Climate Risk Assignment

Due: December 8, 2022

Please work in groups of 3 to complete this assignment.

1 Climate Adjusted PD from Merton Model

In the Merton framework for default, the asset value (A), Equity (E) and Debt (D) of a firm satisfy the equations

$$E = A\Phi(d_+) - e^{-rT}D\Phi(d_-) \tag{1}$$

$$E\sigma_E = A\sigma_A\Phi(d_+) \tag{2}$$

where

$$d_\pm = \frac{\ln(A/D) + (r \pm \sigma_A^2/2)T}{\sigma_A\sqrt{T}}. \tag{3}$$

In the above, Φ is the CDF of the standard normal and σ_A and σ_E are the asset volatility and equity volatility, respectively. In Merton's framework the probability of default is given by $PD = \Phi(-d_-)$. In this assignment we will use public data from Exxon Mobil to assess the increased transition risk from net-zero aligned pathways. The carbon price climate scenario data are taken from the MESSAGEix-GLOBIOM 1.1 model.

For the purposes of this exercise fix the risk free rate to be $r = 0.05$ for simplicity and we will focus on 1-year PD ($T = 1$).

1.1 Estimate model parameters

In the first section you will estimate parameters needed for the Merton model using historical data.

1.1.1 Estimate equity volatility

Use the time-series data of the share price to estimate the equity volatility needed in the Merton formulation.

1.1.2 Estimate asset volatility

It is common to use the market capitalization as E and we will follow the KMV approach and take D to be the short term debt plus half the long term debt. The outstanding shares and debt information are provided in the excel sheet. Now you will estimate A and σ_A by using the Merton equations above. Combine the historical data with the equity vol estimates and numerically solve the Merton equations to obtain estimates of A and σ_A. You will need to use a root-finding algorithm like Newton's method to solve the system of equations.

With the model parameters estimated produce a time-series of the PD from 2012-2021.

1.2 Emissions Pricing

A recent estimate of Exxon's scope 1 and 2 emissions is given as 112 million tonnes of CO_2 per year and their scope 3 emissions are estimated to be at least 650 million tonnes of CO_2 per year.

1.2.1 Constant emissions

As a first approximation, hold the parameters in the Merton model fixed, except for the asset value. Further, assume that Exxon keeps their emissions profile fixed in the future. Use the carbon prices in the 3 climate scenarios and reduce the asset value of the company by the carbon price times the scope 1 and 2 emissions. Argue why this approach is reasonable for an oil company. What further data would you need to support your argument? With this new asset value, compute the PD at the forward looking time steps under the 3 climate scenarios using the Merton framework.

Repeat the PD calculation above, but also include the scope 3 emissions in the estimate of the future asset value. In what situations would it make economic sense to include scope 3 emissions in this calculation?

1.2.2 Emissions pathway

Exxon has a plan to reduce scope 1 and 2 emissions to zero by 2050. Assume that the emissions pathway of the scope 1 and 2 emissions is linear from today and reaches 0 by 2050.

Using the linear emissions pathway, compute the PD under the 3 climate scenarios using the Merton framework including only the scope 1 and 2 emissions in the future asset value.

Using the linear emissions pathway, compute the PD under the 3 climate scenarios using the Merton framework including all emissions in the future asset value (only assume the pathway applies to scope 1 and 2 emissions, hold scope 3 constant). What information would you need to make assumptions about how the scope 3 emissions are changing under the scenarios?