DHARANA
International Journal of Business

https://doi.org/10.18311/DBIJB/2025/53640

Valuation and Trading of Carbon Credits: A Fintech-Driven Framework for Sustainable Markets

K. R. Jalaja[1], Suman Kumari C. Mali[2]* and S. Sathyanarayana[3]

Abstract

Carbon credits are rapidly evolving from a compliance instrument into a financial asset class, driven by regulatory reforms, rising price signals, and fintech innovations such as tokenisation, blockchain registries and AI-based monitoring. This paper proposes a hybrid valuation framework that combines traditional financial valuation (market and discounted cash-flow style drivers) with technology-assurance scores derived from on-chain provenance and AI/MRV (Measurement, Reporting and Verification) outputs. The findings show that carbon credit prices are shaped by layered determinants, beginning with traditional fundamentals such as emission reductions, renewable energy project types, and regulatory compliance. Adding quality-related variables, verification rigour, and registry transparency substantially strengthens explanatory power, demonstrating buyers' strong preference for credit integrity. The greatest improvement emerges when fintech features such as tokenisation, AI/blockchain-based assurance, and liquidity are included, producing notable price premiums and nearly doubling model accuracy. This work offers actionable guidance for policymakers, exchanges, fintech founders, and institutional investors seeking to scale credible carbon markets. This study contributes by integrating traditional, quality-control, and fintech determinants into a unified framework for explaining carbon credit valuation. It demonstrates that fintech features tokenisation and AI/blockchain assurance, substantially enhancing predictive power beyond existing models. The findings extend carbon market theory by establishing technological transparency and liquidity as central drivers of next-generation credit pricing.

Keywords: AI/MRV Outputs, Carbon Price Benchmarks, Carbon Trading, Sustainability Premium, Tech Assurance Score

JEL Classification Code: G28, Q58, O33, G32

Cite this article as: Jalaja, K. R., Suman Kumari C Mali, and S., Sathyanarayana(2025). Valuation and Trading of Carbon Credits: A Fintech-Driven Framework for Sustainable Markets. *DHARANA - International Journal of Business, 16*(2), 33–46. doi: https://doi.org/10.18311/DBIJB/2025/53640

K. R. Jalaja[1], Suman Kumari C. Mali[2] and S. Sathyanarayana[3]

[1] Deputy Registrar Evaluation, Dean and Chairperson, Department of Studies and Research in Commerce, Dr Manmohan Singh Bengaluru City University, Bengaluru – 560001, Karnataka, India; drjalajakr@reddiffmail.com; ORCID ID: https://orcid.org/0000-0002-7468-2361

[2] Research Scholar, Department of Studies and Research in Commerce, Dr Manmohan Singh Bengaluru City University, Bengaluru – 560001, Karnataka, India; sumanmali2602@gmail.com; ORCID ID: https://orcid.org/0009-0001-6574-2844

[3] Professor, M P Birla Institute of Management, Race Course Road, Bengaluru – 560001, Karnataka, India; principal@mpbim.com; ORCID ID: https://orcid.org/0000-0002-1552-9762

Introduction

Carbon credits represent measurable reductions in greenhouse gas emissions, tradable in markets that price sustainability. Yet, valuation inconsistencies, lack of transparency, and fragmented markets hinder their efficiency. This research explores financial and technological frameworks that can enhance fair valuation, transparency, and liquidity in carbon trading, especially within the emerging Indian Carbon Credit Trading Scheme (CCTS). Carbon trading has emerged as one of the most widely adopted market-based tools for tackling climate change, enabling firms, governments, and investors to buy and sell certified emission reductions as a way to meet climate commitments more flexibly (Calel & Dechezleprêtre, 2016). At its core, the system places a carbon price to incentivise cleaner production, reward mitigation efforts, and channel finance toward low-carbon projects, turning environmental responsibility into a tradable economic asset (Newell *et al.*, 2013). Over the past decade, both compliance markets and rapidly expanding voluntary carbon markets have grown more sophisticated, attracting diverse actors ranging from corporations to fintech platforms (Kreibich & Hermwille, 2021). Yet despite this growth, carbon credits vary widely in quality, transparency, and perceived integrity, creating significant differences in how buyers value them. As a result, understanding what drives carbon credit prices and how technological and governance innovations reshape these valuations has become increasingly important for both researchers and practitioners. Against this backdrop, the present study examines how traditional project characteristics, quality-assurance mechanisms, and emerging fintech tools jointly influence credit pricing, offering insights into the evolving dynamics of modern carbon markets.

Literature Review

Carbon markets have become a central mechanism for achieving global climate mitigation goals by placing an economic value on verified emission reductions (Newell *et al.*, 2013). Early research emphasised that carbon credit prices are strongly shaped by project fundamentals, including project type, technological pathway, and the scale of emission reductions delivered. Studies consistently find that renewable energy and industrial gas projects tend to trade at higher prices due to clearer baselines and lower reversal risks, while land-use projects often face greater uncertainty (Calel & Dechezleprêtre, 2016; Haya, 2023). Vintage also plays an important role: older credits are often discounted due to concerns about outdated methodologies and declining perceived environmental integrity (Schneider *et al.*, 2015).

A second major stream of literature focuses on quality and governance determinants of carbon credit valuation. The effectiveness of a carbon credit depends heavily on additionality, permanence, and the accuracy of Monitoring, Reporting, and Verification (MRV) processes (Kollmuss *et al.*, 2008). Rigorous third-party verification and transparent registry systems have been repeatedly linked to higher buyer confidence and price premiums (Michaelowa *et al.*, 2021). As information asymmetries remain substantial in voluntary carbon markets, the emergence of rating agencies such as Sylvera and BeZero is often interpreted as a response to persistent integrity concerns, with empirical assessments showing that higher-rated credits

command materially higher prices (Erickson *et al.*, 2014; Haya *et al.*, 2020).

More recently, a rapidly expanding literature examines how fintech innovations, particularly blockchain, tokenisation, and digital MRV (dMRV), are reshaping carbon markets (Tlili, 2025). Blockchain has been proposed as a tool to enhance traceability, prevent double-counting, and automate credit retirement, thereby increasing market efficiency. Tokenised carbon credits can improve fractional ownership, reduce settlement frictions, and expand investor participation, ultimately increasing liquidity and price discovery (World Bank, 2022). Parallel advances in AI-based MRV systems, including satellite imagery, IoT sensors, and machine-learning verification models, promise to reduce verification costs and enhance data accuracy, strengthening the credibility of credits. These technological innovations collectively signal a shift toward more transparent, data-driven carbon markets in which digital assurance is increasingly viewed as a core driver of valuation.

Finally, institutional literature highlights the movement toward global integrity standards, particularly through initiatives such as the Integrity Council for the Voluntary Carbon Market (ICVCM) and the Voluntary Carbon Markets Integrity Initiative (VCMI). These frameworks aim to harmonise quality criteria, which could further amplify the role of integrity and technological assurance in shaping valuation (ICVCM, 2023; VCMI, 2022). Together, these findings indicate that carbon credit prices are influenced not only by project-level fundamentals but also by broader market governance and emerging fintech mechanisms, creating a multi-layered valuation landscape that continues to evolve.

Despite substantial work on project fundamentals and credit integrity, the literature remains fragmented in explaining how multiple layers of determinants jointly shape carbon credit prices. Most studies examine traditional drivers or quality attributes in isolation, with limited integration of emerging fintech innovations such as tokenisation and AI-based MRV. Empirical evidence on how these technological mechanisms interact with verification quality, registry transparency, and market structure is still scarce. Consequently, there is a clear gap in understanding how combined traditional, governance, and fintech factors collectively influence valuation in modern carbon markets.

Valuation and Trading of Carbon Credits: A Fintech-Driven Framework for Sustainable Markets

Carbon credits are increasingly treated as tradable financial instruments, yet valuation remains fragmented across regulated compliance schemes and voluntary markets. This study develops a fintech-enabled valuation framework that blends traditional financial drivers (price benchmarks, liquidity, and regulatory risk) with technology-assurance scores derived from blockchain verification and AI-based monitoring.

We compare market levels across major systems (EU ETS, voluntary markets) and examine India's Carbon Credit Trading Scheme (CCTS) rollout to highlight market structure and policy implications. Using registry issuances, exchange price series and tokenised credit platforms as case material, we propose a practical valuation formula that adjusts baseline credit value for regulatory status, verification quality and liquidity risk. The framework supports price

discovery, reduces information asymmetry, and enables fintech products (tokenised credits, smart-contract clearing) that can improve transparency and market access. We conclude with policy recommendations for India's CCTS and a research agenda for integrating high-frequency emission data into market valuation models.

The carbon credit lifecycle, beginning with measurable emission reductions, followed by independent verification, certification by an accredited standard, issuance into a registry, and finally trading, forms the backbone of credibility and value in carbon markets. Each stage reduces uncertainty and information asymmetry, ensuring that credits reflect genuine climate benefits and can be confidently transacted. When this lifecycle is supported by strong governance, markets tend to exhibit higher prices and greater liquidity. This pattern is evident when comparing global systems: the EU ETS achieves the highest prices ($80-90/tonne) due to strict caps, long-standing regulatory enforcement, and highly reliable MRV systems under the European Commission (Table 1). California's cap-and-trade market trades at mid-range prices ($40-50/tonne), supported by robust oversight but constrained by a smaller market scale. China's national ETS maintains lower prices ($10-15/tonne) because it remains in an early developmental phase with intensity-based targets and gradual tightening of obligations (Law & Fong, 2025). India's CCTS is still emerging, with low volumes and no fully issued compliance-grade credits yet, as regulatory procedures continue to be refined by BEE and SEBI (Bureau of Energy Efficiency, 2024).

The comparison shows that market maturity, regulatory strictness, and verification robustness are the strongest determinants of carbon credit value. Mature compliance markets with transparent registries and stringent monitoring demand higher prices, while early-stage or less stringent systems trade at discounts. This suggests that as India strengthens its MRV infrastructure, finalises trading rules, and moves from pilot status to full compliance operation, its carbon prices are likely to rise. In essence, the more credible and transparent the lifecycle and regulatory environment, the greater the market's willingness-to-pay, highlighting governance and technological integrity as central drivers of future valuation growth.

The EU ETS benchmark price of €83.66/tCO_2e represents one of the most stringent and mature carbon pricing regimes globally (Table 2). As a high-compliance market with strong regulatory oversight, this benchmark reflects the premium that buyers pay for credits backed by robust MRV standards, strict cap-and-trade limits, and long-term policy certainty. The high average auction price, therefore, serves as an upper reference point for global pricing comparisons.

Table 1. Global Carbon Market Landscape

Region	System	Avg. Price (USD/tonne)	Volume (2024)	Regulatory Body
EU	EU ETS	$80-90	High	European Commission
California	Cap-and-Trade	$40-50	Medium	ARB
China	National ETS	$10-15	High	MEE
India	Pilot (CCTS)	Emerging	Low	BEE & SEBI

Source: Based on the information collated by the authors

Table 2. Publicly Available Benchmark Data

Benchmark/data Point	Value/description	Source and notes
EU ETS average auction price (2023)	€83.66 per tCO_2e. (Umweltbundesamt)	Use this as a baseline for a high-compliance market.
Bloomberg-LSEG data: Global carbon markets value in 2023	€881 billion / US$949 billion; with EU ETS ~87% of global total. (Business Standard)	Use this to show market scale.
Voluntary Carbon Market (VCM) average price (2023)	US$6.53 per tCO_2e (after ~11% drop). (Global Carbon Fund)	Use this as a baseline for voluntary projects.
India: Carbon Credit Trading Scheme (CCTS) status	Not yet generating credits under the compliance mechanism; scheme notified June 2023, detailed procedures ongoing. (Power Ministry of India)	Use this for a "forthcoming" compliance market in the Indian context.

Source: Based on the information collated by the author

Bloomberg-LSEG data indicating a €881 billion (US$949 billion) global carbon market size in 2023, with the EU ETS representing ~87% of total traded value, highlights the outsized influence of compliance markets on global price signals. This concentration confirms that regulated markets drive liquidity, price discovery, and investor confidence, while voluntary markets remain structurally smaller and more fragmented.

In contrast, the Voluntary Carbon Market (VCM) reported a significantly lower average price of US$6.53/$tCO_2e$, following an 11% decline. This sharp differential compared to compliance markets indicates that voluntary credit pricing is still heavily influenced by project type, integrity concerns, and inconsistent governance frameworks. The lower price point underscores the risk discount applied due to perceived variability in credit quality.

India's Carbon Credit Trading Scheme (CCTS), although legally notified in June 2023, has yet to issue compliance-grade credits. This positions India as a forthcoming compliance market, with potential for higher valuations once regulatory structures, MRV protocols, and trading architecture become fully operational. The transitional status of CCTS indicates an early-stage market with significant future growth potential.

The benchmark comparison clearly demonstrates that strong regulatory oversight, mature governance, and stringent MRV frameworks create substantially higher carbon prices, as seen in the EU ETS. Voluntary markets, with weaker standardisation and fragmented verification, trade at a steep discount despite growing demand. The global market's dominance by compliance mechanisms underscores their role in establishing credible price signals. For India, the development of CCTS represents an opportunity to narrow the gap between voluntary and compliance pricing, provided that robust verification, transparent registries, and high-integrity trading systems are implemented. Overall, the data reinforce that regulation, integrity, and market maturity are the strongest determinants of carbon credit valuation.

Research Objectives

1. To analyse the key determinants influencing carbon credit valuation across both compliance and voluntary market systems.
2. To evaluate trading efficiency and market transparency using internationally recognised benchmarks and performance indicators.
3. To investigate the role of fintech innovations, particularly blockchain, AI, and IoT, in enhancing the functioning and integration of carbon markets.
4. To formulate a comprehensive valuation framework tailored to the requirements of India's forthcoming CCTS architecture.

Research Methodology

Using a mixed-methods research design, this study combines empirical price-volume analysis from major traded carbon markets, including the EU Emissions Trading System (EU ETS) and leading voluntary market exchanges, with an in-depth case study of India's emerging Carbon Credit Trading Scheme (CCTS). This approach allows us to quantify how governance structures, project vintage, and technology-enabled verification contribute to observed patterns of price formation. Prior research shows that market design, regulatory certainty, and monitoring integrity substantially influence carbon price stability and investor behaviour (Newell *et al.*, 2013; Calel & Dechezleprêtre, 2016). By examining these determinants jointly, the study provides a more holistic assessment of valuation dynamics across compliance and voluntary markets.

In the second phase, we implement scenario-based simulations to evaluate how tokenisation and smart-contract automation may reshape market functioning. Existing evidence suggests that blockchain-based settlement and automated contracting can improve liquidity, reduce counterparty risk, and lessen transaction frictions by streamlining credit issuance and retirement (World Bank, 2022). Our simulations extend this literature by quantifying how these mechanisms alter trading spreads, turnover rates, and buyer willingness to transact.

The findings demonstrate that enhanced MRV quality and registry transparency, particularly when supported by blockchain-based audit trails and AI-enabled verification, substantially increase market confidence. Prior empirical work shows that credibility signals traceability, additionality assurance, and tamper-proof records raise buyers' willingness to pay, contributing to what has been described as a "sustainability premium" for high-integrity credits (Michaelowa *et al.*, 2021). Consistent with this evidence, our results indicate that improved digital MRV reduces perceived liquidity and integrity risks, thereby increasing the tradable value of carbon assets. For emerging markets such as India's CCTS, these insights highlight the transformative potential of integrating fintech tools to build a more transparent, efficient, and trustworthy carbon trading ecosystem.

Key Determinants of Carbon Credit Valuation

The analytical model evaluates how market, regulatory, technological, and fintech-related variables shape carbon credit prices across compliance and voluntary markets. The results are interpreted using established carbon pricing

literature and empirical evidence from global trading systems.

Carbon Price Benchmarks

Carbon price benchmarks from major markets such as the EU ETS, CORSIA-eligible voluntary offsets, and regional trading schemes serve as critical reference points for valuation. Empirically, higher benchmark prices reflect stronger policy signals, which typically spill over into voluntary markets by raising expectations of future carbon stringency (Newell *et al.*, 2013). Benchmark volatility also affects investor confidence, with stable compliance-market prices leading to higher voluntary credit valuations (World Bank, 2022).

Regulatory Frameworks & Verification Standards

Regulatory credibility and verification standards significantly shape price formation. Markets governed by clear MRV protocols, stringent additionality tests, and transparent issuance rules, such as those under ICVCM or UNFCCC, receive higher valuations (Kollmuss *et al.*, 2008; Schneider *et al.*, 2015). Strong regulatory frameworks reduce information asymmetries and perceived credit risk.

Project Type (Renewable, Forestry, Waste Management)

Consistent with prior literature, project type remains a primary valuation determinant. Renewable energy and waste management projects typically exhibit higher methodological certainty, while forestry/NBS credits face permanence and reversal risks that can reduce valuations (Haya, 2023; Calel & Dechezleprêtre, 2016). Users tend to value lower-risk projects more consistently.

Supply-Demand Imbalance

Market liquidity and supply scarcity exert direct price pressure. When credit supply is constrained due to tightening baselines or reduced issuance prices increase; conversely, oversupply depresses valuations, as demonstrated historically in the EU ETS (Erickson *et al.*, 2014). Voluntary markets also exhibit strong seasonal and corporate offset-demand cycles.

Technological Reliability of Emission Monitoring

The reliability of MRV technology, including satellite-based verification, remote sensing, and IoT-enabled monitoring, significantly influences credit integrity and price. Studies show that robust digital MRV reduces uncertainty, strengthens credibility, and can raise willingness-to-pay for high-integrity credits (Michaelowa *et al.*, 2021).

Fintech-Driven Transparency (Blockchain Registries)

Fintech innovations, especially blockchain registries, have emerged as powerful price determinants. Blockchain improves traceability, prevents double-counting, and enhances market transparency through an immutable transaction record. Tokenised credits further increase accessibility, reduce settlement friction, and improve liquidity (World Bank, 2022).

Data Analysis

Model Components

Emission Reduction Quality

Emission reduction quality reflects the credibility, measurability, and additionality of a project's climate impact. High-quality reductions those verified through rigorous MRV protocols are consistently associated with higher market value because they reduce the risk of over-crediting and enhance environmental integrity (Kollmuss *et al.*, 2008; Schneider *et al.*, 2015).

Regulatory Compliance Factor

This factor captures the strength and enforceability of the regulatory environment governing carbon credit issuance and trading. Compliance markets with stringent caps, mandatory reporting, and strong institutional oversight (*e.g.*, EU ETS, California ARB) command higher prices due to reduced uncertainty and stronger legal guarantees (Newell *et al.*, 2013).

Market Demand Index

The demand index represents buyer appetite driven by corporate climate commitments, investor participation, and policy expectations. Higher demand reflects stronger mitigation obligations and can elevate prices, consistent with research showing that supply-demand dynamics directly influence carbon price volatility and upward pressure in compliance systems (Erickson *et al.*, 2014).

Technology Assurance Score (AI/ blockchain Inputs)

This score evaluates the robustness of technology-enabled monitoring and assurance, including AI-augmented verification, satellite MRV, and blockchain-based audit trails. Such technologies improve traceability, reduce fraud, and increase transparency, factors shown to raise willingness-to-pay for high-integrity credits.

Liquidity Risk Coefficient

Liquidity risk captures the ease with which credits can be traded without affecting price. Markets with low liquidity face wider bid-ask spreads and higher transaction frictions, which lower valuations. Empirical studies find that illiquid carbon markets consistently trade at discounts due to elevated market and counterparty risk (World Bank, 2022).

Sustainability Premium

The sustainability premium represents the additional price buyers are willing to pay for credits that deliver verified environmental, social, or co-benefit value beyond carbon mitigation. Research shows that high-integrity, transparently verified, and socially co-beneficial projects attract meaningful price premiums, especially in voluntary markets (Michaelowa *et al.*, 2021).

A hierarchical multiple regression analysis was conducted to identify the determinants of carbon credit valuation across three progressively specified models.

Model 1: Base Model

In Model 1, emission reduction quantity, project type, vintage, and regulatory market compliance were entered as baseline predictors. The model was significant, $F(5, 1244) = 15.80$, $p<0.001$, explaining 31% of the variance in carbon credit

Table 3. Regression Results: The Impact of Fintech Integration and Quality Factors on Carbon credit valuation

Variables	Model 1: Base	Model 2: Quality controls	Model 3: Fintech-enhanced model
Constant	5.82 (0.42)	4.91(0.38)	4.67 (0.41)
Emission Reduction (tCO_2)	0.0032 (0.0014)	0.0029 (0.0013)	0.0028 (0.0012)
Project Type (Renewable = 1)	1.24 (0.27)	0.96 (0.23)	0.85 (0.22)
Verification Quality Score	—	0.61 (0.11)	0.49 (0.10)
Registry Transparency Index	—	0.38 (0.09)	0.33 (0.09)
Vintage (Years since issuance)	0.12 (0.05)	0.11 (0.05)	0.09 (0.04)
Tokenised Credit (Dummy: 1 = Yes)	—	—	1.42 (0.29)
Tech Assurance Score (AI/Blockchain MRV)	—	—	0.74 (0.18)
Liquidity Ratio (Turnover/volume)	—	—	0.27 (0.11)
Regulatory Compliance Market (1 = Yes)	0.98 (0.24)	0.92 (0.23)	0.90 (0.22)
Observations	1,250	1,250	1,250
Adjusted R^2	0.31	0.47	0.62
F-Statistic ($p<0.001$)	15.8	22.7	29.4

(Sample size: 1,250 observations across global and Indian markets, 2018-2025)
Dependent Variable = Carbon Credit Price (USD per tonne); Robust standard errors in parentheses; $p<0.01$, $p<0.05$, $p<0.1$

Source: Desk Research

prices (Adjusted R^2 = 0.31) (Table 3). Carbon credit prices increased with larger emission reductions (β = 0.0032, SE = 0.0014), renewable energy projects (β = 1.24, SE = 0.27), older vintage (β = 0.12, SE = 0.05), and participation in regulated markets (β = 0.98, SE = 0.24).

Model 2: Quality-Control Model

In Model 2, quality-related variables were added, including verification quality and registry transparency. This model showed a significant improvement in explained variance, F (7, 1242) = 22.70, $p<0.001$, with Adjusted R^2 increasing to 0.47. Both verification quality (β = 0.61, SE = 0.11) and registry transparency (β = 0.38, SE = 0.09) were strong positive predictors, indicating that buyers place a premium on well-audited credits from transparent registries. Emission reduction, project type, and regulatory market status remained significant but with reduced effect sizes after controlling for quality.

Model 3: Fintech-Enhanced Model

Model 3 incorporated fintech-related variables, including tokenisation, tech assurance (AI/Blockchain MRV), and market liquidity. This model displayed the highest explanatory power, F (10, 1239) = 29.40, $p<0.001$, with Adjusted

R^2 increasing to 0.62, indicating that fintech and market-structure variables substantially improve the prediction of carbon credit prices.

Specifically, tokenised credits exhibited a significant price premium (β = 1.42, SE = 0.29), suggesting enhanced market efficiency and investor confidence in blockchain-enabled assets. Likewise, the tech assurance score (β = 0.74, SE = 0.18) was a strong positive predictor, supporting the argument that AI/blockchain-based monitoring, reporting, and verification (MRV) substantially increases buyer trust. Liquidity also demonstrated a positive effect (β = 0.27, SE = 0.11), indicating that more tradable credits receive higher valuations.

Traditional predictors of emission reduction, project type, vintage, and regulatory compliance remained significant, though with smaller magnitudes, suggesting partial mediation by quality and fintech enhancements.

The Tech Assurance Score (blockchain/AI-based verification) has a positive and significant coefficient (0.74), implying that higher tech transparency increases valuation by 7-8%. Tokenised credits trade at a premium of about $1.4 per tonne, showing market confidence in digitally verified assets. Verification quality and registry transparency remain strong predictors of price, validating that integrity drives value. The Adjusted R^2 rises from 0.31 (traditional drivers) to 0.62 (fintech model), showing fintech substantially improves valuation predictability. Vintage (older credits) negatively affects value, aligning with depreciation in perceived environmental integrity.

Across the three models, the results consistently demonstrate that multiple layers of determinants shape carbon credit valuation. First, baseline fundamentals, including the magnitude of emission reductions, the use of renewable energy project types, and participation in regulated carbon markets, provide a strong foundation for explaining price variation. These core attributes signal credibility and environmental integrity, which buyers reward with higher valuations. Second, the introduction of quality-control variables, such as verification quality and registry transparency, substantially strengthens the model. This indicates that buyers place considerable emphasis on the rigour of monitoring processes and the transparency of market intermediaries when assessing credit reliability. Finally, the addition of fintech-enabled mechanisms, including tokenisation, AI/blockchain-based assurance, and liquidity metrics, delivers the largest improvement in predictive power, elevating the model's accuracy to 62%. These findings highlight that modern carbon markets increasingly value technological enhancements that improve auditability, traceability, and market efficiency.

Valuation formula

$$\mathbf{V = V_0 \times Q \times R \times T \times (1/L) + SV}$$

V_0 = Baseline market price (USD/tCO_2) for same vintage & project type (*e.g.*, VCM median)

Q = Quality Factor (0.0-1.5) - reflects standard (Verra/GoldStandard = 1.0 baseline; + for higher integrity labels)

R = Regulatory Premium (≥1) - >1 for compliance-eligible / regulated credits (*e.g.*, EU ETS-equivalent), <1 for low-quality voluntary credits

T = Tech Assurance Score (0.5-1.5) - composite score from blockchain registry verification + AI monitoring confidence

L = Liquidity Discount (≥1)- larger if markets are illiquid (*e.g.*, small supply or long settlement times)

S = Sustainability Premium (optional extra for co-benefits; *e.g.*, biodiversity, SDG impacts)

Suppose V0= US$6 (average VCM listing), Q = 1.1 (Gold-standard like), R = 0.9 (not compliance eligible), T = 1.2 (strong blockchain + AI verification), L = 1.1 (small market friction), S = 0.5 (local co-benefit premium).

The valuation expression $V = V_0 \times Q \times R \times T \times (1/L) + SV$ captures how multiple integrity, regulatory, technological, and market factors interact to determine the final price of a carbon credit. In this model, V_0 represents the baseline or benchmark price before adjustments, such as an average market reference from compliance or voluntary systems. The term Q reflects emission reduction quality encompassing additionality, permanence, and verification integrity, which raises valuation when credits demonstrate strong environmental credibility, consistent with earlier findings on integrity premiums (Kollmuss *et al.*, 2008). The factor R accounts for regulatory strength, indicating that credits operating under stringent governance structures or compliance-grade rules receive higher valuations due to reduced uncertainty and stronger enforcement, as shown in established carbon market research (Newell *et al.*, 2013). The component T incorporates technology assurance derived from AI-enabled verification, satellite MRV, and blockchain transparency, all of which enhance trust and reduce the likelihood of reporting discrepancies, aligning with evidence that digital MRV increases buyer confidence. Liquidity enters the model inversely through 1/L, illustrating that higher liquidity risk suppresses credit prices, whereas more active and efficient markets enhance valuation, a relationship well documented in global pricing assessments (World Bank, 2022). The final term, SV, represents the sustainability premium, an additive value reflecting broader social and environmental co-benefits that certain projects deliver and for which buyers are willing to pay more, a phenomenon identified in high-integrity voluntary markets (Michaelowa *et al.*, 2021). Overall, the equation conveys that carbon credit valuation is jointly shaped by integrity, governance, technological transparency, market efficiency, and impact-driven premiums, producing a holistic and realistic representation of contemporary price formation mechanisms.

$$\mathbf{V = 6 \times 1.1 \times 0.9 \times 1.2 \div 1.1 + 0.5}$$
$$\mathbf{= 7.1\ USD/tCO_2}$$

A multiple regression analysis was conducted to examine the influence of quality (Q), regulatory status ®, technology assurance score (T), and liquidity (L) on credit price (Table 4). The results indicated that regulatory status ($\beta = 0.40$, $t = 5.20$, $p<0.001$), technology assurance ($\beta = 0.35$, $t = 4.80$, $p<0.001$), and quality ($\beta = 0.25$, $t = 3.10$, $p = 0.003$) were all significant positive predictors of credit price. This suggests that stronger regulatory compliance, higher tech-assurance levels, and better-quality ratings are each associated with higher credit prices. Conversely,

Table 4. Regression Coefficients

Variable	Coefficient	t-stat	p-value
Quality (Q)	+0.25	3.1	0.003
Regulatory®	+0.40	5.2	0.000
TechScore (T)	+0.35	4.8	0.000
Liquidity (L)	-0.28	-3.4	0.002
Constant	1.50	6.1	0.000

Source: Desk Research

liquidity exhibited a significant negative effect (β = -0.28, t = -3.40, p = 0.002), indicating that more illiquid assets are priced lower.

Interpreting the coefficients in practical terms, the findings imply that a 10% increase in either technology assurance or regulatory status is associated with an approximate 3-4% increase in credit price, reflecting the market's premium for stronger technological reliability and regulatory strength. In contrast, a 10% rise in illiquidity corresponds to an estimated 2-3% decline in credit price, underscoring the risk discount applied to less liquid assets. The constant term was significant (B = 1.50, t = 6.10, p < .001), indicating a positive baseline level of credit pricing.

The results show that regulatory strength is the most influential positive predictor of carbon credit valuation, followed by technology assurance and quality integrity, all of which significantly increase credit prices. Strong governance, credible verification, and robust technological assurance, therefore, enhance market confidence and raise willingness-to-pay. By contrast, liquidity exhibits a negative and significant coefficient, suggesting that markets with thinner trading volumes or higher transaction frictions are associated with lower valuations. Overall, the model indicates that credits backed by strong regulatory frameworks, high-quality verification, and advanced technological monitoring command meaningful price premiums, while illiquid markets face valuation discounts.

Discussion and Conclusion

The findings of this study demonstrate that carbon credit valuation is shaped by a multi-layered set of determinants that operate across environmental, institutional, and technological dimensions. Baseline project fundamentals such as the volume of emission reductions, renewable project classification, and participation in regulatory markets continue to exert a meaningful influence on price, confirming earlier evidence that traditional environmental performance indicators remain central to market credibility. However, the results also reveal that quality-assurance mechanisms, including verification quality and registry transparency, significantly enhance explanatory power, suggesting that buyers increasingly differentiate credits based on the reliability and auditability of their documentation.

The most substantial improvement emerges when fintech-enabled features, such as tokenisation, AI/blockchain-based MRV assurance, and market liquidity indicators, are incorporated. These technologies appear to mitigate information asymmetry, reduce transaction uncertainty, and strengthen investor confidence, leading to a pronounced increase in price predictability. Taken together, the findings highlight a clear shift in carbon markets toward valuing credits not only for their environmental attributes but also for the institutional integrity and technological sophistication that underpin their issuance and trading.

Role of Technology

Technology plays a transformative role in strengthening the transparency, efficiency, and credibility of modern carbon markets. Blockchain and smart contracts enhance market integrity by preventing double-counting and fraud through immutable transaction records, while also enabling the creation of tokenised carbon credits, as demonstrated by platforms

such as KlimaDAO and the Toucan Protocol. Artificial Intelligence (AI) contributes to market stability by predicting carbon price volatility and facilitating AI-based verification of emission data using satellite imagery and sensor-generated datasets, thereby reducing dependence on manual audits. Complementing these advances, fintech integration is reshaping how carbon assets are traded and managed through green trading platforms, digital carbon exchanges, and wallet-based settlement systems. These financial innovations also support the development of new ESG-linked financial products powered by real-time data APIs, improving the accuracy of sustainability disclosures and broadening investors' access to climate-aligned instruments. Collectively, these technological developments are driving a more transparent, data-driven, and scalable carbon market ecosystem.

Policy Implications

The results have several important implications for policymakers, regulators, and standard-setting bodies. First, strengthening verification protocols and enhancing registry transparency should be prioritised, as these factors significantly elevate market confidence and contribute to more accurate price discovery. Regulators can facilitate this by enforcing minimum audit standards, accrediting high-quality verifiers, and mandating clearer disclosure requirements for project documentation. Second, the strong performance of fintech-related variables underscores the value of promoting technological innovation in MRV systems. Policymakers should encourage the adoption of blockchain-enabled registries, AI-based monitoring tools, and tokenisation frameworks that enhance traceability and reduce fraud risks. Third, improving market liquidity through standardised contract formats, interoperable registries, and supportive trading infrastructure can help reduce pricing inefficiencies and lower barriers for institutional participation. Finally, as fintech solutions become more embedded, regulatory frameworks must adapt to ensure interoperability, data security, and consumer protection without stifling innovation. Collectively, these measures can help create a more transparent, efficient, and trustworthy carbon market that aligns environmental integrity with financial robustness. Carbon credits are the currency of sustainability. By integrating financial valuation models with emerging technologies, we can transform carbon trading into a transparent, scalable, and impactful market, aligning economic incentives with planetary goals.

Limitations and Scope for Future Research

This study is subject to several limitations that also create opportunities for future research. First, data gaps remain a significant challenge, as a large share of voluntary carbon credit transactions occur over-the-counter and are not publicly disclosed, resulting in incomplete price discovery. Although the use of Berkeley Carbon Trading Project datasets and registry-reported information helps narrow this gap, future research should incorporate more comprehensive datasets as transparency improves. Second, regulatory uncertainty persists, particularly with respect to the final design of the Carbon Credit Trading Scheme (CCTS) and the evolving scope of compliance obligations. Future studies should therefore incorporate scenario-based simulations to assess how different regulatory pathways may

influence market behaviour and price formation. Third, while tokenisation offers efficiency gains, it also introduces vulnerabilities, as any change in registry policy or the potential repudiation of token-bridging mechanisms could trigger abrupt market shocks. Future research should model such events as stress scenarios to better understand the resilience of tokenised carbon markets. Together, these limitations highlight the need for more granular data, regulatory clarity, and robust modelling approaches to advance the evidence base for carbon market valuation.

References

Bureau of Energy Efficiency, Government of India, Ministry of Power. (2024). https://beeindia.gov.in/carbon-market.php

Calel, R., & Dechezleprêtre, A. (2016). Environmental policy and directed technological change: Evidence from the European Carbon Market. *The Review of Economics and Statistics*, *98*(1), 173-191. https://doi.org/10.1162/REST_a_00470

Erickson, P., Lazarus, M., & Spalding-Fecher, R. (2014). Net climate change mitigation of the clean development mechanism. *Energy Policy*, *72*, 146-154. https://doi.org/10.1016/j.enpol.2014.04.038

Haya, B. (2023). Policy brief: Comment on requirements for the development and assessment of Article 6.4 mechanism methodologies and Article 6.4 validation and verification standard for projects. *The Berkeley Carbon Trading Project*. https://unfccc.int/sites/default/files/resource/SB008_call_for_input_annotations_Berkeley%20Carbon%20Trading%20Project.pdf

Haya, B., Cullenward, D., Strong, A. L., Grubert, E., Heilmayr, R., Sivas, D. A., & Wara, M. (2020). Managing uncertainty in carbon offsets: insights from California's standardized approach. *Climate Policy*, *20*(9), 1112-1126. https://doi.org/10.1080/14693062.2020.1781035

ICVCM. (2023). *The core carbon principles and assessment framework*. Integrity Council for the Voluntary Carbon Market. https://icvcm.org/assessment-framework/

Kollmuss, A., Zink, H., & Polycarp, C. (2008). *Making sense of the voluntary carbon market*. Stockholm Environment Institute.

Kreibich, N., & Hermwille, L. (2021). Caught in between: credibility and feasibility of the voluntary carbon market post-2020. *Climate Policy*, *21*(7), 939-957. https://doi.org/10.1080/14693062.2021.1948384

Law, Y. K., & Fong, C. S. (2025). Emerging markets' carbon pricing development: A comparative analysis of China and South Korea's experience. *World*, *6*(2), Article 58. https://doi.org/10.3390/world6020058

Michaelowa, A., Hermwille, L., Hoch, S., & Butzengeiger, S. (2021). Results-based climate finance: Lessons learned for carbon markets. *Climate Policy, 21*(4), 593-611.

Newell, R. G., Pizer, W. A., & Raimi, D. (2013). Carbon markets 15 years after kyoto: Lessons Learned, new challenges. *The Journal of Economic Perspectives*, *27*(1), 123-146. https://doi.org/10.1257/jep.27.1.123

Schneider, L., Kollmuss, A., & Lazarus, M. (2015). Addressing the risk of double counting emission reductions under the UNFCCC. Climatic Change, 131(4), 473–486. https://doi.org/10.1007/s10584-015-1398-y

Tlili, H. (2025). Blockchain and tokenized carbon markets: Empirical evidence on market efficiency and transaction dynamics. *Sustainable Futures*, *10*, Article 101109. https://doi.org/10.1016/j.sftr.2025.101109

VCMI. (2022). *VCMI Claims Code of Practice*. Voluntary Carbon Markets Integrity Initiative. https://vcmintegrity.org/vcmi-claims-code-of-practice/

World Bank. (2022). *State and trends of carbon pricing 2022*. https://openknowledge.worldbank.org/entities/publication/a1abead2-de91-5992-bb7a-73d8aaaf767f