Online probabilistic estimation of carbon beta and carbon Shapley values for financial and climate risk

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Online Probabilistic Estimation of Carbon Beta and Carbon Shapley Values

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Beta, Carbon beta, Carbon Shapley value

Beta : $R_i(t) = \alpha_i + \beta_{mkt,i} R_{mkt}(t) + \epsilon_i(t)$ (1)

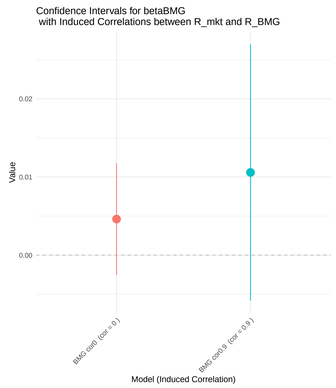
- $R_i(t)$ = Return of individual stock i at time $t > 0$
- $R_{mkt}(t)$ = Return of the global stock market (e.g CAC40, DAX, ...) at time t
- α_i = Expected return of individual stock i when market return $== 0$
- $\epsilon_i(t)$ is the model's error term for stock i at time t
- $\beta_{mkt,i}$ = **beta for stock** i

Carbon Beta : $R_i(t) = \alpha_i + \beta_{mkt,i} R_{mkt}(t) + \beta_{BMG,i} R_{BMG}(t) + \epsilon_i(t)$ (2)

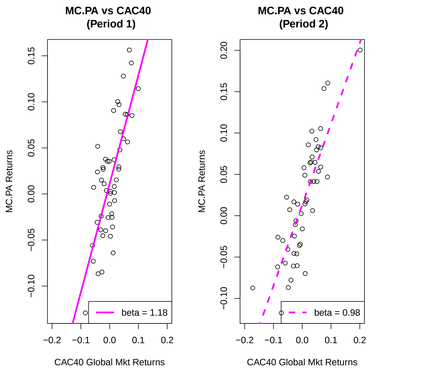
- $R_{BMG}(t)$ = return of Brown Minus Green (BMG) portfolio (long Brown, short Green)
- Brown = Less *Climate Friendly* stocks
- Green = More *Climate Friendly* stocks
- $\beta_{BMG,i}$ = **Carbon beta for stock** i
- high $\beta_{BMG,i} \rightarrow$ **greener economy will make stock value decrease**

Remarks

- Assumption: linear relationships between returns
- "Extreme" case; Multicollinearity: potential high variance for $\beta_{mkt,i}$ and $\beta_{BMG,i}$ estimation



- $\beta_{mkt,i}$ and $\beta_{BMG,i}$: not constant and random

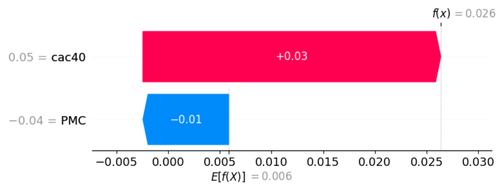


- **Paper:** Uses a prospective Machine Learning-based (ML) estimation with numerical derivatives = β sensitivities.
- **Paper:** Compares **Random Forest** model, Rolling **Linear** model, **Random Vector Functional Link (RVFL)** networks model.
- **Paper:** **Random Vector Functional Link (RVFL)** networks model = (non)linear and regularized + **Online learning (update model as observations arrive)**
- **Paper:** **Carbon** β = **numerical derivative of ML model prediction** $\hat{R}_i(t)$ relative to $R_{BMG}(t)$ changes
- **Paper:** In addition to **Carbon** β, uses **Carbon Shapley values** in ML
- **Paper:** Shapley values for BMG factor = how much $\hat{R}_i(t)$ changes when $R_{BMG}(t)$ joins different coalitions (subsets of other factors)
- **Paper:** *Cool* thing about Shapley values: **additivity no matter the ML estimation model**, i.e

$$\hat{R}_i(t) = \hat{R}_i + Shapleyvalue_{\text{mkt}} + Shapleyvalue_{BMG}$$

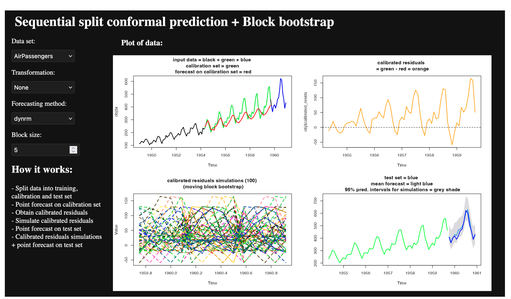
In layman terms:

Predicted return stock i = Average historical return for stock i on a given period + Market contribution to return for stock i + BMG portfolio contribution to return for stock i



In this specific example: **transitioning to a lower carbon economy would have a positive effect on average stock return.**

- Uncertainty around **Carbon** β quantified via **sequential split conformal prediction**.



Results

Figure: Between-models Carbon Shapley values aggregated over time

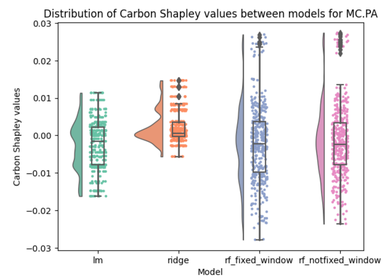


Figure: Carbon Beta and Carbon Shapley values over time - 10 days ahead (RVFL)

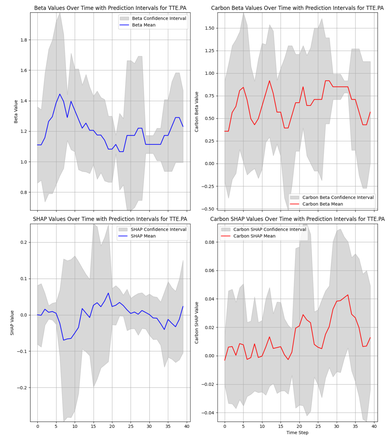
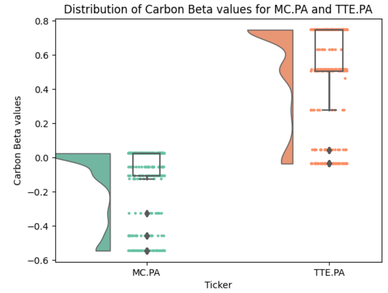


Figure: Comparison of Carbon Beta values aggregated over time for 2 stocks (RVFL)



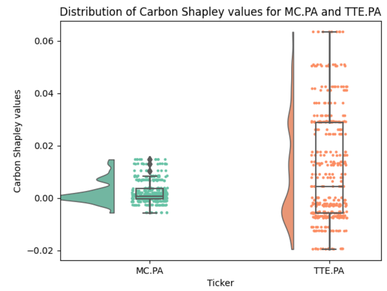


Figure: Comparison of Carbon Shapley values aggregated over time for 2 stocks (RVFL)

Conclusion

- Novel estimation approach for Carbon Beta and introducing Carbon Shapley values.
- More extensive experiments on more stocks would be useful.
- Would be great to have updated versions of BMG portfolio.

References

- Paper described here: https://www.researchgate.net/publication/387577137_Online_probabilistic_estimation_of_carbon_beta_and_carbon_Shapley_values_for_financial_and_climate_risk
- Görgen et al. (2020) - Carbon Risk.
- Roncalli et al. (2020) - Time-varying Carbon Beta estimation.
- Lundberg & Lee (2017) - Shapley values in machine learning.