Carbon Inequality: Price Discovery and Market Dynamics in the Voluntary Carbon Market

Ying Liu

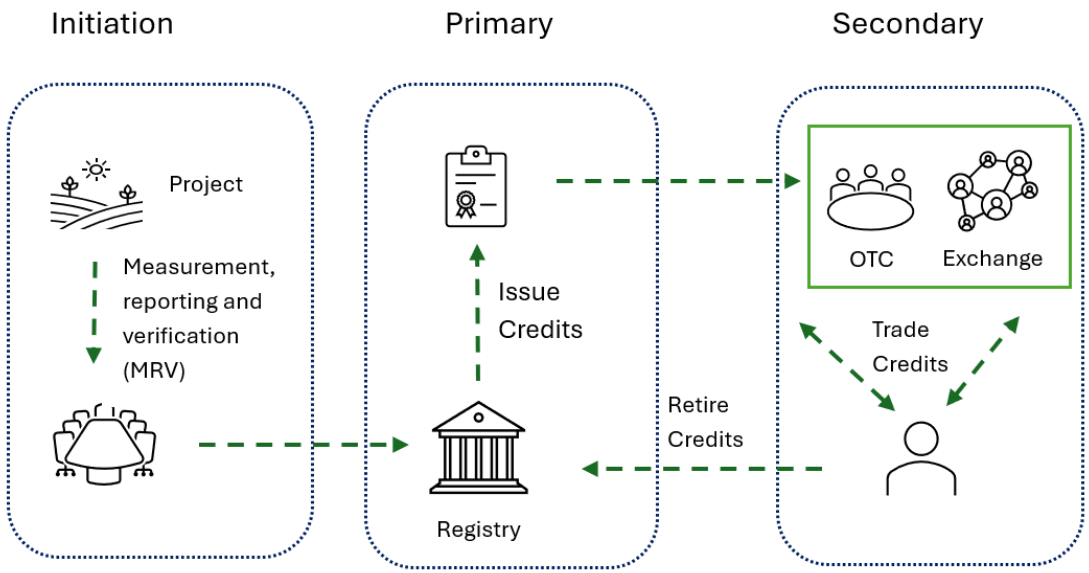
World Federation of Exchanges

February 2026

Voluntary Carbon Market

- The VCM allows firms to purchase and trade carbon credits/offsets.
  - Each credit represents one tonne of verified CO_2 reduced or removed from the atmosphere

- Market Process:

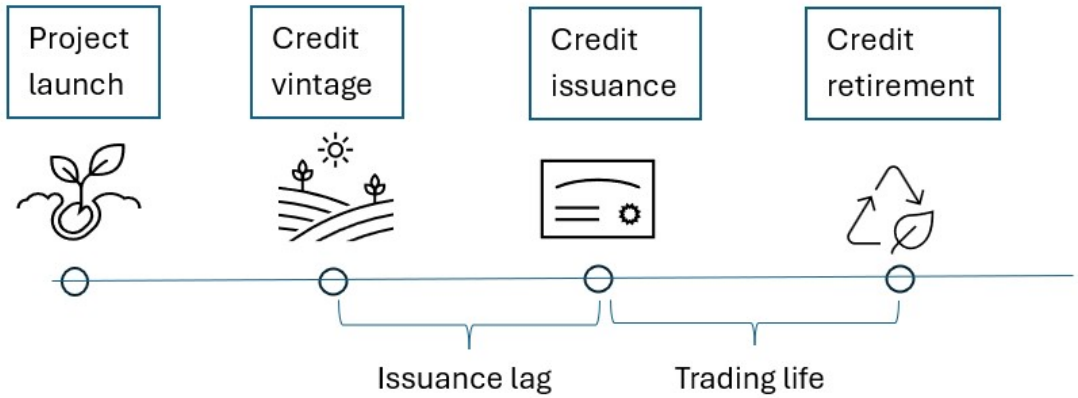


  - Credits generated by projects (e.g., forestry, renewable energy).
  - Independent registries verify, issue, and track credits.(e.g. Verra, Gold Standard)
  - Buyers retire credits to compensate for emissions

Background

- **Compliance Carbon Markets (CCMs):**
  - Established under mandatory national or regional regulatory frameworks
  - Examples include the EU Emissions Trading System and the California Cap-and-Trade Program
  - Trading instrument: *carbon allowances*=right to emit (carbon credit = evidence of emission reduction elsewhere)
  - Regulated firms must surrender allowances to cover their verified emissions

More of Carbon Credits



- Credit vintage year: the year when the CO_2 emission reduction or removal took place
- VCM is more concentrated in emerging market and developing economies (EMDEs): (*Liu and Gurrola-Pérez, 2025, The dynamics of voluntary carbon markets*)
  - 74% of the projects are developed in EMDEs, collectively generating 75% of the total carbon credits.
  - Top 5 countries: United States, India, China, Brazil, Turkey

Research Questions

- What determines the price of carbon credits in the voluntary carbon market?
- Do carbon credits from advanced economies and from emerging and developing economies trade at different prices?
  - If there is a price difference, what factors help explain it?

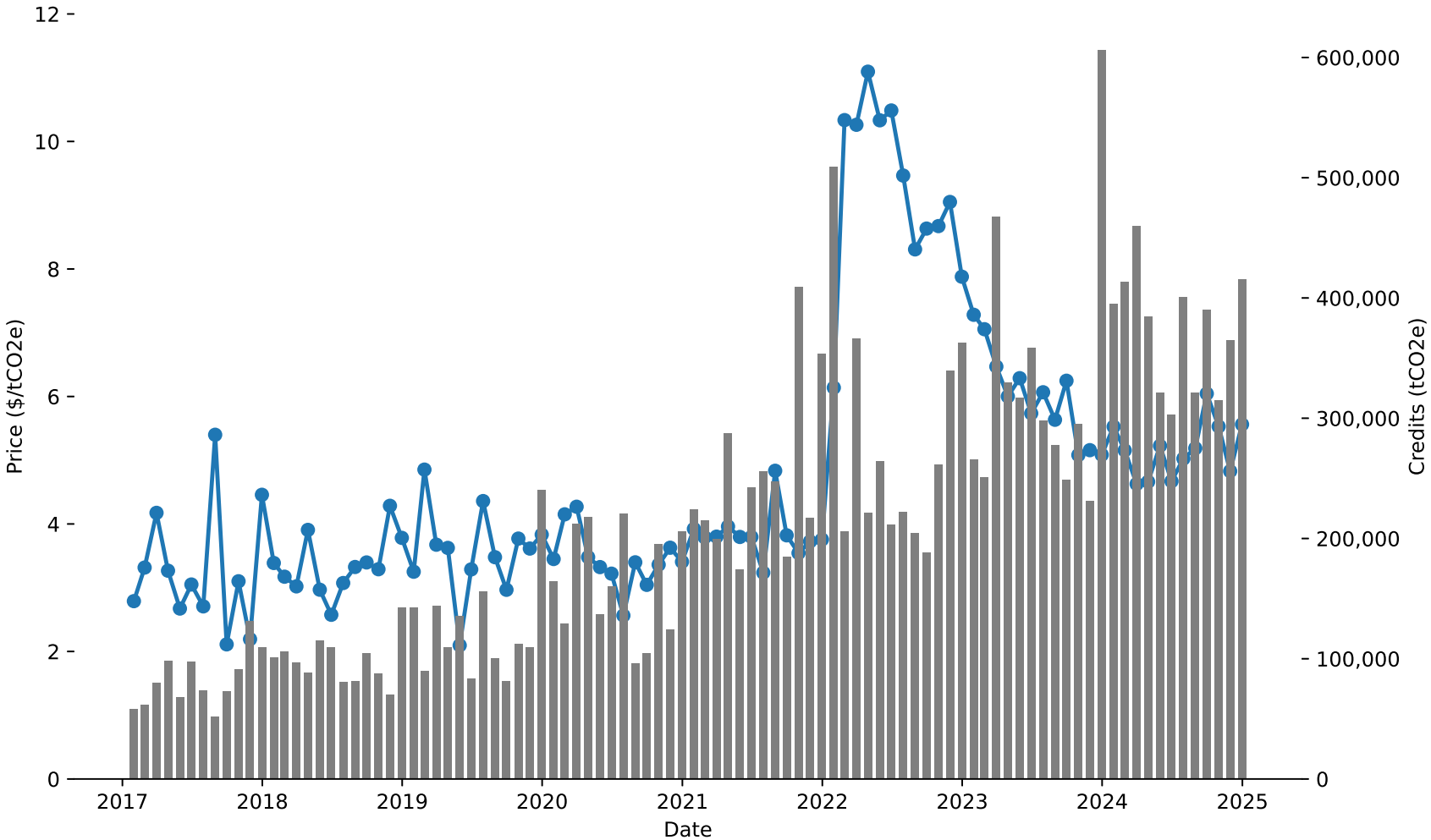
Main Results

- **Price Discovery:**
  - Prices differ widely across project types: nature-based credits (Agriculture($7.97); Forestry & Land Use($7.39)) trade at much higher prices than technology-based credits (e.g. Renewable Energy($3.02)).
  - Determinants of price:
    - Older credits trade at a discount (*Credit Age* $-$)
    - Mature projects command a premium (*Project Age* $+$)
    - Larger inventories depress future returns (*Inventory* $-$)
    - Evidence of mean reversion in past returns (*Lag Return* $-$)
- **Price Disparity:**
  - Credits from advanced economies trade at a sizeable premium (about $6.9 vs. $4.98 per tonne, or roughly 28% premium).
    - Project quality ✗
    - Investor home bias ✗
    - Governance quality of the project jurisdiction (rule of law, control of corruption)✓

Data

- Transaction-level data from January 2017 to December 2024
  - Credit retirement transaction
- Covers 259,967 records from 2,207 projects
- Four Major Registries: ACR, CAR, Verra, Gold Standard
- Eight Project Sectors (e.g., Forestry & Land Use, Renewable Energy, Agriculture, Waste Disposal)
- Aggregate at monthly frequency (value-weighted price), winsorized at percentiles 2.5, 97.5

Market Dynamics



Summary Statistics

	Mean	SD	Min	Median	Max	No.
Price ($/tCO2e)	5.21	3.69	0.72	4.42	16.03	30,679
Monthly Volume (tCO2e)	666.23	1,522.66	1.00	310	80,520	30,679
Cash Volume ($)	3,501	10,237	0.38	1,153	784,721	30,679
No. retire/Month	8.46	52.40	1.00	2.00	3,378	30,679
Return (%)	0.05	20.72	-51.11	-0.33	67.68	22,357
Credit Age (Year)	5.63	3.20	1.00	5.00	14.00	30,679
Project Age (Year)	9.19	4.14	3.00	9.00	18.00	30,679
CCB	0.10	0.30	0.00	0.00	1.00	30,679
No.SDG	2.67	3.00	0.00	4.00	17.00	30,679

- Infrequent trading
- CCB: Climate, Community & Biodiversity (Verra)
- SDG: United Nations Sustainable Development Goals

Project Sector and price

	Price ($)	Volume (tCO2e)	Credit Age (year)	Project Age (year)	No. trans. per Month	No. SDG	CCB	Nob
Agriculture	7.97	734.37	6.42	10.02	4.73	1.74	0.20	171
ChemProc/IndManuf	4.58	743.04	6.09	7.78	6.10	3.15	0.00	923
EnergyEff/FuelSwitch	4.70	442.10	6.04	9.90	4.38	1.42	0.00	928
Forestry and Land Use	7.39	925.01	6.72	10.54	13.31	1.72	0.41	7,168
Household Devices	6.67	465.57	4.01	7.12	5.67	5.23	0.00	7,750
Renewable Energy	3.02	655.78	5.78	9.39	8.48	1.84	0.00	12,253
Transportation	5.35	438.47	10.48	14.70	1.60	0.77	0.00	260
Waste Disposal	5.50	676.86	6.05	11.63	4.56	1.45	0.00	1,226

- Nature-based projects trade at a premium relative to technology-based projects.
- Renewable energy projects account for the largest share of projects by number.

Price Discovery

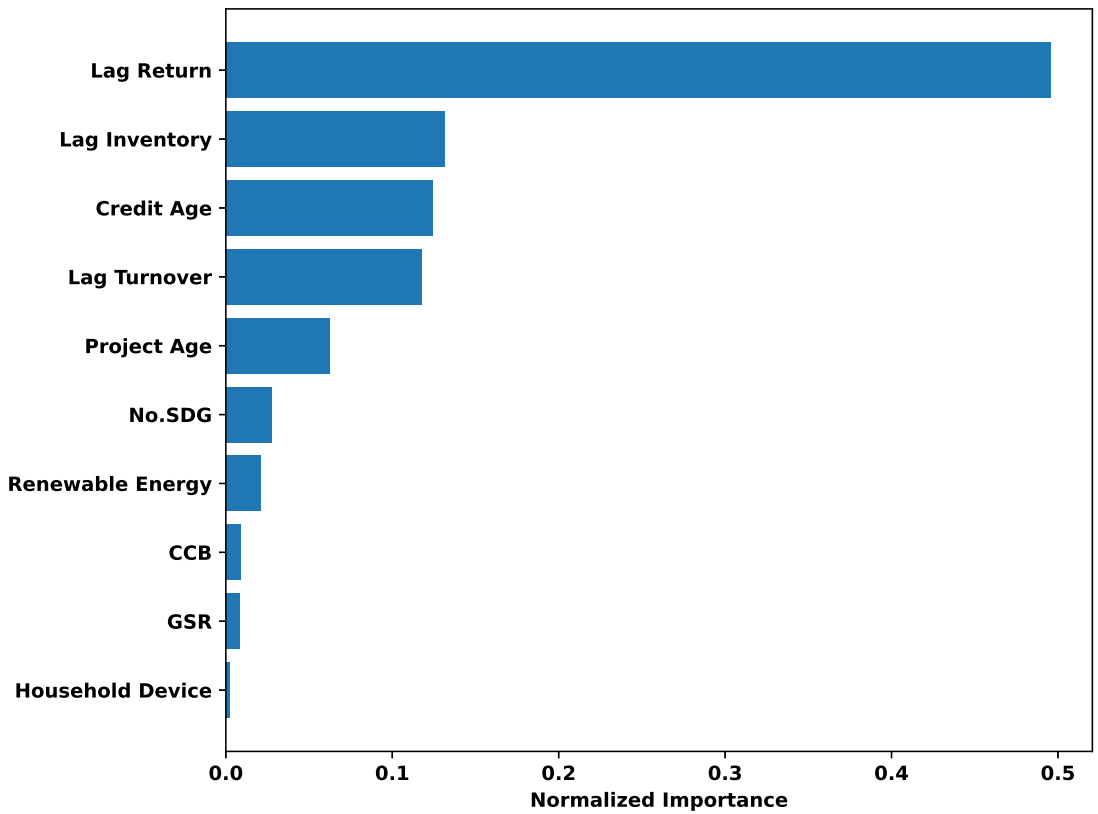
$$\text{Return}_{i,t} = \alpha + \beta_i \cdot X_{i,t-1} + \lambda_t + \lambda_{registry} + \lambda_{sector} + \epsilon_{i,t}. \quad (1)$$

	Dependent Variable: $\text{Return}_{i,t}$			
	(1)	(2)	(3)	(4)
$\text{Credit Age}_{i,t}$	-0.45***	-0.42***	-0.44***	-0.48***
	(-3.87)	(-3.86)	(-3.90)	(-3.78)
$\text{Project Age}_{i,t}$	0.20***	0.21***	0.20***	0.20**
	(3.02)	(3.07)	(2.94)	(2.54)
$\text{Return}_{i,t-1}$	-0.31***	-0.31***	-0.31***	-0.32***
	(-17.34)	(-17.21)	(-17.32)	(-16.20)
CCB_i	-0.35	0.73	-0.28	-0.24
	(-0.79)	(1.20)	(-0.67)	(-0.51)
No.SDG_i	0.05	0.04	0.03	0.03
	(0.92)	(0.90)	(0.85)	(1.14)
$\text{Log(Inventory)}_{i,t-1}$	-0.23**	-0.21*	-0.22**	-0.38***
	(-2.03)	(-1.88)	(-2.07)	(-3.01)
$\text{Turnover}_{i,t-1}$	-0.10	-0.07	-0.10	-0.29
	(-0.56)	(-0.38)	(-0.54)	(-1.12)
$\text{Volatility}_{i,t-1}$				0.07***
				(4.01)
Project Sector FEs	Yes	No	Yes	Yes
Registry FEs	No	Yes	Yes	Yes
Year-Month FEs	Yes	Yes	Yes	Yes
Num.Obs.	18560	18560	18560	13259
R2 Adj.	0.250	0.249	0.249	0.258

Feature Importance in Carbon Credit Pric

WORLD FEDERATION OF EXCHANGES

- Complementary machine learning models (Ridge, LightGBM) used to validate OLS results
- Both models consistently identify:
  - **Lag Return**: strongest predictor (short-term reversal dynamics)
  - **Lag Inventory**: key supply-side factor (oversupply depresses prices)



Retirement seasonality: December

Month	No. Transaction	Month Volume (tCO2e)	Month Vol./ Annual Vol. (%)	Price ($/tCO2e)
Jan	2549	232,332	8.79	4.40
Feb	2040	183,849	7.06	5.12
Mar	2938	253,240	9.53	4.97
Apr	2589	216,967	8.60	4.95
May	2236	191,557	7.68	4.53
Jun	1955	195,677	7.87	4.55
Jul	2891	213,388	8.43	4.45
Aug	2223	172,378	6.51	4.69
Sep	2527	171,781	6.70	4.35
Oct	3608	220,900	8.74	4.40
Nov	2969	198,465	8.01	4.41
Dec	**3929**	**304,386**	**12.08**	**4.61**
Dec-Mar	992	51,146	2.55	-0.37
t-value	1.23	2.01	2.65	-0.96

- December consistently records the highest level of carbon credit retirements.
- This pattern is consistent with firms' sustainability reporting cycles and year-end offset commitments.

Price Disparity

	AE	EMDE
Total Issued Credits (Million tCO2e)	34.23	609.63
Total Retired Credits (Million tCO2e)	2.00	18.44
Price ($/tCO2e)	6.90	4.98
No. Projects	321	1,883

- Credit retirement rate: Advanced economies (AEs) 5.84% vs. EMDEs 3.02%
- Average price of AE credits: $6.90 vs. $4.98 for EMDEs (∼28% premium, ∼ $1.92 more per tonne)

Explaining the Price Inequality

- We consider three competing explanations:
  - Project quality
  - Investor home bias
  - Governance quality of the project jurisdiction

Mechanism-Product Quality

- Is the price difference driven by differences in project or credit characteristics?
- Matching similar projects from AE and EMDE:
  - Same project sector and registry
  - Difference in credit age $\leq$ 2 year
  - Difference in project age $\leq$ 2 years
  - Difference in lagged inventory (log-transformed) $\leq$ 1/3

Variable	EMDE	AE	Diff.	T-Value	No.
Price ($/tCO2e)	3.95	5.61	-1.65	-6.79	1,407
Credit Age (Year)	5.24	5.20	0.04	0.38	1,407
Project Age (Year)	10.05	10.06	-0.01	-0.09	1,407
Lag Log(Inventory)	13.61	13.62	-0.01	-0.85	1,407

Mechanism-Investor Home Bias

	Dependent Variable: Log(Price)$_{i,t}$			
	(1)	(2)	(3)	(4)
EMDE$_i$	-0.11**	-0.11**	-0.12**	-0.11**
	(-2.43)	(-2.32)	(-2.47)	(-2.39)
SameCountry$_{i,t}$		0.01		
		(0.20)		
SameContinent$_{i,t}$			-0.01	
			(-0.73)	
Distance$_{i,t}$				0.00
				(0.05)
Controls	Yes	Yes	Yes	Yes
Project Sector FEs	Yes	Yes	Yes	Yes
Registry FEs	Yes	Yes	Yes	Yes
Year-Month FEs	Yes	Yes	Yes	Yes
Num.Obs.	5382	5382	5382	5382
R2 Adj.	0.807	0.807	0.807	0.807

- SameCountry: dummy variable equal to 1 if the buyer and the project are located in the same country
- SameContinent: dummy variable equal to 1 if the buyer and the project are located on the same continent
- Distance: geographic distance between the capital cities of the buyer's country and the project's country (in thousand km)

Mechanism-Country Governance Quality

- Worldwide Governance Indicator (World Bank)
- Government Effectiveness (GE)
- Regulatory Quality (RQ)
- Rule of Law (RL)
- Control of Corruption (CC)

	Dependent Variable: Log(Price)$_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
EMDE$_i$	-0.09***	0.03	-0.22**	0.15	0.04
	(-4.14)	(0.45)	(-2.04)	(1.14)	(0.33)
$CC_{i,t-1}$		0.09*			
		(1.84)			
$CC_{i,t-1} \times$ EMDE$_i$		-0.09*			
		(-1.83)			
$GE_{i,t-1}$			-0.09		
			(-1.35)		
$GE_{i,t-1} \times$ EMDE$_i$			0.07		
			(1.00)		
$RL_{i,t-1}$				0.17*	
				(1.94)	
$RL_{i,t-1} \times$ EMDE$_i$				-0.19**	
				(-2.18)	
$RQ_{i,t-1}$					0.08
					(1.20)
$RQ_{i,t-1} \times$ EMDE$_i$					-0.07
					(-0.99)
Controls	YES	YES	YES	YES	YES
Sector FEs	YES	YES	YES	YES	YES
Registry FEs	YES	YES	YES	YES	YES
Year-Month FEs	YES	YES	YES	YES	YES
Num.Obs.	28393	28297	28297	28297	28297
R2 Adj.	0.849	0.849	0.850	0.849	0.849

Policy Implications

- Strengthen governance and legal certainty in EMDEs to narrow the price gap
- Enhance credibility through governance-aware standards: market participants price institutional risk, suggesting that verification and integrity frameworks should explicitly account for jurisdictional governance.
- Support fair access to climate finance for EMDEs: persistent price discounts imply that climate finance may not flow efficiently to regions where mitigation potential is greatest.

Conclusion

- **Price discovery in the voluntary carbon market:**
  - Older credits trade at systematic discounts, while more established projects command price premia
  - Supply conditions and liquidity dominate price dynamics: larger inventories depress future returns and prices exhibit strong mean reversion
- **Persistent cross-country price inequality:** carbon credits from advanced economies trade at a substantial premium (USD 6.90 vs. USD 4.98, approximately 28%), driven primarily by differences in country-level governance quality

Thank you!