# Problem Set 2: Risk Parity

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Due on Wednesday 4/18. This is an **individual assignment**, but you can discuss it with your classmates. If you discuss with other classmates, indicate their names in your write-up. Please submit R code as well as a separate write-up. Explain the procedure and your answers clearly in the write-up (such that someone unfamiliar with the problem could solve it). Code must be formatted as instructed in order to receive a grade. Use CCLE to submit your answers.

You should submit two files:

- .R **PS2_YourStudentID** (for example, PS2_012345678.R), with **only** the functions described below and the packages needed to run them
- .pdf **PS2_YourStudentID** (for example, PS2_012345678.pdf), with discussion on how you answered the questions written below, as well as responses to any particular questions asked

**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 2017, at a monthly frequency.

- Function name: **PS2_Q1**
  - Inputs
    - data.table **CRSP_Bonds**, with columns:

| Variable Name | Variable type |
|---|---|
| KYCRSPID | Character |
| MCALDT | Date |
| TMRETNUA | Numeric |
| TMTOTOUT | Integer |

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

[1] Available at WRDS: `https://wrds-web.wharton.upenn.edu/wrds/`. Bond data are available from WRDS: CRSP > Annual Update> Treasuries > CRSP TREASURIES - Issue Descriptions and Monthly Time Series.

- Output
  - data.table, with each row corresponding to a unique year and month, with columns

| **Variable Name** | **Variable type** | **Variable description** |
|---|---|---|
| Year | Integer | Year |
| Month | Integer | Month |
| Bond_lag_MV | Integer | Total market value the previous month (in millions) |
| Bond_Ew_Ret | Numeric | Equal-weighted returns |
| Bond_Vw_Ret | Numeric | Value-weighted returns |

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

**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 2017, at a monthly frequency.

- Function name: **PS2_Q2**
  - Inputs
    - data.table **Monthly_CRSP_Stocks**, an extended version of the output of **PS1_Q1** (Jan 1926 - Dec 2017 instead of Feb 1926 - Dec 2017).
    - data.table **Monthly_CRSP_Bonds**, the output of **PS2_Q1**
    - data.table **Monthly_CRSP_Riskless**[2], with columns:

| Variable Name | Variable type |
|---|---|
| caldt | Date |
| t90ret | Numeric |
| t30ret | Numeric |

      - This should be the data as pulled from WRDS, with one exception. Format the caldt column as a Date type. This should be the full dataset available on WRDS; do not pre-filter by caldt.
  - Output
    - data.table, 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 | Numeric | Total market value the previous month (in millions) |
| Stock_Excess_Vw_Ret | Numeric | Value-weighted return above riskless rate |
| Bond_lag_MV | Integer | Total market value the previous month (in millions) |
| Bond_Excess_Vw_Ret | Numeric | Value-weighted return above riskless rate |

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

[2] Available at WRDS: `https://wrds-web.wharton.upenn.edu/wrds/`. Treasury data is available from WRDS: CRSP > Annual Update> Index / Treasury and Inflation > US Treasury and Inflation Indexes.

**3.** Calculate the monthly unlevered and levered risk-parity portfolio returns as defined by Asness, Frazzini, and Pedersen (2012).[3] 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 2017, at a monthly frequency.

- Function name: **PS2_Q3**
  - Inputs
    - data.table **Monthly_CRSP_Universe**, the output of **PS2_Q2**
  - Output
    - data.table, 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 | Numeric | |
| Bond_Excess_Vw_Ret | Numeric | |
| Excess_Vw_Ret | Numeric | Value-weighted portfolio return above riskless rate |
| Excess_60_40_Ret | Numeric | 60-40 portfolio return above riskless rate |
| Stock_inverse_sigma_hat | Numeric | As defined by Asness et al. (2012) |
| Bond_inverse_sigma_hat | Numeric | As defined by Asness et al. (2012) |
| Unlevered_k | Numeric | As defined by Asness et al. (2012) |
| Excess_Unlevered_RP_Ret | Numeric | Unlevered RP portfolio return above riskless rate |
| Levered_k | Numeric | To match $\hat{\sigma}$ of Excess_Vw_Ret |
| Excess_Levered_RP_Ret | Numeric | RP portfolio return above riskless rate |

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

[3] "Leverage Aversion and Risk Parity" by Clifford S. Asness, Andrea Frazzini, and Lasse H. Pedersen (2012, Financial Analysts Journal, Volumne 68, Number 1).

**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 1930 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 a nonzero difference?

- Function name: **PS2_Q4**
  - Input
    - data.table **Port_Rets**, the output of **PS2_Q3**
  - Output
    - $6 \times 6$ numeric matrix, 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.