Carbon Metrics and Climate VaR: Measuring Carbon, Pricing the Risk

Module 4 Companion 4 of 6 lessons

For complete beginners. After this companion you will be able to work out how much carbon a bank "finances," summarise a portfolio's carbon in one number, and explain what Climate Value-at-Risk measures.

A bank's carbon is inside the companies it lends to

A bank chief executive is asked a simple question by a regulator: "How much carbon exposure does your bank have?" The room goes quiet. Nobody can answer, because the carbon is not in the bank's own offices; it is inside the thousands of companies the bank has lent to. The tools that answer that question turn the answer into a number about money at risk.

Start Here: what you need to know first

This is the most number-heavy lesson, so the groundwork matters. Take these slowly.

a portfolio of loans. A **portfolio** is the whole collection of loans or investments an institution holds, looked at together. A bank's **loan portfolio** (or **loan book**) is every loan it has made. The amount tied up in any single borrower or sector is called the **exposure** to that borrower or sector. We care about the portfolio because a shock that hits many loans at once (a flood across a whole farming region) is far more dangerous than one borrower failing on their own.

emissions and the tCO2e unit. Greenhouse gases, mainly carbon dioxide from burning fossil fuels, trap heat and warm the planet. Because several gases are involved, we add them up in a common unit, the **tonne of carbon-dioxide equivalent**, written tCO2e. When this module talks about a company's or a portfolio's emissions, it means the tonnes of CO2-equivalent it is responsible for.

enterprise value and revenue. A company is worth more than the cash in its till. Its **enterprise value** is roughly what it would cost to buy the whole business: the value of its shares (equity) plus its debt. A close cousin used in carbon accounting is **EVIC**, enterprise value including cash. **Revenue** is the company's sales in a year. We need these because a bank's share of a company's emissions is scaled by how much of the company it has financed.

the credit-risk triad, in brief. When a bank lends money it asks three questions about each loan. **PD**, the **probability of default**, is the chance the borrower fails to repay (for example a 5 percent chance, written 0.05). **LGD**, the **loss given default**, is the share of the money the bank would lose if that happens, after selling any collateral (for example 0.60, meaning it recovers 40 percent). **EAD**, the **exposure at default**, is how much is owed at that moment (for example 300 million). Multiplying the three gives the **expected loss**, the average amount the bank expects to lose on the loan: EL = PD × LGD × EAD. Climate risk raises PD (borrowers hit by disasters default more often) and LGD (flooded collateral is worth less), so it raises the expected loss.

expected value. The **expected value** of something uncertain is the average outcome if you could repeat it many times, found by weighting each possible result by its probability. If a loan loses 100 with probability 0.05 and nothing otherwise, the expected loss is 0.05 times 100, which is 5. It is the everyday meaning of "on average," and it is what the expected-loss formula computes.

standard Value-at-Risk. Banks like a single number that answers "how bad could a normal bad day be?" That number is **Value-at-Risk**, or VaR. A one-day 95 percent VaR of one million dollars means: on 95 days out of 100 the loss is smaller than a million, and on the worst 5 it could be more. It has two dials: a **confidence level** (the 95 percent) and a **time horizon** (the one day). Hold onto VaR, because Lesson 4's Climate VaR borrows the idea and stretches the horizon to decades.

reading a regression. Often we want to know how one thing moves with another: does a hotter year raise loan defaults? A **regression** draws the best straight line through the data and hands back a **coefficient**, a number saying how much the result changes when the cause rises by one unit. Two companions to it: the **t-statistic** says whether the relationship is strong enough to trust (a rule of thumb is bigger than about 2), and the **R-squared** says how much of the variation the line explains. You will not run a regression here; you only need to read what a coefficient and a t-statistic are telling you.

The core idea 1: financed emissions, the hidden majority

If a bank lends money to a cement factory, who is responsible for the factory's smoke? The modern answer is: partly the bank. The idea is called *financed emissions*, and the rule is fair. You count the borrower's emissions, then keep only the slice that matches how much of the company you have financed. The slice is your loan divided by the company's enterprise value:

$$\text{Financed emissions} = \frac{\text{your loan}}{\text{enterprise value}} \times \text{company emissions.}$$

For a bank, these financed emissions dwarf its office and electricity emissions, which is why they are the heart of the measurement.

Worked example, every step shown

A bank has lent $50 million to a steel company whose enterprise value is $500 million, and the company emits 200,000 tonnes of CO2-equivalent a year.
Step 1, the slice. The bank financed 50/500 = 0.10, that is 10 percent of the company.
Step 2, its share of the smoke. 0.10 × 200,000 = 20,000 tCO2e. The bank "owns" 20,000

tonnes of this one borrower's emissions on its books.

The core idea 2: one number for the whole portfolio, WACI

Twenty thousand tonnes for one borrower is fine, but a bank has thousands. To compare and track, banks squeeze the whole portfolio into one number: the Weighted Average Carbon Intensity, or WACI. "Intensity" means emissions per dollar of the borrower's revenue (so big and small firms can be compared fairly), and "weighted" means each holding counts in proportion to its size:

$$\text{WACI} = \sum_i w_i \times \frac{\text{emissions}_i}{\text{revenue}_i}.$$

Worked example, every step shown

A small portfolio has three holdings. A power firm (weight 0.40) with intensity 800; a manufacturer (weight 0.35) with intensity 200; a bank (weight 0.25) with intensity 15.
Multiply and add: $0.40 \times 800 + 0.35 \times 200 + 0.25 \times 15 = 320 + 70 + 3.75 = 393.75$.
The portfolio's WACI is about 393. A lone WACI figure means little; it earns its keep when tracked over time and set against a Paris-aligned benchmark, showing whether the portfolio is getting cleaner.

The core idea 3: from carbon to money, Climate VaR

Carbon numbers describe the problem; Climate Value-at-Risk puts a money figure on it. Recall standard VaR, the "how bad could a normal bad day be" number. Climate VaR borrows the idea but changes two dials: it looks decades ahead, and it asks what a given climate scenario would do. In plain terms, it is today's portfolio value minus its expected value under a hard climate future. It splits into two parts: a *physical* piece (storms and floods hitting borrowers) and a *transition* piece (carbon prices hitting the dirtiest borrowers). A useful surprise is that the physical piece, falling on uninsured farms, can be larger than the transition piece, even though the farms emit far less than a coal plant.

Beyond this companion: see the lecture deck

Does the stock market already punish dirty firms? Researchers test this with a carbon factor in a returns model, $R_i = \alpha + \beta_{\text{mkt}} R_m + \beta_{\text{carbon}} \text{CI}_i$, and find a small positive "carbon premium" (Bolton and Kacperczyk, 2021). Related tools are the event study, which looks for abnormal returns around a policy date, and difference-in-differences, whose estimator $\hat{\delta}$ compares treated and control firms. The lecture deck develops these; here, knowing what a coefficient means is enough.

Now you are ready

You can now measure a portfolio's carbon and explain Climate VaR. Next, **Handout Chapter 4** works through the data-quality tiers and a fuller Vietnam example (where, notably, coal is around half of power generation). Then **Lesson 4 (Deck L4)** adds the asset-pricing and causal-inference tools from the advanced box.

Check yourself

1. A bank lends \$20m to a firm worth \$200m that emits 100,000 tonnes. What are its financed emissions? *(*$0.10 \times 100{,}000 = 10{,}000$ *tCO2e.)*
2. Why divide emissions by revenue to get intensity? *(So large and small firms can be compared fairly.)*
3. Name the two pieces Climate VaR splits into. *(Physical and transition.)*
4. How does Climate VaR differ from standard VaR? *(It looks decades ahead and is tied to a climate scenario, not one ordinary day.)*

Mini-glossary. *Financed emissions:* your financed slice of a borrower's emissions. *WACI:* one weighted number for a portfolio's carbon intensity. *Climate VaR:* the value a portfolio could lose under a climate scenario over decades.

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