International Journal of World Economic Research
ISSN: 3080-9886 (Print), ISSN: 3080-9894 (Online) | Vol. 3, No. 1, 2026

Green Capital Expenditure Commitments and Subsequent Environmental Performance Outcomes: A Longitudinal Case Study of Baosteel

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Abstract: Green capital expenditure is often treated as the mechanism through which corporate environmental ambition becomes measurable environmental change, yet firm-level longitudinal evidence about what such spending is followed by remains thin, and it is thinnest where the exposure variable itself is rarely disclosed in numeric form. This study examines Baoshan Iron & Steel over the fiscal years 2018 to 2025 through a longitudinal single-case design built entirely from official annual and sustainability filings. The case was selected on documented grounds, because a prior screening of 48 firm-years drawn from a stratified sample of 80 Chinese A-share firms located only two qualifying forward numeric green capital expenditure disclosures, and both belonged to this firm. Three findings follow. The company does not report one continuous green capital expenditure measure but three successive and definitionally distinct ones, which limits the length of any series that can honestly be constructed. Conventional pollutants fell steeply across the window, with sulphur oxides lower by 66.0%, nitrogen oxides by 57.7%, particulates by 71.3% and chemical oxygen demand by 62.4%, while greenhouse-gas intensity fell by only 8.0% and energy intensity by 0.6%. Disclosed budgets and subsequently realised spending correspond closely, at realisation ratios of 117.4% in FY2024 and 93.3% in FY2025. Green capital expenditure is disclosed in only five years inside the window, so no coefficient reported here supports inference and no causal claim is made.

Keywords: Green capital expenditure, Environmental performance, Corporate environmental investment, Environmental disclosure, Longitudinal analysis.

1. Introduction

Iron and steelmaking is among the most difficult industrial activities to reconcile with deep decarbonisation, because the emissions arise from the chemistry of ore reduction rather than from combustion alone, and because the assets that perform that reduction have service lives measured in decades [1, 2]. Firms in the sector are nonetheless expected to spend on environmental improvement, and the argument that well-designed environmental requirements can prompt offsetting innovation rather than pure cost has shaped policy expectations for three decades [3]. What that expectation requires empirically is a measurable quantity of environmental capital spending at the level of the firm, followed by an observable movement in that same firm's environmental outcomes, over a period long enough for installed assets to operate.

Obtaining such a measurement is harder than the framing suggests. Disclosed environmental capital expenditure has been used as a firm-level variable since the early accounting literature on the subject [4], yet the definitions behind the disclosed number are set by the reporting firm and change as reporting requirements change [5]. Third-party environmental ratings do not resolve the problem, because the divergence between rating providers arises substantially from differences in what is measured rather than from differences in judgement about the same measurements [6]. Any study that treats a green spending figure as a stable construct across a long window therefore risks measuring the evolution of a disclosure rule rather than the evolution of a firm.

The Chinese setting sharpens both the interest and the difficulty. Chinese listed firms report environmental information under requirements that have tightened repeatedly, and the substance behind that reporting has been a recurring research question rather than an assumption [7]. There is credible evidence that disclosure requirements in China have been followed by real reductions in industrial emissions [8], which makes the firm-level question worth asking rather than dismissing. At the same time, a research design that requires a numeric forward green capital expenditure commitment will find very few observations, which is what motivated the design adopted here.

This study asks three questions about one firm. First, how does Baosteel disclose green capital expenditure over time, and what does the structure of that disclosure permit or prevent. Second, how did the firm's measured environmental performance move over the analytical window, and does the movement differ between conventional pollutants on one side and carbon and energy intensity on the other. Third, how closely do disclosed forward budgets correspond with subsequently realised spending, and can any association be observed between disclosed spending and subsequent environmental outcomes.

Baosteel is a useful place to ask them. It is one of the largest steelmakers in the world, it operates the integrated blast furnace route that makes carbon reduction genuinely difficult, it has published sustainability reporting continuously for more than a decade, and it is subject to the full weight of Chinese environmental enforcement. If a numeric account of green capital spending and its subsequent environmental record can be assembled anywhere among Chinese listed firms, it should be assemblable here, and the difficulties encountered in doing so are therefore informative about the wider reporting environment rather than peculiar to a weak reporter.

The design is a longitudinal single case, which is appropriate where the phenomenon is rare, where the value of the case lies in what it makes visible rather than in what it represents, and where the researcher can trace a process over time within one organisation [9, 10]. Baosteel is not offered as representative of Chinese A-share firms, and no inference about that population is drawn from it. The firm was selected because a prior screening exercise found that qualifying forward numeric green capital expenditure disclosure was concentrated in this single issuer, which makes it an information-rich case for examining what such disclosure looks like when it exists at all.

Three contributions follow. The first is descriptive and methodological, in that the paper documents how a large issuer's green capital expenditure disclosure changed definition twice within twelve years, and shows why the resulting series cannot be spliced without fabricating comparability. The second is empirical, in that the paper places a carefully bounded exposure series alongside seven environmental outcome series measured on a stable reporting perimeter, and reports a marked asymmetry between the steep decline in conventional pollutants and the shallow decline in carbon and energy intensity. The third is evidentiary discipline, in that the paper reports exploratory statistics with their sample sizes attached, states plainly that none of them supports inference, and treats the discontinuity of the exposure measure as a finding about corporate environmental reporting rather than as a nuisance to be smoothed away.

The remainder of the paper is organised as follows. Section 2 reviews the relevant literature and sets out the conceptual framework. Section 3 describes the data, the measurement rules and the analytical strategy. Section 4 reports results. Section 5 discusses them and states the limitations in full. Section 6 concludes.

2. Literature Review and Conceptual Background

2.1. Environmental Capital Expenditure as a Measurable Construct

The treatment of disclosed environmental capital expenditure as a quantitative firm-level variable was established in accounting research on the pulp and paper industry, where capital spending on environmental assets was shown to carry valuation consequences that differ from those of ordinary spending [4]. A parallel tradition in environmental economics uses realised pollution abatement expenditure at plant level and relates it to productivity through a production function, which establishes realised spending rather than announced intention as the quantity that can actually be measured [11]. That distinction matters for the present study, because the same asymmetry appears in the Chinese filings examined here, where realised amounts are disclosed far more often than forward commitments.

Where abatement occurs within the production process is at least as consequential as how much is spent, since reductions achieved by changing the process itself behave differently from reductions achieved by treating emissions at the end of the pipe [12]. Because environmental capital assets must be installed and commissioned before they operate, any relationship between spending and outcomes should be expected to appear with a delay rather than contemporaneously, an expectation supported by early evidence that emission reductions take time to register in firm outcomes [13] and by later work showing that the sign of the environmental and financial relationship depends on the horizon over which it is examined [14]. The innovation channel through which environmental requirements might produce offsetting benefits also operates with a delay rather than immediately [15]. Meta-analytic work indicates that much of the apparent disagreement in this literature is attributable to differences in how the underlying constructs are measured, which is a direct warning against pooling measures whose definitions differ [16].

Two further findings shape what should be expected of an incumbent heavy-industry firm. Environmental requirements influence not only how much plants invest but when they invest and which technology vintage they choose, so environmental capital spending is lumpy and timed rather than smooth [17]. New plant vintages respond far more strongly to price and policy signals than existing plants do, which implies that an established producer improves gradually through retrofit rather than abruptly [18].

2.2. Disclosure Quality as the Binding Constraint

Environmental disclosure divides into hard verifiable items that a poor performer would find costly to imitate and soft claims that anyone can make, and only the former carries information about underlying performance [19]. Firms with genuinely better performance tend to supply the verifiable variety [20]. Against this, the greenwashing literature catalogues selective disclosure across categories and vague commitment language as the characteristic forms of misleading environmental communication [21], identifies the organisational and market conditions under which such behaviour becomes more likely [22], and shows internationally that firms subject to weaker scrutiny disclose selectively, revealing some categories while remaining silent on others [23]. A line item that appears in one reporting period and vanishes in the next is therefore a phenomenon the literature anticipates, and it can be described without alleging deception.

Mandatory reporting requirements change both what firms report and when they report it, which offers a plausible institutional explanation for definitional changes that would otherwise appear arbitrary [5]. Reliance on third-party environmental scores would not repair the problem, since rating divergence decomposes into differences in scope, measurement and weighting [6], and greater disclosure volume can increase rather than reduce disagreement between raters [24]. Reported corporate carbon data are themselves substantially estimated rather than directly measured, which is a specific caution for any carbon series constructed from company reports [25]. Sustainability reports also vary widely in whether and how they are externally assured [26].

2.3. The Chinese Institutional Setting

Whether corporate social and environmental reporting by Chinese firms reflects substantive activity or symbolic compliance has been examined directly, with results that depend on ownership and on the intensity of external pressure [7]. Greenwashing has been operationalised for Chinese listed firms by combining disclosure with outcome data rather than treating disclosure alone as evidence [27]. On the substantive side, China's 2008 disclosure mandate was followed by measurable reductions in industrial emissions in mandated cities, which indicates that reporting rules there have been associated with real outcomes rather than with reporting alone [8]. More recent work links regulatory tightening to changes in both disclosure and firm performance [28].

Ownership is directly relevant to the present case. Whether Chinese state-owned enterprises achieve better environmental outcomes than their peers is contested rather than settled, and the answer depends on the regulatory instrument in question and on the environmental strategy the firm adopts [29]. Enforcement intensity also varied sharply within the observation window, since central environmental protection inspection functioned as a substantial enforcement shock associated with changes in corporate environmental and governance performance [30], and the regional carbon market pilots were followed by increased low-carbon patenting among regulated firms [31].

2.4. Technology, Capital Vintage and the Pollutant Asymmetry

Integrated steelmaking generates conventional air pollutants disproportionately at the sintering stage, so targeted retrofits of sintering and coking equipment can reduce sulphur oxides, nitrogen oxides and particulates substantially while leaving the carbon intensity of ore reduction untouched [32]. The scale of what such retrofits achieve is documented for Chinese power generation, where ultra-low emission standards were followed by large measured reductions [33], and more directly for Chinese iron and steelmaking, where the same standards were followed by substantial sector-level emission reductions [34].

Carbon is a different problem. Comparative assessment of low-carbon steelmaking routes indicates that deep reductions require capital commitments far larger than those needed for pollutant control, and that the economics differ by route [35]. Hydrogen-based direct reduction, the most discussed alternative to the blast furnace, would require replacement of core production assets rather than their modification [36], and modelling of green hydrogen direct reduction sets out how large the achievable reduction could be once such replacement occurs [37]. Energy-intensive industries face long investment cycles that lock in an emissions profile for the life of the asset [2], and at sector level in China output growth has repeatedly offset efficiency gains, so carbon intensity has moved slowly even where efficiency improved [38].

2.5. Conceptual Framework and Research Questions

The framework applied here is deliberately simple and is shown in Figure 1. Disclosed green capital expenditure at year t funds asset installation and commissioning, which changes operating emissions and resource use, which is then observable in subsequent environmental performance at t+1 to t+3. The implementation lag between the first and last stage is the reason the analysis examines lagged as well as contemporaneous relationships, and the reason a short series is a serious constraint rather than a minor one. The framework also implies the asymmetry described above, since pollutant control equipment sits at the end of the chain and can be retrofitted, whereas carbon intensity is determined by the production route and moves only when the route changes.

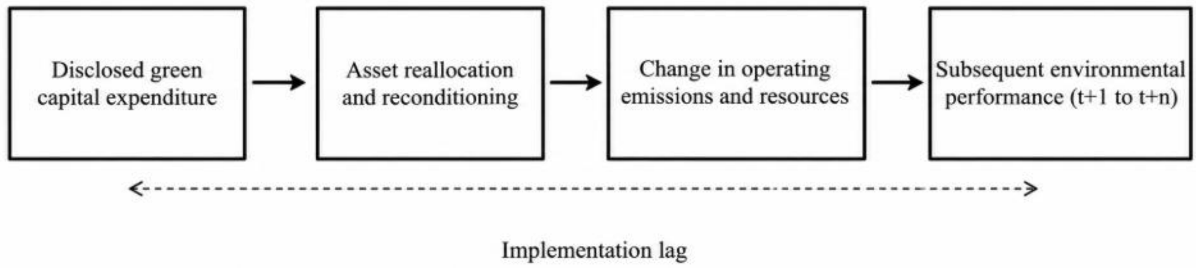

Figure 1. Conceptual framework linking disclosed green capital expenditure to subsequent environmental performance

The three research questions follow from the framework. RQ1 concerns the structure and continuity of the exposure disclosure itself. RQ2 concerns the movement of environmental outcomes across the window and the difference between pollutant and carbon trajectories. RQ3 concerns the correspondence between forward budgets and realised spending, and whether any association between exposure and subsequent outcomes can be observed given the available number of years.

3. Data and Methodology

3.1. Design and Case Selection

The study is a longitudinal single-case design of the kind used to trace change processes within one organisation over an extended period [39]. Single cases are defensible where they motivate a question, illustrate a mechanism or make a rare phenomenon visible [9], and the objection that a single case cannot support general knowledge has been addressed at length [10]. The reporting here follows the construct, internal, external and reliability criteria that reviewers apply to case research [40], and the general logic of building an argument from case evidence follows established practice [41]. The pitfalls of qualitative and case-based accounting research, particularly the temptation to over-read a small number of observations, are taken seriously rather than acknowledged and then ignored [42].

Case selection was determined by a prior screening exercise rather than chosen at the outset. That exercise applied a repaired and validated extraction procedure to 48 firm-years drawn from a stratified sample of 80 Chinese A-share firms, and after independent dual coding and adjudication it identified only two firm-years containing a qualifying forward numeric green capital expenditure disclosure. Both belonged to Baosteel. The same exercise established that realised green capital expenditure is disclosed far more often than forward commitments, which fixed realised spending as the primary exposure construct for this study and is the reason the title refers to green capital expenditure rather than to commitments. The screening is reported here only to document how the case was chosen.

3.2. Sources and Provenance

All firm data are drawn from Baosteel annual reports and sustainability reports retrieved from official disclosure channels. Each document was stored locally with its source location and a SHA-256 hash, and every extracted value is held with its reporting year, document type, page, the source text from which it was read, its printed unit and any boundary or restatement note attached to it. Primary filings were used in preference to third-party environmental scores throughout, on the grounds that such scores diverge substantially in scope and measurement [6]. External assurance of the environmental figures is not uniform across years, and this is treated as a limitation rather than resolved by assumption [26].

Monetary amounts are reported in the unit used in the filings, RMB hundred million, and are never converted between regimes or summed across them. Table 1 lists every variable used, with its definition, unit, source and the number of years for which it is available.

Table 1. Variables, definitions, units and sources

Variable	Definition	Unit	Source	Years available
Green CAPEX, capitalised environmental cost	Capitalised environmental protection cost	RMB 100m	sustainability report, capitalised cost component of environmental protection cost	6
Environmental investment total, no capital split	Total environmental investment, no capital split	RMB 100m	sustainability report,	1
Green CAPEX, energy-saving and low-carbon investment	Energy-saving and low-carbon investment, realised	RMB 100m	sustainability report, energy-saving and low-carbon investment	3
Green CAPEX budget, stated one year ahead	Energy-saving and low-carbon investment, budget for the year	RMB 100m	sustainability report, stated one year ahead	2
Sulphur oxides	Sulphur dioxide emissions	t	sustainability report performance table	9
Nitrogen oxides	Nitrogen oxides emissions	t	sustainability report performance table	8
Particulates	Particulate emissions	t	sustainability report performance table	9
Chemical oxygen demand	Chemical oxygen demand in discharged water	t	sustainability report	9
Water withdrawal	Water withdrawal	10k m3	sustainability report	11
Solid waste generated	Solid waste generated	10kt	sustainability report	8
Greenhouse gases, total (revised factors)	Total GHG, four bases, revised 2023 factors	10kt CO2e	sustainability report, 2023 restatement	6
Greenhouse-gas intensity (revised factors)	GHG intensity, revised factors	t CO2e/t crude steel	sustainability report	6
Energy intensity	Comprehensive energy consumption per tonne of crude steel	MWh/t	sustainability report, 2019 onward basis	7
Operating revenue	Operating revenue	RMB m	annual report	12
Total capital expenditure	Cash paid for fixed, intangible and other long-term assets	RMB m	annual report cash flow statement	12

Note. All variables are drawn from Baosteel annual reports and sustainability reports retrieved from CNINFO. Years available counts non-missing observations in FY2014-FY2025.

3.3. The Exposure Variable and Its Three Disclosure Regimes

Baosteel does not report one continuous green capital expenditure measure. Three successive and definitionally distinct measures appear across FY2014 to FY2025, and they are set out in Table 2. Regime R1, covering FY2014 to FY2019, is the capitalised component of environmental protection cost, which the company itself separates from the expensed component, and which is available for six years with values ranging from 8.03 to 43.30. Regime R2, covering FY2020 to FY2022, is a total environmental investment figure with no capital split, and only one year could be located, FY2020 at 35.28. Regime R3, covering FY2023 to FY2025, is energy-saving and low-carbon investment tied to named retrofit projects, available for three years with values ranging from 18.9 to 32.0, and accompanied from FY2023 onward by a budget stated one year ahead.

Table 2. Successive green capital expenditure disclosure regimes

Regime	Period	Disclosed measure	Capital nature	Years disclosed	Range (RMB 100m)
R1	FY2014-FY2019	Capitalised component of environmental protection cost	Explicit, the company itself separates capitalised from expensed cost	6	8.03-43.30
R2	FY2020-FY2022	Total environmental investment, no capital split	Not established, mixes capital works with maintenance and R&D	1	35.28
R3	FY2023-FY2025	Energy-saving and low-carbon investment	Evidenced, tied to named retrofit projects	3	18.9-32.0

Note. The three measures are not spliced into a single series because their definitions and reporting boundaries differ. The FY2017 absorption of Wuhan Iron & Steel falls inside regime R1 and changes the reporting entity.

The three measures are held as separate variables and are never spliced into a single series, because their definitions and their reporting perimeters differ, and a spliced series would present a change of accounting definition as a change in behaviour. This treatment follows the distinction between hard verifiable disclosure and softer aggregates [19], since only R1 and R3 carry evidence of capital nature while R2 mixes capital works with maintenance and research spending. A year in which no measure is disclosed is recorded as missing and is never coded as zero. Two scaled versions of the exposure are also computed where both components exist, being green capital expenditure as a share of total capital expenditure and as a share of revenue.

3.4. Outcome Variables

Seven environmental outcomes are used, being sulphur oxides, nitrogen oxides, particulates, chemical oxygen demand in discharged water, water withdrawal, greenhouse-gas intensity and energy intensity per tonne of crude steel, together with solid waste generated as a supplementary series. Pollutant figures before FY2018 are reported by the company as per-tonne intensities rather than as totals, so they measure a different construct and are excluded rather than converted. Greenhouse-gas figures are used on the revised emission-factor basis throughout, and the general caution that reported corporate carbon data are substantially estimated rather than directly measured applies to them [25]. Table 3 presents the outcome series across the analytical window.

Table 3. Environmental performance, FY2018-FY2025

Fiscal year	SOx (t)	NOx (t)	Particulates (t)	COD (t)	Water withdrawal (10k m3)	GHG intensity (t CO2e/t)	Energy intensity (MWh/t)
2018	17,736	42,868	13,014	1,080	15,797		
2019	14,426	37,622	9,575	827	15,196		4.70
2020	10,996	31,768	14,994	868	15,000	2.130	4.67
2021	9,158	25,332	7,047	795	12,500	2.080	4.62
2022	7,912	21,102	6,266	664	12,200	2.080	4.61
2023	6,556	19,845	4,725	561	13,276	2.040	4.58
2024	5,981	18,366	4,274	491	12,644	1.996	4.50
2025	6,035	18,148	3,741	406	12,990	1.960	4.67

Note. Greenhouse-gas intensity is stated on the revised emission-factor basis introduced in the FY2023 report, which restated FY2020-FY2022 upward. Pre-FY2018 pollutant figures are reported by the company as per-tonne intensities and are therefore excluded.

3.5. Reporting Boundary and Restatement

Two features of the filings constrain what may be compared. The FY2017 absorption of Wuhan Iron & Steel changed the reporting entity, which is confirmed in the filings themselves, since FY2014 to FY2016 disclosures cover the Baoshan and Meishan operations while FY2017 onward disclosures cover four production bases. No series is spliced across that break, and no year-on-year comparison spanning it is interpreted.

The second feature is restatement. The FY2023 sustainability report restated greenhouse-gas figures for FY2020 to FY2022 upward following a national emission-factor revision, so that the FY2020 four-base total moved from 8,860.6 to 10,070.4 ten-thousand tonnes of carbon dioxide equivalent, an upward revision of roughly 13.7% that reflects a change in factors rather than a change in operations. Both the original and the revised values are preserved in the dataset and the revised basis is used for analysis. A related reporting feature appears in FY2024, where Scope 2 emissions are stated as negative at -13.6 ten-thousand tonnes of carbon dioxide equivalent, reflecting the deduction of purchased green power. Consolidation perimeters also vary between the annual report and the sustainability report for certain pollutant lines, and where they do the difference is recorded rather than reconciled silently.

3.6. Analytical Window and Analytical Strategy

The analytical window is FY2018 to FY2025. It was chosen because a level series crossing FY2017 would mix two reporting entities and two measurement constructs, and because pollutant totals only become available from FY2018. The window was fixed on comparability grounds before any relationship was examined, and it was not adjusted afterwards.

The analysis proceeds from the simplest description to the most demanding and stops where the data stop supporting it. Annual series, year-on-year changes and series indexed to FY2018 are reported first. Correspondence between disclosed budgets and subsequently realised spending is then examined for the two years in which both exist. Lagged relationships between exposure and each outcome are computed at lags of zero to three years, using both Pearson and Spearman coefficients, with a minimum of four paired observations required before any coefficient is reported at all. Ninety-six lag combinations were computed and thirty-six met that minimum. A direction-agreement count is also reported, recording for each outcome how many of the available change pairs show the change in exposure and the subsequent change in the outcome moving in opposite directions, which is the direction that would be expected if spending were followed by abatement. Sensitivity is examined across three exposure scalings, being the unscaled amount, the share of total capital expenditure and the share of revenue. The expectation that any relationship would appear with a delay rather than contemporaneously follows the lag logic established in earlier work on abatement spending and emission reduction [11, 13].

3.7. What the Design Cannot Do

Green capital expenditure is disclosed in only five years inside the window, being FY2018, FY2019, FY2023, FY2024 and FY2025, and there is a three-year gap in the middle of that sequence. The maximum number of paired observations available for any lag is therefore five, and for most lags it is three or four. No coefficient computed on such a series can support statistical inference, and several of the reported coefficients reach the boundary values of the statistic purely because the sample is small. No identification strategy is available, no counterfactual is observed, and no causal claim is made anywhere in this paper. All statistical output is reported for completeness and is interpreted descriptively.

4. Results

4.1. Green Capital Expenditure Across Three Disclosure Regimes

Table 4 reports annual green capital expenditure with its scaling measures, and Figure 2 shows the same amounts grouped by disclosure regime with the FY2017 boundary break marked. Under regime R1 the capitalised component of environmental protection cost rose in every year from 8.03 in FY2014 to 43.30 in FY2019, more than a fivefold increase over six years, with the sharpest single-year rise of 89.7% occurring between FY2018 and FY2019. Regime R2 yields a single located observation, an environmental investment total of 35.28 for FY2020 that carries no capital and operating split and therefore cannot be compared with the amounts on either side of it. Under regime R3 the disclosed energy-saving and low-carbon investment was 23.80 in FY2023, 18.90 in FY2024 and 32.00 in FY2025, a fall of 20.6% followed by a rise of 69.3%.

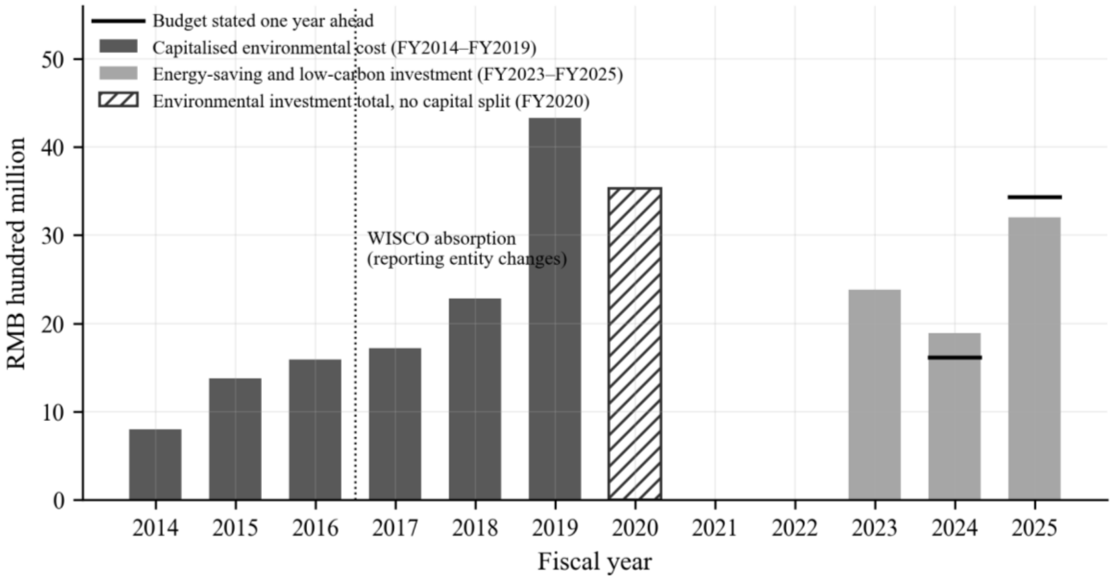

Figure 2. Disclosed green capital expenditure by reporting regime, FY2014–FY2025.

Table 4. Annual green capital expenditure and scaling measures

Fiscal year	Green CAPEX (RMB 100m)	Regime	Total CAPEX (RMB m)	Share of total CAPEX (%)	Revenue (RMB m)	Share of revenue (%)
2014	8.03	R1	21,609	3.72	187,414	0.428
2015	13.74	R1	23,979	5.73	163,790	0.839
2016	15.90	R1	11,540	13.78	185,459	0.857
2017	17.22	R1	13,277	12.97	289,093	0.596
2018	22.83	R1	12,760	17.89	304,779	0.749
2019	43.30	R1	17,624	24.57	291,594	1.485
2020		not disclosed	19,573		283,674	
2021		not disclosed	23,922		364,349	
2022		not disclosed	22,423		367,778	
2023	23.80	R3	21,029	11.32	344,500	0.691
2024	18.90	R3	19,336	9.77	322,116	0.587
2025	32.00	R3	18,507	17.29	317,508	1.008

Note. Green CAPEX is the regime-appropriate disclosed measure and is not comparable across regimes. Ratios are computed only where both components exist.

Within the analytical window the exposure is available for five years. Green capital expenditure represented between 9.77 and 24.57% of total capital expenditure in those years, with a mean of 16.17%, and between 0.587 and 1.485% of revenue, with a mean of 0.904%. The scaled measures behave differently from the unscaled one, since the unscaled amount was 40.2% higher in FY2025 than in FY2018 while its share of total capital expenditure was 3.4% lower, reflecting the rise in the company's total capital spending from 12,760 to 18,507 million yuan over the same period. Table 5 reports these and the other window statistics together with the number of observations behind each.

Table 5. Descriptive statistics over the analytical window, FY2018-FY2025

Variable	n	First value	Last value	Mean	Change (%)
Green CAPEX, primary measure	5	22.83	32.0	28.166	40.2
Green CAPEX as a share of total capital expenditure	5	17.89	17.29	16.168	-3.4
Green CAPEX as a share of revenue	5	0.749	1.008	0.904	34.6
Sulphur oxides	8	17736.0	6035.0	9849.982	-66.0
Nitrogen oxides	8	42868.0	18148.0	26881.433	-57.7
Particulates	8	13014.0	3741.0	7954.516	-71.3
Chemical oxygen demand	8	1080.0	406.0	711.555	-62.4
Greenhouse-gas intensity (revised factors)	6	2.13	1.96	2.048	-8.0
Energy intensity	7	4.7	4.67	4.621	-0.6
Water withdrawal	8	15797.0	12990.0	13700.375	-17.8
Solid waste generated	5	2986.909	3362.538	3166.71	12.6
Operating revenue	8	304779.0	317508.0	324537.25	4.2
Total capital expenditure	8	12759.633	18507.326	19396.819	45.0

Note. First and last values are the earliest and latest non-missing observations within the window, which for green capital expenditure are FY2018 and FY2025 respectively.

4.2. Environmental Performance Across the Window

Table 3 and Figure 3 report the outcome series, and Figure 4 shows the same series indexed to FY2018. The movements divide sharply into two groups.

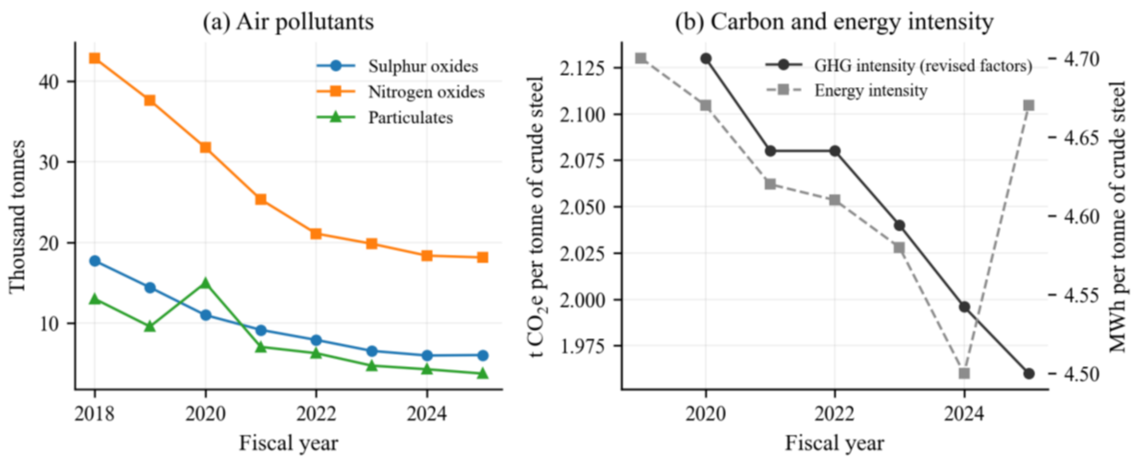

Figure 3. Environmental performance over the analytical window, FY2018–FY2025.

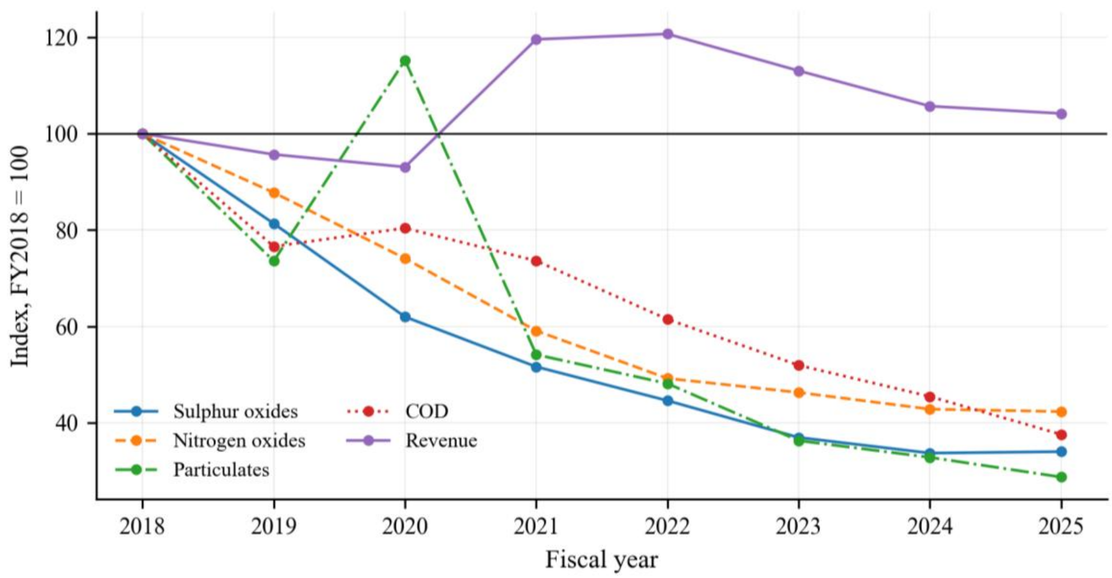

Figure 4. Environmental outcomes and revenue indexed to FY2018 = 100

Conventional pollutants fell steeply and almost monotonically. Sulphur oxides fell from 17,736 tonnes in

FY2018 to 6,035 tonnes in FY2025, a reduction of 66.0%. Nitrogen oxides fell from 42,868 to 18,148 tonnes, a reduction of 57.7%. Particulates fell from 13,014 to 3,741 tonnes, a reduction of 71.3%. Chemical oxygen demand in discharged water fell from 1,080 to 406 tonnes, a reduction of 62.4%. Water withdrawal fell by 17.8%. Over the same eight years revenue rose by 4.2%, so the indexed series in Figure 4 show the pollutant lines falling steeply away from an approximately flat revenue line. Two departures from the pattern should be noted. The FY2020 particulate figure of 14,994 tonnes is higher than the figures on either side of it, but that value is drawn from a wider consolidation perimeter covering the company and its significant subsidiaries, and a later report states 9,736 tonnes for the same year on the four-base perimeter, so the apparent rise is a perimeter difference rather than an operational deterioration. Sulphur oxides also rose marginally in the final year, by 0.9% from 5,981 to 6,035 tonnes.

Carbon and energy moved far less. Greenhouse-gas intensity on the revised emission-factor basis fell from 2.13 to 1.96 tonnes of carbon dioxide equivalent per tonne of crude steel between FY2020 and FY2025, a reduction of 8.0% across six years and never more than 2.4% in any single year. Energy intensity fell from 4.70 megawatt hours per tonne of crude steel in FY2019 to 4.67 in FY2025, a reduction of 0.6%, and that series was not monotonic, since it reached 4.50 in FY2024 before rising by 3.8% in FY2025. Solid waste generated rose by 12.6% across the five years in which it is available on a comparable basis, while the comprehensive utilisation rate for that waste remained at or above 99.0% throughout and reached 99.93% in FY2025. The contrast between a 71.3% reduction in particulates and a 0.6% reduction in energy intensity over broadly the same period is the single clearest pattern in the data.

4.3. Association Between Exposure and Subsequent Outcomes

Table 6 reports the lagged rank correlations and Figure 5 plots green capital expenditure at year t against sulphur oxides at t+1 with every observation labelled by its year pair. The results must be read against the sample sizes attached to them. At most five paired observations are available at any lag. Of the ninety-six combinations computed across all exposures, outcomes and lags, sixty fell below the minimum of four paired observations, and fourteen of the twenty-four combinations shown in Table 6 are blank for that reason.

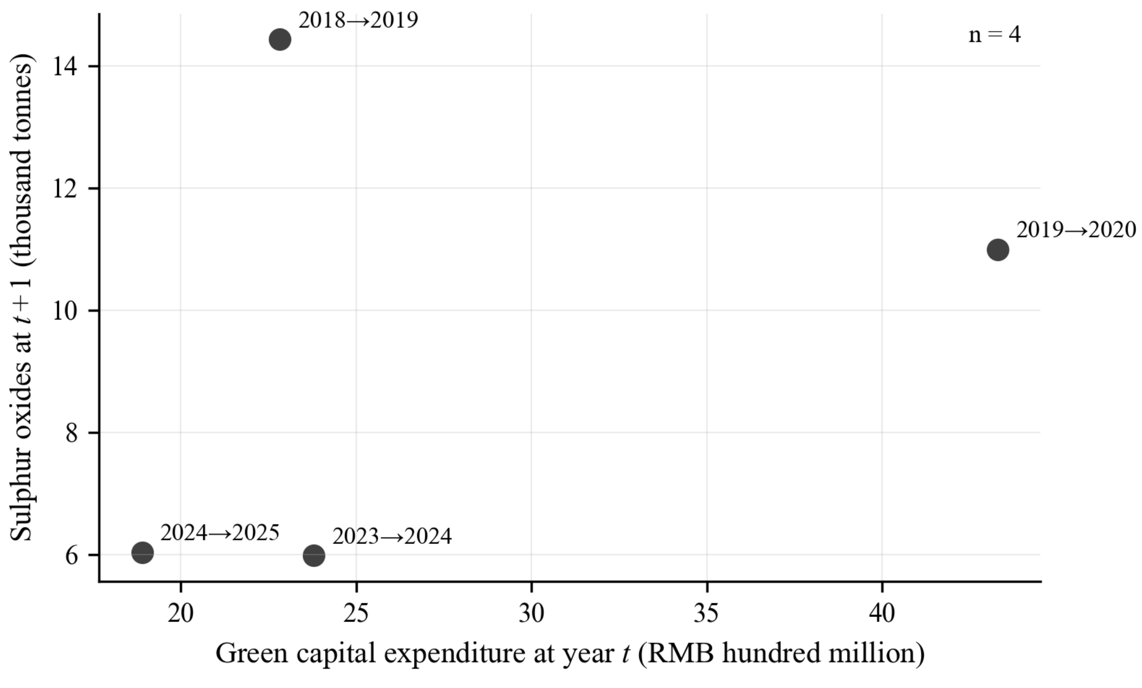

Figure 5. Green capital expenditure at year t against sulphur oxides at t+1.

Table 6. Exploratory lagged rank correlations between green capital expenditure and subsequent environmental performance

Outcome	Lag (years)	n	Spearman rho	p
Sulphur oxides	0	5	0.3	0.6238
Sulphur oxides	1	4	0.0	1.0
Sulphur oxides	2	3		
Sulphur oxides	3	2		
Nitrogen oxides	0	5	0.0	1.0
Nitrogen oxides	1	4	0.4	0.6
Nitrogen oxides	2	3		
Nitrogen oxides	3	2		
Particulates	0	5	0.0	1.0
Particulates	1	4	0.8	0.2
Particulates	2	3		
Particulates	3	2		
COD	0	5	0.0	1.0
COD	1	4	0.8	0.2
COD	2	3		
COD	3	2		
GHG intensity	0	3		
GHG intensity	1	3		
GHG intensity	2	3		
GHG intensity	3	2		
Energy intensity	0	4	1.0	0.0
Energy intensity	1	4	-0.316	0.6838
Energy intensity	2	3		
Energy intensity	3	2		

Note. Reported for completeness only. With at most five exposure years inside the window, no coefficient supports inference, and several reach the boundary values of the statistic purely because n is small. Blank cells indicate n below four.

Among the coefficients that met the minimum, the contemporaneous rank correlations between the unscaled exposure and the pollutant outcomes are close to zero, at 0.30 for sulphur oxides and 0.00 for nitrogen oxides, particulates and chemical oxygen demand, each on five observations. At a one-year lag the coefficients are 0.00 for sulphur oxides, 0.40 for nitrogen oxides and 0.80 for both particulates and chemical oxygen demand, each on four observations with p values no smaller than 0.20. The rank correlation between the unscaled exposure and contemporaneous energy intensity reaches 1.00 on four observations, and the corresponding correlation using the share of total capital expenditure against particulates at a one-year lag also reaches 1.00. These boundary values are artefacts of ranking four points and carry no evidential weight whatever. Under the sensitivity check across the three exposure scalings, coefficients for the same outcome and lag change substantially in magnitude and in one case in sign, which is itself an indication that none of them is identifying a stable relationship. Taken together, no coefficient in Table 6 supports inference, no coefficient is interpreted as an effect, and no specification was selected after inspecting significance.

The direction-agreement counts are more informative than the coefficients, though they too rest on very few observations. At a one-year lag, all three available change pairs for sulphur oxides show the change in green capital expenditure and the subsequent change in emissions moving in opposite directions, which is the direction expected if spending were followed by abatement, and the same holds for all three pairs for water withdrawal and for both available pairs for energy intensity. For nitrogen oxides two of three pairs move in opposite directions. For particulates and for chemical oxygen demand only one of three pairs does so, meaning that in two of the three cases the outcome and the exposure moved in the same direction. Three pairs cannot distinguish a relationship from a coincidence, and these counts are reported as description rather than as evidence.

4.4. Budgets and Realised Spending

Table 7 and Figure 6 report the correspondence between budgets stated one year ahead and the amounts subsequently realised. The FY2024 budget of 16.1 was followed by realised spending of 18.9, a realisation ratio of 117.4%, and the FY2025 budget of 34.3 was followed by realised spending of 32.0, a realisation ratio of 93.3%. Two pairs cannot establish a pattern, but within this narrow evidence the disclosed budgets were neither systematically optimistic nor systematically conservative, and the realised amounts sat within nine% of what had been stated a year earlier. A budget of 11.0 is disclosed for FY2026, which is roughly one third of the FY2025 budget and roughly one third of FY2025 realised spending, and it represents a sharp planned reduction whose outcome falls outside the observation window.

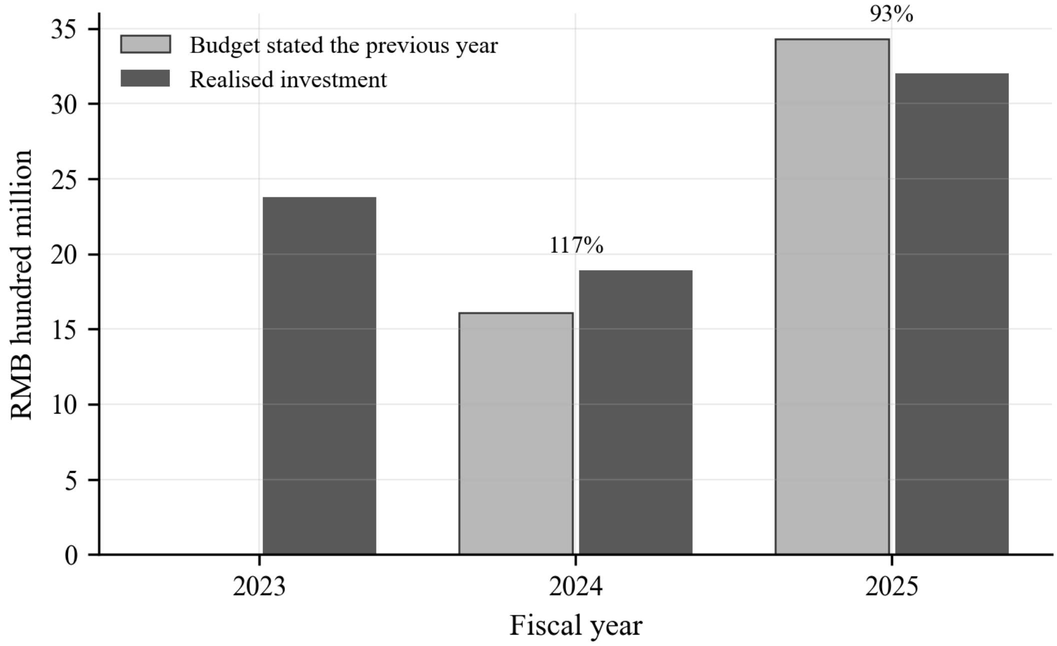

Figure 6. Disclosed budgets and subsequently realised green capital expenditure

Table 7. Green capital expenditure budgets and realised investment

Fiscal year	Budget stated the previous year (RMB 100m)	Realised investment (RMB 100m)	Difference (RMB 100m)	Realisation ratio (%)
2023		23.8		
2024	16.1	18.9	2.8	117.4
2025	34.3	32.0	-2.3	93.3

Note. Budgets are stated one year ahead in the preceding sustainability report. The FY2026 budget is disclosed but its outcome falls outside the observation window. Budgets and realised amounts are never summed.

5. Discussion

5.1. Two Speeds of Environmental Improvement

The most substantial pattern in this case is the gap between the steep reduction in conventional pollutants and the shallow reduction in carbon and energy intensity across the same firm, the same period and the same reporting perimeter. This asymmetry corresponds closely with what the technical literature on integrated steelmaking would anticipate. Conventional pollutants are generated disproportionately at the sintering stage and can be addressed by installing and upgrading control equipment without altering the production route [32], and reductions of the magnitude observed here are consistent with the sector-level reductions documented for Chinese iron and steelmaking after ultra-low emission standards were introduced [34] and with the comparable reductions documented for Chinese power generation under the same policy family [33].

Carbon behaves differently because it is determined by the chemistry of ore reduction rather than by what is fitted to the exhaust. Meaningful reductions require replacement of core production assets rather than their modification [36], at a capital cost well above that of pollutant control [35], and the reductions that become achievable once such replacement occurs are modelled rather than observed at this firm during the window [37]. Long investment cycles in energy-intensive industry lock in an emissions profile for the life of the asset [2], and at sector level in China efficiency gains have repeatedly been offset by output growth [38]. An 8.0% reduction in greenhouse-gas intensity across six years, and a 0.6% reduction in energy intensity across seven, are the movements that this literature would lead one to expect from an incumbent integrated producer improving through retrofit rather than replacement [18]. The pattern is also consistent with the observation that returns to pollution reduction depend on where in the process the abatement occurs [12], and with the broader assessment that regulation-induced improvement is real but modest and slow [43].

5.2. Discontinuous Disclosure as a Finding

The exposure measure changed definition twice within twelve years, which is a finding about corporate environmental reporting rather than merely an inconvenience for the analysis. A capitalised environmental cost line reported for six consecutive years was replaced by an undifferentiated environmental investment total, which was in turn replaced by an energy-saving and low-carbon investment line attached to named projects. Each of the three is defensible on its own terms and each was reported consistently within its own period, yet the sequence makes a twelve-year series impossible to construct honestly. Changes in reporting requirements offer a plausible institutional explanation for shifts of this kind [5], and the enforcement environment in China moved substantially within the same period [30]. The greenwashing literature would also read selective and shifting category disclosure as a recognised pattern rather than an anomaly [21, 23], and disclosure has long been analysed as a means of managing legitimacy [44]. Nothing in the present evidence establishes which explanation applies, and no allegation of deception is made or implied.

What can be said is narrower and more useful. The R3 disclosures are the most verifiable of the three, because they attach amounts to named retrofit projects and are accompanied by a budget stated a year in advance against which realisation can be checked, which is the sort of hard disclosure that carries information about underlying performance [19,20]. The close correspondence between budget and realisation in FY2024 and FY2025, on two observations, is at least consistent with those disclosures reflecting real activity, and it stands in contrast to the finding that greater disclosure volume alone can increase rather than reduce disagreement about a firm's environmental position [24]. Combining disclosure with outcome data, rather than reading disclosure alone, remains the appropriate way to evaluate such claims [27].

5.3. Attribution and Confounding

The environmental improvements documented here cannot be attributed to the firm's green capital expenditure. Several alternative explanations operate over the same period and are not separable with these data. Ultra-low emission standards for the steel sector, central environmental protection inspection and the pilot and national carbon markets all applied to this firm during the window, and each has been associated with emission reductions or with low-carbon innovation in the wider Chinese evidence [30, 31, 45]. Demand and output cycles affect emission totals directly, and the firm's revenue and output varied materially across the window. State ownership itself is associated with a distinct environmental strategy and a distinct exposure to administrative pressure, and the direction of that association is contested [29]. Any of these could account for part or all of the observed movement, and the design cannot apportion between them.

5.4. Limitations

The limitations are substantial and are stated without qualification. The study observes one firm, so no inference about Chinese A-share firms, about the Chinese steel sector or about state-owned enterprises generally is available from it, and none is offered. The analytical window contains eight years and the exposure is disclosed in only five of them, with a three-year gap in the middle, so the maximum number of paired observations at any lag is five. Correlations computed on such a series cannot support inference, several reach boundary values as an artefact of small samples, and the sensitivity check shows coefficients changing substantially with the choice of exposure scaling. The exposure measure is discontinuous by construction and its three regimes are not comparable with one another, so what is analysed within the window is a five-point series drawn from two different definitions rather than a single continuous variable.

All data are self-disclosed by the firm, external assurance is not uniform across years and reporting perimeters differ between the annual report and the sustainability report for some lines. Reported carbon figures are substantially calculated rather than measured [25]. The FY2017 corporate combination changed the reporting entity, which is why the window begins in FY2018, and comparisons across that break are not made. Greenhouse-gas figures for FY2020 to FY2022 were restated upward after an emission-factor revision, so the carbon series reflects a measurement convention as well as a physical quantity, and the negative FY2024 Scope 2 figure reflects a green-power deduction convention rather than a physical removal of emissions. No identification strategy, control group or counterfactual is available, and confounding from regulation and from demand cycles is unresolved. The relationships described in this paper are associations observed in one firm over eight years and nothing more.

6. Conclusion

This study followed one large Chinese steelmaker across the fiscal years 2018 to 2025 and placed its disclosed green capital expenditure alongside its subsequently measured environmental performance, using only official filings and holding every figure to its stated definition, unit and reporting perimeter.

Three conclusions follow. The first concerns measurement. The firm reported green capital expenditure under three successive and definitionally distinct regimes within twelve years, and only five annual observations fall inside a window over which environmental outcomes are comparable, so the constraint on learning about corporate green investment at this firm is the structure of the disclosure rather than the availability of outcome data. The second concerns the outcomes themselves. Conventional pollutants fell by between 57.7 and 71.3% across the window while revenue was broadly flat, whereas greenhouse-gas intensity fell by 8.0% and energy intensity by 0.6%, an asymmetry that corresponds with the technical distinction between control equipment that can be retrofitted and a production route that cannot. The third concerns credibility. Where the firm stated a budget one year in advance, realised spending came within nine% of it in both available years, which is a small but checkable form of accountability that the earlier reporting regimes did not permit.

What this case cannot do is equally clear. It cannot establish that the spending produced the improvement, it cannot separate the firm's investment from the regulatory and demand conditions surrounding it, and it cannot speak for any firm other than itself. Its value lies in making visible, at one information-rich firm, how a rare disclosure behaves when it exists and what it does and does not allow a researcher to conclude [9, 10].

Two implications for future research follow. Continuity of definition and clarity about capital nature in environmental spending disclosure are prerequisites for the firm-level evidence this field has sought, and their absence rather than any shortage of statistical technique is what limits the present study. Where those prerequisites are absent, careful description with sample sizes attached is preferable to inference the data cannot bear, a caution that applies with particular force to case-based accounting research [42]. A productive next step would be to assemble comparable realised green capital expenditure across several heavy-industry issuers whose disclosure survives the same definitional tests, since the measurement choices behind such variables account for much of the disagreement in the existing literature [16].

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