Project

The puzzle of Carbon Allowance spread.

Financial Engineering AY 2023-2024

Consider the provided dataset for the EU ETS phase III time-period (see e.g. [1]).

a. The folder "futures" contains the HIGH, LOW, OPEN, CLOSE prices and VOLUME of all EUA December futures. When NA is reported no futures traded that day.
b. The file "Volumes_extra_futures" contains the volume of EUA futures of the March, June and September maturity (consider NA volumes as zero).
c. The file "Open_Interest" contains open interest for December futures.
d. The file "Daily_Future" contains the daily future HIGH, LOW, OPEN, CLOSE prices and VOLUME.
e. The folder Bonds contains the bond dataset. The file "valid_bonds" contains the list of all bonds that should be considered in the analysis. For every bond you have the Instrument identifier (ISIN) together with Coupon Rate, Maturity Date, Original Amount Issued, Coupon Frequency (number of coupons paid per year) and parent company ticker. Consider a 30/360 daycount for all bonds coupons. Moreover, for every issuer, you will find in the folder a csv file that contains the time-series of the bond prices of all issues of a specific issuer (e.g. in the file ENI you will find all the bonds issued by ENI that you should consider in the analysis) identified by their ISIN code.
f. The file "Extra_variables" contains some financial control variables that will be used in the analysis.
g. The file "OIS_data" contains all Euro Overnight Indexed Swap (OIS) rates for every business day. For every day you have 1,2,3 weeks, 1 to 11 months, 1 year, 15, 18 and 21 months, 1 to 10 years. For the zero-rate, use flat extrapolation after.

Questions:

1. For every date in the dataset, bootstrap the risk-free interest rate from OIS rates following the methodology described in equations (2) and (3) of [2]. If you find any empty rate fill it up with the value from the previous available day.
2. Verify that the front December EUA future is the most liquid one in terms of volume. The front contract is the December future with the expiry closest to the value date (the same year) while the next contract is the one expiring December of the next year.
3. C-spread.
   a. For every year compute the C-spread defined in equation 2.1 of [1] for the front and the next December contract. As in [1], utilize the daily future as proxy of the spot prices for EUA.
   b. Construct a single time-series of C-spread. For every year, select the front contract C-spread until the 15th of November and the next contract C-spread after (Roll-over rule).
4. Z-index. Consider the same issuers listed in table 2 of [1]. Compute the Z-index following the methodology described in section 3.2 of [2].
5. The 3-months risk-free rate is the zero-rate associated to the three months OIS rate.
6. Plot the time-series of C-spread (C_t), Z-index (Z_t) and risk-free rate (r_t). Plot their correlograms (ACF and PACF) and compute their average and standard deviation in the period. Check if the three time-series are integrated of order 1 with an ADF-GLS test. Check that differences are not integrated.
7. Follow the Johansen procedure to establish whether the time-series are cointegrated. How many cointegration relationships exists? Write down the cointegration relationship.

8. Estimate the error correction model in eq. (4.2) of [1]. Estimate the instantaneous variance of the EU-ETS spot with a GARCH(1,1) on the daily future return time-series.
9. In the following, repeat the analysis of the previous points introducing one by one the robustness checks listed below:
   a. Consider an EWMA volatility estimate with parameter $\lambda = 0.95$ instead of the GARCH(1,1).
   b. Consider all available dates in phase III and phase IV (up until end of October 2022).
   c. Consider a different construction of the single time-series of C-spread. Change the roll-over rule in point 3.b (to switch from the front contract C-spread to the next contract C-spread):
      i) switch when the open interest of the next future is above the open interest of the front future for the first time;
      ii) switch exactly one month before the expiry of the front futures;
      iii) switch exactly one week before that expiry.

   Comment on the robustness of the econometric results.
10. Consider a quantile regression (QR) for the time-series of the error correction model in [1]. In particular, estimate the quantile regressions on models (I) and (VI). Present the results as is done in table 4 of [3] and comment.
11. Could a corporate involved in the scheme use a synthetic repo to finance itself? Explain why.

Hints:

1. Compute the C-spread only when the future time-series is available.
2. To compute the z-spread of a bond pay attention to the bond time-to-maturity and coupon frequency reported in the file valid_bonds.

Realize a library in Matlab. Optional Python.

[1] Azzone, Michele, Roberto Baviera, and Pietro Manzoni. "The Puzzle of Carbon Allowance Spread" *Available at SSRN 4731338* (2024).

[2] Baviera, Roberto, and Alessandro Cassaro. "A note on dual-curve construction: Mr. Crab's Bootstrap" *Applied Mathematical Finan*ce 22.2 (2015): 105-132.

[3] Palao, Fernando, and Ángel Pardo. "The inconvenience yield of carbon futures." *Energy Economics* 101 (2021): 105461.

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