A Note on ESG Factor Models*

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1. Introduction

Global efforts to achieve net-zero carbon emissions by 2050 and mitigate climate change are intensively driven by capital market functions, including ESG investing. In this context, we have previously developed an ESG Asset Pricing Model (Ishijima and Maeda 2008), which extends conventional asset pricing models (Cochrane 2005). In our model, the asset price is the sum of the present value of future cash flows and ESG dividends. ESG dividends are a bundle of benefits related to environmental, social, and governance factors, such as reducing carbon emissions. Because ESG dividends are non-financial, they are converted to monetary value using the extended stochastic discount factor. Our model represents a concept called the double bottom line (DBL) for ESG investing. While the ESG Asset Pricing Model is theoretically compelling, it is difficult to conduct empirical studies to demonstrate the DBL in the market. To this end, this paper develops an ESG Factor Model that is theoretically equivalent to the ESG Asset Pricing Model. Since the ESG Factor Model is represented in a linear regression form, empirical studies to demonstrate DBL can be easily implemented. In the literature, much empirical work - including Bolton and Kacperczyk (2021, 2023) - has been devoted to finding DBL in the market. In this regard, this study serves as a foundation for empirical research to show whether or not ESG investing allows us to achieve DBL. As a typical application, Bolton and Kacperczyk (2021, 2023) used a version of the ESG Factor Model to show carbon risk premiums in the stock market.

The remainder of this paper is organized as follows: In Section 2, we develop an ESG Factor Model based on the ESG Asset Pricing Model. We also discuss its features and applications. Section 3 concludes.

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2. ESG Factor Models

Ishijima and Maeda (2018) developed an asset pricing model for ESG investing, which is briefly reviewed below. They assume an economy in which N assets are traded in discrete time $t = 0,1,\cdots$ and consider a representative agent investing in asset i $(= 1,\cdots,N)$. At each point in discrete time t, asset i is traded at price $P_{i,t}$. The agent invests in a portfolio consisting of N assets. The agent has an initial endowment at any point in discrete time t. She then earns income Y_t and consumes non-durable goods C_t. She invests in a portfolio $\boldsymbol{\theta}_t$ consisting of N assets by imposing self-financing. At time $t+1$, she receives dividends $D_{i,t+1}$ and closes her investment position by selling the portfolio at price $P_{i,t+1}$. By investing in a unit amount of asset i at time t, the agent can consume $\boldsymbol{b}_{i,t+1} = \left(b_{ik,t+1}\right)_{k=1,\cdots,K}$ amount of ESG attribute k $(= 1,\cdots,K)$ at time $t+1$. The representative agent will receive the expected utility from the consumption of non-durable goods, C_t, as well as that of the ESG attribute, $\boldsymbol{b}_{i,t}$, along a discrete-time horizon from the present to the future. She maximizes her expected utility, subject to the consumption dynamics of non-durable goods and those of ESG attributes. In conjunction with market clearings at any point in discrete time t $(= 0,1,\cdots)$, the first-order necessary condition (FOC) gives an equilibrium asset price of EGS investing as Theorem 1.

Theorem 1 (ESG Asset Pricing Model. Ishijima and Maeda 2018)

At any discrete time, an equilibrium asset price of ESG investing is endogenously given in perfect competition.

$$P_{i,t} = E_t\left[\left(D_{i,t+1} + P_{i,t+1}\right) \cdot M^C_{t:t+1}\right] + E_t\left[\delta \cdot \boldsymbol{b}_{i,t+1} \cdot \boldsymbol{M}^Z_{t:t+1}\right] \tag{1}$$

where we define the intertemporal marginal rate of substitution (IMRS) by $M^C_{t:t+1} \coloneqq \delta \cdot \left(\frac{\partial u(C_{t+1},\boldsymbol{Z}_{t+1})}{\partial C_{t+1}} / \frac{\partial u(C_t,\boldsymbol{Z}_t)}{\partial C_t}\right)$. *In addition, we define the intertemporal marginal rate of substitution between the consumption of ESG attributes and non-durable goods, which we will call "ESG-IMRS,"* $\boldsymbol{M}^Z_{t:t+1} \coloneqq \frac{\partial u(C_{t+1},\boldsymbol{Z}_{t+1})}{\partial \boldsymbol{Z}_{t+1}} / \frac{\partial u(C_t,\boldsymbol{Z}_t)}{\partial C_t}$. □

The ESG Asset Pricing Model is theoretically compelling. However, it is not adequate for use in empirical analyses to show DBL in the market. To this end, this paper develops an ESG Factor Model that can be easily used for such empirical analyses and is theoretically equivalent to the ESG Asset Pricing Model.

Theorem 2 (ESG Factor Model)

Under certain technical assumptions, the ESG Asset Pricing Model is equivalent to the ESG Factor Model, where the risk premium of each asset is a linear combination of the risk premium of ESG factors, including carbon emissions. □

The ESG Factor Model has many favorable features for conducting empirical analyses to show DBL for ESG investing. Also, a typical application of the ESG Factor Model is the regression model used in Oshika et al. (2009), Saka and Oshika (2011), Bolton and Kacperczyk (2021, 2023), Ishijima et al. (2024a, 2024b) to estimate the carbon risk premium in the stock market as shown below.

$$R_{i,t} = \alpha_t \cdot CO2_{i,t} + \boldsymbol{c}_t'\boldsymbol{CTRL}_{i,t} + \tau \cdot \mathbf{1}_{\{TIME\ t\}} + \gamma \cdot \mathbf{1}_{\{SECTOR\ j\}} + \eta \cdot \mathbf{1}_{\{FIRM\ i\}} + \varepsilon_{i,t} \quad (2)$$

In the regression model, the dependent variable is the stock return observed in the market, $R_{i,t}$ $(i = 1, \cdots, n; t = 1, \cdots, T)$, and the independent variable of interest is, $CO2_{i,t}$, carbon emissions. The regression coefficient, α_t, represents the carbon risk premium - the percentage increase in the stock price if it emits a unit of carbon dioxide. In this regard, this study serves as a basis for empirical research to show whether or not ESG investing allows us to achieve DBL.

3. Conclusion

We have developed an ESG Factor Model equivalent to the ESG Asset Pricing model, which allows us to perform sophisticated empirical analyses of ESG investing. In our future work, we plan to apply our model to show the double bottom line in both the financial and real estate markets.

References

Bolton, P. and Kacperczyk, M. (2021) "Do Investors Care about Carbon Risk?" *Journal of Financial Economics*, 142(2), 517–549.

Bolton, P. and Kacperczyk, M. (2023) "Global Pricing of Carbon-Transition Risk," *Journal of Finance*, 78(6), 3677–3754.

Cochrane, J.H. (2009) *Asset Pricing: Revised Edition*, Princeton University Press.

References in Japanese

Ishijima, H. and A. Maeda (2018) "An Asset Pricing Model Incorporating ESG Factors," 75th Annual

Conference, Japan Economic Policy Association, Doshisha University, 2018-05-27.

Ishijima, H., T. Ito, T. Manabe, and A. Maeda (2024a), “Carbon Emissions and Corporate Finance,” *JAREFE Journal* (Accepted in September 2024).

Ishijima, H., T. Ito, T. Manabe, and A. Maeda (2024b) “Negative Carbon Risk Premium,” *JAREFE Journal* (Accepted in September 2024).

Oshika, T., H. Obata, C. Saka, and Y. Hirose (2009) “Part 4: Corporate Valuation Model for Transforming Financial Reporting,” Final Report Research on Transformation of Financial Reporting, Japan Accounting Association, pp. 35-62.

Saka, C. and T. Oshika (2011) “Explanatory Power of CO2 Emissions on Stock Prices and the Impact of Information Disclosure,” Accounting Progress, 12, pp. 1-12.

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