Rhoda Dadzie-Dennis
rdadzied@uwaterloo.ca

Dept. Statistics and Actuarial Science
University of Waterloo

Portfolio Optimization under Climate Change

Joint work with Professor Mary Hardy & Professor Ben Feng

AFRIC 2023

Question

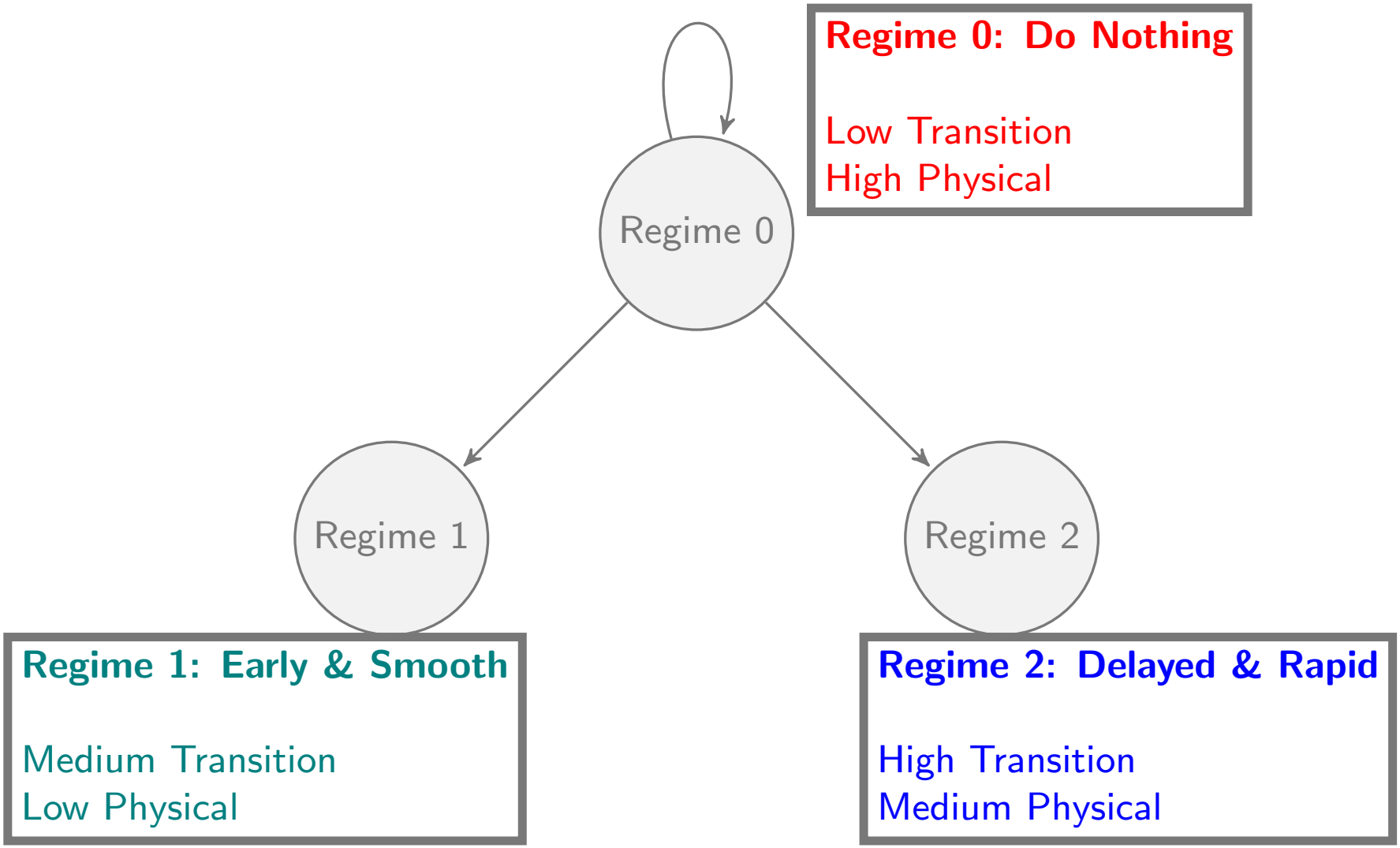
Explore long-term and short-term returns of pension plan[1] portfolios while adapting to a low-carbon economy.

[1] Fund and Portfolio managers

Climate Risks

1. Transition Risks
   - Increasing operational costs
   - Government taxes
   - Consumer preference and demand
2. Physical Risks
   - Extreme events
   - Floods
   - Wildfires
   - Climate migration

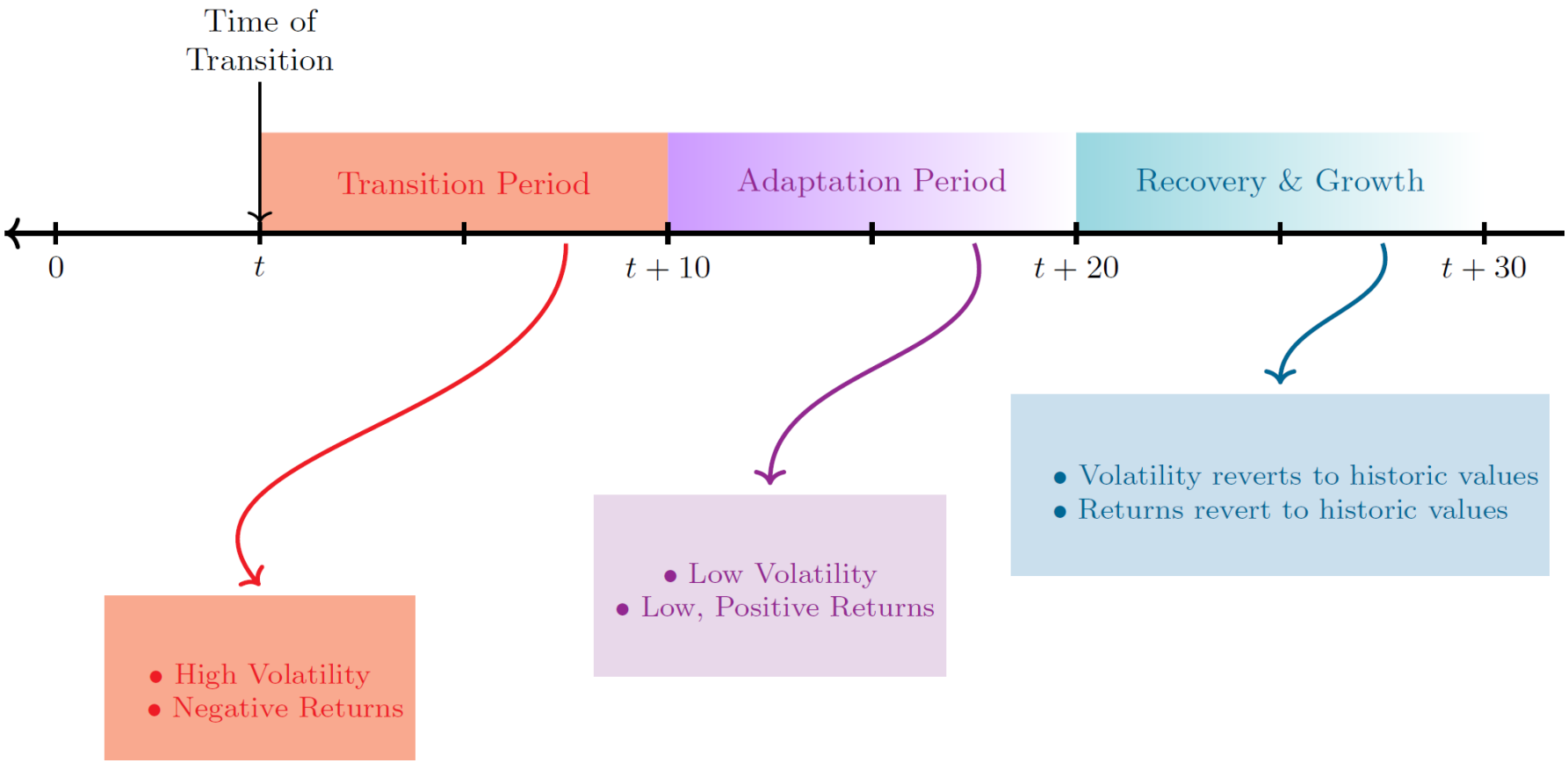
Climate Scenario Assumptions



Climate Model

- **Conditional Multivariate Normal Model**
  - Simulated quarterly returns
  - Allow for impacts of physical and transition risks, depending on
    - Sector of the economy
    - Regime
    - Time since the transition

Climate Risk Phase



Exogenous vs Endogenous Processes

Exogenous Process: Economic Scenarios

1. No Transition
2. Early Transition
   - Transition to Regime 1 at $t = 2$
3. Mid Transition
   - Transition to Regime 2 at $t = 5$

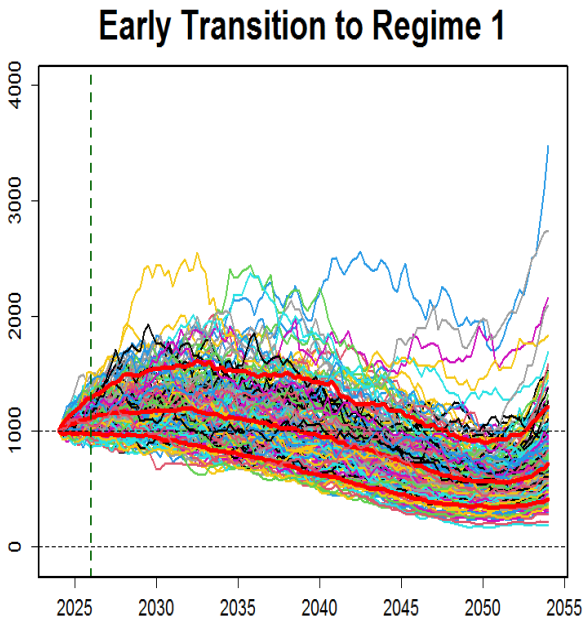
Endogenous Process: Decarbonization Strategy

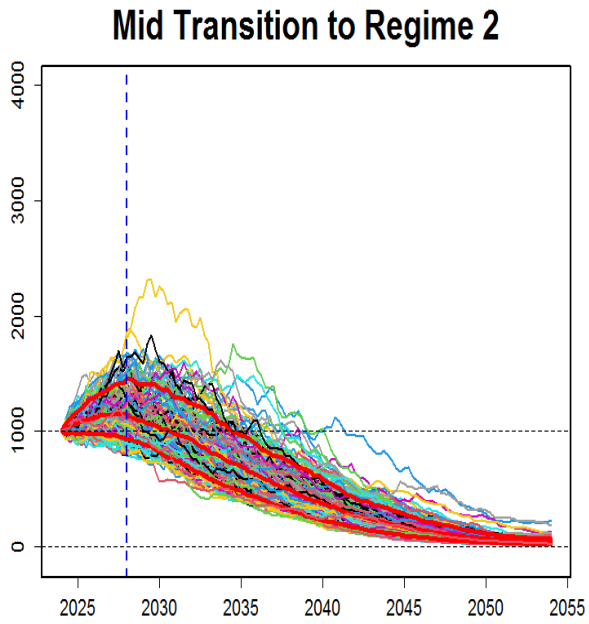
1. No Decarbonization
2. Slow Decarbonization
   - 10-year decarbonization pathway: untargeted
3. Quick Decarbonization
   - 5-year decarbonization pathway: untargeted

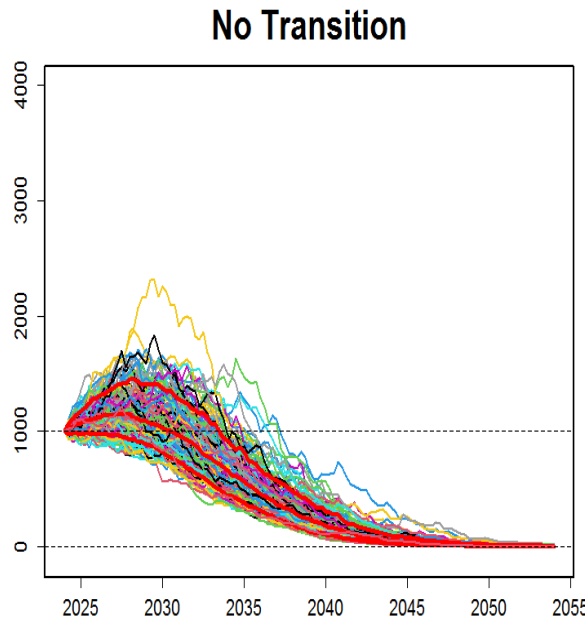
Portfolio Assumptions

1. **Assets:**
   - Consider 12 sector funds
   - 3 carbon-intensive sectors
2. **Base Strategy; no decarbonization**
   - Long-Term $\frac{1}{12}$ Investor $(T = 30)$
   - Yearly Rebalancing
3. **Decarbonization**
   - Shift over time from $\frac{1}{12}$ to $\frac{1}{9}$

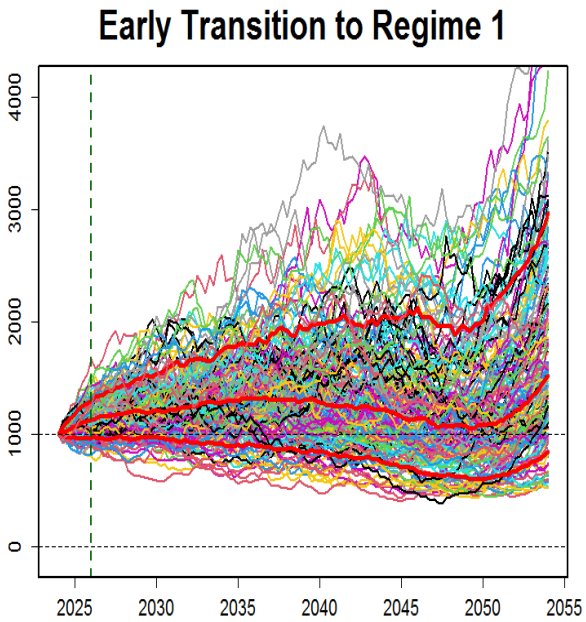
Wealth Process: No Decarbonization

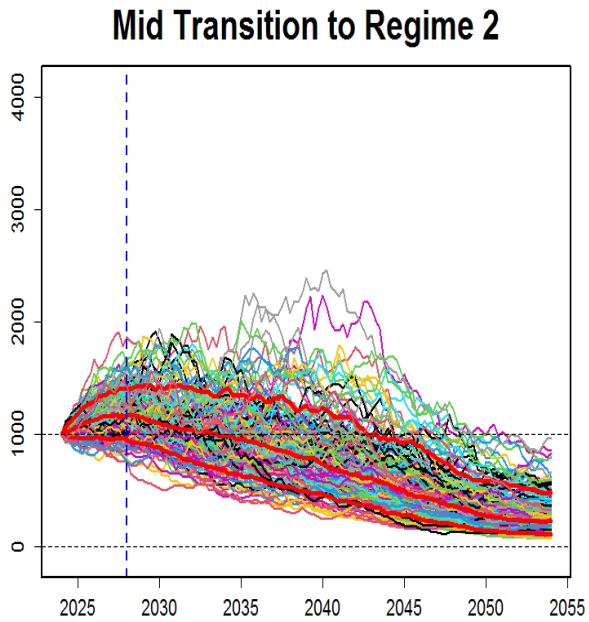


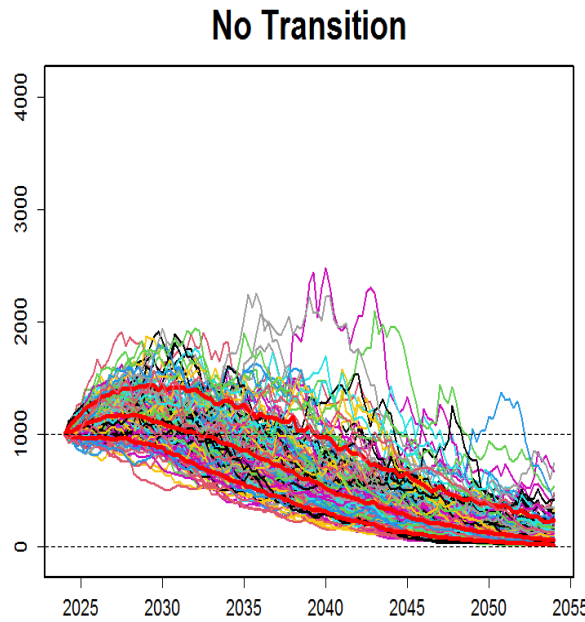




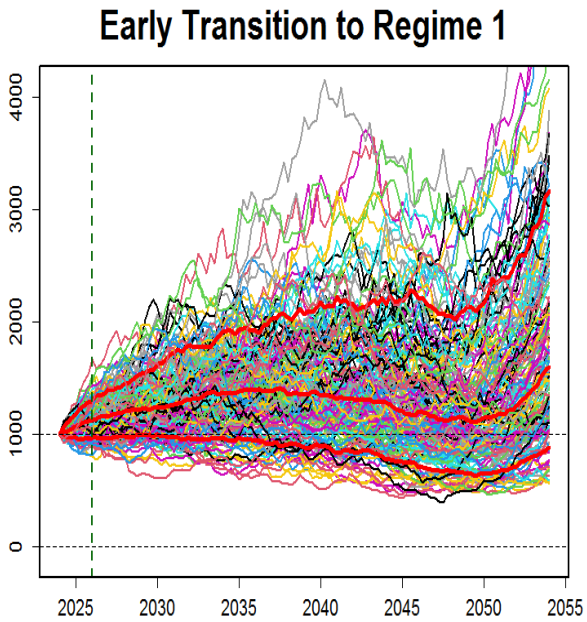
Wealth Process: Slow Decarbonization

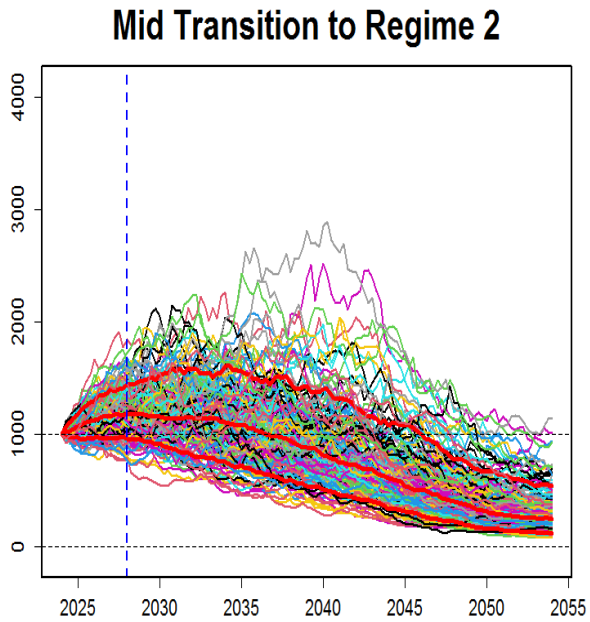


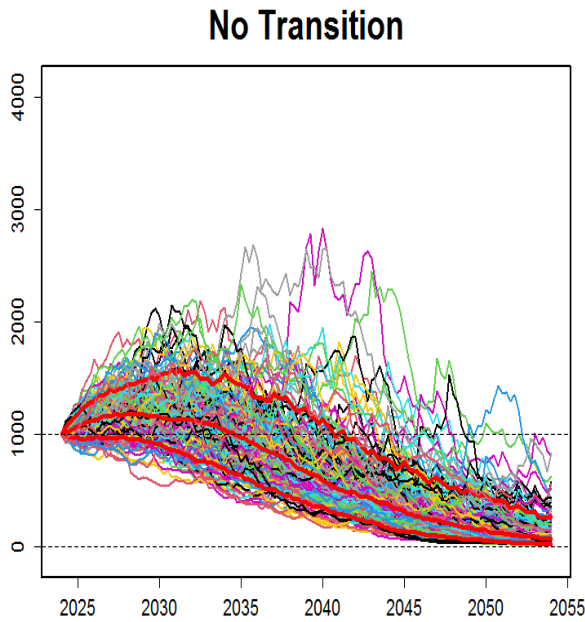




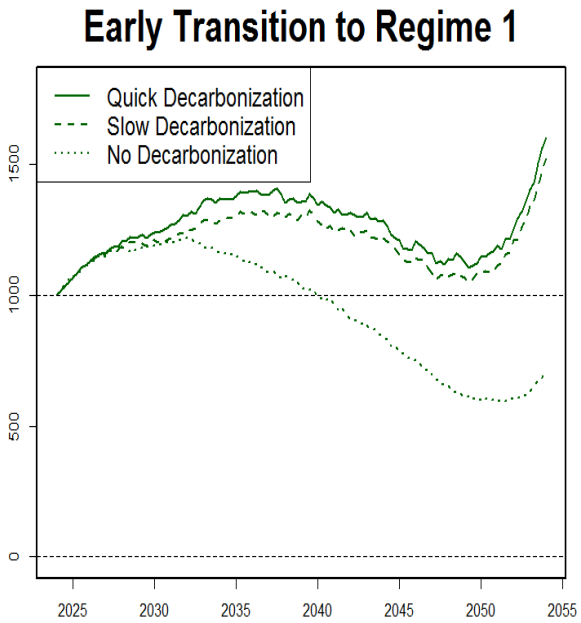
Wealth Process: Quick Decarbonization

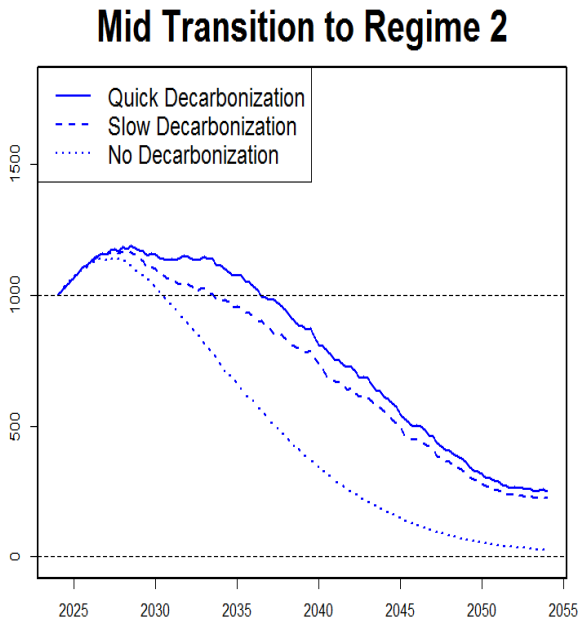


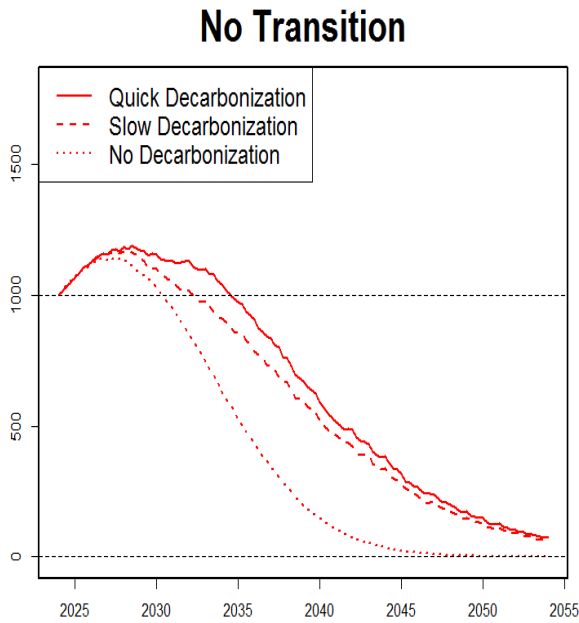




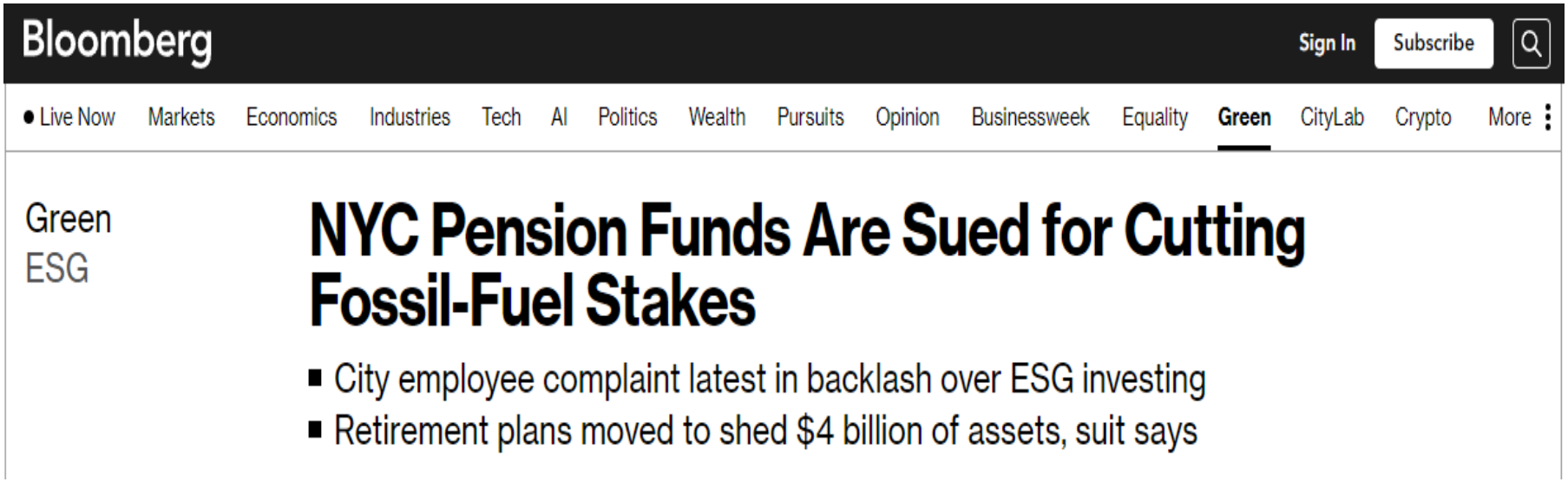
Comparison at Median







Plan Participant Backlash



Case against Decarbonization?

1. Short term views
   - Brown energy remains high performing
2. Climate change skepticism
   - Disagreement on timing
   - Disagreement on capital market impact

Quick Recap

Under this model and given the assumptions:

1. Early transition to a low carbon economy is beneficial
2. A quick decarbonization performs better (marginally) than a slow decarbonization under all deterministic climate transitions.
   - Explore targeted decarbonization
3. Decarbonizing alone cannot eliminate climate risks from a plans' portfolio.

References

1. Scott Kelly, Zhiyi Yeo, Andrew Coburn, Jennifer Copic, Doug Crawford-Brown, Aideen Foley, Eugene Neduv, Danny Ralph, and Farzad Saidi. Unhedgeable Risk: How Climate Change Sentiments Impacts Investors. *University of Cambridge*, 2015.

2. Kevin Doran and Elias Quinn. Climate change risk disclosure: A sector by sector analysis of sec 10-k filings from 1995-2008. *North Carolina Journal of International Law and Commercial Regulation*, 34, 03 2009.

3. Iqbal Owadally, Jean-Rene Mwizere, Neema Kalidas, Kalyanie Murugesu, and Muhammad Kashif. Long-term sustainable investment for retirement. *Sustainability*, 13(9), 2021.

4. Davide Benedetti, Enrico Biffis, Fotis Chatzimichalakis, Luciano Lilloy Fedele, and Ian Simm. Climate change investment risk: Optimal portfolio construction ahead of the transition to a lower-carbon economy. *Annals of Operations Research*, 299(1):847–871, 2021.

Climate Model

Annual Expected return & volatility under sector s, at time t

$$\mu_{t,s} = \mathbb{E}[R_{t,s}|\mathscr{F}_t] = \overline{r}_{t,s} + {}^{T}\omega_{\rho_t} \times {}^{T}I_s \times f(\tau) + {}^{P}\omega_{\rho_t} \times {}^{P}I_s \tag{1}$$

$$\sigma_{t,s} = \sqrt{Var[R_{t,s}|\mathscr{F}_t]} = \sqrt{\overline{v}_{t,s} + \left({}^{T}\omega_{\rho_t} \times {}^{T}I_s \times f(\tau)\right)^2 + \left({}^{P}\omega_{\rho_t} \times {}^{P}I_s\right)^2} \tag{2}$$

Climate Transition Risk Cycle

$$f(\tau) = \begin{cases} \alpha & \text{if } \tau = 0 \\ (1-\alpha) \times \left(1 - \frac{\tau}{10}\right) & \text{if } 0 < \tau \leq 10 \\ \beta \times \left(\frac{\tau - 20}{10}\right) & \text{if } \tau \geq 20 \quad \& \quad {}^{T}I_S < 0 \\ 0 & \text{if } \tau \geq 20 \quad \& \quad {}^{T}I_S \geq 0 \\ 1 & \text{otherwise} \end{cases} \tag{3}$$

Rhoda Dennis (rdadzied@uwaterloo.ca) University of Waterloo, Actuarial Science

Plan Portfolio Assumptions

1. **Investment Strategy:** Long-Term $\frac{1}{N}$ Investor $(T = 30)$
2. **Asset Structure:**
   - Consider 12 sector funds
   - **Wealth Process:**

$$\boldsymbol{P_{t+1}} = \boldsymbol{P_t} \exp\left(\hat{\boldsymbol{\mu}}_{\boldsymbol{t}} \Delta t + \left(\boldsymbol{\Sigma_{t,ij}}\right)^{\frac{1}{2}} \sqrt{\Delta t} \boldsymbol{Z_t}\right) \tag{4}$$

where $Z_t \sim N(0,1)$ and $\Sigma_{t,ij} = \hat{\sigma}_{t,ij}$