Climate Risk Hedging

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June 6, 2024

Contents

Introduction

Chapter 1

Climate Risks

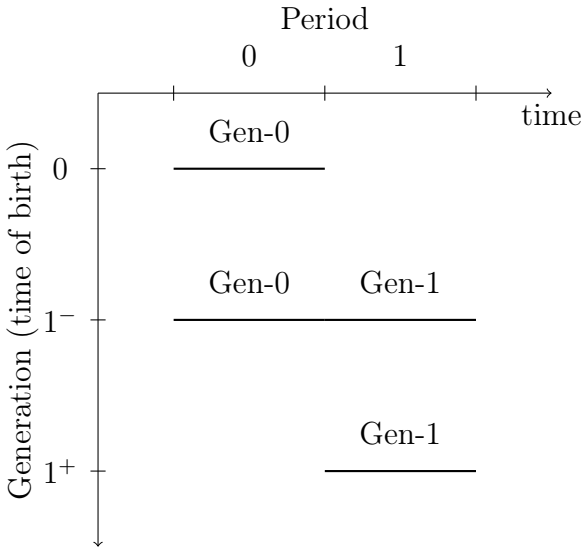

Figure 1.1: The One-Period Overlapping Generation Model

X the payoff (profit) by the firm in period 1. It is known at 1^- (the beginning of period 1) but received at 1^+ (the end of period 1). We denote $\tilde{X}$ this payoff per dollar invested in period 0: $\tilde{X} = \frac{X}{P_0}$.

Assume we have two sources of risk (uncertainty), $\tilde{M}$ a macroeconomic factor and $\tilde{CC}$ a climate risk factor. These shocks occurs at 1^-. The unexpected payoff in period 1 is:

$$\tilde{X} - E_0(\tilde{X}) = \beta_m \tilde{M} + \beta_{cc} \tilde{CC} + \varepsilon_1 \tag{1.1}$$

The payoff is known at 1^-, so we can comput the price of the stock:

$$\tilde{P_1} = \beta^{-1} \tilde{X} \tag{1.2}$$

This is the payoff for $Gen - 0$ at 1^-.
It's expected value when $Gen - 0$ invested in period 0 was:

$$E_0(\tilde{P_1}) = \beta^{-1} E_0(\tilde{X}) \tag{1.3}$$

$$\begin{aligned} \tilde{P_1} &= \frac{P_1}{P_0} \\ &= R_1 \end{aligned} \tag{1.4}$$

$$\begin{aligned} E_0(\tilde{P_1}) &= \frac{E_0(P_1)}{P_0} \\ &= E_0(R_1) \end{aligned} \tag{1.5}$$

So the unexpected change in price for the $Gen - 0$ $\tilde{P_1} - E_0(\tilde{P_1})$ is in fact the unexpected return $R_1 - E_0(R_1)$:

$$\begin{aligned} \tilde{P_1} - E_0(\tilde{P_1}) &= R_1 - E_0(R_1) \\ &= \beta^{-1}(\tilde{X} - E_0(\tilde{X})) \\ &= \beta^{-1}(\beta_m \tilde{M} + \beta_{cc} \tilde{CC} + \varepsilon_1) \end{aligned} \tag{1.6}$$

Chapter 2

Climate Risks Exposure

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

Green Factor from Pastor

2.3 Scenario-Based Approach

Chapter 3

Climate Risks Hedging

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

3.1 Climate Risk Portfolios

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

3.1.1 Climate Risk Premia

3.2 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:

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

3.3 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