Markov model

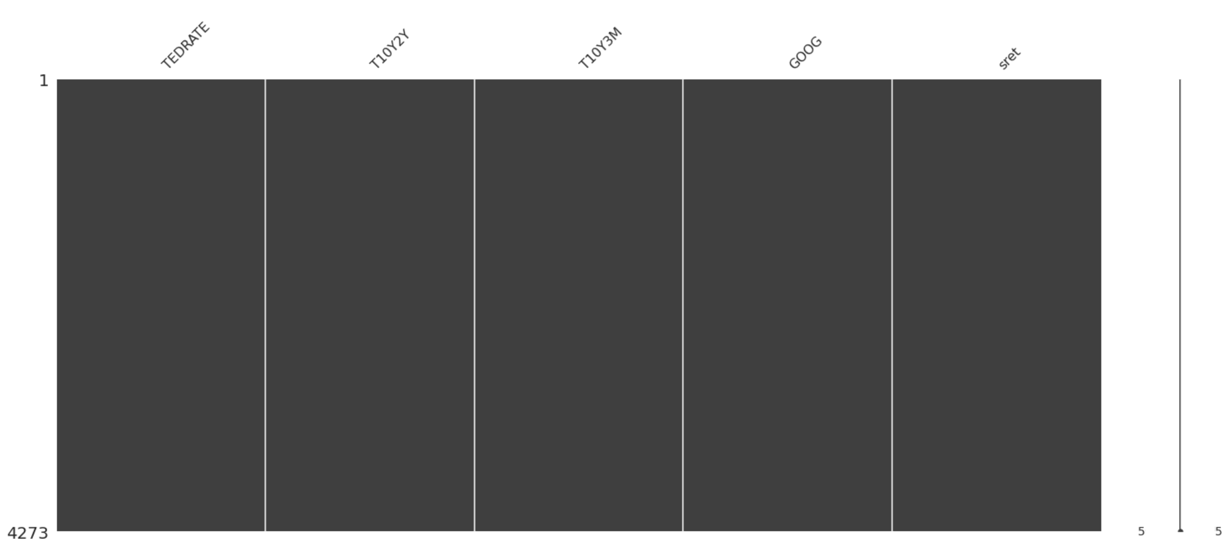
Google

In [19]:
```
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 [21]:
```python
# 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('2000-01-01')
end = pd.datetime.today()

mkt = 'GOOG'
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)
```

```
<ipython-input-21-cfbf8721336b>:8: FutureWarning: The pandas.datetime class is
deprecated and will be removed from pandas in a future version. Import from dat
etime module instead.
  end = pd.datetime.today()

            TEDRATE  T10Y2Y  T10Y3M       GOOG      sret
2004-08-20     0.28    1.78    2.75  53.952770  0.076433
2004-08-23     0.23    1.78    2.74  54.495735  0.010013
2004-08-24     0.24    1.78    2.74  52.239197 -0.042289
2004-08-25     0.25    1.75    2.72  52.802086  0.010718
2004-08-26     0.26    1.74    2.67  53.753517  0.017858
```

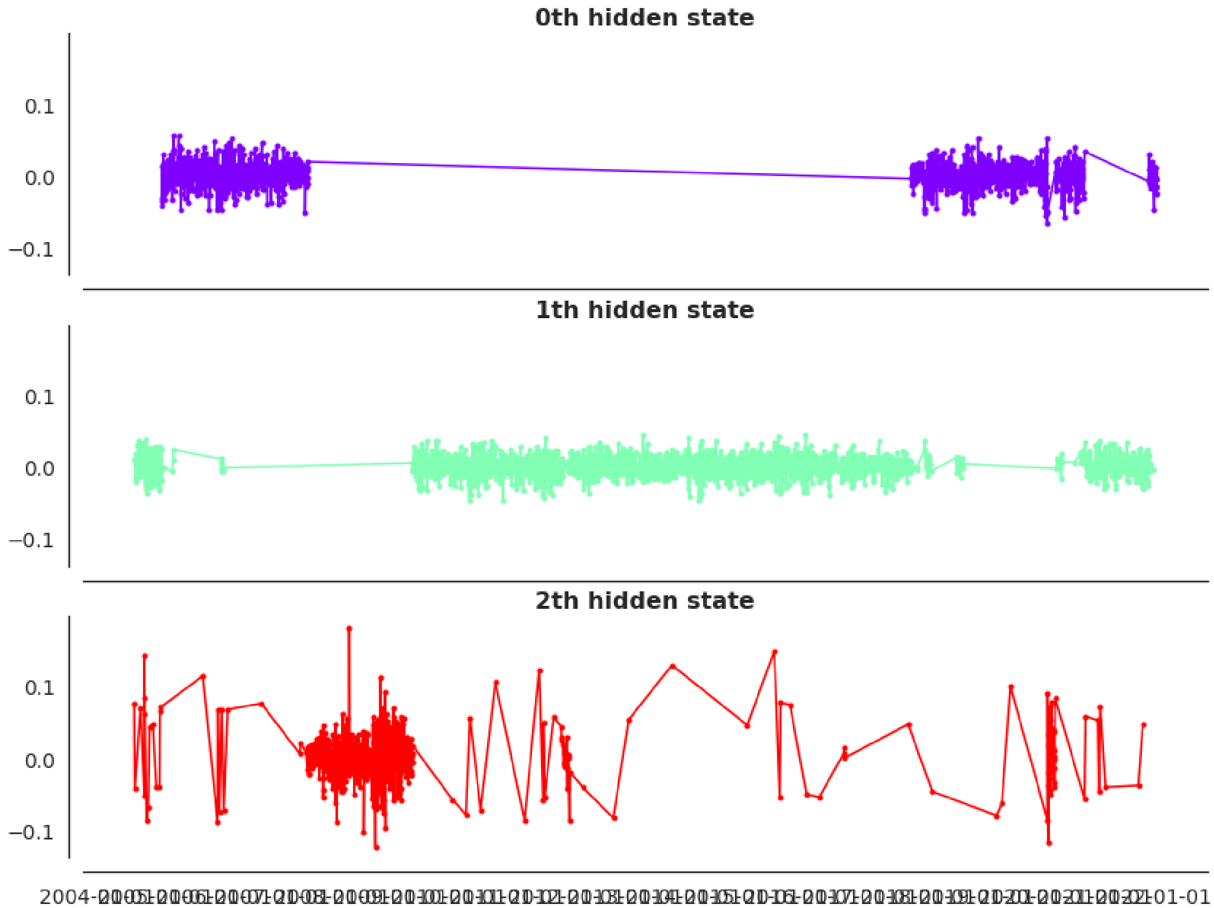
Out[21]: <AxesSubplot:>



```
In [22]: # 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': 3, 'ytick.major.size': 3,
                       '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 =  [0.36858269 0.22824175 0.37124565 0.00063252]
var =  [2.21705342e-02 6.00619085e-02 3.20953138e-01 2.81538338e-04]

1th hidden state
mean =  [2.64232936e-01 1.63983468e+00 2.08255555e+00 9.67519722e-04]
var =  [1.24073162e-02 4.70338498e-01 6.14857235e-01 1.58789458e-04]
```

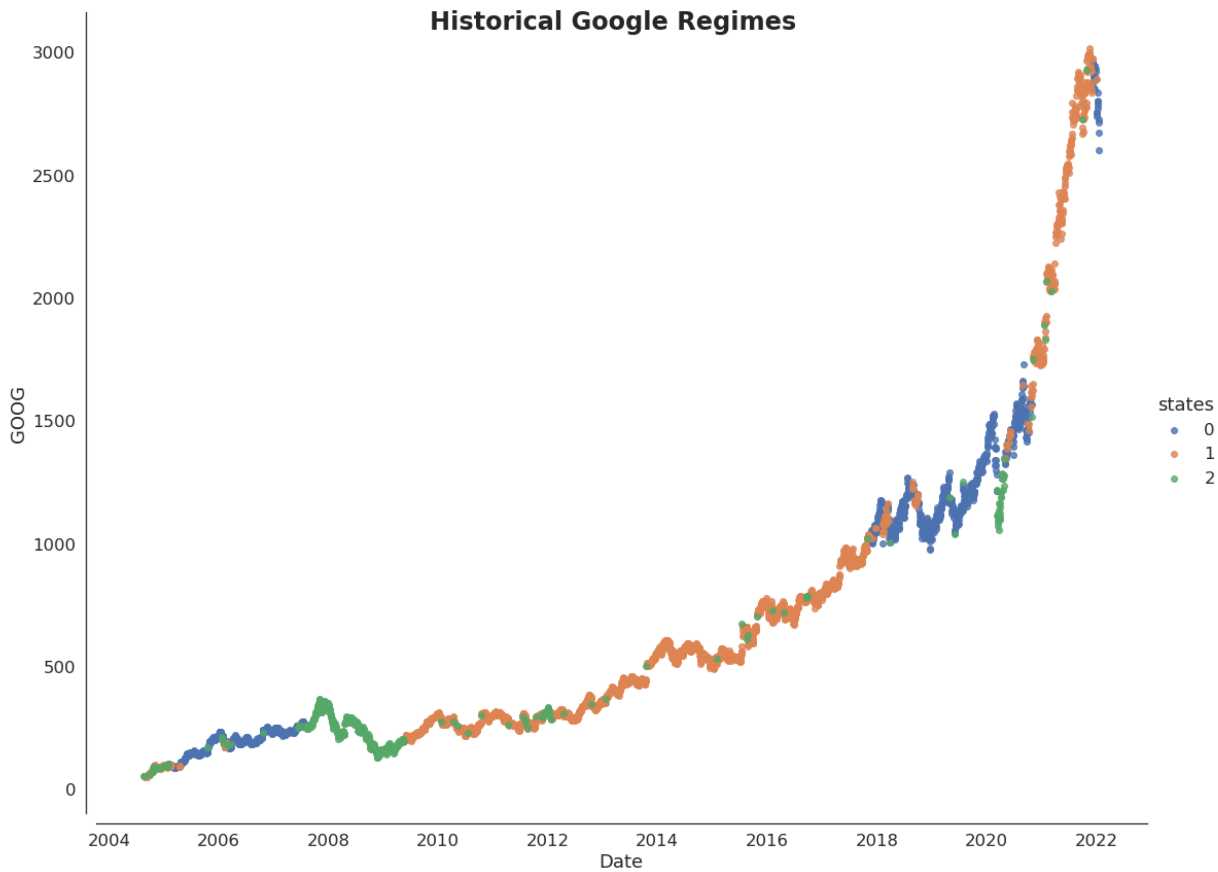
```
2th hidden state
mean =  [1.15084313e+00 1.37817721e+00 1.83002082e+00 2.51123522e-04]
var =  [0.52270993 0.38150874 0.84637247 0.00127313]
```



In [23]:
```
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 Google Regimes', fontsize=24, fontweight='demi')
fg.savefig('Hidden Markov (Mixture) Model_GOOG Regimes.png')
```

	Date	states	TEDRATE	T10Y2Y	T10Y3M	GOOG	sret	mkt_cret
0	2004-08-20	2	0.28	1.78	2.75	53.952770	0.076433	0.076433
1	2004-08-23	1	0.23	1.78	2.74	54.495735	0.010013	0.086446
2	2004-08-24	2	0.24	1.78	2.74	52.239197	-0.042289	0.044157
3	2004-08-25	1	0.25	1.75	2.72	52.802086	0.010718	0.054875
4	2004-08-26	1	0.26	1.74	2.67	53.753517	0.017858	0.072733

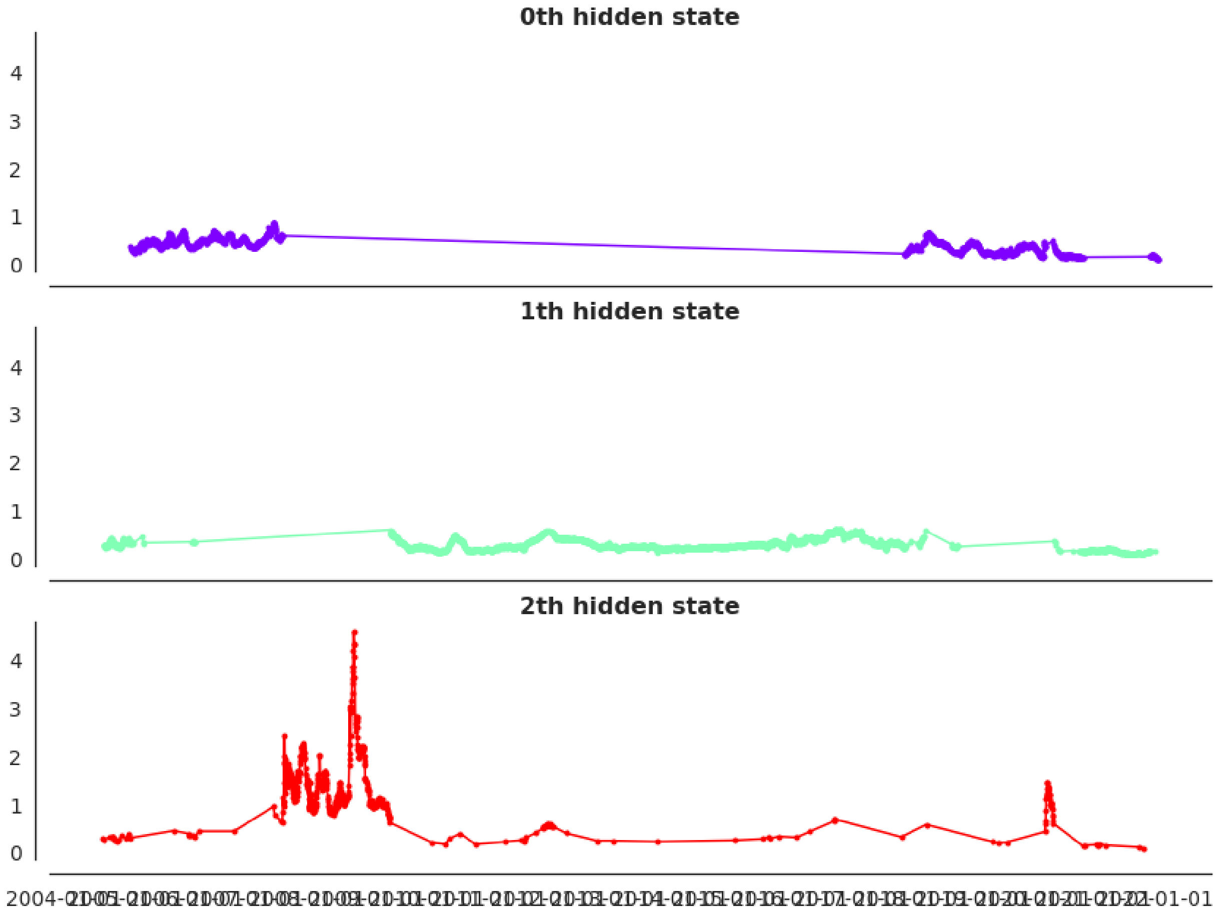
```
C:\ProgramData\Anaconda3\lib\site-packages\seaborn\axisgrid.py:316: UserWarnin
g: The `size` parameter has been renamed to `height`; please update your code.
  warnings.warn(msg, UserWarning)
```



In [24]:
```python
#TEDRATE  T10Y2Y  T10Y3M
col = 'TEDRATE'
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': 3, 'ytick.major.size': 3,
              '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')
```

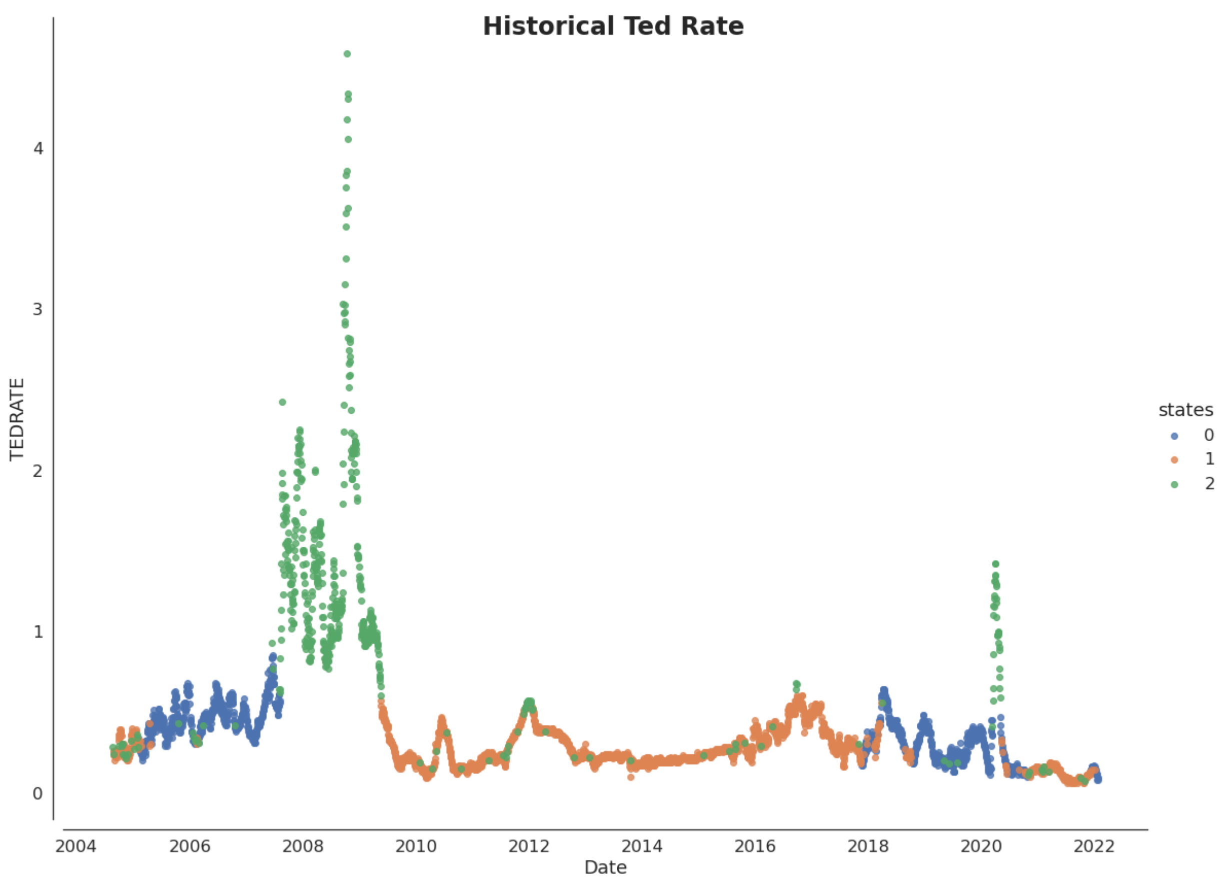
```
Means and vars of each hidden state
0th hidden state
mean =  [0.36858269 0.22824175 0.37124565 0.00063252]
var =  [2.21705342e-02 6.00619085e-02 3.20953138e-01 2.81538338e-04]

1th hidden state
mean =  [2.64232936e-01 1.63983468e+00 2.08255555e+00 9.67519722e-04]
var =  [1.24073162e-02 4.70338498e-01 6.14857235e-01 1.58789458e-04]

2th hidden state
```

```
mean =  [1.15084313e+00 1.37817721e+00 1.83002082e+00 2.51123522e-04]
var =  [0.52270993 0.38150874 0.84637247 0.00127313]
```



In [14]:
```
sns.set(font_scale=1.5)
states = (pd.DataFrame(hidden_states, columns=['states'], index=select.index)
          .join(select, how='inner')
          .assign(mkt_cret=select.TEDRATE.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','TEDRATE', alpha=0.8).add_legend()
sns.despine(offset=10)
fg.fig.suptitle('Historical Ted Rate', fontsize=24, fontweight='demi')
fg.savefig('Ted Rate.png')
```

```
        Date  states  TEDRATE  T10Y2Y  T10Y3M       GOOG      sret  mkt_cret
0 2004-08-20       2     0.28    1.78    2.75  53.952770  0.076433      0.28
1 2004-08-23       1     0.23    1.78    2.74  54.495735  0.010013      0.51
2 2004-08-24       2     0.24    1.78    2.74  52.239197 -0.042289      0.75
3 2004-08-25       1     0.25    1.75    2.72  52.802086  0.010718      1.00
4 2004-08-26       1     0.26    1.74    2.67  53.753517  0.017858      1.26

C:\ProgramData\Anaconda3\lib\site-packages\seaborn\axisgrid.py:316: UserWarnin
g: The `size` parameter has been renamed to `height`; please update your code.
  warnings.warn(msg, UserWarning)
```



Finding Equillibrium Matrix

In [26]:
```
start = pd.to_datetime('2002-01-01')
end = pd.datetime.today()

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

```
&lt;ipython-input-26-a2edceaac1b3&gt;:2: FutureWarning: The pandas.datetime class is
deprecated and will be removed from pandas in a future version. Import from dat
etime module instead.
  end = pd.datetime.today()
```

In [27]:
```
df
```

Out[27]:

Date	High	Low	Open	Close	Volume	Adj Close
2004-08-19	51.835709	47.800831	49.813290	49.982655	44871361.0	49.982655
2004-08-20	54.336334	50.062355	50.316402	53.952770	22942874.0	53.952770
2004-08-23	56.528118	54.321388	55.168217	54.495735	18342897.0	54.495735
2004-08-24	55.591629	51.591621	55.412300	52.239197	15319808.0	52.239197
2004-08-25	53.798351	51.746044	52.284027	52.802086	9232276.0	52.802086
...	...	...	...	...	...	...
2022-04-22	2509.040039	2382.810059	2500.000000	2392.280029	2317600.0	2392.280029
2022-04-25	2465.560059	2375.385010	2388.590088	2465.000000	1726100.0	2465.000000
2022-04-26	2455.000000	2383.237061	2455.000000	2390.120117	2469700.0	2390.120117
2022-04-27	2350.000000	2262.485107	2287.459961	2300.409912	3111900.0	2300.409912
2022-04-28	2408.770020	2302.877686	2342.300049	2389.600098	1538414.0	2389.600098

4455 rows × 6 columns

In [30]:
```
df["state"]=df["Close"].astype(float).pct_change()
df['state']=df['state'].apply(lambda x: 'Upside' if (x > 0.001) else ('Downside'
df
```

Out[30]:

Date	High	Low	Open	Close	Volume	Adj Close	state
2004-08-19	51.835709	47.800831	49.813290	49.982655	44871361.0	49.982655	Consolidation
2004-08-20	54.336334	50.062355	50.316402	53.952770	22942874.0	53.952770	Upside
2004-08-23	56.528118	54.321388	55.168217	54.495735	18342897.0	54.495735	Upside
2004-08-24	55.591629	51.591621	55.412300	52.239197	15319808.0	52.239197	Downside
2004-08-25	53.798351	51.746044	52.284027	52.802086	9232276.0	52.802086	Upside
...	...	...	...	...	...	...	...
2022-04-22	2509.040039	2382.810059	2500.000000	2392.280029	2317600.0	2392.280029	Downside
2022-04-25	2465.560059	2375.385010	2388.590088	2465.000000	1726100.0	2465.000000	Upside
2022-04-26	2455.000000	2383.237061	2455.000000	2390.120117	2469700.0	2390.120117	Downside
2022-04-27	2350.000000	2262.485107	2287.459961	2300.409912	3111900.0	2300.409912	Downside
2022-04-28	2408.770020	2302.877686	2342.300049	2389.600098	1538414.0	2389.600098	Upside

4455 rows × 8 columns

In [31]:
```
df.tail()
```

Out[31]:

Date	High	Low	Open	Close	Volume	Adj Close	state	prio
2022-04-22	2509.040039	2382.810059	2500.000000	2392.280029	2317600.0	2392.280029	Downside	Dov
2022-04-25	2465.560059	2375.385010	2388.590088	2465.000000	1726100.0	2465.000000	Upside	Dov
2022-04-26	2455.000000	2383.237061	2455.000000	2390.120117	2469700.0	2390.120117	Downside	l
2022-04-27	2350.000000	2262.485107	2287.459961	2300.409912	3111900.0	2300.409912	Downside	Dov
2022-04-28	2408.770020	2302.877686	2342.300049	2389.600098	1538414.0	2389.600098	Upside	Dov

In [32]:
```
df['priorstate']=df['state'].shift(1)
df.tail()
```

Out[32]:

Date	High	Low	Open	Close	Volume	Adj Close	state	prio
2022-04-22	2509.040039	2382.810059	2500.000000	2392.280029	2317600.0	2392.280029	Downside	Dov
2022-04-25	2465.560059	2375.385010	2388.590088	2465.000000	1726100.0	2465.000000	Upside	Dov
2022-04-26	2455.000000	2383.237061	2455.000000	2390.120117	2469700.0	2390.120117	Downside	l
2022-04-27	2350.000000	2262.485107	2287.459961	2300.409912	3111900.0	2300.409912	Downside	Dov
2022-04-28	2408.770020	2302.877686	2342.300049	2389.600098	1538414.0	2389.600098	Upside	Dov

Coding Transition Matrix for Markov Chain Model

In [35]:
```
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  0.000000  1.000000
Downside       0.505286  0.494714
Upside         0.514430  0.485570
```

In [2]:
```
## Forecasting Futures Probabilities of States using Python
```

In [36]:
```
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    0.470894  0.529106
Upside      0.477147  0.522853
```

In [37]:
```
t_0 = transition_matrix.copy()
t_1 =t_0.dot(t_0)
t_1
```

Out[37]:

state	Downside	Upside
priorstate		
Downside	0.474202	0.525798
Upside	0.474163	0.525837

In [38]:
```
t_0 = transition_matrix.copy()
t_1 =t_0.dot(t_0)
t_1
```

Out[38]:

state priorstate	Downside	Upside
Downside	0.474182	0.525818
Upside	0.474182	0.525818

Equilibrium Matrix using Python

In [39]:
```
## 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: 9
state       Downside    Upside
priorstate
Downside    0.474182  0.525818
Upside      0.474182  0.525818
```

The equilibrium Matrix is a stationary state. So, As per the theory of the Markov Chain, This figure will stay the same for foreseeable data points

In [40]:
```
import datetime
```

In [41]:

```
##Random Walk

symbol = "GOOG"
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("SPY", '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: 11
state        Downside    Upside
priorstate
Downside     0.461052  0.538948
Upside       0.461052  0.538948
```