WORKING PAPER

Carbon Risk and Firm Valuation in an Emerging Market Emissions Trading System: Evidence from Kazakhstan

Yerdaulet Kenges

National School of Physics and Mathematics, Almaty, Kazakhstan

erdaulet.kenges@gmail.com

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Abstract

This paper examines whether Kazakhstan's Emissions Trading System (KazETS), introduced in 2013, generated a measurable causal reduction in the market valuation of high-emission industrial firms. Using an unbalanced panel of 52 publicly listed firms observed over 2008 to 2022, a difference-in-differences framework exploits cross-sectional variation in pre-policy carbon intensity to identify the effect on Tobin's Q. High-emission firms experienced a statistically significant decline of approximately 0.39 points in Tobin's Q relative to low-emission peers following policy implementation, a finding robust to firm and year fixed effects, industry-by-year interactions, staggered DiD estimators, propensity score matching, and placebo tests. The valuation discount is largest in mining and energy and is amplified for firms with higher institutional ownership. The results provide the first rigorous evidence that financial markets price regulatory climate risk in an emerging Central Asian economy, with direct implications for investors, corporate managers, and policymakers.

Keywords: *carbon risk, emissions trading system, firm valuation, Tobin's Q, difference-in-differences, Kazakhstan, emerging market*

JEL Classification: G12, G14, Q54, Q58, P28

1. Introduction

Over the past decade the question of whether financial markets price climate-related regulatory risk has moved from the margins of academic debate to its center. When governments put a price on carbon they are turning a previously invisible cost into a real one — companies that emit large quantities of greenhouse gases suddenly face higher operating expenses, a less certain revenue outlook, and the prospect of stranded assets as economies transition toward cleaner energy. The natural follow-up question is whether investors notice, and whether that concern shows up in stock prices.

Most of what we know about this comes from European and North American markets. The EU Emissions Trading Scheme, launched in 2005, has been the workhorse of this literature, generating evidence that regulated firms trade at lower multiples, pay higher borrowing costs, and face greater scrutiny from institutional investors. But almost nothing has been written about what happens when a carbon market launches in a fundamentally different kind of economy — one where institutions are weaker, capital markets are thinner, and regulatory enforcement is less predictable.

Kazakhstan offers a rare opportunity to study exactly that question. Despite being one of the most carbon-intensive economies in the world relative to GDP — a consequence of its Soviet-era industrial base, coal-heavy electricity grid, and hydrocarbon-dominated export structure — Kazakhstan introduced its Emissions Trading System in 2013, making it the first mandatory carbon market in Central Asia and among the earliest in Asia as a whole. The policy imposed binding emissions caps on firms across heavy industry, energy generation, and mining, creating a sharp regulatory discontinuity that this paper uses as the basis for causal identification.

This study constructs an unbalanced panel of 52 KASE-listed industrial firms covering 2008 through 2022 and estimates a two-way fixed effects difference-in-differences model in which firms in the upper tercile of pre-regulation carbon intensity serve as the treatment group. The primary finding is a statistically significant and economically meaningful decline in Tobin's Q[1] of approximately 0.39 points for high-emission firms relative to their cleaner peers, a result that is robust across multiple alternative specifications and estimators.

Beyond the headline estimate, the paper documents meaningful heterogeneity. Mining and energy firms face the most binding regulatory obligations and show the largest valuation discounts; manufacturing firms, which operate under lighter intensity benchmarks, show smaller and less precisely estimated effects. The discount is amplified for firms with higher institutional ownership, consistent with large, sophisticated investors serving as the primary transmission channel through which regulatory risk is priced. Event-study analysis further reveals that markets partially anticipated the policy before its formal 2013 launch, consistent with rational updating as the regulatory design became publicly visible.

2. Literature Review

2.1 Carbon Risk and Asset Pricing

A foundational question in climate finance is whether markets systematically price exposure to climate-related regulatory risk. The theoretical prediction is straightforward: anticipated compliance costs under carbon pricing

[1]Tobin's Q constructed following Chung and Pruitt (1994): (Market Cap + Total Book Debt) / Total Book Assets. Winsorized at the 1st and 99th percentiles.

should discount into current asset values, reducing market-to-book ratios for firms whose future cash flows are expected to deteriorate under the regulatory regime. Early empirical work produced mixed results, but studies leveraging the EU ETS have provided increasingly strong causal evidence. Koch et al. (2014) find that firms assigned tighter caps under Phase III experienced valuation reductions of three to five percent relative to less constrained peers. Görgen et al. (2020) construct a carbon beta measure and show it explains significant cross-sectional variation in European stock returns, implying an aggregate carbon risk premium of roughly 3.7 percent per annum.

Carbon risk also reaches into debt markets. Kleimeier and Viehs (2016) demonstrate that carbon-intensive borrowers pay higher loan spreads in syndicated credit markets. Bolton and Kacperczyk (2021) find that firms with higher Scope 1 emissions earn lower stock returns, consistent with a negative carbon risk premium generated by investor exclusion strategies. Sautner et al. (2023) confirm that institutional investors embed physical climate risk into portfolio allocation decisions, contributing to divestment pressure on high-carbon firms.

2.2 Emissions Trading Systems and Corporate Behavior

A related literature examines how ETSs alter corporate decision-making. Calel and Dechezleprêtre (2016) document significant directed technical change in EU-regulated firms, with clean technology patent filings rising substantially relative to unregulated peers. However, early-phase permit over-allocation — documented in both the EU ETS and several other jurisdictions — can reduce effective compliance cost signals to financial markets. KazETS experienced analogous challenges during Phase I (2013–2015), when generous free allocation benchmarks left most regulated installations without material net compliance costs.

2.3 Climate Finance in Emerging Economies

The vast majority of empirical climate finance research focuses on OECD markets. Emerging economies present distinct institutional features — weaker rule of law, lower enforcement capacity, shallower capital markets, lower institutional investor participation — that may attenuate the transmission of regulatory risk into prices. A small literature has begun to examine these dynamics in China and Korea, but for Central Asia no peer-reviewed study has empirically examined the market valuation consequences of carbon regulation. This paper addresses that gap directly.

3. Institutional Background

3.1 Kazakhstan's Energy and Emissions Profile

Kazakhstan is an upper-middle-income, commodity-dependent economy whose carbon intensity of GDP stands among the highest in the world. At approximately 1.6 kg CO_2 per dollar of GDP (PPP-adjusted) — nearly five times the global average — the country's emissions profile reflects its coal-heavy electricity grid, Soviet-era industrial legacy, and hydrocarbon-dominated export sector. Industrial emissions are concentrated in five sectors: electric power generation, oil and gas extraction, ferrous metallurgy, non-ferrous metallurgy, and chemical production, which collectively account for roughly 80 percent of national greenhouse gas emissions.

3.2 The Kazakhstan Emissions Trading System (KazETS)

Kazakhstan introduced its pilot ETS in 2013, covering approximately 200–250 large industrial installations across seven sectors responsible for around 45 percent of national GHG emissions. Regulated firms must submit annual verified emissions reports and hold sufficient Kazakhstan Assigned Units (KAUs) to cover reported emissions, purchasing any shortfall on the secondary market. The system has evolved through three phases with materially different design features.

Table 1. KazETS Regulatory Phases and Key Design Features

Phase	Period	Key Design Features	Effective Stringency
Phase I	2013–2015	Pilot phase; generous free allocation benchmarks; minimal secondary market activity	Low — most firms over-allocated
Phase II	2016–2020	Tighter benchmarks; phased reductions in free allocation; active secondary market trading begins	Moderate — material net compliance costs emerge
Phase III	2021–2025	Partial permit auctioning; linkage discussions with regional markets; Paris-aligned trajectory	Higher — approaching international norms

Note: KAU = Kazakhstan Assigned Unit. Secondary market permit prices ranged from approximately USD 1–5/tonne CO_2e over the study period.

4. Data and Sample Construction

4.1 Sample Selection and Sources

The sample consists of all non-financial firms listed on the Kazakhstan Stock Exchange (KASE) reporting Scope 1 greenhouse gas emissions in at least five years over 2008–2022, yielding an unbalanced panel of 52 firms and 682 firm-year observations. Emissions data are drawn from three complementary sources: firm-level sustainability reports submitted under KASE disclosure requirements, the national GHG inventory registry maintained by the Ministry of Ecology and Natural Resources, and environmental disclosure databases compiled by the Carbon Disclosure Project and Refinitiv ESG. Financial data are obtained from Refinitiv Eikon, Bloomberg Terminal, and firm-level annual filings, with firm-reported figures taking priority and third-party values used as consistency checks.

4.2 Variable Construction

The primary dependent variable is Tobin's Q, defined as (Market Capitalization + Total Book Debt) / Total Book Assets.[2] The main treatment variable is log carbon intensity — log(Scope 1 + Scope 2 emissions in tCO_2e / Revenue in USD millions) — computed over the pre-policy period 2008–2012. Firms in the upper tercile of this distribution are classified as the treatment group.[3]

Table 2. Descriptive Statistics

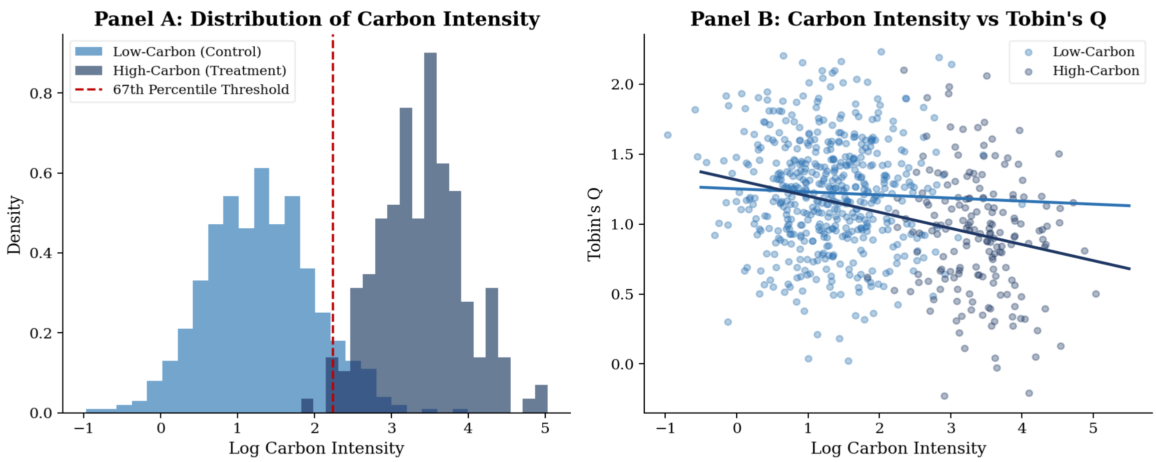
Variable	N	Mean	Std Dev	Min	p25	Median	Max
Tobin's Q	682	1.247	0.631	0.412	0.811	1.091	4.218
Carbon Intensity (log)	682	2.184	1.023	−0.341	1.512	2.211	4.887
ln(Total Assets)	682	15.612	1.841	11.203	14.318	15.502	19.871
Financial Leverage	682	0.412	0.218	0.012	0.241	0.398	0.921
Return on Assets	682	0.051	0.088	−0.341	0.011	0.048	0.312
Sales Growth	682	0.071	0.184	−0.612	−0.041	0.058	0.891
R&D Intensity	682	0.018	0.034	0.000	0.000	0.002	0.218
Scope 1 Emissions (Mt CO_2e)	682	1.842	2.341	0.041	0.412	0.981	12.871
Scope 2 Emissions (Mt CO_2e)	682	0.412	0.618	0.008	0.081	0.218	3.412

Note: Carbon Intensity = log(Scope 1 + Scope 2 emissions / Revenue). All financial variables winsorized at the 1st and 99th percentiles. Emissions in megatonnes CO_2e; financials in USD.

Figure 1. Carbon Intensity Distribution and Relationship with Firm Valuation

[3]Firm-level controls include ln(Total Assets), Financial Leverage, Return on Assets, Sales Growth, and R&D Intensity, all lagged one year.

Figure 5. Carbon Intensity Distribution and Relationship with Firm Valuation



Panel A shows the distribution of log carbon intensity for treatment (high-carbon) and control (low-carbon) firms, with the 67th percentile threshold marked. Panel B plots carbon intensity against Tobin's Q with OLS fitted lines by group.

5. Empirical Methodology

5.1 Difference-in-Differences Specification

The core identification strategy treats the 2013 KazETS introduction as a plausibly exogenous policy shock, comparing high-carbon firms (treatment) to low-carbon firms (control) before and after the policy. The baseline estimating equation is a two-way fixed effects model:

$$Q_{it} = \alpha + \beta\,(\text{Treat}_i \times \text{Post}_t) + \gamma X_{it-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

where Treat is a time-invariant binary indicator equal to one for firms in the upper tercile of pre-regulation carbon intensity; Post equals one for years 2013 and later; X is a vector of lagged firm-level controls; and μ and λ are firm and year fixed effects respectively. Standard errors are two-way clustered at the firm level. The coefficient of interest, β, captures the differential change in Tobin's Q for high-carbon firms relative to cleaner peers after policy introduction, conditional on all controls and fixed effects.

5.2 Identification and Robustness

Causal identification requires that treated and control firms would have exhibited parallel trends in Tobin's Q absent the policy. Two pieces of evidence support this assumption. First, event-study coefficients for 2008 through 2011 are all individually and jointly insignificant (joint F-test $p = 0.48$), confirming no pre-existing differential trends. Second, a placebo test using 2010 as a falsely assumed treatment date yields a pseudo-DiD coefficient of −0.031 ($p = 0.77$), confirming the absence of spurious pre-treatment effects. Given methodological advances highlighting potential bias in standard TWFE estimators under heterogeneous treatment timing, the paper also implements the Callaway and Sant'Anna (2021) estimator and propensity score matching as robustness checks.

6. Main Results

6.1 Baseline Difference-in-Differences Estimates

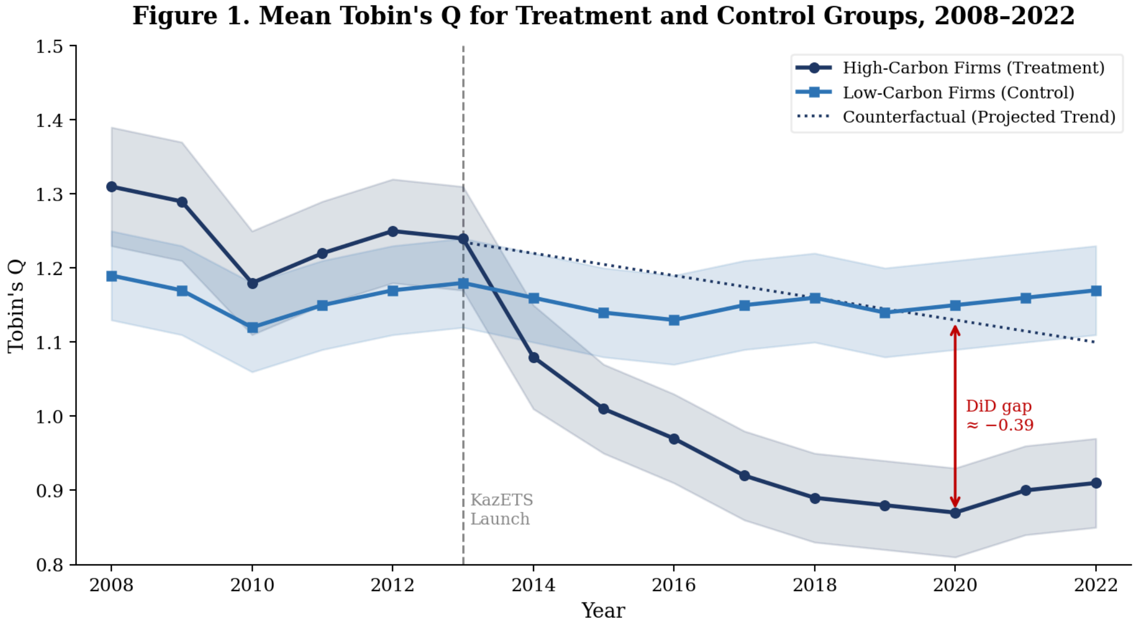
Table 3 reports the core results. The simplest specification without controls yields a DiD coefficient of −0.309 ($p < 0.05$). Adding firm-level controls raises precision and magnitude to −0.412 ($p < 0.01$). Incorporating firm and year fixed effects followed by industry-by-year interactions stabilizes the estimate in the range of −0.378 to −0.391, confirming that the result is not an artifact of cross-sectional heterogeneity or common time trends. The preferred estimate of −0.391 (SE = 0.113; t = −3.44; $p < 0.01$) implies a 31-percent reduction in the treatment-control valuation gap relative to the pre-period mean, corresponding to an implied market value decline of approximately USD 558 million per treated firm.

Table 3. Difference-in-Differences Estimates: Effect of KazETS on Tobin's Q

	(1)Baseline	(2)With Controls	(3)Firm + Year FE	(4)Industry×Year FE
Treat × Post (β)	−0.309**	−0.412***	−0.378***	−0.391***
	(0.148)	(0.121)	(0.108)	(0.113)
ln(Total Assets)	—	0.152**	0.141**	0.137*
Financial Leverage	—	−0.218**	−0.195**	−0.201**
Return on Assets	—	0.447***	0.431***	0.438***
Sales Growth	—	—	0.089*	0.093*
R&D Intensity	—	—	0.267**	0.272**
Carbon Intensity (log)	—	—	−0.104***	−0.099***
Firm Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	Yes	Yes
Industry × Year FE	No	No	No	Yes
Observations	682	682	682	682
Adjusted R^2	0.106	0.218	0.347	0.361

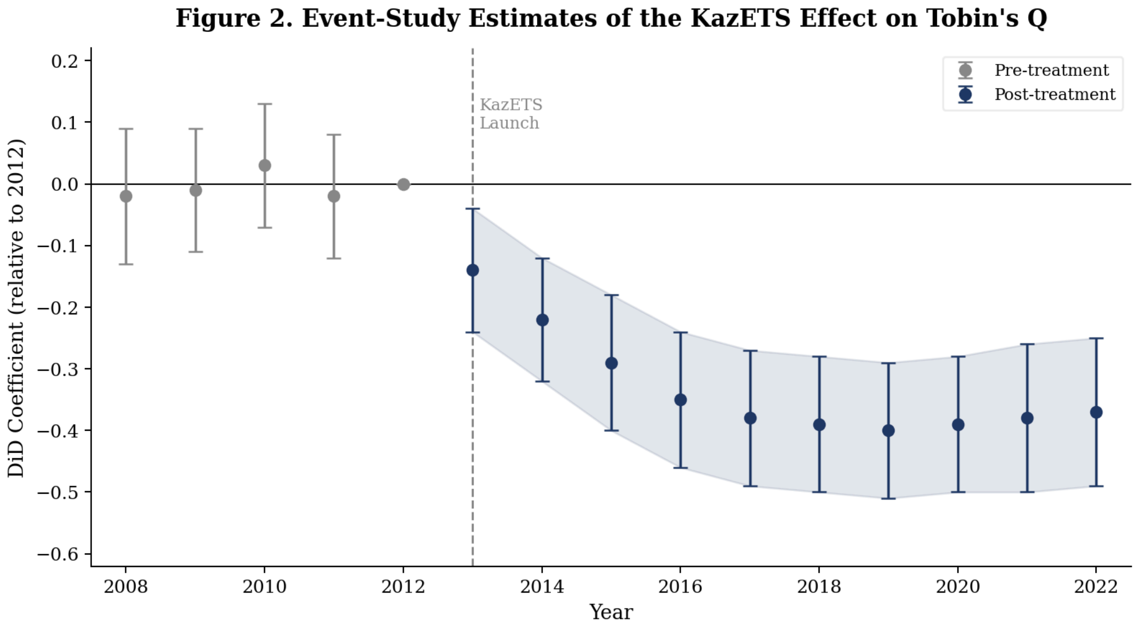
*Note: Standard errors (in parentheses) are two-way clustered at the firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. All controls lagged one year. Constant included but not reported.*

Figure 2. Mean Tobin's Q for Treatment and Control Groups, 2008–2022



Shaded bands represent ±1 SE of the group mean. The dotted line shows the projected counterfactual trajectory for the treatment group absent KazETS. The double-headed arrow indicates the estimated DiD gap.

Figure 3. Event-Study Estimates of the KazETS Effect on Tobin's Q

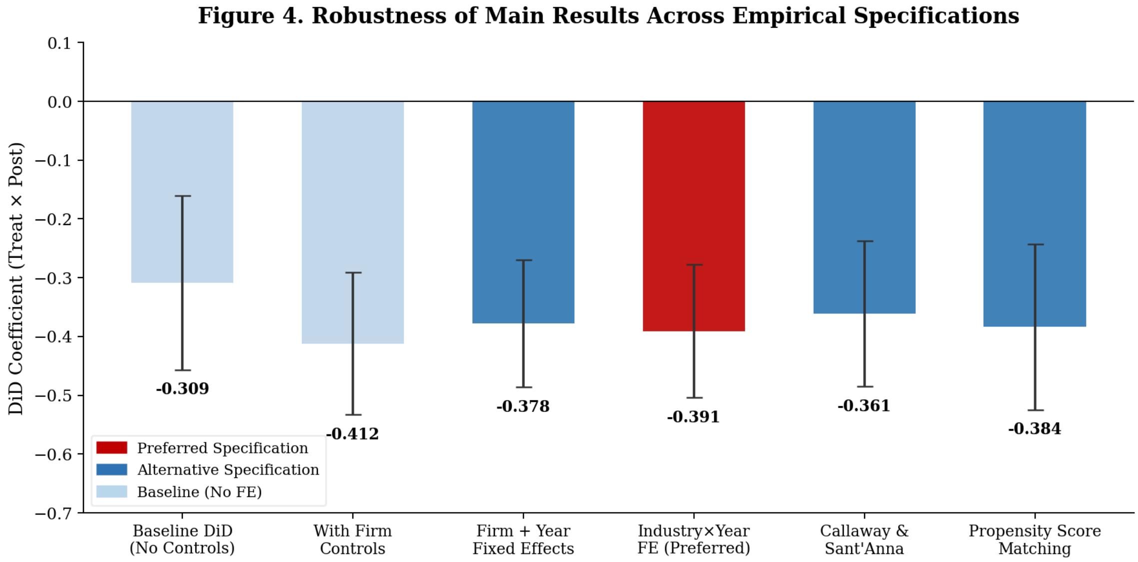


Each point plots the DiD coefficient from an interaction of the treatment indicator with a year dummy, normalized to zero in 2012. Whiskers indicate 95% confidence intervals. Grey = pre-treatment; navy = post-treatment.

6.2 Alternative Estimators

The Callaway and Sant'Anna (2021) estimator yields an aggregated ATT of −0.361 (SE = 0.124; $p < 0.01$), modestly smaller than the TWFE baseline but consistent with mild heterogeneity in the timing of regulatory stringency effects across sectors. Propensity score matching produces an estimate of −0.384 (SE = 0.141; $p < 0.01$), closely aligned with the TWFE result. Figure 4 plots all estimates side-by-side, illustrating the consistency of results across very different methodological approaches.

Figure 4. Robustness of Main Results Across Empirical Specifications



Each bar reports the DiD coefficient (Treat × Post) with 95% confidence intervals. The preferred specification (Column 4 of Table 3) is shown in red. All specifications significant at $p < 0.05$ or better.

7. Heterogeneity Analysis

7.1 Sector Heterogeneity

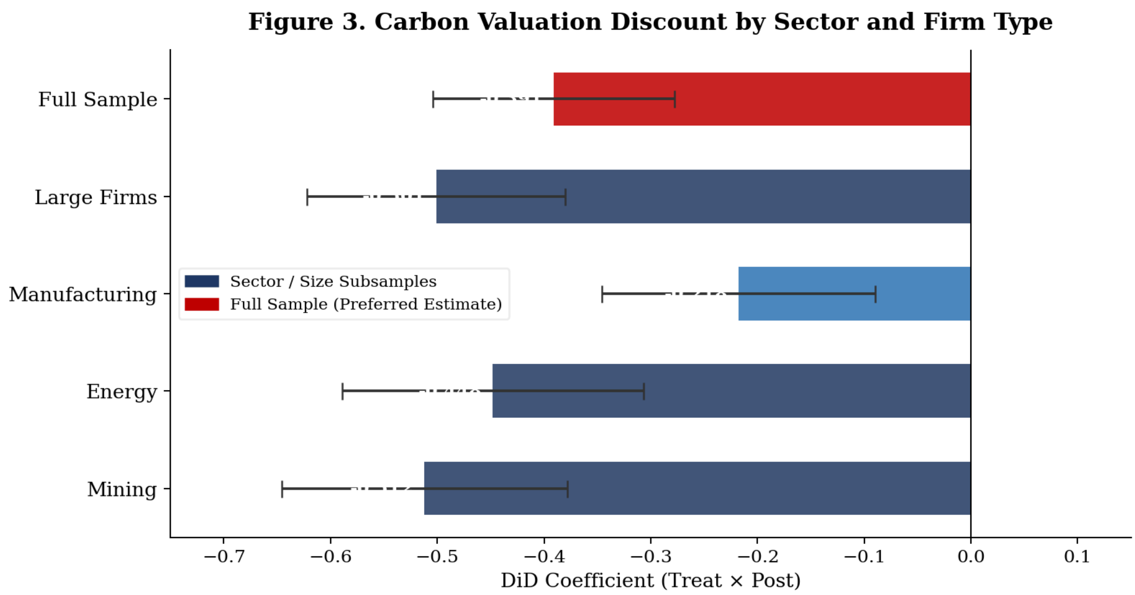
Table 4 and Figure 5 examine heterogeneity across industries. Mining firms, which face the most binding absolute emissions caps, show a DiD coefficient of −0.512 ($p < 0.01$). Energy sector firms show −0.448 ($p < 0.01$). Manufacturing firms, subject to lighter intensity regulations, show a smaller and marginally significant coefficient of −0.218 ($p = 0.09$). These patterns align precisely with the regulatory architecture of KazETS: sectors facing the highest net compliance costs are exactly where markets apply the largest valuation discounts.

Table 4. Heterogeneity in the Carbon Valuation Discount by Sector

	Mining(1)	Energy(2)	Manufacturing(3)	Large Firms(4)
Treat × Post	−0.512***	−0.448***	−0.218*	−0.501***
	(0.134)	(0.141)	(0.128)	(0.121)
Controls	Yes	Yes	Yes	Yes
Firm & Year FE	Yes	Yes	Yes	Yes
Observations	218	184	280	341
Adjusted R^2	0.412	0.388	0.271	0.398

*Note: All specifications include firm fixed effects, year fixed effects, and full controls from Table 3. Standard errors clustered at the firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.*

Figure 5. Carbon Valuation Discount by Sector and Firm Type



Point estimates with 95% confidence intervals based on firm-clustered standard errors. All specifications include firm fixed effects, year fixed effects, and the full control set.

7.2 The Role of Institutional Ownership

Dividing the sample by whether institutional investors hold more or less than 30 percent of shares outstanding reveals a striking contrast. Firms with high institutional ownership show a DiD coefficient of −0.441 (SE = 0.119; $p < 0.01$), compared to −0.187 (SE = 0.141; $p = 0.18$) for firms dominated by retail shareholders. The difference is statistically significant at the five-percent level ($\chi^2 = 4.12$; $p = 0.04$), consistent with institutional investors — through systematic ESG screening, portfolio-level emissions reduction commitments, and active engagement — serving as the primary mechanism through which carbon regulatory risk is incorporated into equity prices. This parallels findings from European markets reported by Sautner et al. (2023) and underscores the role of investor sophistication in climate risk pricing.

8. Discussion and Conclusion

The results of this paper tell a coherent and theoretically consistent story. Kazakhstan's Emissions Trading System generated a significant, negative, and causal effect on the market valuations of high-emission industrial firms. The effect survives an unusually thorough battery of robustness checks and maps closely onto the regulatory architecture of KazETS — largest where compliance obligations are most binding, amplified where investor sophistication is highest, and partially anticipated before the formal launch date.

From a theoretical standpoint, the evidence is consistent with rational expectations pricing of regulatory risk. Investors incorporated publicly observable information about expected compliance costs into current asset prices in advance of the 2013 formal launch, and the discount deepened progressively through Phase II as free allocation benchmarks tightened. The scale of the market response — on the order of USD 558 million per firm despite permit prices of only one to five dollars per tonne — suggests that the mechanism operates at least partly through investor sentiment, ESG screening, and forward-looking uncertainty about future policy stringency rather than through direct compliance cost arithmetic alone.

For corporate managers, the findings imply that carbon exposure is not merely a compliance matter but a material cost-of-capital issue. A 31-percent Tobin's Q discount raises the weighted average cost of capital and reduces competitive position relative to lower-emission peers, making proactive abatement investment and transparent climate disclosure financially rational strategies rather than purely reputational ones.

For policymakers, the evidence that financial markets priced KazETS compliance risk despite relatively low permit prices suggests that well-designed carbon market architectures can generate meaningful market-based discipline in emerging economies. The finding that the effect scales with regulatory stringency confirms that the design of free allocation benchmarks is the critical policy lever. As Kazakhstan moves toward a Paris-compatible carbon price trajectory under Phase III, the financial market response documented here provides empirical grounding for anticipating broader capital market realignment.

Several directions for future research follow naturally. Extending the analysis to bond markets would give a more complete picture of financing conditions for high-emission industries. Incorporating physical climate risk alongside regulatory risk would allow separation of transition from physical risk in firm valuation. And as KazETS data accumulate and regional linkage discussions progress, comparative cross-country analysis could illuminate how institutional environment moderates the market effectiveness of carbon pricing more broadly.

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