Research Article

Primary and Secondary ETS Markets: Carbon Derivatives and the Economic Nature of CO_2

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We examine how the regulated supply of allowances within the EU Emissions Trading System is reflected in observed carbon prices through the interaction between primary auctions and secondary spot and derivatives markets over the period 2021–2026. We interpret the ETS as a forward-looking and time-integrated market, in which expectations, hedging demand and financial intermediation play a structural role in price formation. The empirical strategy combines descriptive data on participants' positioning, drawn from ICE's weekly market reports and EEX spot data, with a synthetic indicator of financialisation and four sequentially estimated reduced-form econometric specifications that move from contemporary positioning to intertemporal expectations embedded in the futures curve and, finally, to the spot-futures spread as a measure of the intertemporal risk premium. Three findings emerge. First, financial intermediaries account for a dominant share of gross derivative positions, whilst obligated parties remain predominantly net long and the financialisation ratio remains above unity throughout the sample. Second, the slope of the futures curve is the dominant determinant of EUA allowance price levels: the inclusion of the forward slope increases the explanatory power of the pricing model. Thirdly, the basis is systematically correlated with net financial positioning, consistent with an intertemporal risk premium. We argue that the pricing of EUA allowances increasingly reflects the interaction between regulatory scarcity, expectations of future tightening, and the financial architecture through which carbon price risk is intermediated over time. These results imply that the effectiveness of the carbon price signal depends both on the level of the cap and on the credibility of the long-term scarcity trajectory, the predictability of the governance of the Market Stability Reserve, and the resilience of forward market liquidity.

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 doi.org/10.32388/OCI53Z

1. Introduction

Carbon pricing is the cornerstone of the European Union's climate strategy, and the EU Emissions Trading System (EU ETS) is its central instrument. Since 2005 it has placed a market price on greenhouse-gas emissions across the power sector, energy-intensive industry and, progressively, aviation and maritime transport, and emissions from the covered sectors are now roughly half their 2005 level (European Commission, 2024). Understanding how prices form in this market, therefore, matters well beyond the trading floor, because the carbon price is the signal that guides billions of euros of abatement and investment decisions and serves as the principal yardstick of the policy's effectiveness.

This question has acquired new urgency. Between 2017 and 2021, EUA prices rose roughly tenfold, exceeding EUR 80 per tonne, and have remained historically elevated since, reshaping investment across the electricity and industrial sectors[1]. This surge coincided with major reforms tightening future supply, the strengthening of the Market Stability Reserve and the Fit for 55 package, and with the growing integration of carbon pricing into broader industrial policy through the Carbon Border Adjustment Mechanism (CBAM). Recent work argues that a reduced supply of allowances alone cannot fully account for the price rise, and that increasingly forward-looking behaviour and the credibility of long-term climate commitments have played a central role[1][2]. This makes the mechanics of EUA price formation, and in particular the role of expectations and financial intermediation, a first-order question for both research and policy.

In the EU ETS, the quantity of allowances is determined ex ante by regulation, whilst prices emerge through decentralised market interactions. Unlike conventional commodity markets, where scarcity typically reflects physical extraction constraints or marginal production costs, scarcity in the EU ETS is created administratively through the annual reduction trajectory, the rules governing the free allocation of allowances and the auction schedule. Previous literature has emphasised that scarcity in the system is fundamentally determined by political and regulatory decisions rather than by physical resource constraints[3][4][5]. The carbon price therefore reflects the market valuation of regulated scarcity rather than the direct price of a scarce resource.

The political nature of the allowance supply, and the issues of credibility and design that it raises for long-term price formation, has been highlighted in the literature on reforms[6]. In the EU ETS, price formation cannot be understood solely through emissions demand or short-term marginal abatement costs. Instead, allowance prices incorporate expectations regarding regulation, macroeconomic

conditions, energy market developments, technological adaptation capacity and the credibility of decarbonisation policies in the medium term.

Carbon prices are therefore inherently forward-looking asset prices, determined at the intersection of environmental regulation, industrial policy and financial markets. In particular, in the presence of full banking provisions, intertemporal arbitrage links prices across different maturities, implying that current prices are anchored to expectations of future scarcity rather than determined by contemporary market conditions[7][8].

The coexistence of a primary market (auction of allowances) and a secondary market (spot and derivatives trading) is central to this mechanism. The primary market determines the initial allocation of auctioned allowances and constitutes the main supply channel through which scarcity enters the system. The secondary market enables intertemporal reallocation, hedging, the provision of liquidity and price discovery.

Where a regulated asset is widely traded through derivatives markets, observed prices may reflect immediate compliance fundamentals as well as risk premiums, portfolio reallocations, changes in expectations, shifts in market positioning and temporary liquidity conditions.

It is therefore relevant to what extent the transmission from regulatory scarcity to observed prices is mediated by financial market dynamics[9][10][11]. As more restrictive limits attract investors and funds to the quota markets, financial participation provides liquidity and price discovery but may, if excessive, distort price formation[2].

This issue is particularly significant during the 2021–2026 period, which is characterised by European Union Allowances (EUA) prices at record highs, exceptional volatility in European energy markets, a gradual tightening of future allowance supply, and the increasing integration of carbon pricing into broader industrial policy instruments, such as the Carbon Border Adjustment Mechanism (CBAM). By extending a carbon cost to the embedded emissions of imported cement, iron and steel, aluminium, fertilisers, electricity and hydrogen. The CBAM is designed to place imports on the same carbon-price footing as EU producers and thereby curb carbon leakages as free allowances are phased out, which ties the EUA price directly to industrial competitiveness and trade policy[12].

A further key institutional component is the Market Stability Reserve (MSR), originally introduced to absorb the structural surplus of allowances accumulated following the financial crisis and which has

progressively become a central mechanism shaping expectations of future shortages and the market's overall resilience.

Recent policy discussions on the future calibration of the MSR[13] confirm that carbon market governance concerns both the management of surpluses and the prevention of excessive tightening, disorderly price adjustments and liquidity stress. This shift is reflected in the literature: Quemin and Trotignon[14] show that the MSR reshapes intertemporal supply and thus the expectations embedded in prices; Koch et al.[15] demonstrate that regulatory decisions act as catalysts for price formation, and Pahle et al.[16] argue that, as the cap tightens, the reserve becomes central to the credibility of the long-term scarcity signal.

In this context, we address three research questions. First, to what extent are EUA allowance prices in the 2021–2026 period explained by current compliance and financial positioning relative to forward-looking expectations. Secondly, how does the structural balance between financial intermediation and compliance-related positioning evolve over the reference period? Thirdly, we examine whether the spot-futures spread behaves as an intertemporal risk premium systematically correlated with financial positioning.

We anticipate that the slope of the futures curve is the dominant determinant of EUA price levels, thereby supporting the interpretation of allowances as future-oriented intertemporal assets. Furthermore, we discuss a financialisation indicator that summarises, over a multi-year horizon, the structural balance between financial intermediation and compliance positioning, an aspect previously described only in qualitative terms. Finally, we interpret the spot-futures spread through the lens of the holding cost and risk premium framework, offering new insights into the intermediation of carbon price risk in a regulated market where supply is administratively fixed.

The novelty of the study lies in the integration of these three dimensions within a single empirical framework during a historical period characterised by high prices, which allows us to analyse price levels, market structure and forward premiums jointly rather than in isolation.

The remainder of the paper is organised as follows. Section 2 reviews the relevant literature and develops the research questions and hypotheses. Section 3 presents the research design, including the analytical framework, the data and the four econometric specifications. Section 4 presents the empirical evidence on participants' positioning and on the determinants of prices and the basis. Section 5 discusses the

results in the light of the existing literature on the intertemporal dynamics of the carbon market and the Market Stability Reserve. Section 6 highlights the policy implications, whilst Section 7 concludes.

2. Literature review

This section situates the study within three related strands of research and, on this basis, develops the research questions (RQs) and hypotheses. It pursues three specific objectives. Firstly, it clarifies the theoretical foundations explaining why EU allowances (EUAs) behave as forward-looking and intertemporally linked assets rather than as instruments whose price depends exclusively on contemporary scarcity. Secondly, it brings together the scientific literature on the determinants of carbon pricing, regulatory events and the financialisation of the market. Thirdly, it draws on this synthesis to identify the specific gap that the study addresses. The review is therefore selective and argument-driven, organised around the questions this paper aims to answer.

2.1. Allowances as forward-looking and intertemporally linked assets

The first strand of the study concerns the economics of intertemporal quota markets. The contributions by Rubin[7] and Kling and Rubin[8] show that, when accumulation and borrowing are permitted, rational firms equalise the discounted marginal value of allowances across periods, so that the equilibrium price of allowances follows an arbitrage path anchored to expected future scarcity rather than solely to contemporary abatement costs. This reasoning has been specifically extended to the EU ETS, where allowances are considered storable financial assets whose price reflects the discounted shadow price[17]. In this framework, intertemporal arbitrage ensures that the forward curve actively anchors the spot price. This theoretical perspective underpins part of the present study, which argues that the slope of the futures curve should be a key explanatory factor for the price levels of EUA allowances.

2.2. Price-determining factors, regulatory events and the Market Stability Reserve

Previous studies have identified the key factors to which allowance prices react, each isolating a distinct channel: some demonstrate that energy prices, together with weather events, influence EUA allowance prices[18]. Others link allowance prices to the marginal abatement cost of fuel switching in the electricity sector[5], whilst still others note that carbon prices also move in tandem with macroeconomic and financial conditions[19]. Subsequent studies have summarised this evidence on price and market behaviour across successive trading phases[11].

Regulatory and institutional decisions are themselves key determinants of prices: Koch et al.[20] attribute much of the post-2008 price collapse to the interaction between recession, compensation schemes and overlapping renewable energy policies, whilst Koch et al.[15] demonstrate that regulatory events act as catalysts for price formation. The MSR has become central to this discussion, as, by conditioning future supply on the surplus in circulation, it directly shapes expectations of future scarcity[14][16], a mechanism whose stabilising and price-forming effects have been critically examined by Borghesi et al.[21]. It is also worth noting that overlapping climate policies interact with the ETS cap in ways that are reflected in the price[22]. These studies imply that the current supply and demand mechanism hardly explains the price and that forward-looking expectations, driven by regulation, must be explicitly incorporated.

2.3. Financialisation and the outlook for commodity futures

The classical theory of inventory and the decomposition of the risk premium in futures prices show that a futures price incorporates both an expectation of the future spot price and a risk premium[23]. Subsequent studies clarify how this premium behaves; for example, Gorton et al.[24] link risk and commodity futures premiums to inventory levels rather than to net speculative positions, and the participation of active hedge funds in both equity and commodity markets strengthens the correlation between these markets[25]. It is also interesting that the returns obtained by futures investors underwent a substantial change following the influx of financial operators in the mid-2000s[26]. The aforementioned studies support the interpretation of the forward basis and slope of EUA prices as reflecting both an expectations component and a brokerage premium.

Bredin and Muckley[27] note that, from Phase II onwards, EUA futures increasingly conform to a holding cost equilibrium consistent with a maturing market. Daskalakis[28] reports that EUA futures achieved weak-form efficiency from 2010 onwards, indicating once again increasing maturity; furthermore, informed and strategic trading determines liquidity and price formation[29]. This is also confirmed by instances of price movements following energy and policy announcements rather than fundamentals, confirming the sensitivity of carbon prices to expectations[30]. The market monitoring reports of the European Securities and Markets Authority[31][32] document, in parallel, the growing share of investment funds and credit institutions in EUA derivatives.

An analysis of the aforementioned literature reveals a gap: a time-series indicator that summarises the structural balance between intermediaries' activity and compliance positioning over a multi-year

horizon, a gap that this study fills with the financialisation ratio.

2.4. Research gap

Taken together, these three strands leave two unresolved issues. Firstly, although the interpretation of allowances as intertemporal assets is theoretically well-established, it has rarely been tested directly against contemporary positioning data within a single nested framework that allows the forward slope to compete with net financial and compliance positions as explanatory factors for price levels. Secondly, the financialisation of the EUA market is widely described but rarely captured in a transparent and replicable indicator that can be monitored over time and linked to price formation. This paper addresses both gaps within a single framework: it constructs a synthetic indicator of financialisation from participant-level positioning data and incorporates the forward slope, together with net financial and compliance positions, into a sequence of nested specifications culminating in a basic equation for the intertemporal risk premium. The relevant research questions and hypotheses, as well as how each is matched to a specific, are outlined at the start of the research design (Section 3.1).

3. Research Design

This section outlines the research design underpinning the empirical analysis of this study. It is organised so that the questions to be answered are stated first and the tools used to answer them follow. Subsection 3.1 sets out the research questions and the hypotheses, mapping each to the specification that tests it. Subsection 3.2 presents the analytical framework, clarifying the economic nature of EU Allowances as regulated assets whose supply is determined ex ante by policy rather than by production costs, and explaining how full banking and intertemporal arbitrage anchor current prices to the discounted value of expected future scarcity. Subsection 3.3 describes the data used in the empirical analysis, including weekly market observations over January 2021–March 2026 from ICE EUA derivatives positioning records, EEX spot prices and the corresponding front-year and second-year futures contracts. Subsection 3.4 defines the market-structure indicators used in the analysis, including gross and net positions for financial and compliance participants, the synthetic financialisation ratio, the spot-futures basis and the slope of the forward curve, situating these variables within a standard asset-pricing framework. Subsection 3.5 specifies four reduced-form econometric models, progressively introducing financial positioning, compliance positioning, and the slope of the futures curve, and concludes with the basis specification used to isolate the intertemporal risk-premium component of carbon-price formation.

Together, these components ensure that the empirical evidence reported in the results section below is supported by, and consistent with, the analytical framework of the study.

3.1. Hypotheses and Research Questions

Building on the identified research gap, the empirical analysis is structured around three research questions, each addressed by one or more of the sub-questions set out below. Firstly, to what extent are EUA price levels in the period 2021–2026 explained by forward-looking expectations embedded in the slope of the futures curve relative to current compliance and financial positioning? Secondly, how does the structural balance between financial intermediation and relative positioning regarding compliance evolve within the sample, and is the financial positioning sufficiently large to be considered a structural feature of the market? Thirdly, does the spot-futures spread behave as an intertemporal risk premium systematically correlated with financial positioning? Each question is formalised as a hypothesis expressed in null (H0) and alternative (H1) forms, with the theoretical assumptions underpinning them. The hypotheses are tested directly by the four econometric specifications outlined in Section 3.5, such that each empirical model corresponds to a specific research question. $H1_0$ EUA price levels are explained exclusively by contemporary net positioning; the slope of the futures curve adds no significant explanatory power. $H1_1$ The slope of the futures curve is a dominant determinant of EUA price levels, in line with the view of intertemporal arbitrage of allowances as forward-looking assets. $H2_0$ The extent of financial positioning does not systematically exceed compliance-related positioning; any excess is episodic. $H2_1$ Gross financial positioning structurally exceeds compliance positioning across the entire sample (a financialisation ratio persistently greater than one). $H3_0$ The spot-futures spread is not correlated with market positioning. $H3_1$ The spread is systematically associated with net financial positioning, in line with an endogenous intertemporal risk premium.

3.2. Analytical Framework

In the EU ETS, the supply of allowances is defined ex ante through the cap trajectory, the linear reduction factor and the operation of the MSR. Consequently, scarcity is not an endogenous outcome of market conditions, but an exogenously determined policy variable that reflects policy objectives.

In a market characterised by complete banking and intertemporal arbitrage, the relationship between spot and forward prices is not merely informative, but also binding: equilibrium prices reflect the discounted value of expected future scarcity, conditioned by intertemporal equilibrium and the absence of

arbitrage. The forward curve does not merely reveal expectations, but links current prices through arbitrage. This anchoring presupposes that the EUA allowance market is sufficiently efficient for the spot-forward relationship to hold, and the empirical literature supports this premise: Daskalakis[28] notes that EUA futures on the ICE have achieved weak-form efficiency since 2010, whilst Bredin and Muckley[27] demonstrate that, from Phase II onwards, EUA spot and forward prices have moved towards a stable holding cost equilibrium, both indicating a market in which the absence of arbitrage is economically significant. The market monitoring reports of the European Securities and Markets Authority[31][32] complete the picture from the participants' perspective, documenting that a significant proportion of derivatives activity is linked to hedging demand from compliance-bound entities, whilst financial intermediaries provide liquidity and take on offsetting positions. This is a market in which price formation reflects both regulatory scarcity and the intermediation of risk linked to the carbon price over time.

The analytical framework operationalises this view through three sequential steps, summarised in Fig. 1. The first step characterises market structure: it describes participant positioning (financial versus compliance entities) and condenses it into a synthetic financialisation indicator that tracks the balance between intermediation and compliance (research question RQ2, hypothesis H2). The second step models price levels, estimating a specification in which the slope of the forward curve competes with positioning variables as a determinant of EUA prices (RQ1, H1). The third step models forward premia, estimating a basis equation that isolates the intertemporal risk premium (RQ3, H3). The three steps are deliberately sequential rather than parallel, moving from market structure to price levels and finally to forward premia, so that each step constrains the interpretation of the next.

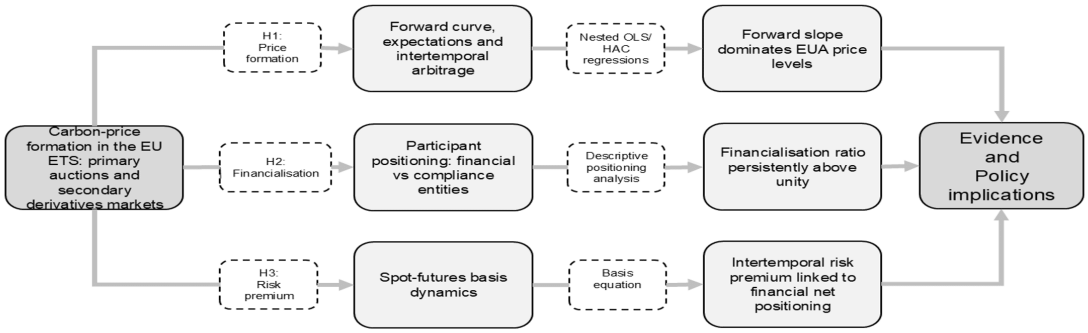


Figure 1. Research design.

Source: authors' own elaboration. Note: the diagram summarises the three sequential steps of the research design and the research questions and hypotheses each addresses. Step 1 characterises market structure through participant positioning and the financialisation indicator; Step 2 models EUA price levels, letting the slope of the forward curve compete with positioning variables; and Step 3 models the spot-futures basis as an intertemporal risk premium. The steps run from market structure to price levels, and finally to forward premia, providing evidence and policy implications.

3.3. Data

The empirical analysis in this study is based on weekly market data covering the period from January 2021 to March 2026. The dataset combines information from two main market sources. Data on EUA derivatives positioning is drawn from ICE market information, which provides weekly long and short positions by participant category. Spot price information is derived from EEX reference data, whilst the futures price series are based on the EUA reference contracts for the current and following year. Together, these sources enable a joint analysis of market structure, participant behaviour and price formation dynamics. Market participants are grouped into two broad categories: financial participants (investment funds and investment/credit institutions) and compliance participants (obligated parties and industrial operators). This grouping provides a manageable framework for assessing the relative role of intermediation in risk transfer and compliance demand in the market. Where appropriate, the selected variables are normalised to reduce the influence of outliers, whilst preserving the economic content of the series.

Table 1 presents the descriptive statistics of the variables used in the econometric specifications, calculated on the weekly sample (January 2021 – March 2026).

Variable	Label	Observations	Mean	SD	Min	Max
fut_front	Price of one-year EUA futures (EUR/tCO_2)	272	72.45022	14.08281	31.74	99.8
fut_secondo	Price of two-year EUA futures (EUR/tCO_2)	272	74.60985	14.96449	31.96	104.81
fut_slope	Slope of the forward curve ('s price for the following year minus that of the previous year)	272	2.159632	1.333422	0	5.01
spot_price	EEX EUA spot price (EUR/tCO_2)	272	71.49713	13.71677	31.64	97.58
basis	Spot-futures basis (current year futures minus spot)	272	.9530882	.9069103	0	3.32
fin_net	Net position of financial intermediaries (long minus short, tCO_2)	272	-399,635.4	125,026.6	-706,165.4	-203,130.5
comp_net	Net position of entities subject to compliance (long minus short, tCO_2)	272	87,161.47	34,799.54	41,107.77	445,205.6
fin_ratio	Financialisation ratio (gross financial positions relative to compliance positions)	272	8.354808	2.455815	1.343969	13.90161
fin_gross	Gross position of financial intermediaries (long minus short, tCO_2)	272	841,881.5	136,710.7	531,288.1	1,101,872
comp_gross	Gross position of entities subject to compliance (long plus short, tCO_2)	272	109,663.1	49,143.63	59,706.46	631,080.1

Table 1. Descriptive statistics of the variables used in the econometric analysis (weekly, 2021–2026)

Source: Authors' calculations based on ICE Commitments of Traders data and ICE/EEX data on the price of EUA allowances

doi.org/10.32388/OCI53Z

Several features of the descriptive statistics shown in Table 1 are worth highlighting. Firstly, the average price of futures maturing in the following year (€72.5/tCO_2) is slightly above the average spot price (€71.5/tCO_2), resulting in a small positive average basis (€0.95/tCO_2). Secondly, the forward slope is positive on average (2.16) but varies considerably (from 0 to 5.01), providing the variation over time that pricing models exploit to identify the role of intertemporal expectations. Thirdly, the positioning variables reveal a structurally asymmetric market: financial intermediaries hold a substantial average gross position (around 842,000 lots) and are systematically net short (average net position of around -400,000 lots), whilst institutional investors hold smaller gross positions and are on average net long. The resulting financialisation ratio averages 8.35 and never falls below 1.34. Fourthly, all variables are observed on a weekly balanced panel covering the period 2021–2026, so that differences in fit between specifications reflect explanatory power.

3.4. Research methodology

This study combines qualitative-descriptive and quantitative-econometric evidence to address various but interdependent questions. The descriptive component is necessary for analysing the structural configuration of the market, including who holds gross and net positions and how the balance between financial intermediation and compliance evolves over time. The econometric component is necessary to test whether this configuration, together with the forward curve, is systematically reflected in prices and the basis. Their combination lies in the convergence of independent lines of evidence towards a single conclusion[33][34]. The design is explanatory and sequential: the descriptive characterisation and the synthetic indicator of financialisation first establish the structural configuration, and the econometric models then verify whether it is priced in, so that the description motivates and interprets the specifications whilst the regressions constrain the description[35][36]. This interdependence is at the heart of the methodological contribution of our article.

3.4.1 Market structure indicators

Four key positioning indicators are calculated on a weekly basis. The gross positions of financial and compliance operators are calculated as the sum of long and short positions ($FinancialGross_t$ and $ComplianceGross_t$), measuring the extent of market participation and brokerage activity. Net positions are calculated as the difference between long and short positions, ($FinancialNet_t$ and

$ComplianceNet_t$), providing information on directional exposure and hedging patterns. To assess the relative intensity of financial participation, a synthetic financialisation metric is defined as in Eq. 1 below:

$$FinancialRatio_t = \frac{FinacialGross_t}{ComplianceGross_t} \quad (1)$$

Where $FinancialGross_t$ and $ComplianceGross_t$ are, respectively, the sum of the long and short positions of financial and compliance participants in week$t$. Values persistently above unity indicate that financial intermediation activity exceeds the scale of compliance-related positioning. Two indicators of price structure are also used: the basis is defined as the difference between the price of the current year's futures and the spot price of EUAs, as in Eq. 2.

$$basic_t = fut_front_t - spot_t \quad (2)$$

The slope of the futures curve is defined as the relative spread between second-year and current-year futures contracts, as in Eq. 3.

$$fut_slope_t = \frac{fut_second_t - fut_front_t}{fut_front_t} \quad (3)$$

The net positions used below are defined as the difference between long and short positions, thus: $FinancialNet_t = FinancialLong_t - FinancialShort_t$, and $ComplianceNet_t = ComplianceLong_t - ComplianceShort_t$. Gross positions are defined as the sum of long and short positions: $FinancialGross_t = FinancialLong_t + FinancialShort_t$, and $ComplianceGross_t = ComplianceLong_t + ComplianceShort_t$. These variables reflect, respectively, the risk premium embedded in forward contracts and the market price of future scarcity conditions[37][38][39].

3.4.2. Econometric specifications

Four econometric specifications are estimated in reduced form using weekly observations covering the period 2021–2026. Model 1 in eq. 4regresses the price of the following year's futures against net financial positioning, as shown in Equation 4. The four specifications are estimated in sequence to isolate the different dimensions of carbon price formation within the EU ETS. The modelling strategy moves from contemporary market positioning (Models 1 and 2) to the intertemporal expectations embedded in the futures curve (Model 3) and finally to the determination of forward premium prices via the basic equation (Model 4). This step-by-step approach allows us to assess whether EUA allowance prices reflect only

current market positions or also the transmission of expectations of future scarcity and risk intermediation.

$$fut_front_t = \beta_0 + \beta_1 FinancialNet_t + \varepsilon_t \tag{4}$$

Model 2 introduces the net compliance position, as in Eq. 5.

$$fut_front_t = \beta_0 + \beta_1 FinancialNet_t + \beta_2 ComplianceNet_t + \varepsilon_t \tag{5}$$

In line with hedging pressure theory, regulated entities can be interpreted primarily as hedgers seeking protection from future compliance costs, whilst financial market participants can provide liquidity and absorb the risk associated with the carbon price. Model 3 introduces the intertemporal structure of prices through the slope of the futures curve, as in Eq. 6.

$$fut_front_t = \beta_0 + \beta_1 FinancialNet_t + \beta_2 ComplianceNet_t + \beta_3 fut_slope_t + \varepsilon_t \tag{6}$$

Whilst Models 1–3 focus on the determinants of the level of EUA futures prices, Model 4 addresses a different issue by examining the determinants of the spread between futures and spot prices. This distinction is important because the spread can capture the intertemporal premium required to transfer carbon price risk over time, thereby providing evidence on the role of financial intermediation beyond the mere signal of scarcity. Therefore, this specification helps us to verify whether carbon prices are linked not only to current market positioning, but also to future expectations regarding regulatory tightening and the evolving role of the Market Stability Reserve[23][24]. Model 4 estimates the base equation, as in Eq. 7.

$$basic_t = \gamma_0 + \gamma_1 FinancialNet_t + \gamma_2 ComplianceNet_t + \mu_t \tag{7}$$

A positive association between net financial positioning and the basis would be consistent with the hypothesis that financial intermediation contributes to the formation of a market-based premium in the forward prices of EUA allowances. The inference is conducted using both OLS standard errors and heteroscedastic and autocorrelated (HAC) standard errors. The empirical strategy does not aim to identify causal effects. Rather, it is designed to assess whether financial positioning, compliance demand and intertemporal market expectations show systematic associations with both EUA allowance price levels and forward premiums. Together, the four models provide a coherent framework for analysing the growing role of expectations and financial intermediation in carbon price formation.

4. Results

This section presents the empirical evidence organised into subsections that progress from a descriptive characterisation of market positioning to an econometric assessment of price formation and the broader implications for the regulatory architecture. First, it documents the extent of financial intermediation by comparing the gross positions held by financial and compliance operators over the period 2021–2026. It then examines the differentiated roles of compliance and financial operators through their net positioning patterns, interpreting the observed configuration within the framework of hedging pressure. It then reports on the evolution of the financialisation ratio, summarising the structural relationship between intermediation activity and compliance positioning across the entire sample. It then presents the econometric estimation of the determinants of EUA futures prices through the four nested models, identifying the dominant role of the slope of the forward curve in explaining price levels. Finally, it isolates the underlying dynamics and interprets the spot-futures spread as a proxy for the intertemporal risk premium embedded in carbon prices. Together, these six subsections support an integrated assessment of how the ETS has evolved from a static compliance mechanism into a forward-looking, financially intermediated pricing system.

4.1. Gross positions: the scale of financial intermediation

Data for the period 2021–2026 confirm that the EUA derivatives market operates on a substantially larger scale than the positioning directly attributable to compliance entities. The gross positions held by financial operators consistently exceed those associated with obligated operators across the entire sample, indicating that the secondary market performs a broad intermediation function that goes well beyond immediate regulatory compliance needs. This trend is consistent with data from the European Securities and Markets Authority[32], according to which investment firms and credit institutions account for a substantial share of trading volumes and positions in the EUA derivatives markets (Figure 2)[30][40]. The scale of financial intermediation has direct implications for price formation: where the volume of intermediaries' positions significantly exceeds compliance-related positions, observed carbon prices may increasingly reflect not only immediate demand for allowances, but also risk assessment, changes in expectations and shifts in market sentiment.

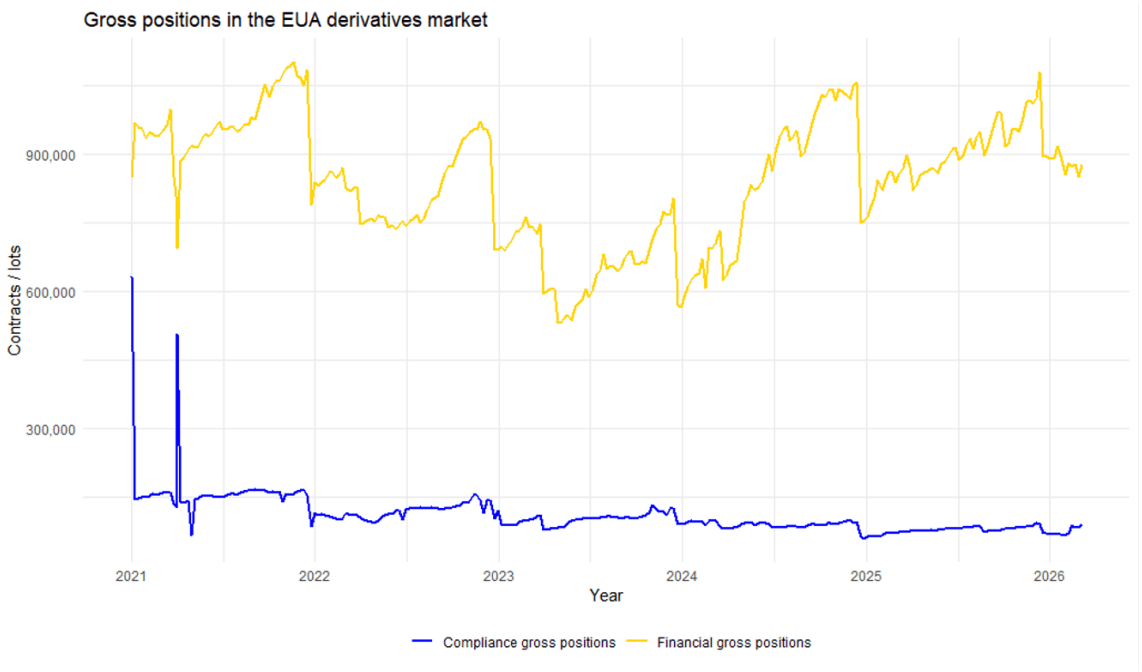


Figure 2. Gross positions in the EUA derivatives market: financial operators vs compliance operators (2021–2026).

Source: Authors' own calculations based on ICE Commitments of Traders data.

4.2. Net positions: distinct roles of compliance and financial participants

Net positioning over the 2021–2026 period reveals a clear structural pattern. Compliance operators are predominantly positioned on the long side of the market, reflecting their need to hedge future issuance obligations. Conversely, financial intermediaries, particularly investment and credit firms, tend to hold persistent short positions on the market, in line with their role as liquidity providers and absorbers of hedging demand. This configuration is consistent with the findings of the European Securities and Markets Authority[31] (Figure 3), which indicate that regulated entities use derivatives markets primarily for hedging purposes, whilst financial participants provide liquidity by taking the opposite position to those positions. This configuration is economically consistent with the institutional structure of the ETS: obligated entities and public utilities are naturally exposed to future allowance requirements and therefore have incentives to secure forward hedging against rising carbon prices, whilst the persistent net short positioning of financial operators suggests that intermediaries play an important role as counterparties by absorbing the demand for forward protection.

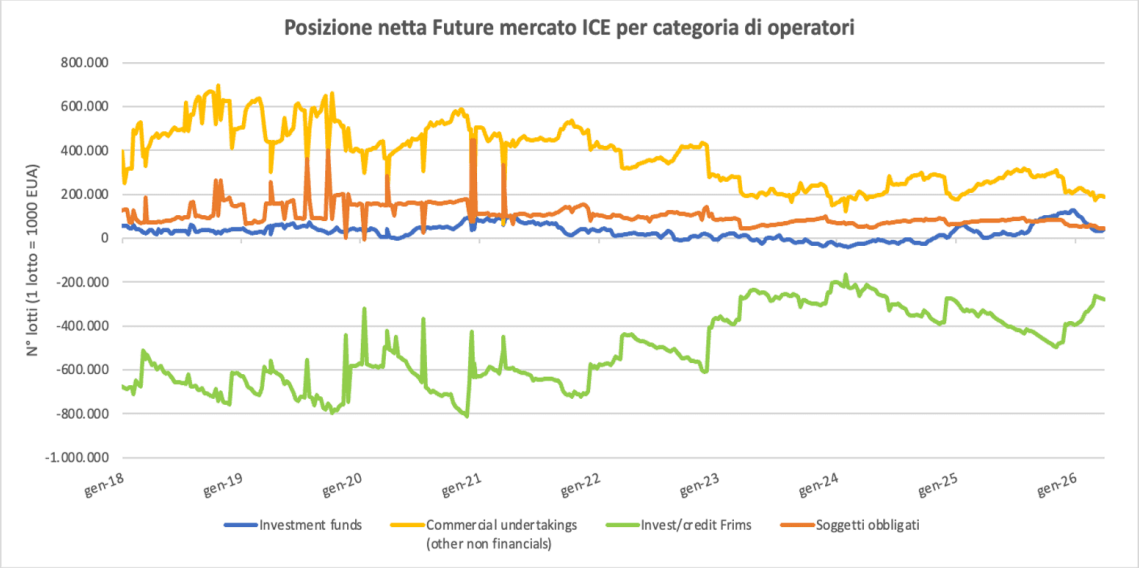


Figure 3. Net positions in the EUA derivatives market by participant category (ICE, 2021–2026).

Source: Authors' own calculations based on ICE Commitments of Traders data. The figure plots weekly net positions (long minus short) of financial and compliance participants in EUA derivatives over 2021-2026: compliance entities are persistently net long, consistent with forward hedging of future surrender obligations, while financial intermediaries are net short, absorbing that demand and providing liquidity.

4.3. Financialisation index

The financialisation ratio remains consistently above one across the entire sample, often by a substantial margin, indicating that gross financial positioning exceeds compliance-related activity for the entire 2021–2026 period. This evidence confirms that the scale of financial intermediation is not episodic but structural: the EUA market operates in a configuration where the volume of intermediation activity systematically exceeds the volume directly associated with regulatory compliance. The temporary fluctuations observed in the first part of the sample are consistent with the exceptional market conditions associated with the post-pandemic reopening phase. The indicator should not be interpreted as a sign of market imbalance, but as a reflection of the role of financial operators in enabling the market to function by providing liquidity, absorbing hedging demand and facilitating intertemporal trading. At the same time, a persistently high financialisation ratio (Figure 4) has direct implications for price formation: where financial positioning dominates market activity, observed carbon prices may increasingly reflect the conditions under which carbon price risk is intermediated among participants.

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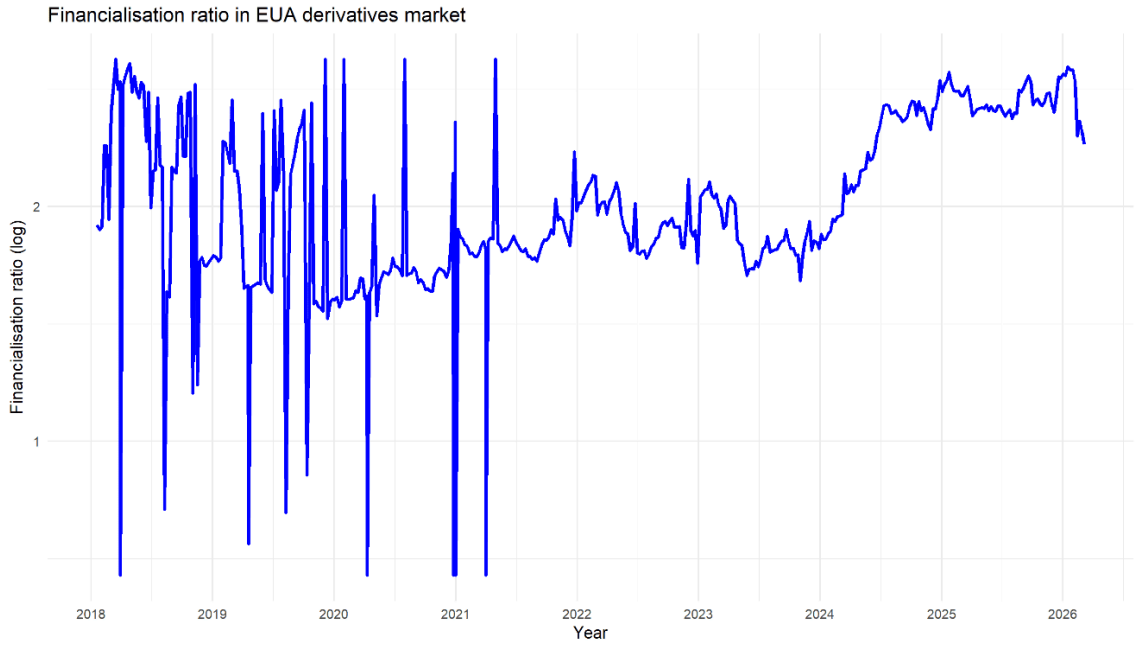


Figure 4. Financialisation index in the EUA derivatives market (2021–2026).

Source: Authors' calculations based on ICE Commitments of Traders data. Note: logarithm of the ratio of gross financial positions to gross compliance positions.

4.4. Determinants of EUA futures prices

The estimation of the four models on 272 weekly observations provides a consistent picture. In Model 1, net financial positioning is included with a positive coefficient (0.000082, t = 8.74) that is significant at the 1% level, with R^2 = 0.221. Periods characterised by higher net financial exposure tend to coincide with higher carbon prices (Table 2; Figure 5), reflecting the joint response of both variables to shared expectations regarding future scarcity and market conditions. In Model 2, the coefficient for net financial positioning remains positive and statistically significant (0.000061, t = 5.92) but of reduced magnitude, whilst net compliance positioning is negative (-0.000028, t = -1.91), in line with the interpretation that regulated entities use derivatives primarily to hedge future allowance requirements rather than for speculative directional demand; R^2 rises to 0.264.

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Figure 5. Short-term ICE EUA futures price (2021–2026, EUR/tCO_2).

Source: Authors' calculations based on ICE EUA futures data.

Variable	Model 1 (OLS)	Model 2 (OLS)	Model 3 (OLS)	Model 3 (HAC)
fin_net	0.000082*** (8.74)	0.000061*** (5.92)	0.000019* (1.94)	0.000019
comp_net	—	-0.000028* (-1.91)	-0.000011 (-0.88)	-0.000011
fut_slope	—	—	7.84*** (11.63)	7.84***
Constant	66.41***	68.22***	41.73***	41.73***
Observations	272	272	260	260
R^2	0.221	0.264	0.598	0.598

Table 2. Determinants of EUA futures prices (weekly, 2021–2026)

*Source: Authors. t-statistics in brackets. *** p<0.01, ** p<0.05, * p<0.10.*

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Model 3 represents the key empirical result. The inclusion of the slope of the forward curve substantially increases the explanatory power, with R^2 rising from 0.264 to 0.598 (260 observations). The coefficient associated with fut_slope is large, positive and highly significant (7.84, t = 11.63) in both OLS and HAC estimations. This indicates that current EUA prices are strongly associated with the market's assessment of tighter future scarcity conditions embedded in the futures curve (Figures 6 and 7), in line with the interpretation of EUAs as forward-looking assets, whose price reflects expected future regulatory scarcity[16] (Osorio et al., 2021). The coefficient relating to net financial positioning becomes smaller (0.000019, t = 1.94) and loses robustness once HAC corrections are applied, suggesting that part of the previous association between positioning and prices reflects expectations already priced into the forward structure of futures prices. Compliance positioning also becomes statistically weaker once the slope is introduced, reinforcing the idea that direct hedging demand alone does not fully explain price levels. Beyond statistical significance, the magnitude of the slope coefficient is economically meaningful: since fut_slope is expressed as the relative spread between second-year and current-year contracts, the estimate of 7.84 implies that a one-percentage-point increase in the forward curve slope is associated with an increase in the current-year price of approximately €0.08 per tonne, so that the moderate change in the curve slope observed over the 2021–2026 period translates into price differences of several euros per tonne. The near doubling of the explanatory power, from an R^2 of 0.26 to 0.60, further indicates that the forward slope captures a primary, rather than marginal, dimension of price formation.

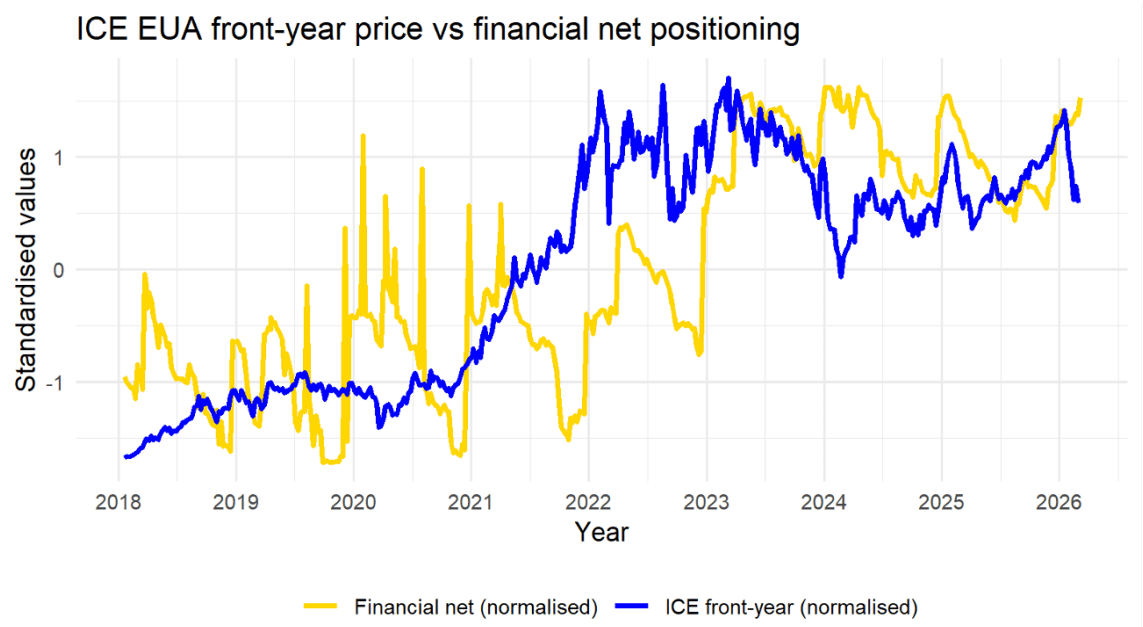


Figure 6. EUA allowance price and net financial positioning (normalised, 2021–2026).

Source: Authors' calculations based on ICE EUA futures and ICE Commitments of Traders data.

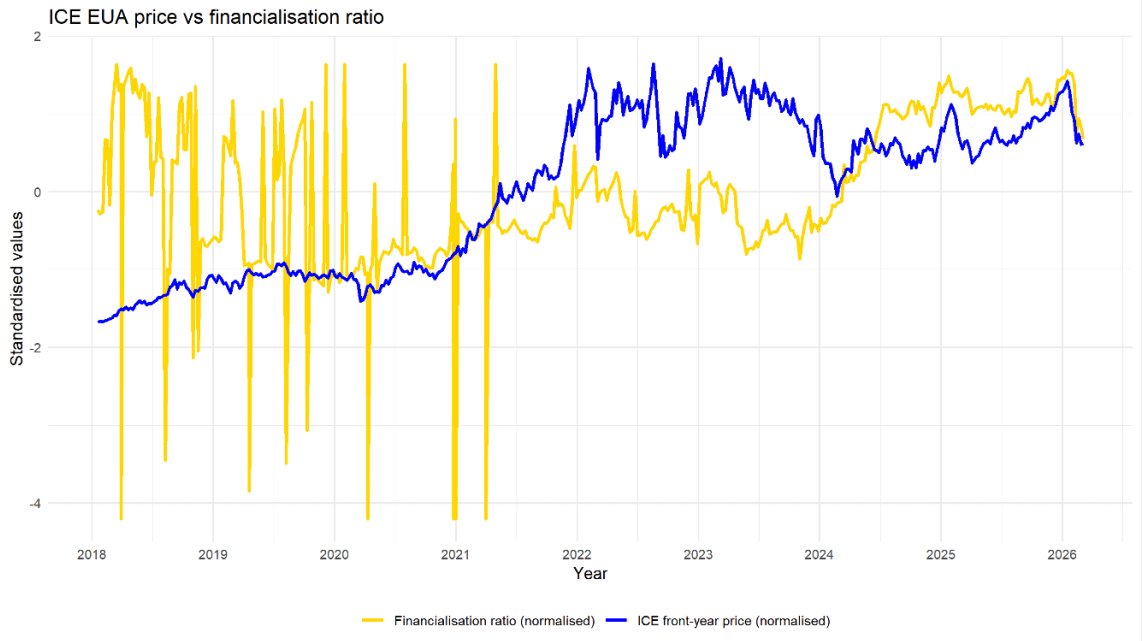


Figure 7. EUA allowance price and financialisation index (normalised, 2021–2026).

Source: Authors' own calculations based on ICE EUA futures and ICE Commitments of Traders data.

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4.5. Underlying dynamics and risk premium

The basis specification (Model 4) isolates the risk premium component in carbon price formation. It was found that the basis is systematically associated with market positioning and forward-looking indicators, suggesting that a non-negligible component of observed carbon prices may reflect risk assessment rather than merely current compliance demand. This does not imply market inefficiency: it is consistent with the functioning of a financially intermediated market in which risk premiums emerge endogenously as part of normal price formation. However, it implies that the actual cost of carbon borne by firms may include, in addition to the regulatory scarcity signal, a component linked to intertemporal risk assessment and market conditions. From a policy perspective, this distinction is relevant when interpreting short- and medium-term variations in the carbon price (Figure 8; Table 3), as changes in risk premiums can amplify or attenuate the transmission of regulatory scarcity signals to industrial operators.

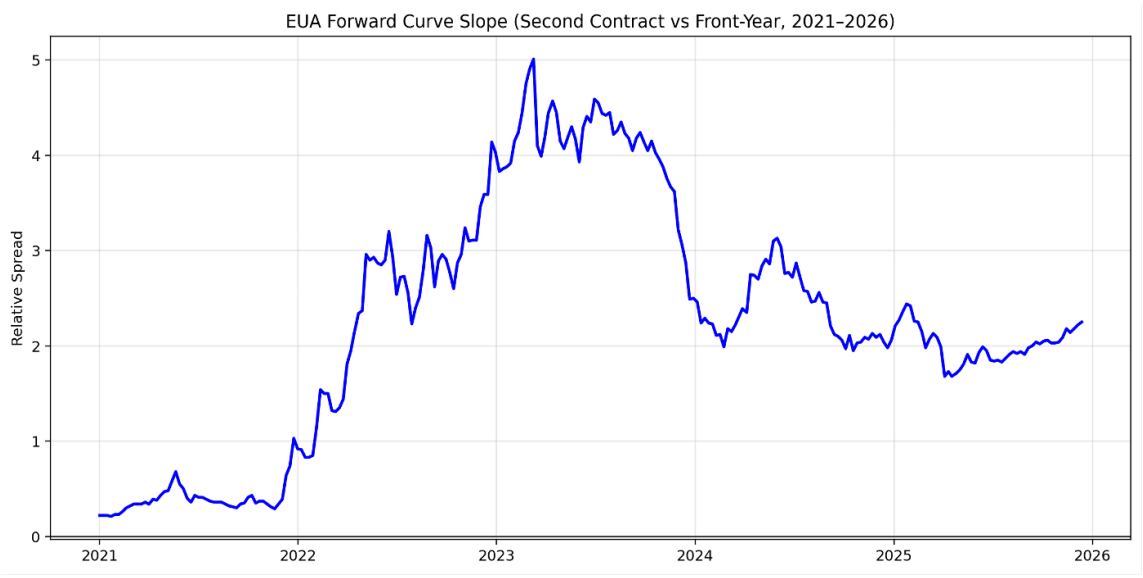


Figure 2. Slope of the EUA forward curve (second contract relative to the base year, 2021–2026)

Source: Authors' calculations based on ICE EUA futures data.

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Variable	Model 4 (OLS)	Model 4 (HAC)
fin_net	0.000021*** (4.12)	0.000021***
comp_net	−0.000009 (−1.21)	−0.000009
Constant	3.87***	3.87***
Observations	431	431
R^2	0.18	0.18

Table 3. Determinants of the EUA basis (risk premium)

*Source: Authors. t-statistics in brackets. *** p<0.01, ** p<0.05, * p<0.10.*

In conclusion, the evidence shows that the regulatory scarcity in the EU ETS is reflected in the carbon prices observed over the period 2021–2026. Three findings stand out. Firstly, the descriptive analysis reveals a structurally financialised market: financial intermediaries dominate gross positions in derivatives and are net sellers, while regulated entities are net buyers, and the financialisation ratio remains consistently above one. Secondly, the slope of the forward curve is the dominant determinant of EUA price levels, increasing the explanatory power of the pricing model. Thirdly, the spot-futures spread is systematically associated with net financial positioning, consistent with an intertemporal risk premium.

5. Discussion

Our three central findings, the dominant role of the futures-curve slope in explaining EUA price levels, a financialisation ratio that remains above unity across the entire sample, and a spot-futures basis systematically correlated with net financial positioning-engage two strands of the literature, confirming some expectations while qualifying others. The first is the theory of intertemporal allowance markets, according to which, when allowances can be freely accumulated, equilibrium prices reflect the present value of expected future scarcity rather than merely current compliance demand. The predominance of the forward slope provides direct empirical support for this thesis during periods of high prices and is consistent with the evidence that EUA prices respond strongly to anticipated changes in long-term

scarcity and to the calibration of the Market Stability Reserve (Osorio et al., 2021), a sensitivity that regulators have also highlighted[41]. The second is the tradition of commodity futures, which provides the framework for interpreting the basis. Fama and French[23] establish that a futures price combines an expected future spot price with a risk premium; Gorton et al.[24] link this premium to inventory conditions; and the literature on financialisation shows that the entry of cross-market investors reshapes premiums and correlations[25] and alters the returns obtained by futures investors[26]. The systematic association between the EUA basis and financial positioning documented here is precisely what this theoretical framework predicts when a regulated, fixed-supply asset becomes the subject of financial intermediation, and it is the point at which the two strands of literature converge.

We argue that the EU ETS can no longer be interpreted exclusively as a static compliance mechanism, given that carbon price formation increasingly depends on the interaction between cap setting, expectations regarding future scarcity, liquidity conditions, hedging demand and the resilience of the financial architecture through which exposure to carbon risk is transmitted over time. The added value of our study lies in providing a coherent econometric framework that explicitly models the role of the futures curve slope alongside financial and compliance positioning, allowing for a direct empirical test of the relative importance of forward-looking expectations and the contemporary market structure in determining observed EUA allowance price levels.

A substantial body of early and mid-stage work attributes movements in EUA prices primarily to contemporary fundamentals, fuel switching, electricity and gas prices, weather conditions and industrial production, rather than to anticipated future scarcity[18][5][42]. More recently, the debate has been explicitly framed as fundamentals versus market sentiment, attributing most of the variability in EUA prices jointly to carbon policy and financial factors, with the economic cycle and emissions intensity playing a marginal role[43] or by interpreting high carbon prices as a signal of policy credibility and forward-looking, future-oriented behaviour[1]. Three considerations help to reconcile the present results with the line of thinking that sees fundamentals as predominant. Firstly, the sample period (2021–2026) follows the 2018 reform of the Market Stability Reserve, following which the credibility of the long-term cap increased significantly, making expectations of future scarcity more relevant to price determination than in the Phase II and early Phase III samples—dominated by surplus—used by much of the previous literature. Secondly, the specification used here allows the forward slope to compete directly with positioning variables within a single nested model, whereas studies reporting the dominance of fundamentals typically omit the term structure, which may absorb the explanatory role otherwise

attributed to spot fundamentals. Thirdly, the financialisation indicator measures gross intermediation rather than directional speculative pressure; this is consistent with the evidence that speculative activity is concentrated in the shortest-term contract, whilst hedging is concentrated in the next delivery contract[44], meaning that the indicator and measures of directional speculation capture different phenomena. Placing the results within this active and unresolved debate strengthens, rather than weakens, the contribution of this paper.

The findings of this paper contribute to the literature. Firstly, the documentation of the dominant role of the futures curve slope in explaining EUA price levels, with R^2 rising from 0.26 to 0.60 once the slope is introduced and the coefficient remaining significant according to HAC inference, provides direct empirical support for the interpretation of EUAs as intertemporal, future-oriented asset prices, anchored to expectations of future cumulative scarcity rather than merely contemporary compliance demand. This complements and extends the analytical contributions of Koch et al.[20] on the causes of the decline in EU ETS prices and Perino et al.[22] on the interaction between overlapping climate policies and the ETS price.

Secondly, the documentation of a persistent financialisation ratio greater than one over the 2021–2026 period contributes to the empirical literature on the financialisation of carbon markets, which had previously documented the growing role of investment funds and credit institutions in EUA derivatives markets[31][32] but had rarely provided a synthetic time-series indicator capable of summarising the structural pattern over a multi-year horizon. The added value lies in the construction of a transparent and replicable indicator that can be monitored over time to track the evolution of the balance between hedging demand and intermediaries' risk-bearing capacity. This perspective is particularly relevant for ESMA, ACER and national regulators within the broader REMIT and MiFID II supervisory framework[41].

Furthermore, interpreting the spread as an indicator of the intertemporal risk premium in EUA forward prices contributes to the broader literature on derivatives markets and asset pricing[37][38], by applying the standard theoretical framework of holding costs and risk premiums to a regulated asset whose supply is determined exogenously. The empirical finding that the basis is systematically associated with market positioning and forward-looking indicators suggests that a non-negligible component of observed carbon prices may reflect risk assessment rather than merely current compliance demand. This has direct implications for the calibration of the Market Stability Reserve: as the MSR increasingly influences not only the scarcity of allowances per se, but also the dynamics of forward price determination, liquidity conditions and intertemporal market expectations, its calibration becomes increasingly central to the credibility of long-term carbon price signals. The European Commission's 2026 proposal amending

Decision (EU) 2015/1814 confirms that approximately 3.2 billion allowances have already been invalidated and proposes to discontinue the invalidation mechanism in order to preserve a larger reserve as a liquidity buffer, a policy stance consistent with the evidence presented in this paper regarding the increasingly intertemporal and financially intermediated nature of carbon price formation.

A further issue concerns the interpretation of the persistent financialisation ratio exceeding unity. A high ratio does not necessarily, in itself, indicate excessive speculation: it is consistent with the fact that intermediaries manage largely netting accounts and perform the functions of liquidity provision and price discovery on which compliance hedging depends. At the same time, the literature warns that, as stricter limits attract investors and funds into the allowance markets, financial participation may shift from stabilising intermediation towards destabilising speculation, with negative effects on price formation and market functioning[2]. The data available here do not allow a decision to be made between these two interpretations, as the indicator measures gross intermediation rather than directional pressure; what it does establish is that the structural weight of financial participation is substantial and persistent, which is precisely the condition under which the monitoring tools advocated in that literature become relevant. This reinforces, rather than contradicts, the document's policy argument that monitoring the balance between compliance and finance should be integrated into routine market supervision.

These interpretative points have concrete consequences in terms of governance. The following section translates them into policy implications for the next reform cycle, focusing on the credibility of the long-term scarcity trajectory, the predictability of the governance of the Market Stability Reserve, the resilience of forward market liquidity, and the monitoring of the balance between compliance and finance.

5.1. Implications of the CBAM

This subsection discusses the implications of the Carbon Border Adjustment Mechanism (CBAM) for the functioning of the primary and secondary EUA markets, considering how the integration of operators covered by the CBAM may reshape the demand for hedging and the structural role of the futures markets. The implementation of the CBAM pursuant to Regulation (EU) 2023/956 introduces a significant new structural dimension to the functioning of the primary and secondary markets for EUAs. By aligning the carbon costs borne by certain importers of goods covered by the CBAM with the price of EUAs applicable to EU producers, the mechanism progressively integrates non-EU emitters into the European carbon

pricing framework and substantially expands the pool of economic actors directly exposed to the pricing of EUAs. The integration of CBAM operators into the derivatives market is expected to broaden the scope of compliance-related hedging demand, increase forward hedging requirements and strengthen the structural role of the secondary market as the primary channel for carbon pricing and risk transfer. At the same time, the practical effectiveness of CBAM as a carbon pricing instrument depends crucially on the resilience of futures markets, the depth of forward liquidity, and the ability of the broader market architecture to absorb additional hedging demand without amplifying intertemporal volatility. In conclusion, a market in which financial intermediation is structurally extensive, price levels are governed by the forward curve, and the basis carries an intermediation premium. The following section interprets these results in the light of the theoretical and empirical literature and draws implications for how carbon pricing should be understood.

5.2. Future work

The results must be interpreted in light of certain limitations that suggest interesting directions for future research. Prices, market participants' positioning and the structure of the forward curve are in fact determined jointly and influenced by common market expectations. Future research could therefore employ more advanced causal identification strategies, such as quasi-experimental approaches, instrumental variables or exogenous policy shocks. Secondly, classifying market participants into the aggregate categories of 'financial' and 'compliance participants' ensures consistency with the available data and interpretative simplicity, but does not allow for the heterogeneity within individual groups to be captured. Future studies could benefit from more granular data, capable of distinguishing between different types of financial intermediaries, utilities and industrial operators, in order to analyse their behaviour and hedging strategies more precisely. Finally, differences in sample size across the various empirical specifications, due to the availability of information for certain variables, suggest caution when directly comparing results. A future extension could focus on constructing more comprehensive and harmonised datasets, allowing for further robustness checks and greater comparability between the different analyses.

5.3. Limitations of the study

The limitations of our study lie in the fact that the econometric specifications are of a reduced form: they identify statistically robust associations within a transparent framework, but should not be interpreted as causal estimates, since prices, positioning and forward slopes are determined jointly and respond to

common expectations[19][45]. Secondly, the taxonomy of participants groups heterogeneous actors into the categories ‘financial’ and ‘compliance’; this is manageable and consistent with disclosure data, but masks the heterogeneity within the categories, so the interpretation of the net position should be considered indicative of average behaviour rather than that of a single type of actor[11]. Thirdly, the differing actual sample sizes across the various specifications (in particular the larger base sample) reflect data availability and should be explicitly reconciled, as noted.

6. Policy implications

Our findings have direct implications for the governance of the EU ETS. The finding that the slope of the futures curve is the dominant explanatory variable for EUA price levels suggests that current carbon prices are anchored to expectations of future cumulative scarcity through intertemporal arbitrage rather than to contemporary compliance demand alone. The complementary finding that financial operators consistently account for the largest share of gross positions, whilst compliance entities remain predominantly in a net long position, indicates that the European carbon market now operates as a financially mediated price-setting system in which the credibility of long-term regulatory signals, the depth of forward liquidity and the resilience of the market architecture jointly determine the effectiveness of the carbon price signal transmitted to industrial operators. The calibration of the MSR has therefore become a key determinant of expectations regarding future scarcity, and not merely a tool for absorbing the structural surplus of allowances: changes in entry and exit thresholds, the percentage rule, the cancellation mechanism or the reserve cap can be transmitted to spot prices via the forward structure of futures contracts, suggesting that predictability in the governance of the MSR may play an important role in preserving the anchoring function of the futures markets.

This gives rise to three further implications.

- The persistence of a financialisation ratio greater than one across the entire 2021–2026 sample suggests that the European supervisory architecture built around MAR, MiFID II and REMIT continues to evolve in a manner consistent with the structural role that financial operators now play, including through the integration of synthetic indicators of the balance between compliance and finance into the periodic supervisory reporting of ESMA and ACER.
- The gradual integration of operators covered by the CBAM pursuant to Regulation (EU) 2023/956 is likely to expand the population of economic actors directly exposed to EUA price formation, and the

effectiveness of the new mechanism will depend on the capacity of the current futures market architecture to absorb the additional demand for hedging without amplifying intertemporal volatility or fragmenting market access for smaller importers.

- Consistency between the EU ETS, the new ETS2 covering buildings and road transport, and the broader set of complementary climate policy instruments has a substantial influence on the credibility of the long-term price signal, as empirical evidence indicates that EUA allowance prices are particularly sensitive to expectations of future scarcity and the predictability of the broader policy mix.

Therefore, the effectiveness of the EU ETS depends not only on the absolute level of the carbon price or the structure of the cap, but also on the credibility of the long-term scarcity trajectory, the resilience of the financial architecture through which carbon price risk is intermediated, and the consistency of the broader policy mix that shapes expectations.

7. Conclusion

We have examined how regulatory scarcity within the EU ETS translates into observed carbon prices through the interaction between primary auctions and secondary spot and derivatives markets over the period 2021–2026, combining descriptive evidence on participants' positioning with four reduced-form econometric specifications linking EUA prices and the current-year spot basis to net financial and compliance positions and the slope of the futures curve. The main finding is that the slope of the futures curve is the dominant explanatory variable for EUA price levels, increasing R^2 from 0.26 to 0.60 once included and remaining significant under HAC inference, whilst financial operators account for a dominant share of gross positions and compliance entities remain predominantly net long. Evidence suggest that the EU ETS increasingly exhibits the economic characteristics of a regulated intertemporal asset pricing framework, in which current carbon prices are determined jointly by expectations of future scarcity, hedging demand, financial intermediation and the structure of forward markets. Therefore, it should no longer be analysed as a contemporary compliance mechanism in which prices reflect current demand for emissions relative to a fixed cap. This interpretation has broader implications: the effectiveness of carbon pricing depends on the formal structure of the cap and on the credibility, liquidity and institutional resilience of the market architecture through which regulated scarcity is reflected in observed prices.

The key policy implication follows directly: because the carbon price is increasingly governed by expectations and by the forward-market architecture rather than by contemporaneous compliance demand alone, safeguarding the effectiveness of the EU ETS requires policymakers to protect the credibility of the long-term cap trajectory, to make Market Stability Reserve interventions rule-based and predictable, and to monitor the liquidity and resilience of the derivatives market through which carbon-price risk is intermediated, priorities that become more pressing as the free-allocation phase-out and CBAM draw additional compliance actors into forward hedging.

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Declarations

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.