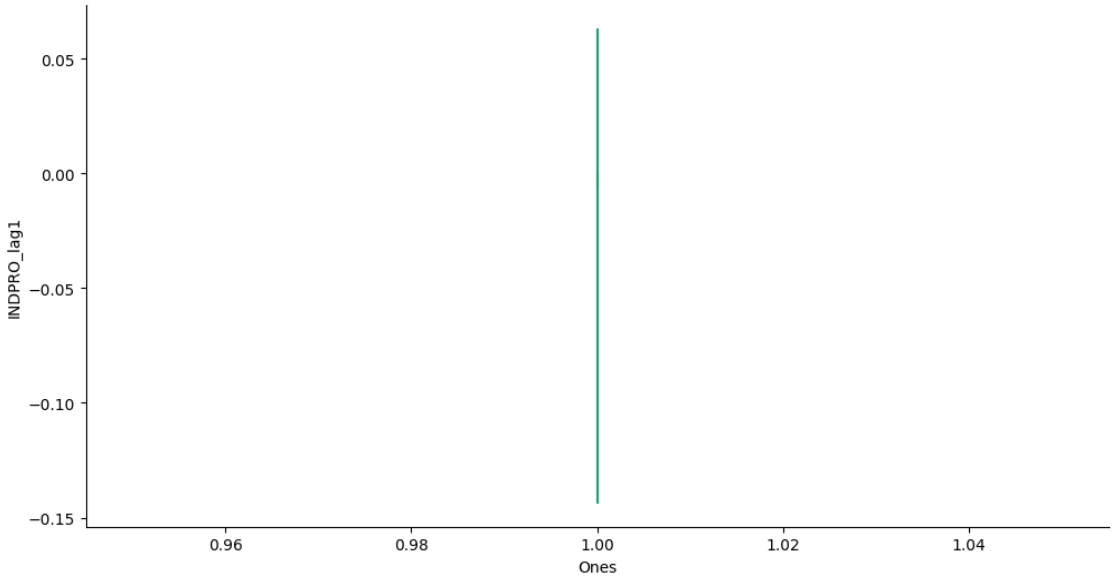


[ ]:
```
# @title INDPRO_lag1 vs INDPRO_lag2

from matplotlib import pyplot as plt
X.plot(kind='scatter', x='INDPRO_lag1', y='INDPRO_lag2', s=32, alpha=.8)
plt.gca().spines[['top', 'right',]].set_visible(False)
```

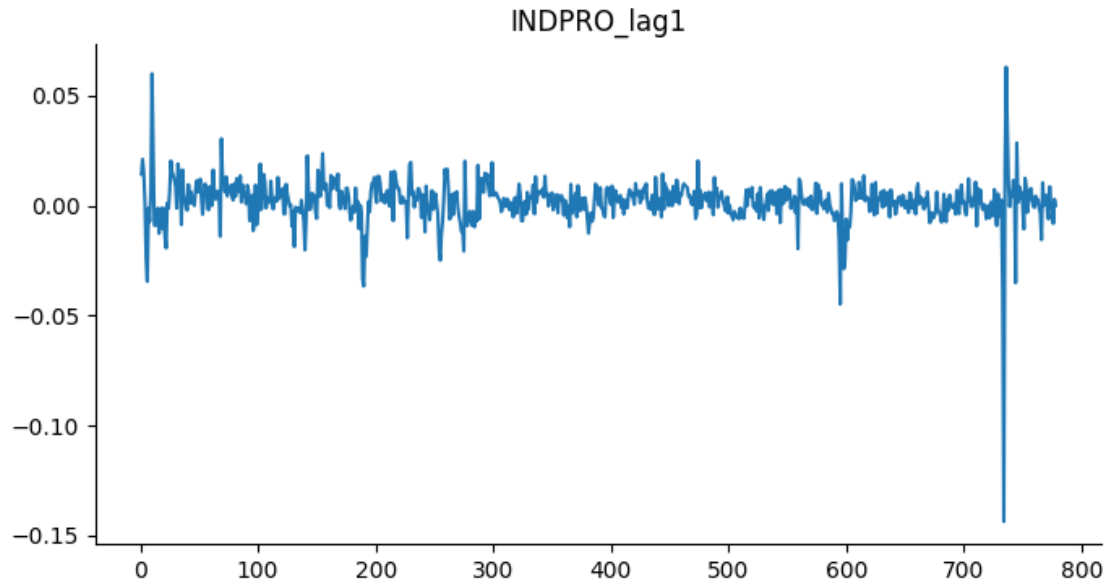


[ ]:
```
# @title Ones vs INDPRO_lag1

from matplotlib import pyplot as plt
import seaborn as sns
def _plot_series(series, series_name, series_index=0):
  palette = list(sns.palettes.mpl_palette('Dark2'))
  xs = series['Ones']
  ys = series['INDPRO_lag1']

  plt.plot(xs, ys, label=series_name, color=palette[series_index %␣
 ↪len(palette)])

fig, ax = plt.subplots(figsize=(10, 5.2), layout='constrained')
df_sorted = X.sort_values('Ones', ascending=True)
_plot_series(df_sorted, '')
```

```
sns.despine(fig=fig, ax=ax)
plt.xlabel('Ones')
_ = plt.ylabel('INDPRO_lag1')
```



[ ]:
```
# @title INDPRO_lag1

from matplotlib import pyplot as plt
X['INDPRO_lag1'].plot(kind='line', figsize=(8, 4), title='INDPRO_lag1')
plt.gca().spines[['top', 'right']].set_visible(False)
```



[ ]:
```
y = Yraw.shift(-num_leads)
y
```

[ ]:
```
0      0.021075
1      0.014955
2      0.001141
3     -0.024240
4     -0.034465
         …
774   -0.008147
775    0.002915
776    0.000005
777   -0.000951
778         NaN
Name: INDPRO, Length: 779, dtype: float64
```

[ ]:
```
## Save last row of X (converted to numpy)
X_T = X.iloc[-1:].values
## Subset getting only rows of X and y from p+1 to h-1
## and convert to numpy array
y = y.iloc[num_lags:-num_leads].values
X = X.iloc[num_lags:-num_leads].values

##
X_T
```

[ ]:
```
array([[ 1.00000000e+00, -9.51056709e-04,  4.86991246e-06,
         2.91450984e-03, -8.14668061e-03,  9.25729878e-04,
         7.21400503e-04,  7.26467817e-04,  8.11330254e-04,
        -2.79891559e-03, -1.51527417e-03, -2.00000000e-02,
        -3.00000000e-02, -7.00000000e-02,  2.00000000e-02,
         2.00000000e-02]])
```

[ ]:
```
##Estimation
from numpy.linalg import solve
# Solving for the OLS estimator beta: (X'X)^{-1} X'Y
beta_ols = solve(X.T @ X, X.T @ y)

## Produce the One step ahead forecast
## % change month-to-month INDPRO
forecast = X_T@beta_ols*100
forecast
```

[ ]:
```
array([0.08445815])
```

[ ]:
```
#Forecasting Exercise
def calculate_forecast(df_cleaned,
                       p=4,
                       H=[1, 4, 8],
                       end_date='12/1/1999',
                       target='INDPRO',
                       xvars=['CPIAUCSL', 'TB3MS']):

    # Subset df_cleaned to use only data up to end_date
    rt_df = df_cleaned[df_cleaned['sasdate'] <= pd.Timestamp(end_date)]

    # Get the actual values of the target at different steps ahead
    Y_actual = []
    for h in H:
        os = pd.Timestamp(end_date) + pd.DateOffset(months=h)
        Y_actual.append(df_cleaned[df_cleaned['sasdate'] == os][target] * 100)
        ## Now Y contains the true values at T+H (multiplying * 100)

    Yraw = rt_df[target]
    Xraw = rt_df[xvars]
    X = pd.DataFrame()

    # Add the lagged values of Y
    for lag in range(0, p):
        # Shift each column in the DataFrame and name it with a lag suffix
        X[f'{target}_lag{lag}'] = Yraw.shift(lag)
    for col in Xraw.columns:
        for lag in range(0, p):
            X[f'{col}_lag{lag}'] = Xraw[col].shift(lag)

    # Add a column of ones (for the intercept)
    X.insert(0, 'Ones', np.ones(len(X)))

    # Save the last row of X (converted to a `numpy` array)
    X_T = X.iloc[-1:].values

    Yhat = []
    for h in H:
        y_h = Yraw.shift(-h)
        # Subset getting only rows of X and y from p+1 to h-1
        y = y_h.iloc[p:-h].values
        X_ = X.iloc[p:-h].values
        # Solving for the OLS estimator beta: (X'X)^{-1} X'Y
        beta_ols = solve(X_.T @ X_, X_.T @ y)
        # Produce the One step ahead forecast
        # % change month-to-month INDPRO
        Yhat.append(X_T @ beta_ols * 100)
```

```
    # Calculate the forecasting error and return
    return np.array(Y_actual) - np.array(Yhat)

t0 = pd.Timestamp('12/1/1999')
e = []
T = []
for j in range(0, 10):
    t0 = t0 + pd.DateOffset(months=1)
    print(f'Using data up to {t0}')
    ehat = calculate_forecast(df_cleaned, p=4, H=[1, 4, 8], end_date=t0)
    e.append(ehat.flatten())
    T.append(t0)

# Create a pandas DataFrame from the list
edf = pd.DataFrame(e)

# Calculate the RMSFE, that is, the square root of the MSFE
np.sqrt(edf.apply(np.square).mean())
```

```
Using data up to 2000-01-01 00:00:00
Using data up to 2000-02-01 00:00:00
Using data up to 2000-03-01 00:00:00
Using data up to 2000-04-01 00:00:00
Using data up to 2000-05-01 00:00:00
Using data up to 2000-06-01 00:00:00
Using data up to 2000-07-01 00:00:00
Using data up to 2000-08-01 00:00:00
Using data up to 2000-09-01 00:00:00
Using data up to 2000-10-01 00:00:00
```

[ ]:
```
0    0.337110
1    0.512690
2    0.624035
dtype: float64
```