Climate Risk Hedging

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Introduction

Chapter 1

Climate Risk

Hedge target.

1.1 Climate Risks and Asset Prices

A first step is to identify the factors of climate risks. Why climate risks could have an impact on asset prices?

To get an intuition, we can start from the definition of returns in a one period (*ie.* asset lasts only one period):

$$R_{t+1} = \frac{D_{t+1}}{P_t} \tag{1.1}$$

with R_{t+1} the return of the asset from time t to time $t+1$, D_{t+1} the dividend paid at time $t+1$ and P_t the price of the asset at time t. There is no P_{t+1} in the equation, as we are in a one period model and the stock doesn't exist anymore at time $t+1$. Take the expectations:

$$E_t(R_{t+1}) = \frac{E_t(D_{t+1})}{P_t} \tag{1.2}$$

And solve for P_t:

$$P_t = \frac{E_t(D_{t+1})}{E_t(R_{t+1})} \tag{1.3}$$

These formula represents the price of the asset at time t as the discounted value of future dividends. Dividends are used as a proxy for future cash flows. The idea is:

- Asset prices are determined by expectations of future cash flows or discount rate.
- Climate risks may affect expectations of future cash flows or discount rate.
- Therefore, climate risks may have an impact on asset prices.

1.2 Changes in Expectations about Climate Risks

Now what drives the changes in asset prices? The changes in expectations about future cash flows or discount rate. So, we are not so much interested in the level of expectations of climate risks, but in the changes in beliefs about climate risks.

Investors form expectations about climate risks in an horizon h with information available (those are conditional expectations). Each period, new information arrives and investors update their beliefs about climate risks:

$$\Delta E_t(CC_{t+h}) = E_t(CC_{t+h}) - E_{t-1}(CC_{t+h}) \tag{1.4}$$

with $\Delta E_t(CC_{t+h})$ the *innovation* or *news* in climate risk. On the other hand, we have the *unexpected* returns $\tilde{R}_t$:

$$\tilde{R}_t = R_t - E_{t-1}(R_t) \tag{1.5}$$

with R_t the *realized* returns and $E_{t-1}(R_t)$ the expected returns based on information available at time $t-1$. Because investors reprice assets based on the arrival of new information, we can expect that the innovation in climate risk is reflected in the unexpected returns:

$$\tilde{R}_t = \beta \Delta E_t(CC_{t+h}) + \varepsilon_t \tag{1.6}$$

with β non-null as long as we expect that changes in climate risks affect investors expectations about future cash flows or discount rate.

1.3 Measuring Climate Risks

For non-tradable factors such as macro factors, creating a time series that capture expectations of these factors is not so difficult. You may use data from the central bank, the government, *etc.* They publish leading indicators, surveys, *etc.* The task is more challenging for climate risks.

A common approach in the literature (see Engle et al. (2020) [**?**]) is to use newspapers coverage of climate events as a proxy for the average investor's beliefs about climate risks. As they noted, when there are events that plausibly contains information about changes in climate risk, this will likely leads to newspaper coverage of these events. Newspapers may even be the direct source that investors use to update their beliefs about climate risk.

1.4 Conclusion

In what follow we propose a method to construct hedge portfolios with tradable assets that mimic the behavior of climate risks.

Chapter 2

Climate Risk Hedging Porfolios

2.1 Mimicking Approach

Ross (1976) [?] introduced the concept of *arbitrage pricing theory* (APT). In this model, the expected return of an asset is a linear function of a set of risk factors. Famous examples of risk factors are the *Fama-French factors* (see Fama and French (1993) [?]). Those factors are the excess return of the market, the excess return of small cap stocks over big cap stocks and the excess return of high book-to-market stocks over low book-to-market stocks:

$$E(R_i) = \beta_m R_m + \beta_{smb} R_{smb} + \beta_{hml} R_{hml} \tag{2.1}$$

with $E(R_i)$ the expected return of asset i, R_m the excess return of the market, R_{smb} the excess return of small cap stocks over big cap stocks, R_{hml} the excess return of high book-to-market stocks over low book-to-market stocks, β_m the market beta of asset i, β_{smb} the size beta of asset i and β_{hml} the value beta of asset i. Those factors are tradable, as they are directly traded in financial markets (you can buy the market, small cap stocks and high book-to-market stocks and short sell the opposite side of the trade).

Macroeconomic factors are examples of *non-tradable factors* (think about inflation, industrial growth, *etc*). Economic conditions have pervasive effects on asset returns (see Flannery and Protopapadakis (2002) [?]). A standard way to tackle the problem of non-tradable factors is to use factor mimicking portfolios (FMPs), such as in Jurczenko and Teiletche (2022) [?]. That is, to construct a portfolio of tradable assets that mimics the behavior of non-tradable factors.

Climate risks are non-tradable factors, as they are not directly traded in financial markets (see Jurczenko and Teiletche (2023) [?]). We can use the same approach of FMPs to construct a portfolio of tradable assets that mimics the behavior of climate risks.

$$\Delta E_t(CC_{t+h}) = w^T \tilde{R}_t + \varepsilon_t \tag{2.2}$$

FIGURE 2 IN JURCENZKO MACRO FACTORS WITH THIS METHOD ML macro FMPs vs underlying macro factors

2.2 Narrative Approach

FIGURE 2 IN JURCENZKO MACRO FACTORS WITH THIS METHOD ML macro FMPs vs underlying macro factors

2.3 Risk Premia

Problem with short time series to infer risk premia

2.4 Conclusion

Chapter 3

Hedging Climate Risk for a Fund

An investor might be seeking to hedge the climate risks to improve the risk-return profile of a portfolio.

3.1 Hedging a Fund with Climate Risk Hedging Portfolio

A practical way to would be to determine a combination of an existing portfolio p with, climate FMPs that minimizes the variance of the combined portfolio returns.

More precisely, let's assume that the investors determines a vector "tilt" ω that represents the weights of the FMPs in the combined portfolio.

The vector ω would be determined by:

$$\min_{\omega} \quad T^{-1} \sum_{t=1}^{T} (R_t^p - \omega^T H_t)^2 \tag{3.1}$$

3.2 Backtesting a Climate Risk Hedging Strategy

Figure 3 – Macro Risk Contributions

Figure 4 – Endowment portfolio and its macro-hedged version: Quarterly returns and Maximum Drawdowns