05_conditional_autoencoder_for_asset_pricing_data

September 29, 2021

1 Conditional Autoencoder for Asset Pricing - Part 1: The Data

[1]:
```
from pathlib import Path

import numpy as np
import pandas as pd

from statsmodels.regression.rolling import RollingOLS
import statsmodels.api as sm
import matplotlib.pyplot as plt
import seaborn as sns
```

[2]:
```
idx = pd.IndexSlice
sns.set_style('whitegrid')
```

[3]:
```
results_path = Path('results', 'asset_pricing')
if not results_path.exists():
    results_path.mkdir(parents=True)
```

1.1 Load Data

1.1.1 Prices

[4]:
```
prices = pd.read_hdf(results_path / 'data.h5', 'stocks/prices/adjusted')
```

[5]:
```
prices.info(show_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 17661451 entries, ('A', Timestamp('1999-11-18 00:00:00')) to
('ZYXI', Timestamp('2019-12-31 00:00:00'))
Data columns (total 5 columns):
 #   Column  Non-Null Count     Dtype
---  ------  --------------     -----
 0   close   17661451 non-null  float64
 1   high    17661451 non-null  float64
 2   low     17661451 non-null  float64
 3   open    17661451 non-null  float64
 4   volume  17661451 non-null  float64
```

```
dtypes: float64(5)
memory usage: 742.0+ MB
```

1.1.2 Metadata

[6]:
```
metadata = pd.read_hdf(results_path / 'data.h5', 'stocks/info').
↪rename(columns=str.lower)
```

[7]:
```
metadata.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 6262 entries, A to ZYXI
Columns: 109 entries, zip to impliedsharesoutstanding
dtypes: bool(2), float64(75), int64(3), object(29)
memory usage: 5.2+ MB
```

1.1.3 Select tickers with metadata

[8]:
```
sectors = (metadata.sector.value_counts() > 50).index
```

[9]:
```
tickers_with_errors = ['FTAI', 'AIRT', 'CYBR', 'KTB']
```

[10]:
```
tickers_with_metadata = metadata[metadata.sector.isin(sectors) &
                                 metadata.marketcap.notnull() &
                                 metadata.sharesoutstanding.notnull() &
                                (metadata.sharesoutstanding > 0)].index.
↪drop(tickers_with_errors)
```

[11]:
```
metadata = metadata.loc[tickers_with_metadata, ['sector', 'sharesoutstanding',␣
↪'marketcap']]
metadata.index.name = 'ticker'
```

[12]:
```
prices = prices.loc[idx[tickers_with_metadata, :], :]
```

[13]:
```
prices.info(null_counts=True)
```

```
<ipython-input-13-e4642b41f34d>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  prices.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 17312229 entries, ('A', Timestamp('1999-11-18 00:00:00')) to
('ZYXI', Timestamp('2019-12-31 00:00:00'))
Data columns (total 5 columns):
 #   Column  Non-Null Count     Dtype
---  ------  --------------     -----
 0   close   17312229 non-null  float64
 1   high    17312229 non-null  float64
```

```
 2   low     17312229 non-null  float64
 3   open    17312229 non-null  float64
 4   volume  17312229 non-null  float64
dtypes: float64(5)
memory usage: 727.4+ MB
```

[14]:
```
metadata.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 5749 entries, A to ZYXI
Data columns (total 3 columns):
 #   Column             Non-Null Count  Dtype
---  ------             --------------  -----
 0   sector             5749 non-null   object
 1   sharesoutstanding  5749 non-null   float64
 2   marketcap          5749 non-null   float64
dtypes: float64(2), object(1)
memory usage: 179.7+ KB
```

[15]:
```
close = prices.close.unstack('ticker').sort_index()
close.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 7559 entries, 1990-01-02 to 2019-12-31
Columns: 4420 entries, A to ZYXI
dtypes: float64(4420)
memory usage: 255.0 MB
```

[16]:
```
volume = prices.volume.unstack('ticker').sort_index()
volume.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 7559 entries, 1990-01-02 to 2019-12-31
Columns: 4420 entries, A to ZYXI
dtypes: float64(4420)
memory usage: 255.0 MB
```

1.1.4 Create weekly returns

[17]:
```
returns = (prices.close
           .unstack('ticker')
           .resample('W-FRI').last()
           .sort_index().pct_change().iloc[1:])
returns.info()
```

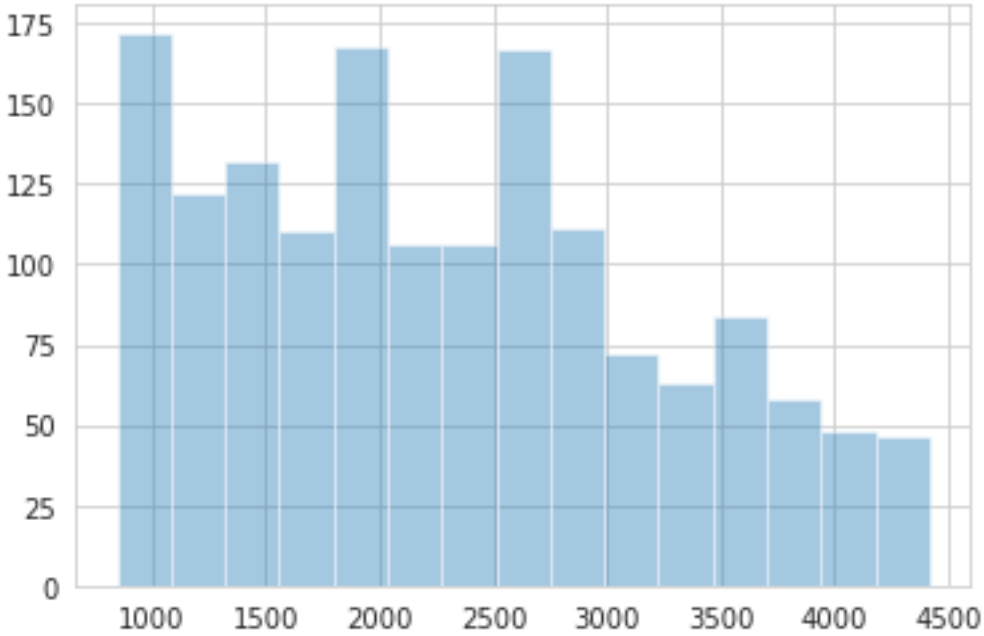
```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 1565 entries, 1990-01-12 to 2020-01-03
Freq: W-FRI
```

```
Columns: 4420 entries, A to ZYXI
dtypes: float64(4420)
memory usage: 52.8 MB
```

[18]:
```
dates = returns.index
```

[19]:
```
sns.distplot(returns.count(1), kde=False);
```

```
/home/stefan/.pyenv/versions/miniconda3-latest/envs/ml4t-dl/lib/python3.8/site-
packages/seaborn/distributions.py:2557: FutureWarning: `distplot` is a
deprecated function and will be removed in a future version. Please adapt your
code to use either `displot` (a figure-level function with similar flexibility)
or `histplot` (an axes-level function for histograms).
  warnings.warn(msg, FutureWarning)
```



[20]:
```
with pd.HDFStore(results_path / 'autoencoder.h5') as store:
    store.put('close', close)
    store.put('volume', volume)
    store.put('returns', returns)
    store.put('metadata', metadata)
```

1.2 Factor Engineering

[21]:
```
MONTH = 21
```

1.2.1 Price Trend

Short-Term Reversal 1-month cumulative return

[22]:
```
dates[:5]
```

[22]:
```
DatetimeIndex(['1990-01-12', '1990-01-19', '1990-01-26', '1990-02-02',
               '1990-02-09'],
              dtype='datetime64[ns]', name='date', freq='W-FRI')
```

[23]:
```
mom1m = close.pct_change(periods=MONTH).resample('W-FRI').last().stack().
↪to_frame('mom1m')
mom1m.info()
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 3580621 entries, (Timestamp('1990-02-02 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Dtype
---  ------  -----
 0   mom1m   float64
dtypes: float64(1)
memory usage: 41.2+ MB
```

[24]:
```
mom1m.squeeze().to_hdf(results_path / 'autoencoder.h5', 'factor/mom1m')
```

Stock Momentum 11-month cumulative returns ending 1-month before month end

[25]:
```
mom12m = (close
            .pct_change(periods=11 * MONTH)
            .shift(MONTH)
            .resample('W-FRI')
            .last()
            .stack()
            .to_frame('mom12m'))
```

[26]:
```
mom12m.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 3375489 entries, (Timestamp('1991-01-04 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   mom12m  3375489 non-null  float64
dtypes: float64(1)
memory usage: 38.8+ MB
```

```
<ipython-input-26-8a049b23d2aa>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  mom12m.info(null_counts=True)
```

[27]:
```
mom12m.to_hdf(results_path / 'autoencoder.h5', 'factor/mom12m')
```

Momentum Change Cumulative return from months t-6 to t-1 minus months t-12 to t-7.

[28]:
```
chmom = (close
         .pct_change(periods=6 * MONTH)
         .sub(close.pct_change(periods=6 * MONTH).shift(6 * MONTH))
         .resample('W-FRI')
         .last()
         .stack()
         .to_frame('chmom'))
```

[29]:
```
chmom.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 3375489 entries, (Timestamp('1991-01-04 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   chmom   3375489 non-null  float64
dtypes: float64(1)
memory usage: 38.8+ MB
```

```
<ipython-input-29-312a8747df17>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  chmom.info(null_counts=True)
```

[30]:
```
chmom.to_hdf(results_path / 'autoencoder.h5', 'factor/chmom')
```

Industry Momentum Equal-weighted avg. industry 12-month returns

[31]:
```
indmom = (close.pct_change(12*MONTH)
          .resample('W-FRI')
          .last()
          .stack()
          .to_frame('close')
          .join(metadata[['sector']]).groupby(['date', 'sector'])
          .close.mean()
          .to_frame('indmom')
          .reset_index())
```

[32]:
```
indmom.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 18495 entries, 0 to 18494
Data columns (total 3 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   date    18495 non-null  datetime64[ns]
 1   sector  18495 non-null  object
 2   indmom  18495 non-null  float64
dtypes: datetime64[ns](1), float64(1), object(1)
memory usage: 433.6+ KB
```

```
<ipython-input-32-fcaeaa0a7b0b>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  indmom.info(null_counts=True)
```

[33]:
```
indmom = (returns
          .stack()
          .to_frame('ret')
          .join(metadata[['sector']])
          .reset_index()
          .merge(indmom)
          .set_index(['date', 'ticker'])
          .loc[:, ['indmom']])
```

[34]:
```
indmom.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 3551199 entries, (Timestamp('1991-01-04 00:00:00'), 'AA') to
(Timestamp('2020-01-03 00:00:00'), 'ZTR')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   indmom  3551199 non-null  float64
dtypes: float64(1)
memory usage: 40.8+ MB
```

```
<ipython-input-34-fcaeaa0a7b0b>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  indmom.info(null_counts=True)
```

[35]:
```
indmom.to_hdf(results_path / 'autoencoder.h5', 'factor/indmom')
```

Recent Max Return Max daily returns from calendar month t-1

[36]:
```
maxret = (close
          .pct_change(periods=MONTH)
          .rolling(21)
          .max()
```

```
            .resample('W-FRI')
            .last()
            .stack()
            .to_frame('maxret'))
```

[37]:
```
maxret.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 3562402 entries, (Timestamp('1990-03-02 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   maxret  3562402 non-null  float64
dtypes: float64(1)
memory usage: 41.0+ MB
```

```
<ipython-input-37-ac905a38795f>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  maxret.info(null_counts=True)
```

[38]:
```
maxret.to_hdf(results_path / 'autoencoder.h5', 'factor/maxret')
```

Long-Term Reversal Cumulative returns months t-36 to t-13.

[39]:
```
mom36m = (close
            .pct_change(periods=24*MONTH)
            .shift(12*MONTH)
            .resample('W-FRI')
            .last()
            .stack()
            .to_frame('mom36m'))
```

[40]:
```
mom36m.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 2967391 entries, (Timestamp('1993-01-01 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   mom36m  2967391 non-null  float64
dtypes: float64(1)
memory usage: 34.2+ MB
```

```
<ipython-input-40-44b3a6a0df39>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  mom36m.info(null_counts=True)
```

[41]:
```
mom36m.to_hdf(results_path / 'autoencoder.h5', 'factor/mom36m')
```

1.2.2 Liquidity Metrics

Turnover Avg. monthly trading volume for most recent three months scaled by number of shares; we are using the most recent no of shares from yahoo finance

[42]:
```
turn = (volume
        .rolling(3*MONTH)
        .mean()
        .resample('W-FRI')
        .last()
        .div(metadata.sharesoutstanding)
        .stack('ticker')
        .to_frame('turn'))
```

[43]:
```
turn.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 3506569 entries, (Timestamp('1990-03-30 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   turn    3506569 non-null  float64
dtypes: float64(1)
memory usage: 40.3+ MB
```

```
<ipython-input-43-1b68d28a79cd>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  turn.info(null_counts=True)
```

[44]:
```
turn.to_hdf(results_path / 'autoencoder.h5', 'factor/turn')
```

Turnover Volatility Monthly std dev of daily share turnover

[45]:
```
turn_std = (prices
            .volume
            .unstack('ticker')
            .div(metadata.sharesoutstanding)
            .rolling(MONTH)
            .std()
            .resample('W-FRI')
            .last()
            .stack('ticker')
            .to_frame('turn_std'))
```

[46]:
```
turn_std.to_hdf(results_path / 'autoencoder.h5', 'factor/turn_std')
```

Log Market Equity Natural log of market cap at end of month t-1

[47]:
```
last_price = close.ffill()
factor = close.div(last_price.iloc[-1])
mvel = np.log1p(factor.mul(metadata.marketcap).resample('W-FRI').last()).
 ↪stack().to_frame('mvel')
```

[48]:
```
mvel.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 3597636 entries, (Timestamp('1990-01-05 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   mvel    3597636 non-null  float64
dtypes: float64(1)
memory usage: 41.4+ MB
```

```
<ipython-input-48-2c361336080a>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  mvel.info(null_counts=True)
```

[49]:
```
mvel.to_hdf(results_path / 'autoencoder.h5', 'factor/mvel')
```

Dollar Volume Natural log of trading volume time price per share from month t-2

[50]:
```
dv = close.mul(volume)
```

[51]:
```
dolvol = (np.log1p(dv.rolling(21)
                   .mean()
                   .shift(21)
                   .resample('W-FRI')
                   .last())
          .stack()
          .to_frame('dolvol'))
```

[52]:
```
dolvol.to_hdf(results_path / 'autoencoder.h5', 'factor/dolvol')
```

Amihud Illiquidity Average of daily (absolute return / dollar volume)

[53]:
```
ill = (close.pct_change().abs()
       .div(dv)
       .rolling(21)
       .mean()
       .resample('W-FRI').last()
       .stack()
       .to_frame('ill'))
```

[54]:
```
ill.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 3210773 entries, (Timestamp('1990-02-02 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   ill     3210773 non-null  float64
dtypes: float64(1)
memory usage: 36.9+ MB
```

```
<ipython-input-54-d1823ec8761b>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  ill.info(null_counts=True)
```

[55]:
```
ill.to_hdf(results_path / 'autoencoder.h5', 'factor/ill')
```

1.2.3 Risk Measures

Return Volatility Standard dev of daily returns from month t-1.

[56]:
```
retvol = (close.pct_change()
          .rolling(21)
          .std()
          .resample('W-FRI')
          .last()
          .stack()
          .to_frame('retvol'))
```

[57]:
```
retvol.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 3580621 entries, (Timestamp('1990-02-02 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   retvol  3580621 non-null  float64
dtypes: float64(1)
memory usage: 41.2+ MB
```

```
<ipython-input-57-b187f925aef0>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  retvol.info(null_counts=True)
```

[58]:
```
retvol.to_hdf(results_path / 'autoencoder.h5', 'factor/retvol')
```

Market Beta Estimated market beta from weekly returns and equal weighted market returns for 3 years ending month t-1 with at least 52 weeks of returns.

[59]:
```
index = close.resample('W-FRI').last().pct_change().mean(1).to_frame('x')
```

[60]:
```
def get_market_beta(y, x=index):
    df = x.join(y.to_frame('y')).dropna()
    model = RollingOLS(endog=df.y,
                       exog=sm.add_constant(df[['x']]),
                      window=3*52)

    return model.fit(params_only=True).params['x']
```

[61]:
```
beta = (returns.dropna(thresh=3*52, axis=1)
        .apply(get_market_beta).stack().to_frame('beta'))
```

[62]:
```
beta.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 2969406 entries, (Timestamp('1993-01-01 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   beta    2969406 non-null  float64
dtypes: float64(1)
memory usage: 34.2+ MB
```

```
<ipython-input-62-f1c77092070c>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  beta.info(null_counts=True)
```

[63]:
```
beta.to_hdf(results_path / 'autoencoder.h5', 'factor/beta')
```

Beta Squared Market beta squared

[64]:
```
betasq = beta.beta.pow(2).to_frame('betasq')
```

[65]:
```
betasq.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 2969406 entries, (Timestamp('1993-01-01 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column  Non-Null Count    Dtype
---  ------  --------------    -----
 0   betasq  2969406 non-null  float64
```

```
dtypes: float64(1)
memory usage: 34.2+ MB
```

```
<ipython-input-65-5559d38d2dd2>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  betasq.info(null_counts=True)
```

[66]:
```
betasq.to_hdf(results_path / 'autoencoder.h5', 'factor/betasq')
```

Idiosyncratic return volatility Standard dev of a regression of residuals of weekly returns on the returns of an equal weighted market index returns for the prior three years.

This takes a while!

[67]:
```
def get_ols_residuals(y, x=index):
    df = x.join(y.to_frame('y')).dropna()
    model = sm.OLS(endog=df.y, exog=sm.add_constant(df[['x']]))
    result = model.fit()
    return result.resid.std()
```

[68]:
```
idiovol = (returns.apply(lambda x: x.rolling(3 * 52)
                         .apply(get_ols_residuals)))
```

[69]:
```
idiovol = idiovol.stack().to_frame('idiovol')
```

[70]:
```
idiovol.info(null_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
MultiIndex: 2969406 entries, (Timestamp('1993-01-01 00:00:00', freq='W-FRI'),
'AA') to (Timestamp('2020-01-03 00:00:00', freq='W-FRI'), 'ZYXI')
Data columns (total 1 columns):
 #   Column   Non-Null Count    Dtype
---  ------   --------------    -----
 0   idiovol  2969406 non-null  float64
dtypes: float64(1)
memory usage: 34.2+ MB
```

```
<ipython-input-70-eec938dfce7b>:1: FutureWarning: null_counts is deprecated. Use
show_counts instead
  idiovol.info(null_counts=True)
```

[71]:
```
idiovol.to_hdf(results_path / 'autoencoder.h5', 'factor/idiovol')
```