In [1]:

```
import pandas as pd
import pandas_datareader.data as web
import sklearn.mixture as mix

import numpy as np
import scipy.stats as scs

import matplotlib as mpl
from matplotlib import cm
import matplotlib.pyplot as plt
from matplotlib.dates import YearLocator, MonthLocator
%matplotlib inline

import seaborn as sns
import missingno as msno
from tqdm import tqdm
p=print
import datetime
```

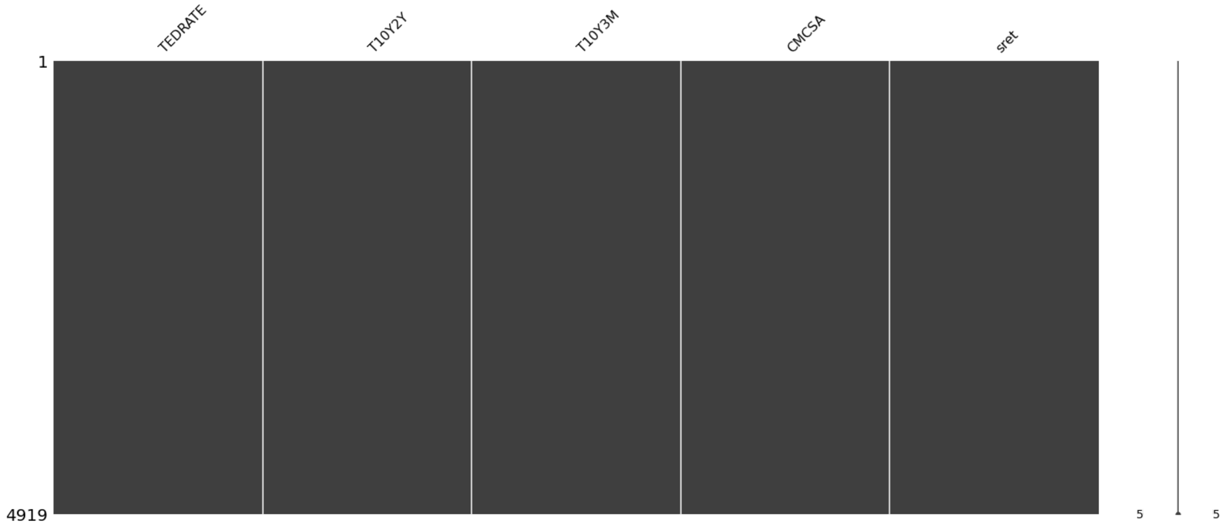
In [2]:

```
# get fed data

f1 = 'TEDRATE' # ted spread
f2 = 'T10Y2Y' # constant maturity ten yer - 2 year
f3 = 'T10Y3M' # constant maturity 10yr - 3m

start = pd.to_datetime('2002-01-01')
end = pd.datetime.today()

mkt = 'CMCSA'
MKT = (web.DataReader([mkt], 'yahoo', start, end)['Adj Close']
       .rename(columns={mkt:mkt})
       .assign(sret=lambda x: np.log(x[mkt]/x[mkt].shift(1)))
       .dropna())

data = (web.DataReader([f1, f2, f3], 'fred', start, end)
        .join(MKT, how='inner')
        .dropna()
       )

p(data.head())

# gives us a quick visual inspection of the data
msno.matrix(data)
```

```
C:\Users\HP\AppData\Local\Temp/ipykernel_3880/4244544400.py:8: FutureWarning: T
he pandas.datetime class is deprecated and will be removed from pandas in a fut
ure version. Import from datetime module instead.
  end = pd.datetime.today()

            TEDRATE  T10Y2Y  T10Y3M     CMCSA      sret
2002-01-03     0.18    1.97    3.43  9.107717 -0.008389
2002-01-04     0.18    1.99    3.46  8.926126 -0.020140
2002-01-07     0.21    2.01    3.41  9.046335  0.013377
2002-01-08     0.19    2.03    3.42  9.399285  0.038274
2002-01-09     0.19    2.07    3.42  9.350694 -0.005183
```

Out[2]:

```
<AxesSubplot:>
```



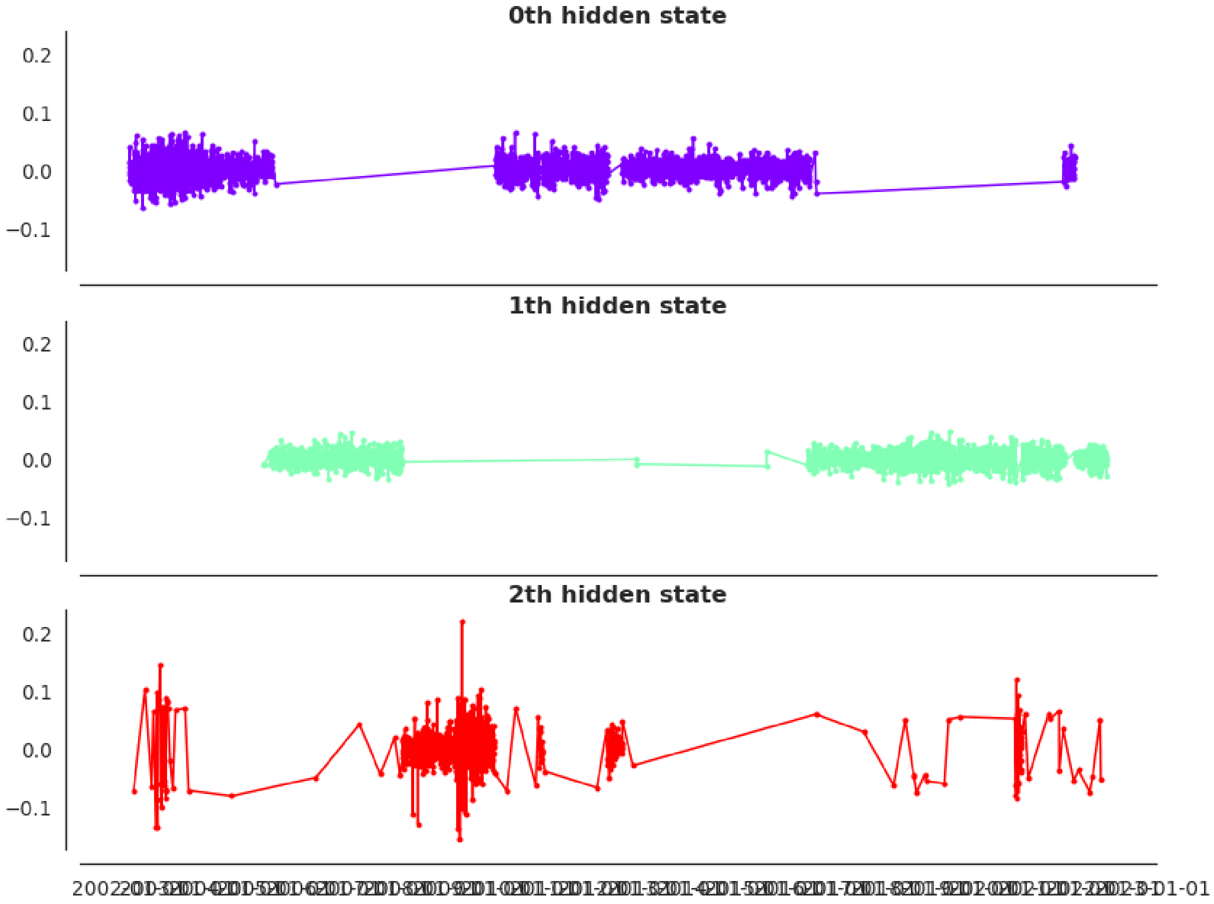
In [3]:

```
# code adapted from http://hmmlearn.readthedocs.io
# for sklearn 18.1

col = 'sret'
select = data.loc[:].dropna()

ft_cols = [f1, f2, f3, 'sret']
X = select[ft_cols].values

model = mix.GaussianMixture(n_components=3,
                            covariance_type="full",
                            n_init=100,
                            random_state=7).fit(X)

# Predict the optimal sequence of internal hidden state
hidden_states = model.predict(X)

print("Means and vars of each hidden state")
for i in range(model.n_components):
    print("{0}th hidden state".format(i))
    print("mean = ", model.means_[i])
    print("var = ", np.diag(model.covariances_[i]))
    print()

sns.set(font_scale=1.25)
style_kwds = {'xtick.major.size': 1, 'ytick.major.size': 1,
              'font.family':u'courier prime code', 'legend.frameon': True}
sns.set_style('white', style_kwds)

fig, axs = plt.subplots(model.n_components, sharex=True, sharey=True, figsize=(12
colors = cm.rainbow(np.linspace(0, 1, model.n_components))

for i, (ax, color) in enumerate(zip(axs, colors)):
    # Use fancy indexing to plot data in each state.
    mask = hidden_states == i
    ax.plot_date(select.index.values[mask],
                 select[col].values[mask],
                 ".-", c=color)
    ax.set_title("{0}th hidden state".format(i), fontsize=16, fontweight='demi')

    # Format the ticks.
    ax.xaxis.set_major_locator(YearLocator())
    ax.xaxis.set_minor_locator(MonthLocator())
    sns.despine(offset=10)
plt.tight_layout()
fig.savefig('Hidden Markov (Mixture) Model_Regime Subplots.png')
```

```
Means and vars of each hidden state
0th hidden state
mean =  [2.26020489e-01 2.05316615e+00 2.63234081e+00 6.20131354e-04]
var =  [4.01004248e-03 2.17252257e-01 4.01657807e-01 2.83616883e-04]

1th hidden state
mean =  [3.38874060e-01 5.42543516e-01 8.08141239e-01 5.43646704e-04]
var =  [2.26713209e-02 2.11039915e-01 5.21164477e-01 1.46794518e-04]
```

```
2th hidden state
mean =  [ 1.04125692e+00  1.52258639e+00  1.97949815e+00 -1.33788378e-03]
var =  [0.52307166 0.39562393 0.84299429 0.00133433]
```

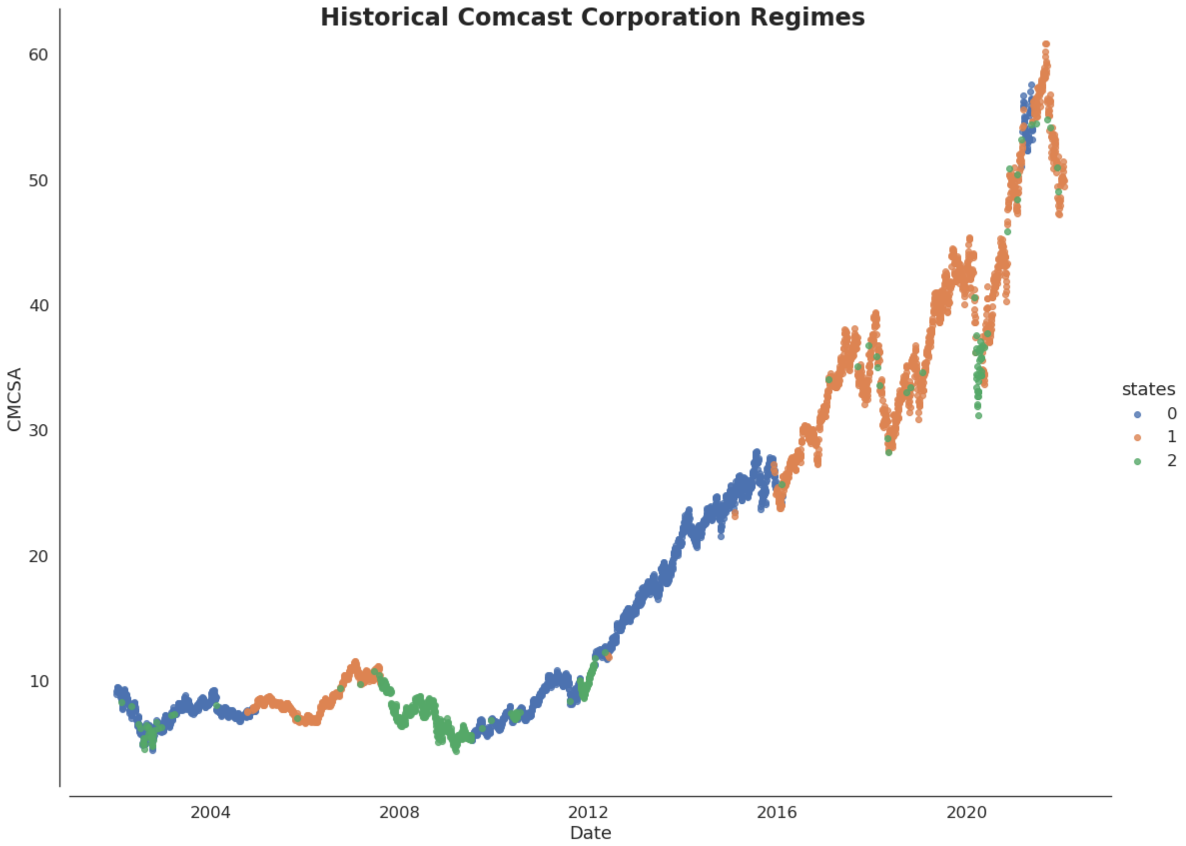
```
findfont: Font family ['courier prime code'] not found. Falling back to DejaVu
Sans.
findfont: Font family ['courier prime code'] not found. Falling back to DejaVu
Sans.
```



In [4]:

```
sns.set(font_scale=1.5)
states = (pd.DataFrame(hidden_states, columns=['states'], index=select.index)
          .join(select, how='inner')
          .assign(mkt_cret=select.sret.cumsum())
          .reset_index(drop=False)
          .rename(columns={'index':'Date'}))
p(states.head())

sns.set_style('white', style_kwds)
order = [0, 1, 2]
fg = sns.FacetGrid(data=states, hue='states', hue_order=order, aspect=1.31, size=
fg.map(plt.scatter, 'Date', mkt, alpha=0.8).add_legend()
sns.despine(offset=10)
fg.fig.suptitle('Historical Comcast Corporation Regimes', fontsize=24, fontweight
fg.savefig('Hidden Markov (Mixture) Model_CMCSA Regimes.png')
```

```
C:\Users\HP\anaconda3\lib\site-packages\seaborn\axisgrid.py:337: UserWarning: T
he `size` parameter has been renamed to `height`; please update your code.
  warnings.warn(msg, UserWarning)
findfont: Font family ['courier prime code'] not found. Falling back to DejaVu
Sans.

        Date  states  TEDRATE  T10Y2Y  T10Y3M     CMCSA      sret  mkt_cret
0 2002-01-03       0     0.18    1.97    3.43  9.107717 -0.008389 -0.008389
1 2002-01-04       0     0.18    1.99    3.46  8.926126 -0.020140 -0.028529
2 2002-01-07       0     0.21    2.01    3.41  9.046335  0.013377 -0.015152
3 2002-01-08       0     0.19    2.03    3.42  9.399285  0.038274  0.023122
4 2002-01-09       0     0.19    2.07    3.42  9.350694 -0.005183  0.017939

findfont: Font family ['courier prime code'] not found. Falling back to DejaVu
Sans.
findfont: Font family ['courier prime code'] not found. Falling back to DejaVu
Sans.
```



```
In [5]: ## Finding Equillibrium Matrix
```

In [6]:

```
start = pd.to_datetime('2002-01-01')
end = pd.datetime.today()

df = web.DataReader("CMCSA", 'yahoo', start, end)
df
```

```
C:\Users\HP\AppData\Local\Temp/ipykernel_3880/629996965.py:2: FutureWarning: Th
e pandas.datetime class is deprecated and will be removed from pandas in a futu
re version. Import from datetime module instead.
  end = pd.datetime.today()
```

Out[6]:

	High	Low	Open	Close	Volume	Adj Close
Date						
2002-01-02	12.013333	11.796667	12.010000	11.970000	970200.0	9.184446
2002-01-03	12.063333	11.733333	11.966667	11.870000	471300.0	9.107716
2002-01-04	11.926667	11.603333	11.873333	11.633333	887100.0	8.926126
2002-01-07	11.833333	11.613333	11.630000	11.790000	418200.0	9.046334
2002-01-08	12.250000	11.733333	11.853333	12.250000	742200.0	9.399286
...	...	...	...	...	...	...
2022-04-25	45.869999	44.860001	45.419998	45.709999	28083200.0	45.709999
2022-04-26	45.849998	44.490002	45.290001	44.570000	29225000.0	44.570000
2022-04-27	45.080002	44.080002	44.610001	44.450001	25547900.0	44.450001
2022-04-28	43.720001	40.759998	42.730000	41.700001	49934000.0	41.700001
2022-04-29	41.820000	39.610001	41.209999	39.759998	44133300.0	39.759998

5118 rows × 6 columns

In [7]:

```
df["state"]=df["Close"].astype(float).pct_change()
df['state']=df['state'].apply(lambda x: 'Upside' if (x > 0.001) else ('Downside'
df
```

Out[7]:

	High	Low	Open	Close	Volume	Adj Close	state
Date							
2002-01-02	12.013333	11.796667	12.010000	11.970000	970200.0	9.184446	Consolidation
2002-01-03	12.063333	11.733333	11.966667	11.870000	471300.0	9.107716	Downside
2002-01-04	11.926667	11.603333	11.873333	11.633333	887100.0	8.926126	Downside
2002-01-07	11.833333	11.613333	11.630000	11.790000	418200.0	9.046334	Upside
2002-01-08	12.250000	11.733333	11.853333	12.250000	742200.0	9.399286	Upside
...	...	...	...	...	...	...	...
2022-04-25	45.869999	44.860001	45.419998	45.709999	28083200.0	45.709999	Upside
2022-04-26	45.849998	44.490002	45.290001	44.570000	29225000.0	44.570000	Downside
2022-04-27	45.080002	44.080002	44.610001	44.450001	25547900.0	44.450001	Downside
2022-04-28	43.720001	40.759998	42.730000	41.700001	49934000.0	41.700001	Downside
2022-04-29	41.820000	39.610001	41.209999	39.759998	44133300.0	39.759998	Downside

5118 rows × 7 columns

In [8]:

```
df['priorstate']=df['state'].shift(1)
df.tail()
```

Out[8]:

	High	Low	Open	Close	Volume	Adj Close	state	priorstate
Date								
2022-04-25	45.869999	44.860001	45.419998	45.709999	28083200.0	45.709999	Upside	Downside
2022-04-26	45.849998	44.490002	45.290001	44.570000	29225000.0	44.570000	Downside	Upside
2022-04-27	45.080002	44.080002	44.610001	44.450001	25547900.0	44.450001	Downside	Downside
2022-04-28	43.720001	40.759998	42.730000	41.700001	49934000.0	41.700001	Downside	Downside
2022-04-29	41.820000	39.610001	41.209999	39.759998	44133300.0	39.759998	Downside	Downside

In [9]:

```
# Transition Matrix for Markov Chain Model
```

In [10]:

```
df["state"]=df["Close"].astype(float).pct_change()
df['state']=df['state'].apply(lambda x: 'Upside' if (x > 0.001) else ('Downside'

df['priorstate']=df['state'].shift(1)

states = df [['priorstate','state']].dropna()
states_matrix = states.groupby(['priorstate','state']).size().unstack().fillna(0)

transition_matrix= states_matrix.apply(lambda x: x/float(x.sum()),axis=1)
print(transition_matrix)
```

```
state          Downside    Upside
priorstate
Consolidation  1.000000  0.000000
Downside       0.503170  0.496830
Upside         0.547023  0.452977
```

In [11]:

```
df["state"]=df["Close"].astype(float).pct_change()
df['state']=df['state'].apply(lambda x: 'Upside' if (x > 0) else 'Downside' )

df['priorstate']=df['state'].shift(1)

states = df [['priorstate','state']].dropna()
states_matrix = states.groupby(['priorstate','state']).size().unstack().fillna(0)

transition_matrix= states_matrix.apply(lambda x: x/float(x.sum()),axis=1)
print(transition_matrix)
```

```
state       Downside    Upside
priorstate
Downside    0.479636  0.520364
Upside      0.508501  0.491499
```

In [12]:

```
t_0 = transition_matrix.copy()
t_1 =t_0.dot(t_0)
t_1
```

Out[12]:

state	Downside	Upside
priorstate		
Downside	0.494656	0.505344
Upside	0.493823	0.506177

In [13]:

```
## Equilibrium Matrix using Python

t_0 = transition_matrix.copy()

t_m = t_0.copy()
t_n = t_0.dot(t_0)

i = 1
while(not(t_m.equals(t_n))):
    i += 1
    t_m = t_n.copy()
    t_n = t_n.dot(t_0)

print("Equilibrium Matrix Number: " + str(i))
print(t_n)
```

```
Equilibrium Matrix Number: 11
state        Downside    Upside
priorstate
Downside     0.494235  0.505765
Upside       0.494235  0.505765
```

In [14]:

```
##Random Walk

symbol = "CMCSA"
days = 10000
end_date = datetime.datetime.now().strftime("%d-%b-%Y")
end_date = str(end_date)

start_date = (datetime.datetime.now()- datetime.timedelta(days=days)).strftime("%
start_date = str(start_date)

#df=index_history("SPY",start_date,end_date)
df = web.DataReader("CMCSA", 'yahoo', start_date, end_date)

df["state"]=df["Close"].astype(float).pct_change()
df['state']=df['state'].apply(lambda x: 'Upside' if (x > 0) else 'Downside' )

df['priorstate']=df['state'].shift(1)

states = df [['priorstate','state']].dropna()
states_matrix = states.groupby(['priorstate','state']).size().unstack().fillna(0

transition_matrix= states_matrix.apply(lambda x: x/float(x.sum()),axis=1)
t_0 = transition_matrix.copy()

t_m = t_0.copy()
t_n = t_0.dot(t_0)

i = 1
while(not(t_m.equals(t_n))):
    i += 1
    t_m = t_n.copy()
    t_n = t_n.dot(t_0)

print("Equilibrium Matrix Number: " + str(i))
print(t_n)
```

```
Equilibrium Matrix Number: 12
state        Downside    Upside
priorstate
Downside     0.501523  0.498477
Upside       0.501523  0.498477
```

```
In [ ]: def get_mkt_data(mkt, start, end, factors):
            """Function to get benchmark data from
                Yahoo and Factor data from FRED

            Params:
                mkt : str(), symbol
                start : pd.DateTime()
                end : pd.DateTime()
                factors : list() of str()
            Returns:
                data : pd.DataFrame()
            """
            MKT = (web.DataReader([mkt], 'yahoo', start, end)['Adj Close']
                   .rename(columns={mkt:mkt})
                   .assign(lret=lambda x: np.log(x[mkt]/x[mkt].shift(1)))
                   .dropna())

            data = (web.DataReader(factors, 'fred', start, end)
                    .join(MKT, how='inner')
                    .dropna())
            return data
```

```
In [ ]: %load_ext watermark
        %watermark
        import pandas as pd
        import pandas_datareader.data as web
        import numpy as np
        import sklearn.mixture as mix
        import scipy.stats as scs

        import matplotlib as mpl
        import matplotlib.pyplot as plt
        %matplotlib inline

        import seaborn as sns
        import missingno as msno
        from tqdm import tqdm

        import warnings
        warnings.filterwarnings("ignore")
        import affirm

        sns.set(font_scale=1.25)
        style_kwds = {'xtick.major.size': 3, 'ytick.major.size': 3,
                      'font.family':u'courier prime code', 'legend.frameon': True}
        sns.set_style('white', style_kwds)

        p=print
        p()
        %watermark -p pandas,pandas_datareader,numpy,scipy,sklearn,matplotlib,seaborn
        # **********************************************************************
        def get_mkt_data(mkt, start, end, factors):
            """Function to get benchmark data from
                Yahoo and Factor data from FRED

            Params:
                mkt : str(), symbol
                start : pd.DateTime()
                end : pd.DateTime()
                factors : list() of str()
            Returns:
                data : pd.DataFrame()
            """
            MKT = (web.DataReader([mkt], 'yahoo', start, end)['Adj Close']
                   .rename(columns={mkt:mkt})
                   .assign(lret=lambda x: np.log(x[mkt]/x[mkt].shift(1)))
                   .dropna())

            data = (web.DataReader(factors, 'fred', start, end)
                    .join(MKT, how='inner')
                    .dropna())
            return data
        # **********************************************************************
        class ModelRunner():
            def __init__(self, *args, **kwargs):
                """Class to run mixture model model

                Params:
```

```
            data : pd.DataFrame()
            ft_cols : list() of feature columns str()
            k : int(), n_components
            max_iter : int(), max iterations
            init : str() {random, kmeans}
        """
        self.data = data
        self.ft_cols = ft_cols
        self.k = k
        self.max_iter = max_iter
        self.init = init

        np.random.seed(123457)  # make results reproducible

    def _run_model(self, bgm=None, **kwargs):
        """Function to run mixture model

        Params:
            data : pd.DataFrame()
            ft_cols : list of str()
            k : int(), n_components
            max_iter : int()
            init : str() {random, kmeans}

        Returns:
            model : sklearn model object
            hidden_states : array-like, hidden states
        """
        X = self.data[self.ft_cols].values

        if bgm:
            model = mix.BayesianGaussianMixture(n_components=self.k,
                                                max_iter=self.max_iter,
                                                init_params=self.init,
                                                **kwargs,
                                               ).fit(X)
        else:
            model = mix.GaussianMixture(n_components=self.k,
                                        max_iter=self.max_iter,
                                        init_params=self.init,
                                        **kwargs,
                                       ).fit(X)

        hidden_states = model.predict(X)
        return model, hidden_states

    def _get_state_est(self, model, hidden_states):
        """Function to return estimated state mean and state variance

        Params:
            model : sklearn model object
            hidden_states : {array-like}
        Returns:
            mr_i : mean return of last estimated state
            mvar_i : model variance of last estimated state
        """
        # get last state
```

```python
        last_state = hidden_states[-1]
        # last value is mean return for ith state
        mr_i = model.means_[last_state][-1]
        mvar_i = np.diag(model.covariances_[last_state])[-1]
        return mr_i, mvar_i

    def _get_ci(self, mr_i, mvar_i, alpha, a, b, nSamples):
        """Function to sample confidence intervals
            from the JohnsonSU distribution

        Params:
            mr_i : float()
            mvar_i : float()
            alpha : float()
            a : float()
            b : float()
            nsamples : int()
        Returns:
            ci : tuple(float(), float()), (low_ci, high_ci)
        """
        rvs_ = scs.johnsonsu.rvs(a, b, loc=mr_i, scale=mvar_i, size=nSamples)
        ci = scs.johnsonsu.interval(alpha=alpha, a=a, b=b,
                                    loc=np.mean(rvs_), scale=np.std(rvs_))
        return ci

    def prediction_cycle(self, *args, **kwargs):
        """Function to make walk forward predictions from cutoff year onwards

        Params:
            year : int(), cutoff year
            alpha : float()
            a : float()
            b : float()
            nsamples : int()
        Returns:
            dict() :
                pred : pd.DataFrame()
                year : str()
                a, b : float(), float()
        """
        cutoff = year
        train_df = self.data.ix[str(cutoff - lookback):str(cutoff)].dropna()
        oos = self.data.ix[str(cutoff+1):].dropna()
        # confirm that train_df end index is different than oos start index
        assert train_df.index[-1] != oos.index[0]

        # create pred list to hold tuple rows
        preds = []
        for t in tqdm(oos.index):
            if t == oos.index[0]:
                insample = train_df

            # run model func to return model object and hidden states using param
            model, hstates = self._run_model(**kwargs)
            # get hidden state mean and variance
            mr_i, mvar_i = self._get_state_est(model, hstates)
            # get confidence intervals from sampled distribution
            low_ci, high_ci = self._get_ci(mr_i, mvar_i, alpha, a, b, nSamples)
            # append tuple row to pred list
            preds.append((t, hstates[-1], mr_i, mvar_i, low_ci, high_ci))

            # increment insample dataframe
            insample = data.ix[:t]

        cols = ['ith_state', 'ith_ret', 'ith_var', 'low_ci', 'high_ci']
        pred = (pd.DataFrame(preds, columns=['Dates']+cols)
                .set_index('Dates').assign(tgt = oos['lret']))

        # logic to see if error exceeds neg or pos CI
        pred_copy = pred.copy().reset_index()
        # Identify indices where target return falls between CI
        win = pred_copy.query("low_ci < tgt < high_ci").index
        # create list of binary variables representing in/out CI
        in_rng_list = [1 if i in win else 0 for i in pred_copy.index]
        # assign binary variables sequence to new column
        pred['in_rng'] = in_rng_list
        return {'pred':pred, 'year':year, 'a':a, 'b':b}

# ***********************************************************************
class ResultEval():
    def __init__(self, data, step_fwd):
        """Class to evaluate prediction results

        Params:
            data : dict() containing results of ModelRunner()
            step_fwd : int(), number of days to evalute post event
        """
        self.df = data['pred'].copy().reset_index()
        self.step_fwd=step_fwd

    def _get_event_states(self):
        """Function to get event indexes
        Index bjects must be called 'too_high', 'too_low'

        Returns:
            dict() : values are index objects
        """
        too_high = self.df.query("tgt > high_ci").index
        too_low = self.df.query("tgt < low_ci").index
        return {'too_high':too_high, 'too_low':too_low}

    def get_post_events(self, event):
        """Function to return dictionary where key, value is integer
        index, and Pandas series consisting of returns post event

        Params:
            df : pd.DataFrame(), prediction df
            event : {array-like}, index of target returns that exceed CI high or
            step_fwd : int(), how many days to include after event
        Returns:
            after_event : dict() w/ values = pd.Series()
        """
        after_event = {}
        for i in range(len(event)):
```

```python
            tmp_ret = self.df.ix[event[i]:event[i]+self.step_fwd, ['Dates','tgt']
            # series of returns with date index
            after_event[i] = tmp_ret.set_index('Dates', drop=True).squeeze()
        return after_event

    def get_end_vals(self, post_events):
        """Function to sum and agg each post events' returns"""
        end_vals = []
        for k in post_events.keys():
            tmp = post_events[k].copy()
            tmp.iloc[0] = 0 # set initial return to zero
            end_vals.append(tmp.sum())
        return end_vals

    def create_summary(self, end_vals):
        """Function to take ending values and calculate summary
        Will fail if count of ending values (>0) or (<0) is less than 1
        """
        gt0 = [x for x in end_vals if x>0]
        lt0 = [x for x in end_vals if x<0]
        assert len(gt0) > 1
        assert len(lt0) > 1
        summary = (pd.DataFrame(index=['value'])
                   .assign(mean = f'{np.mean(end_vals):.4f}')
                   .assign(median = f'{np.median(end_vals):.4f}')
                   .assign(max_ = f'{np.max(end_vals):.4f}')
                   .assign(min_ = f'{np.min(end_vals):.4f}')
                   .assign(gt0_cnt = f'{len(gt0):d}')
                   .assign(lt0_cnt = f'{len(lt0):d}')
                   .assign(sum_gt0 = f'{sum(gt0):.4f}')
                   .assign(sum_lt0 = f'{sum(lt0):.4f}')
                   .assign(sum_ratio = f'{sum(gt0) / abs(sum(lt0)):.4f}')
                   .assign(gt_pct = f'{len(gt0) / (len(gt0) + len(lt0)):.4f}')
                   .assign(lt_pct = f'{len(lt0) / (len(gt0) + len(lt0)):.4f}')
                   )
        return summary
# ********************************************************************
class ModelPlots():
    def __init__(self, mkt, post_events, event_state, project_dir, year):
        """Class to visualize prediction results and summary

        Params:
            mkt : str(), symbol
            post_events : dict() of pd.Series()
            event_state : str(), 'too_high', 'too_low'
            project_dir : str()
            year : int(), cutoff year
        """
        self.mkt = mkt
        self.post_events = post_events
        self.event_state = event_state
        self.DIR = project_dir
        self.year = year

    def plot_equity_timeline(self):
        """Function to plot event timeline with equity curve second axis"""
        agg_tmp = []
        fig, ax = plt.subplots(figsize=(10, 7))
        ax1 = ax.twinx()
        ax.axhline(y=0, color='k', lw=3)
        for k in self.post_events.keys():
            tmp = self.post_events[k].copy()
            tmp.iloc[0] = 0 # set initial return to zero
            agg_tmp.append(tmp)
            if tmp.sum() > 0: color = 'dodgerblue'
            else: color = 'red'
            ax.plot(tmp.index, tmp.cumsum(), color=color, alpha=0.5)
            ax.set_xlim(pd.to_datetime(str(self.year) + '-12-31'), tmp.index[-1]
            ax.set_xlabel('Dates')
            ax.set_title(f"{self.mkt} {self.event_state.upper()}", fontsize=16)
            #sns.despine(offset=2)
        agg_df = pd.concat(agg_tmp).cumsum()
        ax1.plot(agg_df.index, agg_df.values, color='k', lw=5)
        ax.set_ylabel('Event Returns')
        ax1.set_ylabel('Equity Curve')
        fig.savefig(self.DIR + f'{self.mkt} {self.event_state.upper()} post event
        return

    def plot_events_timeline(self):
        """Function to plot even timeline only"""
        fig, ax = plt.subplots(figsize=(10, 7))
        ax.axhline(y=0, color='k', lw=3)
        for k in self.post_events.keys():
            tmp = self.post_events[k].copy()
            tmp.iloc[0] = 0 # set initial return to zero

            if tmp.sum() > 0: color = 'dodgerblue'
            else: color = 'red'
            ax.plot(tmp.index, tmp.cumsum(), color=color, alpha=0.5)
            ax.set_xlim(pd.to_datetime('2009-12-31'), tmp.index[-1])
            ax.set_xlabel('Dates')
            ax.set_title(f"{self.mkt} {self.event_state.upper()}", fontsize=16, f
            sns.despine(offset=2)
        fig.savefig(self.DIR + f'{self.mkt} {self.event_state.upper()} post event
        return

    def plot_events_post(self):
        """Function to plot events from zero until n days after"""
        fig, ax = plt.subplots(figsize=(10, 7))
        ax.axhline(y=0, color='k', lw=3)
        for k in self.post_events.keys():
            tmp = self.post_events[k].copy()
            tmp.iloc[0] = 0 # set initial return to zero

            if tmp.sum() > 0: color = 'dodgerblue'
            else: color = 'red'
            tmp.cumsum().reset_index(drop=True).plot(color=color, alpha=0.5, ax=a
        ax.set_xlabel('Days')
        ax.set_title(f"{self.mkt} {self.event_state.upper()}", fontsize=16, fontw
        sns.despine(offset=2)
        fig.savefig(self.DIR + f'{self.mkt} {self.event_state.upper()} post event
        return

    def plot_distplot(self, ending_values, summary):
        """Function to plot histogram of ending values"""
        colors = sns.color_palette('RdYlBu', 4)
        fig, ax = plt.subplots(figsize=(10, 7))
        sns.distplot(pd.DataFrame(ending_values), bins=15, color=colors[0],
                     kde_kws={"color":colors[3]}, hist_kws={"color":colors[3], "a
        ax.axvline(x=float(summary['mean'][0]), label='mean', color='dodgerblue',
        ax.axvline(x=float(summary['median'][0]), label='median', color='red', lw
        ax.axvline(x=0, color='black', lw=1, ls='-')
        ax.legend(loc='best')
        sns.despine(offset=2)
        ax.set_title(f"{self.mkt} {self.event_state.upper()}", fontsize=16, fontw
        fig.savefig(self.DIR + f'{self.mkt} {self.event_state.upper()} distplot.p
        return

    def plot_pred_results(self, df, year, a, b):
        """Function to plot prediction results and confidence intervals"""
        # colorblind safe palette http://colorbrewer2.org/
        colors = sns.color_palette('RdYlBu', 4)

        fig, ax = plt.subplots(figsize=(10, 7))
        ax.scatter(df.index, df.tgt, c=[colors[1] if x==1 else colors[0] for x in
        df['high_ci'].plot(ax=ax, alpha=0.65, marker='.', color=colors[2])
        df['low_ci'].plot(ax=ax, alpha=0.65, marker='.', color=colors[3])
        ax.set_xlim(df.index[0], df.index[-1])

        nRight = df.query('in_rng==1').shape[0]
        accuracy = nRight / df.shape[0]
        ax.set_title('{:^10}\ncutoff year: {} | accuracy: {:2.3%} | errors: {} |
                      .format(self.mkt, year, accuracy, df.shape[0] - nRight, a,

        in_ = mpl.lines.Line2D(range(1), range(1), color="white", marker='o', mar
        out_ = mpl.lines.Line2D(range(1), range(1), color="white", marker='o', ma
        hi_ci = mpl.lines.Line2D(range(1), range(1), color="white", marker='.', m
        lo_ci = mpl.lines.Line2D(range(1), range(1), color="white", marker='.', m
        leg = ax.legend([in_, out_, hi_ci, lo_ci],["in", "out", 'high_ci', 'low_c
                        loc = "center left", bbox_to_anchor = (1, 0.85), numpoint
        sns.despine(offset=2)
        file_str = self.DIR+f'{self.mkt} prediction success {pd.datetime.today()}
        fig.savefig(file_str, dpi=300, bbox_inches="tight")
        return
```

In [ ]:

```
!pip install watermark
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In [ ]:

```
!pip install affirm
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In [ ]:

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In [ ]:

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