Assignment 2: Pricing Climate Risks

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General information

Submission. Submit your results and answers to the assignment's questions in a report PDF. Additionally, you will have to submit the code you used to generate these results. For the data analysis, please use Python. Do not submit a zip file. Instead, upload the PDF and the Python file separately. Do not upload any data files. Name all files: *Assignment2_Group#*, adding the respective file ending.

Grading. The assignment will be worth 10% of your final grade. The assignment will be graded based on three components:

- *Functioning of the code.* The sole requirement is that the code runs without errors on our machines and produces the results in your report. Include all necessary libraries/modules, give instructions on packages to install if necessary, and indicate path variables that must be changed when running the code on another machine. The Python file in the assignment folder already provides code for the path variables.
- *Quality of the analysis.* We will evaluate the quality of the analysis based on the correctness and clarity of the results, e.g., whether the figures and regression coefficients are correct and the appropriateness of the methods used.
- *Clarity of the presentation.* We will evaluate the clarity of the presentation of the results. Describe your results clearly and exhaustively, consistent with potential visualizations and calculations. Comprehensively label all figures and tables. To answer the questions, do not use bullet points. Think as if you were writing a report for a client or a research paper.

Assignment

Objective. This assignment aims to familiarize you with the model of Pastor et al. (2021) and test some of the model's predictions in the data.

Data. All data for this assignment is provided on the course's website. The file contains stock returns from 2010 to 2019 combined with the climate risk measure from Li et al. (2024) and risk factors from Ken French's website.

1 Pastor et al. (2021) [60 Points]

The solution to this question can be a scan of your handwritten solution as long as it is legible.

Consider the environment of Pastor et al. (2021) with four assets: a risk-free asset with return r_f, and risky assets $\tilde{r}_1$, $\tilde{r}_2$, and $\tilde{r}_3$ with excess returns,

$$\tilde{r}_n = \mu_n + \tilde{\varepsilon}_n, \quad n = 1, 2, 3, \tag{1}$$

where μ_n is the expected excess return of asset n and $\tilde{\varepsilon}_n$ is asset n's idiosyncratic risk. The idiosyncratic shocks are independently and normally distributed with mean zero and variance σ_n^2. Asset 1 is a clean asset with $g_1 > 0$, asset 2 is a neutral asset $g_2 = 0$, and asset 3 is a dirty asset with $g_3 < 0$. The risk-free asset is in zero net supply.

A continuum of investors with exponential utility functions populates this environment. The investor chooses the fractions of wealth invested $x_{i,n}$ to maximize utility. The investors' utility function is given by

$$V(\tilde{W}_{i,1}, x_{i,1}, x_{i,2}, x_{i,3}) = -e^{-A\tilde{W}_{i,1} - d_i(g_1 x_{i,1} + g_2 x_{i,2} + g_3 x_{i,3})}, \tag{2}$$

Each investor is endowed with the same wealth $W_{i,0} := \bar{W}_0$ and has the same absolute risk aversion $A_i := A$. For notational brevity, denote $a := A\bar{W}_0$. Investors are heterogeneous in their preferences for sustainability $d_i \geq 0$.

(a) State the investor's period-1 wealth $\tilde{W}_{i,1}$ and explain its components. [10 Points]

(b) State the general optimization problem. Plug in the period-1 wealth and derive the simplified optimization problem. (*Hint: If X is a random variable with $X \sim N(0, \sigma^2)$, then for any $a \in \mathbb{R}$, e^{aX} is log-normally distributed with $E[e^{aX}] = e^{a^2\sigma^2/2}$.*) [15 Points]

(c) Derive the FOCs of the investor's optimization problem for $x_{i,1}$, $x_{i,2}$, and $x_{i,3}$ and solve for the optimal investment $x_{i,n}$ in each asset. [15 Points]

(d) How does investor i's wealth allocation to asset 2, $x_{i,2}$, change in (1) asset 2's expected returns μ_2, and (2) her preferences for sustainability d_i? Justify your answer. [10 Points]

In equilibrium, asset prices are given by,

$$\mu_n = \mu_m \beta_{m,n} - \frac{\bar{d}}{a} g_n, \quad n = 1, 2, 3, \tag{3}$$

with $\bar{d}$ being the average ESG taste in the economy, μ_m the expected excess return of the market portfolio and β_m the beta of asset n with respect to the market portfolio.

(e) Calculate and compare the CAPM alpha of the three assets. Assuming markets, on average, care about sustainability, rank the assets from highest to lowest CAPM alpha. Explain the results. [10 Points]

2 The ESG Premium [30 Points]

The file "assignment_data.xlsx" contains (among other) the following variables:

- *ISIN*: The International Securities Identification Number of the stock.
- *Date*: The quarter of the stock return expressed as the last date of a quarter.
- *Price Close*: The stock's closing price at the end of a quarter.
- *std_risk*: The each quarter cross-sectionally standardized transition risk exposure measure from Li et al. (2024).
- *RF*: The risk-free rate in the quarter.

(a) For each quarter, form risk-sorted portfolios based on the climate risk exposure measure *std_risk*. Plot the cumulative portfolio returns for the top quintile and bottom quintile portfolios over time. Are the results in line with the predictions of the model of Pastor et al. (2021)? Justify your answer (max. 5 sentences). [10 Points]

(b) Plot the cumulative returns of a Green-Minus-Brown (GMB) portfolio over time. Add to the plot the cumulated sum of innovations in the WSJ index from Engle et al. (2020). How could the GMB portfolio be affected by the WSJ index innovations? (*Hint:* Take the average of the WSJ index innovations within a quarter before cumulating them.) [10 Points]

(c) Can we expect green stocks to outperform brown stocks in the future? Justify your answer (max. 5 sentences). (No calculations or figures are needed.) [10 Points]

3 References

Engle, R. F., Giglio, S., Kelly, B., Lee, H., and Stroebel, J. (2020). Hedging Climate Change News. *Review of Financial Studies*, 33(3):1184–1216.

Li, Q., Shan, H., Tang, Y., and Yao, V. (2024). Corporate Climate Risk: Measurements and Responses. *Review of Financial Studies*, 37(6):1778–1830.

Pastor, L., Stambaugh, R. F., and Taylor, L. A. (2021). Sustainable investing in equilibrium. *Journal of Financial Economics*, 142(2):550–571.