

Notebook

April 28, 2025

Downloading the Data from WRDS

```
[2]: import pandas as pd
import numpy as np
import wrds
from pandas.tseries.offsets import MonthEnd

# Connect to WRDS
conn = wrds.Connection(wrds_username='vthukral')

# -----
# Load CRSP Bond Data
# -----
print('Loading Bond Data... ')
bonds = conn.raw_sql("""
    SELECT kycrspid, mcaldt, tmretnua, tmtotout
    FROM crspq.tfz_mth
""")
bonds['mcaldt'] = pd.to_datetime(bonds['mcaldt']) + MonthEnd(0)
bonds = bonds.rename(columns={
    "kycrspid": "idCRSP",
    "mcaldt": "date",
    "tmretnua": "ret",
    "tmtotout": "me"
}).copy()

# Save bonds data
bonds.to_csv('bonds_data.csv', index=False)

# -----
# Load CRSP T-Bill (Risk-Free) Data
# -----
print('Loading T-Bill Data... ')
rf = conn.raw_sql("""
    SELECT caldt, t30ret, t90ret
    FROM crspq.mcti
""")
rf['caldt'] = pd.to_datetime(rf['caldt']) + MonthEnd(0)
```

```

rf = rf.rename(columns={
    "caldt": "date",
    "t30ret": "rf30",
    "t90ret": "rf90"
}).copy()

# Save risk-free data
rf.to_csv('rf_data.csv', index=False)

# -----
# Close WRDS Connection
# -----
conn.close()
print('Data download complete. Files saved: bonds_data.csv and rf_data.csv')

```

Enter your WRDS username [vthukral]: vthukral

Enter your password:

WRDS recommends setting up a .pgpass file.

Create .pgpass file now [y/n]?: y

Created .pgpass file successfully.

You can create this file yourself at any time with the `create_pgpass_file()` function.

Loading library list...

Done

Loading Bond Data...

Loading T-Bill Data...

Data download complete. Files saved: bonds_data.csv and rf_data.csv

1. Construct the equal-weighted bond market return, value-weighted bond market return, and lagged total bond market capitalization using CRSP Bond data^[1]. Your output should be from January 1926 to December 2024, at a monthly frequency.

Hint: read Appendix A in Asness, Frazzini, and Pedersen (2012), detail on the data construction.

```

[79]: import pandas as pd
import numpy as np

bonds = pd.read_csv('bonds_data.csv')

def PS2_Q1(CRSP_Bonds):
    """
    Constructs Equal-Weighted Return, Value-Weighted Return,
    and Lagged Total Bond Market Capitalization (in millions) with Year and
    Month columns.
    """

    Inputs:

```

```

- CRSP_Bonds: DataFrame with columns ['idCRSP', 'date', 'ret', 'me']

Outputs:
- DataFrame with columns ['Year', 'Month', 'Bond_lag_MV', 'Bond_Ew_Ret', □
↳ 'Bond_Vw_Ret']
"""

"""Ensure 'date' is datetime"""
CRSP_Bonds['date'] = pd.to_datetime(CRSP_Bonds['date'])

"""Filter the sample period"""
CRSP_Bonds = CRSP_Bonds.loc[
    (CRSP_Bonds['date'] >= '1926-01-31') & (CRSP_Bonds['date'] <= □
↳ '2024-12-31')
].copy()

"""Drop rows with missing returns or market cap"""
CRSP_Bonds = CRSP_Bonds.dropna(subset=['ret', 'me'])

"""Group by month"""
grouped = CRSP_Bonds.groupby('date')

"""Calculate Equal-weighted return"""
equal_weighted_return = grouped['ret'].mean()

"""Calculate Value-weighted return"""
value_weighted_return = grouped.apply(lambda x: np.average(x['ret'], □
weights=x['me']))

"""Calculate total market capitalization"""
total_market_cap = grouped['me'].sum()

"""Lagged total market cap and scale to millions"""
lagged_total_market_cap = total_market_cap.shift(1) / 1_000_000

"""Create the result DataFrame"""
result = pd.DataFrame({
    'Bond_Ew_Ret': equal_weighted_return,
    'Bond_Vw_Ret': value_weighted_return,
    'Bond_lag_MV': lagged_total_market_cap
})

"""Add Year and Month columns from the index (date)"""
result['Year'] = result.index.year
result['Month'] = result.index.month

"""Reorder columns to put Year and Month first"""

```

```

    result = result[['Year', 'Month', 'Bond_lag_MV', 'Bond_Ew_Ret', □
↳ 'Bond_Vw_Ret']]]

    return result

```

C:\Users\vikal\AppData\Local\Temp\ipykernel_5652\903751667.py:4: DtypeWarning:
 Columns (0) have mixed types. Specify dtype option on import or set
 low_memory=False.

```
bonds = pd.read_csv('bonds_data.csv')
```

[80]: Q1_output = PS2_Q1(bonds)

C:\Users\vikal\AppData\Local\Temp\ipykernel_5652\903751667.py:36:
 DeprecationWarning: DataFrameGroupBy.apply operated on the grouping columns.
 This behavior is deprecated, and in a future version of pandas the grouping
 columns will be excluded from the operation. Either pass `include_groups=False`
 to exclude the groupings or explicitly select the grouping columns after groupby
 to silence this warning.

```
value_weighted_return = grouped.apply(lambda x: np.average(x['ret'],  

weights=x['me']))
```

[83]: Q1_output.to_csv('PS2_Q1.csv')

[44]: bonds = pd.read_csv('bonds_data.csv')

```

def PS2_Q1(CRSP_Bonds: pd.DataFrame) -> pd.DataFrame:
    """
    Constructs equal-weighted bond market return, value-weighted bond market
    ↳return,
    and lagged total bond market capitalization from CRSP bond data.

```

Parameters:

*CRSP_Bonds (pd.DataFrame): Raw CRSP bond data with columns ['idCRSP', □
↳ 'date', 'ret', 'me']*

Returns:

*pd.DataFrame: A dataframe with ['Year', 'Month', 'Bond_lag_MV', □
↳ 'Bond_Ew_Ret', 'Bond_Vw_Ret']*

*"""Make a copy of the input"""
df = CRSP_Bonds.copy()*

*"""Convert 'date' column to datetime format"""
df['date'] = pd.to_datetime(df['date'])*

*"""Extract Year and Month for grouping"""
df['Year'] = df['date'].dt.year*

```

df['Month'] = df['date'].dt.month

"""Convert 'ret' and 'me' to numeric, forcing errors to NaN"""
df['ret'] = pd.to_numeric(df['ret'], errors='coerce')
df['me'] = pd.to_numeric(df['me'], errors='coerce')

"""Lag market value by one month within each bond"""
df['lag_me'] = df.groupby('idCRSP')['me'].shift(1)

"""Drop rows with missing lagged market values"""
df = df.dropna(subset=['lag_me'])

"""Group data by Year and Month"""
monthly = df.groupby(['Year', 'Month'])

"""Calculate Equal-Weighted Bond Return"""
ew_ret = monthly['ret'].mean().rename("Bond_Ew_Ret")

"""Calculate Value-Weighted Bond Return using lagged market values"""
vw_ret = monthly.apply(lambda x: np.average(x['ret'], weights=x['lag_me'])).\
    rename("Bond_Vw_Ret")

"""Calculate Lagged Total Bond Market Capitalization (in millions)"""
lag_mv = (monthly['lag_me'].sum() / 1e6).rename("Bond_lag_MV")

"""Combine all series into a final DataFrame"""
final_df = pd.concat([lag_mv, ew_ret, vw_ret], axis=1).dropna().\
    reset_index()

"""Restrict to January 1926 to December 2024"""
final_df = final_df[(final_df['Year'] >= 1926) & (final_df['Year'] <= 2024)]

return final_df

# Example Usage:
# CRSP_Bonds = pd.read_csv('bonds_PS2.csv', dtype=str, low_memory=False)
# result_df = PS2_Q1(CRSP_Bonds)
# print(result_df.head(10))

```

```

C:\Users\vikal\AppData\Local\Temp\ipykernel_5652\2434258098.py:1: DtypeWarning:
Columns (0) have mixed types. Specify dtype option on import or set
low_memory=False.

bonds = pd.read_csv('bonds_data.csv')

```

[45]: Q1_output = PS2_Q1(bonds)

```

C:\Users\vikal\AppData\Local\Temp\ipykernel_5652\2434258098.py:42:
DeprecationWarning: DataFrameGroupBy.apply operated on the grouping columns.

```

This behavior is deprecated, and in a future version of pandas the grouping columns will be excluded from the operation. Either pass `include_groups=False` to exclude the groupings or explicitly select the grouping columns after groupby to silence this warning.

```
vw_ret = monthly.apply(lambda x: np.average(x['ret'],
weights=x['lag_me'])).rename("Bond_Vw_Ret")
```

[71]: Q1_output

```
[71]:
```

	Year	Month	Bond_lag_MV	Bond_Ew_Ret	Bond_Vw_Ret
date					
1926-01-31	1926	1	NaN	0.005101	0.006829
1926-02-28	1926	2	0.019502	0.003621	0.003844
1926-03-31	1926	3	0.019500	0.003812	0.003583
1926-04-30	1926	4	0.018736	0.004014	0.006486
1926-05-31	1926	5	0.019227	0.002146	0.002629
...
2024-08-31	2024	8	24.076745	0.010776	0.010137
2024-09-30	2024	9	24.240686	0.010147	0.009613
2024-10-31	2024	10	24.488777	-0.018731	-0.016736
2024-11-30	2024	11	24.537372	0.007938	0.007630
2024-12-31	2024	12	24.807002	-0.013415	-0.011986

[1188 rows x 5 columns]

[49]: Q1_output.to_csv("PS2_Q1.csv")

2. Aggregate stock, bond, and riskless datatables. For each year-month, calculate the lagged market value and excess value-weighted returns for both stocks and bonds. Your output should be from January 1926 to December 2024, at a monthly frequency.

- Suggested function: **PS2_Q2**

- Inputs

- * dataframe **Monthly_CRSP_Stocks**, an extended version of the output of **PS1_Q1**
- * dataframe **Monthly_CRSP_Bonds**, the output of **PS2_Q1**
- * dataframe **Monthly_CRSP_Riskless²**, with columns:

Variable Name	Variable type
caldt	datetime
t90ret	float
t30ret	float

- This should be the data as pulled from WRDS, with one exception. Format the caldt column as a datetime. This should be the full dataset available on WRDS; do not pre-filter by caldt.

- Output

- * dataframe, with each row corresponding to a unique year and month, with columns

Variable Name	Variable type	Variable description
Year	integer	Year
Month	integer	Month
Stock_lag_MV	float	Total market value the previous month (in millions)
Stock_Excess_Vw_Ret	float	Value-weighted return above riskless rate
Bond_lag_MV	float	Total market value the previous month (in millions)
Bond_Excess_Vw_Ret	float	Value-weighted return above riskless rate

- Note: Returns should be formatted in decimal proportion (not percent).

Downloading the Data from WRDS

```
[36]: import pandas as pd
import numpy as np
import wrds
from pandas.tseries.offsets import MonthEnd

"""
Connect to WRDS
"""

conn = wrds.Connection(wrds_username='vthukral')

"""
Load CRSP Stock Returns
"""

print('Loading CRSP Stock Returns Data...')
crsp_raw = conn.raw_sql("""
    SELECT a.permno, a.permco, a.date, b.shrcd, b.exchcd,
        a.ret, a.retx, a.shrout, a.prc, a.cfacshr
```

```

        FROM crspq.msf AS a
        LEFT JOIN crsp.msenames AS b
        ON a.permno = b.permno
        AND b.namedt <= a.date
        AND a.date <= b.nameendt
        WHERE a.date BETWEEN '01/01/1900' AND '12/31/2025'
"""
crsp_raw['date'] = pd.to_datetime(crsp_raw['date']) + MonthEnd(0)
crsp_raw[['permno', 'permco']] = crsp_raw[['permno', 'permco']].astype(int)

"""

Load CRSP Delisting Returns
"""
print('Loading CRSP Delisting Returns Data...')
dlret_raw = conn.raw_sql("""
    SELECT permno, dlret, dlstdt, dlstcd
    FROM crspq.msdelist
""")
dlret_raw['dlstdt'] = pd.to_datetime(dlret_raw['dlstdt'])
dlret_raw['date'] = dlret_raw['dlstdt'] + MonthEnd(0)
dlret_raw['permno'] = dlret_raw['permno'].astype(int)

"""

Load CRSP VW Market Index (Benchmark)
"""
print('Loading CRSP Market Index Data...')
mkt_csrp = conn.raw_sql("""
    SELECT date, VWRETD, totval
    FROM crspq.msi
""")
mkt_csrp['date'] = pd.to_datetime(mkt_csrp['date']) + MonthEnd(0)
mkt_csrp = mkt_csrp.rename(columns={"VWRETD": "mkt_csrp", "totval": "mkt_crsp_mktcap"})

"""

Close WRDS Connection
"""
conn.close()
print('WRDS connection closed.')

"""

Save Raw Files
"""
crsp_raw.to_csv('crsp_raw_PS2.csv', index=False)
dlret_raw.to_csv('dlret_raw_PS2.csv', index=False)
mkt_csrp.to_csv('mkt_csrp_PS2.csv', index=False)

```

```

"""
Process and Create Monthly_CRSP_Stocks
"""

print('Processing Monthly CRSP Stocks...')

# Merge stock returns with delisting returns
crsp = crsp_raw.merge(dlret_raw[['permno', 'date', 'dlret']], on=['permno', ↴'date'], how='left')

# Adjust returns for delisting
crsp['retadj'] = crsp['ret']
mask = ~crsp['dlret'].isnull()
crsp.loc[mask, 'retadj'] = (1 + crsp.loc[mask, 'retadj']) * (1 + crsp.loc[mask, ↴'dlret']) - 1

# Calculate market capitalization
crsp['me'] = crsp['prc'].abs() * crsp['shroutr']

# Filter for valid common stocks
crsp = crsp[
    (crsp['shrcd'].isin([10, 11])) &
    (crsp['exchcd'].isin([1, 2, 3])) &
    (crsp['prc'].abs() > 0) &
    (crsp['shroutr'] > 0) &
    (~crsp['retadj'].isnull())
]

# Group by month
crsp_grouped = crsp.groupby('date')

# Create Monthly CRSP Stocks
Monthly_CRSP_Stocks = pd.DataFrame({
    'Value_Weighted_Return': crsp_grouped.apply(lambda x: np.average(x['retadj'], weights=x['me'])),
    'Total_Market_Cap': crsp_grouped['me'].sum()
}).reset_index()

# Add Year and Month
Monthly_CRSP_Stocks['Year'] = Monthly_CRSP_Stocks['date'].dt.year
Monthly_CRSP_Stocks['Month'] = Monthly_CRSP_Stocks['date'].dt.month

# Save Processed File
Monthly_CRSP_Stocks.to_csv('Monthly_CRSP_Stocks.csv', index=False)

print('Step 1 complete: Files saved - crsp_raw_PS2.csv, dlret_raw_PS2.csv, ↴mkt_csrp_PS2.csv, Monthly_CRSP_Stocks.csv')

```

```

Loading library list...
Done
Loading CRSP Stock Returns Data...
Loading CRSP Delisting Returns Data...
Loading CRSP Market Index Data...
WRDS connection closed.
Processing Monthly CRSP Stocks...
Step 1 complete: Files saved - crsp_raw_PS2.csv, dlret_raw_PS2.csv,
mkt_csrp_PS2.csv, Monthly_CRSP_Stocks.csv

C:\Users\vikal\AppData\Local\Temp\ipykernel_5652\1518014395.py:94:
DeprecationWarning: DataFrameGroupBy.apply operated on the grouping columns.
This behavior is deprecated, and in a future version of pandas the grouping
columns will be excluded from the operation. Either pass `include_groups=False`
to exclude the groupings or explicitly select the grouping columns after groupby
to silence this warning.

'Value_Weighted_Return': crsp_grouped.apply(lambda x: np.average(x['retadj'],
weights=x['me'])),

```

[]:

Step 2: Solve PS2_Q2 — Final Code

```

[96]: import pandas as pd

def PS2_Q2(Monthly_CRSP_Stocks, Monthly_CRSP_Bonds, Monthly_CRSP_Riskless):
    """
    Constructs the final PS2_Q2 DataFrame by aggregating lagged market values
    and excess returns
    for stocks and bonds from January 1926 to December 2024.

    Inputs:
    - Monthly_CRSP_Stocks: DataFrame with columns ['Year', 'Month', 'Stock lag_MV',
      'Stock Ew Ret', 'Stock Vw Ret']
    - Monthly_CRSP_Bonds: DataFrame output from PS2_Q1 with columns ['Year', 'Month',
      'Bond lag MV', 'Bond Ew Ret', 'Bond Vw Ret']
    - Monthly_CRSP_Riskless: DataFrame with risk-free rates (columns ['date',
      'rf30'])

    Output:
    - DataFrame with columns:
      ['Year', 'Month', 'Stock_lag_MV', 'Stock_Excess_Vw_Ret', 'Bond_lag_MV',
      'Bond_Excess_Vw_Ret']
    """

    Step 1: Prepare Risk-Free Rate
    Convert risk-free rate dates into Year and Month format.

```

```

"""
Monthly_CRSP_Riskless['date'] = pd.
    to_datetime(Monthly_CRSP_Riskless['date'])
Monthly_CRSP_Riskless['Year'] = Monthly_CRSP_Riskless['date'].dt.year
Monthly_CRSP_Riskless['Month'] = Monthly_CRSP_Riskless['date'].dt.month
riskless = Monthly_CRSP_Riskless[['Year', 'Month', 'rf30']].copy()

"""

Step 2: Prepare Stock Data
Rename columns to match the internal naming convention and merge with risk-free rate.

df_stocks = Monthly_CRSP_Stocks.copy()
df_stocks = df_stocks.rename(columns={
    'Stock lag MV': 'Stock_lag_MV',
    'Stock Ew Ret': 'Stock_Ew_Ret',
    'Stock Vw Ret': 'Stock_Vw_Ret'
})
df_stocks = df_stocks.merge(riskless, on=['Year', 'Month'], how='left')
df_stocks['Stock_Excess_Vw_Ret'] = df_stocks['Stock_Vw_Ret'] - df_stocks['rf30']
df_stocks["Stock_lag_MV"] = df_stocks["Stock_lag_MV"]/1_000_000

"""

Step 3: Prepare Bond Data
Merge bond returns with risk-free rate and calculate excess bond returns.

df_bonds = Monthly_CRSP_Bonds.copy()
df_bonds = df_bonds.merge(riskless, on=['Year', 'Month'], how='left')
df_bonds['Bond_Excess_Vw_Ret'] = df_bonds['Bond_Vw_Ret'] - df_bonds['rf30']

"""

Step 4: Merge Stock and Bond Information
Merge the processed stock and bond datasets on Year and Month.

final = df_stocks[['Year', 'Month', 'Stock_lag_MV', 'Stock_Excess_Vw_Ret']].
    merge(
        df_bonds[['Year', 'Month', 'Bond_lag_MV', 'Bond_Excess_Vw_Ret']],
        on=['Year', 'Month'],
        how='outer'
    )

return final

```

[97]:

```

Monthly_CRSP_Stocks = pd.read_csv('PS1_Q1.csv')      # Stock data
Monthly_CRSP_Riskless = pd.read_csv('rf_data.csv')    # Risk-free data
Monthly_CRSP_Bonds = pd.read_csv('PS2_Q1.csv')        # Bond data

```

```

Q2_output = PS2_Q2(Monthly_CRSP_Stocks, Monthly_CRSP_Bonds, Monthly_CRSP_Riskless)

# Save the output if needed
Q2_output.to_csv('PS2_Q2_output.csv', index=False)
print('Saved PS2_Q2_output.csv successfully.')

```

Saved PS2_Q2_output.csv successfully.

[98]: Q2_output

```

[98]:      Year Month Stock_lag_MV Stock_Excess_Vw_Ret Bond_lag_MV \
0    1926     1       NaN             NaN             NaN
1    1926     2    27.032345      -0.036744    0.019502
2    1926     3    26.162084      -0.067653    0.019500
3    1926     4    24.506932      0.033663    0.018736
4    1926     5    25.296195      0.011907    0.019227
...   ...   ...
1183 2024     8  53565.917121      0.016517  24.076745
1184 2024     9  54594.988469      0.016805  24.240686
1185 2024    10  55717.449769     -0.009705  24.488777
1186 2024    11  55336.413557      0.065003  24.537372
1187 2024    12  59062.952809     -0.031637  24.807002

      Bond_Excess_Vw_Ret
0            0.003878
1            0.001076
2            0.000805
3            0.003414
4            0.002287
...           ...
1183          0.005718
1184          0.004994
1185         -0.020643
1186          0.003675
1187         -0.015649

[1188 rows x 6 columns]

```

3. Calculate the monthly unlevered and levered risk-parity portfolio returns as defined by Asness, Frazzini, and Pedersen (2012).^[8] For the levered risk-parity portfolio, match the value-weighted portfolio's $\hat{\sigma}$ over the longest matched holding period of both. Your output should be from January 1926 to December 2024, at a monthly frequency.

- Suggested function: **PS2_Q3**

- Inputs
 - * dataframe **Monthly_CRSP_Universe**, the output of **PS2_Q2**
- Output
 - * dataframe, with each row corresponding to a unique year and month, with columns

Variable Name	Variable type	Variable description
Year	integer	Year
Month	integer	Month
Stock_Excess_Vw_Ret	float	
Bond_Excess_Vw_Ret	float	
Excess_Vw_Ret	float	Value-weighted portfolio return above riskless rate
Excess_60_40_Ret	float	60-40 portfolio return above riskless rate
Stock_inverse_sigma_hat	float	As defined by Asness et al. (2012)
Bond_inverse_sigma_hat	float	As defined by Asness et al. (2012)
Unlevered_k	float	As defined by Asness et al. (2012)
Excess_Unlevered_RP_Ret	float	Unlevered RP portfolio return above riskless rate
Levered_k	float	To match $\hat{\sigma}$ of Excess_Vw_Ret
Excess_Levered_RP_Ret	float	RP portfolio return above riskless rate

- Note: Returns should be formatted in decimal proportion (not percent).

```
[99]: import pandas as pd
import numpy as np

def PS2_Q3(Monthly_CRSP_Universe):
    """
    Constructs unlevered and levered Risk-Parity (RP) portfolio returns
    based on Monthly_CRSP_Universe (the output from PS2_Q2).

    Inputs:
    - Monthly_CRSP_Universe: DataFrame with columns:
        ['Year', 'Month', 'Stock_lag_MV', 'Stock_Excess_Vw_Ret', 'Bond_lag_MV', ..., 'Bond_Excess_Vw_Ret']

    Outputs:
    - DataFrame with columns:
        ['Year', 'Month', 'Stock_Excess_Vw_Ret', 'Bond_Excess_Vw_Ret',
        'Excess_Vw_Ret', 'Excess_60_40_Ret',
        'Stock_inverse_sigma_hat', 'Bond_inverse_sigma_hat',
        'Unlevered_k', 'Excess_Unlevered_RP_Ret', ...]
```

```

'Levered_k', 'Excess_Levered_RP_Ret']

"""

"""

Compute rolling volatilities (^) using a 36-month window
"""

Monthly_CRSP_Universe = Monthly_CRSP_Universe.copy()
Monthly_CRSP_Universe['Stock_inverse_sigma_hat'] = 1 / \
    Monthly_CRSP_Universe['Stock_Excess_Vw_Ret'].rolling(36).std()
Monthly_CRSP_Universe['Bond_inverse_sigma_hat'] = 1 / \
    Monthly_CRSP_Universe['Bond_Excess_Vw_Ret'].rolling(36).std()

"""

Compute value-weighted portfolio returns (excess) and 60/40 portfolio
returns (excess)
"""

vw_excess_ret = (Monthly_CRSP_Universe['Stock_lag_MV'] * \
    Monthly_CRSP_Universe['Stock_Excess_Vw_Ret'] + \
        Monthly_CRSP_Universe['Bond_lag_MV'] * \
    Monthly_CRSP_Universe['Bond_Excess_Vw_Ret']) / \
        (Monthly_CRSP_Universe['Stock_lag_MV'] + \
    Monthly_CRSP_Universe['Bond_lag_MV'])
Monthly_CRSP_Universe['Excess_Vw_Ret'] = vw_excess_ret

Monthly_CRSP_Universe['Excess_60_40_Ret'] = 0.6 * \
    Monthly_CRSP_Universe['Stock_Excess_Vw_Ret'] + \
        0.4 * \
    Monthly_CRSP_Universe['Bond_Excess_Vw_Ret']

"""

Compute unlevered RP portfolio returns
"""

inverse_vol_sum = Monthly_CRSP_Universe['Stock_inverse_sigma_hat'] + \
    Monthly_CRSP_Universe['Bond_inverse_sigma_hat']
Monthly_CRSP_Universe['Unlevered_k'] = 1 / inverse_vol_sum

Monthly_CRSP_Universe['Excess_Unlevered_RP_Ret'] = \
    Monthly_CRSP_Universe['Unlevered_k'] * (
        Monthly_CRSP_Universe['Stock_inverse_sigma_hat'] * \
    Monthly_CRSP_Universe['Stock_Excess_Vw_Ret'] + \
        Monthly_CRSP_Universe['Bond_inverse_sigma_hat'] * \
    Monthly_CRSP_Universe['Bond_Excess_Vw_Ret']
)

"""

Compute levered RP portfolio returns (leveraged to match Vw portfolio ^)

```

```

"""
vol_Vw = Monthly_CRSP_Universe['Excess_Vw_Ret'].rolling(36).std()
vol_RP = Monthly_CRSP_Universe['Excess_Unlevered_RP_Ret'].rolling(36).std()
Monthly_CRSP_Universe['Levered_k'] = vol_Vw / vol_RP

Monthly_CRSP_Universe['Excess_Levered_RP_Ret'] = \
    Monthly_CRSP_Universe['Levered_k'] * \
    Monthly_CRSP_Universe['Excess_Unlevered_RP_Ret']

"""

Final output dataframe
"""

result = Monthly_CRSP_Universe[[
    'Year', 'Month',
    'Stock_Excess_Vw_Ret', 'Bond_Excess_Vw_Ret',
    'Excess_Vw_Ret', 'Excess_60_40_Ret',
    'Stock_inverse_sigma_hat', 'Bond_inverse_sigma_hat',
    'Unlevered_k', 'Excess_Unlevered_RP_Ret',
    'Levered_k', 'Excess_Levered_RP_Ret'
]].copy()

return result

```

[107]: Q3_output = PS2_Q3(Q2_output)
Q3_output

	Year	Month	Stock_Excess_Vw_Ret	Bond_Excess_Vw_Ret	Excess_Vw_Ret	
0	1926	1	NaN	0.003878	NaN	
1	1926	2	-0.036744	0.001076	-0.036717	
2	1926	3	-0.067653	0.000805	-0.067602	
3	1926	4	0.033663	0.003414	0.033640	
4	1926	5	0.011907	0.002287	0.011900	
...	
1183	2024	8	0.016517	0.005718	0.016513	
1184	2024	9	0.016805	0.004994	0.016800	
1185	2024	10	-0.009705	-0.020643	-0.009710	
1186	2024	11	0.065003	0.003675	0.064975	
1187	2024	12	-0.031637	-0.015649	-0.031630	
			Excess_60_40_Ret	Stock_inverse_sigma_hat	Bond_inverse_sigma_hat	
0			NaN	NaN	NaN	
1			-0.021616	NaN	NaN	
2			-0.040270	NaN	NaN	
3			0.021564	NaN	NaN	
4			0.008059	NaN	NaN	
...			
1183			0.012198	19.299225	67.939401	

```

1184      0.012081      19.537989      67.671823
1185     -0.014080      19.925321      66.407814
1186      0.040471      19.580052      66.493317
1187     -0.025242      19.502011      65.917702

      Unlevered_k  Excess_Unlevered_RP_Ret  Levered_k  Excess_Levered_RP_Ret
0            1.0             NaN           NaN           NaN
1            1.0             NaN           NaN           NaN
2            1.0             NaN           NaN           NaN
3            1.0             NaN           NaN           NaN
4            1.0             NaN           NaN           NaN
...
1183          ...          ...          ...
1184          1.0          0.008107      2.699263      0.021884
1184          1.0          0.007640      2.667851      0.020383
1185          1.0         -0.018119      2.598028     -0.047073
1186          1.0          0.017626      2.608054      0.045969
1187          1.0         -0.019299      2.589993     -0.049985

```

[1188 rows x 12 columns]

4. Replicate and report Panel A of Table 2 in Asness, Frazzini, and Pedersen (2012), except for Alpha and t-stat of Alpha columns. Specifically, for all strategies considered, report the annualized average excess returns, t-statistic of the average excess returns, annualized volatility, annualized Sharpe Ratio, skewness, and excess kurtosis. Your sample should be from January 1929 to June 2010, at monthly frequency. Match the format of the table to the extent possible. Discuss the difference between your table and the table reported in the paper. It is zero? If not, justify whether the difference is economically negligible or not. What are the reasons for a nonzero difference?

- Suggested function: **PS2_Q4**
 - Input
 - * dataframe **Port_Rets**, the output of **PS2_Q3**
 - Output
 - * 6×6 numeric matrix/dataframe, reproducing part of the Long Sample subtable. Match the formatting of the paper to the extent possible. Rows: CRSP stocks, CRSP bonds, Value-weighted portfolio, 60/40 portfolio, unlevered RP, and levered RP. Columns: Annualized Mean, t-stat of Annualized Mean, Annualized Standard Deviation, Annualized Sharpe Ratio, Skewness, and Excess Kurtosis.

```

[108]: import pandas as pd
import numpy as np
from scipy.stats import skew, kurtosis

def PS2_Q4(Port_Rets):

```

```

"""
    Computes performance statistics for different portfolios from January 1929
    to June 2010.

    Inputs:
    - Port_Rets: DataFrame, the output from PS2_Q3 containing portfolio excess
    returns.

    Outputs:
    - stats_table: DataFrame, a 6 × 6 table reporting Annualized Mean,
    t-statistic of Mean,
    Annualized Volatility, Annualized Sharpe Ratio, Skewness, and Excess
    Kurtosis.

"""

"""Restrict the sample"""
Port_Rets = Port_Rets.copy()
Port_Rets['date'] = pd.to_datetime(Port_Rets['Year'].astype(str) + '-' + 
Port_Rets['Month'].astype(str)) + pd.offsets.MonthEnd(0)
Port_Rets = Port_Rets[(Port_Rets['date'] >= '1929-01-31') &
(Port_Rets['date'] <= '2010-06-30')]

"""Identify the portfolio columns"""
port_cols = [
    'Stock_Excess_Vw_Ret',
    'Bond_Excess_Vw_Ret',
    'Excess_Vw_Ret',
    'Excess_60_40_Ret',
    'Excess_Unlevered_RP_Ret',
    'Excess_Levered_RP_Ret'
]

"""Initialize dictionary to store results"""
results = {}

"""Calculate metrics for each portfolio"""
for col in port_cols:
    rets = Port_Rets[col].dropna()
    n = len(rets)

    ann_mean = 12 * rets.mean()
    ann_vol = np.sqrt(12) * rets.std()
    t_stat = ann_mean / (rets.std() / np.sqrt(n))
    sharpe = ann_mean / ann_vol
    skewness = skew(rets)
    ex_kurt = kurtosis(rets) # Already excess kurtosis (subtracts 3)

```

```

        results[col] = [
            ann_mean,
            t_stat,
            ann_vol,
            sharpe,
            skewness,
            ex_kurt
        ]

    """Create final DataFrame"""
    stats_table = pd.DataFrame(results, index=[
        'Annualized Mean',
        't-stat of Mean',
        'Annualized Volatility',
        'Annualized Sharpe Ratio',
        'Skewness',
        'Excess Kurtosis'
    ]).T

    return stats_table

```

[109]: Q4_output = PS2_Q4(Q3_output)
Q4_output

	Annualized Mean	t-stat of Mean	\
Stock_Excess_Vw_Ret	0.067450	38.303674	
Bond_Excess_Vw_Ret	0.013910	53.816348	
Excess_Vw_Ret	0.067363	38.285007	
Excess_60_40_Ret	0.046034	42.864344	
Excess_Unlevered_RP_Ret	0.021024	64.604804	
Excess_Levered_RP_Ret	0.122175	69.732333	

	Annualized Volatility	Annualized Sharpe Ratio	\
Stock_Excess_Vw_Ret	0.190765	0.353574	
Bond_Excess_Vw_Ret	0.028000	0.496769	
Excess_Vw_Ret	0.190613	0.353402	
Excess_60_40_Ret	0.116343	0.395673	
Excess_Unlevered_RP_Ret	0.035255	0.596355	
Excess_Levered_RP_Ret	0.186378	0.655523	

	Skewness	Excess Kurtosis
Stock_Excess_Vw_Ret	0.229409	7.642783
Bond_Excess_Vw_Ret	0.214356	4.087531
Excess_Vw_Ret	0.227733	7.634805
Excess_60_40_Ret	0.239658	7.399356
Excess_Unlevered_RP_Ret	0.109309	2.684188

Excess_Levered_RP_Ret 0.024889 5.658504

This notebook was converted with convert.ploomber.io