

The Clean Air Penalty: Property Values at Urban Emission Zone Boundaries

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Abstract

Do urban emission zones that clean the air also clean out property values? I exploit the staggered introduction of Clean Air Zones in seven English cities (2021–2023), using a difference-in-discontinuities design on 50,158 residential transactions within 500 meters of zone boundaries. The three-tier charge structure reveals suggestive heterogeneity: Class C zones—which charge commercial vehicles and taxis but exempt private cars—are associated with a 6.9% property premium at the boundary ($p < 0.01$), while Class D zones, which additionally charge private cars, show no net effect. Pre-period evidence reveals a declining trend for inside-boundary properties that reverses post-implementation, complicating but not overturning the causal interpretation. These findings provide initial evidence that emission zone design—specifically, whether private car owners bear direct costs—matters for local property market capitalization.

JEL Codes: Q53, R31, H23, Q58

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1. Introduction

Over 300 low-emission zones now operate across European cities, charging polluting vehicles for entering designated urban areas. Proponents argue these zones improve air quality and public health; critics warn they penalize residents and businesses trapped inside the boundary. Despite the rapid proliferation of these policies, the net effect on local economic activity—and specifically on property values, which capitalize both the amenity benefits and transport costs—remains an open empirical question.

This paper provides the first quasi-experimental evidence on how Clean Air Zones affect residential property values at the boundary of regulation. Between March 2021 and February 2023, seven English cities—Bath, Birmingham, Portsmouth, Bradford, Bristol, Tyneside, and Sheffield—implemented CAZs with sharp geographic boundaries and heterogeneous charge structures. I exploit these boundaries using a difference-in-discontinuities design applied to the universe of HM Land Registry residential transactions. The staggered implementation across cities and the three-tiered charge structure (Class B charging only commercial vehicles, Class C adding taxis and light goods vehicles, Class D adding private cars at £2–9 per day) provide natural dose-response variation in regulatory stringency.

The key identification challenge is that CAZ boundaries are not randomly drawn—they typically follow ring roads and major arterials, creating pre-existing differences in property values on either side. My difference-in-discontinuities design addresses this directly: by comparing the gap in property values at the boundary before versus after CAZ implementation, I absorb any permanent boundary effects and identify the causal impact from the *change* in the discontinuity. Seven cities provide internal replication, and the three charge classes enable tests of whether the effect scales with regulatory stringency.

The theoretical prediction is ambiguous. On one hand, CAZs reduce nitrogen dioxide and particulate matter concentrations inside the zone, creating amenity value that should capitalize into higher property prices—the mechanism documented by [Chay and Greenstone \(2005\)](#) and [Currie et al. \(2015\)](#) for industrial pollution. On the other hand, Class D zones impose daily charges on non-compliant cars owned by zone residents, raising the effective cost of living; reduced commercial vehicle access may also diminish local retail and service amenities. The net effect depends on which channel dominates. The dose-response across charge classes provides a direct test: Class B zones (no car charges) should reveal the pure amenity effect, while Class D zones capture the net of amenity benefits and transport costs.

This paper contributes to three literatures. First, a large literature in environmental economics uses hedonic methods to value air quality improvements ([Rosen, 1974](#); [Chay and Greenstone, 2005](#); [Bajari et al., 2012](#); [Currie et al., 2015](#); [Barwick et al., 2024](#)). Most of this

work exploits industrial plant openings/closings or regulatory changes affecting stationary sources. Urban vehicle emission zones operate through a fundamentally different mechanism—restricting mobile sources along a geographic boundary—and their effects on nearby property markets have not been credibly estimated.

Second, a growing literature evaluates low-emission zones in European cities, focusing primarily on air quality and health outcomes (Gehrsitz, 2017; Wolff, 2014; Holman et al., 2015). Wolff (2014) shows German LEZs accelerated adoption of cleaner vehicles; Gehrsitz (2017) finds infant health improvements. But the economic costs borne by residents at the boundary—the “clean air penalty”—remain unmeasured. Green et al. (2020) study London’s congestion charge, and Simeonova et al. (2021) examine congestion pricing and children’s health in Stockholm. Both focus on city-center charges without spatial discontinuity designs at the boundary.

Third, the paper contributes to the spatial regression discontinuity literature (Keele and Titiunik, 2015; Dell, 2010; Black, 1999). The multi-city setting with staggered implementation is particularly valuable: rather than relying on a single boundary where idiosyncratic local factors might drive results, I estimate effects across seven independent boundaries and test for consistency.

The rest of the paper proceeds as follows. Section 2 describes the UK CAZ policy. Section 3 presents the data. Section 4 develops the empirical strategy. Section 5 reports results and robustness checks. Section 6 discusses implications and Section 7 concludes.

2. Institutional Background

The UK government’s 2017 Air Quality Plan mandated that local authorities with illegally high nitrogen dioxide (NO_2) levels implement measures to achieve compliance “in the shortest possible time” (Department for Environment, Food and Rural Affairs, 2017). The Department for Environment, Food and Rural Affairs (DEFRA) established the Clean Air Zone Framework, defining four charge classes of increasing stringency (Department for Environment, Food and Rural Affairs, 2020).

Charge structure. Class A (non-charging) requires only monitoring and signage. Class B charges non-compliant buses, coaches, taxis, and heavy goods vehicles (HGVs). Class C extends charges to light goods vehicles (LGVs) and private hire vehicles. Class D—the most stringent—additionally charges non-compliant private cars, typically at £2–9 per day. A vehicle is “non-compliant” if it fails to meet Euro 6 for diesel or Euro 4 for petrol engines.

Implementation timeline. Seven cities launched charging CAZs between 2021 and 2023: Bath (March 2021, Class C), Birmingham (June 2021, Class D, £8/day for cars), Portsmouth (November 2021, Class B), Bradford (September 2022, Class C), Bristol (November 2022, Class D, £9/day), Tyneside (January 2023, Class C), and Sheffield (February 2023, Class D, £2/day). Crucially, Bath and Birmingham launched during the post-pandemic recovery, while the later cities launched in a more normal economic environment.

Boundary determination. CAZ boundaries were determined through a combination of air quality modeling and practical considerations. DEFRA required boundaries to encompass roads where NO₂ exceeded legal limits, but local authorities had discretion over the exact perimeter. In practice, boundaries often follow ring roads and major arterials—a natural concern for spatial RDD that I address through the difference-in-discontinuities design.

Enforcement. Automatic Number Plate Recognition (ANPR) cameras at boundary entry points record every vehicle. Non-compliant vehicles that enter without paying receive a Penalty Charge Notice of £120 (reduced to £60 if paid within 14 days). Compliance has been high: Birmingham reported that the proportion of compliant vehicles entering the zone rose from 84% to 94% within 12 months.

3. Data

Property transactions. The primary outcome data come from HM Land Registry Price Paid Data, which records the universe of residential property transactions in England and Wales since 1995. Each record contains the transaction price, date, postcode, property type (detached, semi-detached, terraced, flat), and whether the property is new-build or existing. I extract all transactions from 2018 to 2024 in the seven CAZ city areas, yielding approximately 390,000 transactions. Postcodes are geocoded to latitude-longitude coordinates using the postcodes.io API.

CAZ boundaries. I obtain Clean Air Zone boundary polygons from OpenStreetMap where available, supplemented by circular approximations centered on each city’s zone based on official CAZ maps published by each local authority. Each property is assigned a signed distance to the nearest CAZ boundary: positive values indicate the property is inside the zone, negative values outside.

Sample construction. The analysis sample consists of 172,593 transactions within 2,000 meters of a CAZ boundary, with the primary specification using a 500-meter bandwidth (50,158 transactions: 24,008 inside and 26,150 outside). I assign each transaction to the

nearest city’s CAZ and merge city-specific launch dates and charge classes. The largest samples come from Bristol (11,293 transactions within 500m), Tyneside (9,258), and Sheffield (8,153).

Table 1: Summary Statistics: Property Transactions Within 500m of CAZ Boundaries

Panel A: By Side of Boundary

	N	Mean	Median	SD log(P)	% Flat	% Terr.	% Semi/Det
Inside CAZ	24,008	318,193	227,500	0.865	26.9	50.3	15.8
Outside CAZ	26,150	293,530	212,500	0.804	23.2	49.2	21.6

Panel B: By City

City	Class	N	Mean Price	Launch	% Post
Bristol	D	11,293	424,679	Nov 2022	27.7
Tyneside	C	9,258	211,187	Jan 2023	26.7
Sheffield	D	8,153	277,021	Feb 2023	24.4
Portsmouth	B	7,964	254,336	Nov 2021	41.3
Birmingham	D	4,942	260,910	Jun 2021	48.3
Bradford	C	4,822	127,937	Sep 2022	32.3
Bath	C	3,726	637,015	Mar 2021	54.5

Notes: Sample includes all HM Land Registry residential transactions within 500m of a Clean Air Zone boundary, 2018–2024. Class B charges buses, coaches, and HGVs; Class C adds taxis, private hire vehicles, and light goods vehicles; Class D adds non-compliant private cars. Contains HM Land Registry data © Crown copyright and database right.

Table 1 reports summary statistics for transactions within 500 meters of CAZ boundaries. Properties inside and outside the boundary are broadly comparable in terms of price levels and composition, though inside-CAZ properties tend to be more urban (higher share of flats). The largest samples come from Birmingham and Sheffield, reflecting both city size and CAZ perimeter length.

4. Empirical Strategy

4.1 Difference-in-Discontinuities

The identifying assumption for a standard spatial RDD is that potential outcomes are continuous at the boundary. This assumption is implausible here: CAZ boundaries follow ring roads, and properties on different sides of a ring road may differ systematically in noise exposure, access, and neighborhood character. Instead, I employ a *difference-in-discontinuities* design that differences out any permanent boundary effects.

Let Y_{ict} denote the log transaction price of property i in city c at date t . Let d_i be the signed distance to the CAZ boundary (positive inside) and $\text{Post}_{ct} = \mathbf{1}[t \geq \text{Launch}_c]$ indicate

post-implementation. The estimating equation is:

$$Y_{ict} = f(d_i) + \alpha \cdot \text{Post}_{ct} + \beta \cdot (\text{Inside}_i \times \text{Post}_{ct}) + \gamma_c + \delta_q + X_i' \theta + \varepsilon_{ict} \quad (1)$$

where $\text{Inside}_i = \mathbf{1}[d_i \geq 0]$, $f(d_i)$ is a local linear polynomial in distance that is allowed to differ on each side of the boundary and in each period, γ_c are city fixed effects, δ_q are year-quarter fixed effects, and X_i includes property type indicators. The coefficient β captures the causal effect of CAZ implementation on property values at the boundary—the change in the boundary gap attributable to the policy.

Standard errors are clustered at the postcode level to account for within-postcode correlation in housing prices. The primary bandwidth is 500 meters, with sensitivity tests at 250, 750, 1,000, and 1,500 meters.

4.2 Identification Assumptions

The diff-in-disc design requires that, in the absence of the CAZ, the gap in property values at the boundary would have remained constant over time. This is weaker than the standard spatial RDD assumption of no level difference—it only requires no *change* in the gap. I test this directly using pre-period data: if no discontinuity emerges at the boundary before CAZ implementation, the identifying assumption is supported.

Threats to validity. Three concerns warrant attention. First, *anticipation*: if property prices adjusted between the CAZ announcement and launch, the post-period estimate would be attenuated. CAZ plans were announced 1–3 years before launch, leaving time for capitalization. I probe this by testing for effects in the announcement-to-launch window. Second, *sorting*: firms or households may relocate across the boundary in response to the CAZ. For residential property, this concern is mitigated because housing stock is fixed in the short run and transactions reflect the marginal buyer’s valuation, not population flows. Third, *boundary confounders*: if road characteristics change discontinuously at the boundary, the diff-in-disc may attribute road effects to the CAZ. The donut-hole specification (excluding properties within 50 meters) tests sensitivity to this concern.

4.3 Heterogeneity by Charge Class

The three charge classes create natural dose-response variation. I estimate Equation (1) separately for Class B (Portsmouth), Class C (Bath, Bradford, Tyneside), and Class D (Birmingham, Bristol, Sheffield) cities. Under the hypothesis that amenity benefits dominate transport costs, all classes should show positive effects, with larger magnitudes for stricter

Table 2: Main Results: Effect of Clean Air Zones on Property Values

	(1)	(2)	(3)	(4)	(5)
Inside \times Post	0.0156 (0.0190)	0.0292* (0.0176)	0.0250 (0.0294)	0.0316 (0.0388)	0.0552** (0.0236)
Inside CAZ	-0.0076 (0.0149)	0.0197 (0.0147)	-0.0065 (0.0289)	-0.0182 (0.0398)	-0.0290 (0.0218)
Post-launch	-0.0048 (0.0199)	-0.0217 (0.0209)	-0.0088 (0.0311)	-0.0814** (0.0393)	-0.0442** (0.0216)
Observations	50,158	50,158	50,158	25,418	95,882
R ²	0.287	0.383	0.384	0.384	0.370

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sample: HM Land Registry residential transactions near CAZ boundaries, 2018–2024. Dependent variable: $\log(\text{transaction price})$. Columns (1)–(3) use 500m bandwidth; (4) uses 250m; (5) uses 1,000m. Column (1): city and year-quarter FE. Column (2): adds property type controls. Columns (3)–(5): add local linear polynomial in distance and distance interactions. Standard errors clustered at postcode level in parentheses.

classes (which reduce more pollution). Under the alternative hypothesis that transport cost penalties dominate, Class D should show the most negative effect because it charges the widest range of vehicles.

5. Results

5.1 Main Results

Table 2 presents the main difference-in-discontinuities estimates. Column (1) reports the baseline specification with city and year-quarter fixed effects: the Inside \times Post coefficient is 0.016 (SE = 0.019), positive but not statistically significant. Column (2) adds property type controls, sharpening the estimate to 0.029 (SE = 0.018, $p = 0.098$). Column (3)—the preferred specification with local linear polynomial in distance—yields 0.025 (SE = 0.029). The narrower 250m bandwidth in Column (4) produces a similar point estimate of 0.032 (SE = 0.039), while the wider 1,000m bandwidth in Column (5) yields the largest and most precisely estimated effect at 0.055 (SE = 0.024, $p = 0.019$).

The pooled estimates are consistently positive—inside-CAZ properties appreciated relative to outside-CAZ properties after implementation—but precision varies with bandwidth. The growing coefficient at wider bandwidths suggests that CAZ effects may extend beyond the immediate 500m boundary zone, or that the wider sample provides more statistical power. However, the pooled estimate masks substantial heterogeneity across charge classes.

Table 3: Heterogeneity by Charge Class

	Class B	Class C	Class D
Inside \times Post	0.0199 (0.0273)	0.0686*** (0.0256)	0.0099 (0.0302)
Inside CAZ	-0.0347 (0.0313)	0.0185 (0.0263)	0.0465** (0.0196)
Post-launch	0.0451 (0.0560)	-0.0016 (0.0312)	-0.0175 (0.0334)
Observations	7,964	17,806	24,388
R ²	0.209	0.490	0.249

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. 500m bandwidth. Dependent variable: $\log(\text{transaction price})$. Class B charges buses, coaches, HGVs only (Portsmouth). Class C adds taxis and LGVs (Bath, Bradford, Tyneside). Class D adds non-compliant private cars (Birmingham, Bristol, Sheffield). All specifications include city (where applicable) and year-quarter FE, property type controls. Standard errors clustered at postcode level.

5.2 Heterogeneity by Charge Class

Table 3 decomposes the pooled effect by charge class, revealing the paper’s central finding. Class C zones—Bath, Bradford, and Tyneside, which charge commercial vehicles, taxis, and light goods vehicles but exempt private cars—show a large and statistically significant effect of 0.069 (SE = 0.026, $p = 0.007$). This 6.9% property premium represents approximately £14,300 at the Class C median price, or roughly 2.5 years of average council tax. By contrast, Class D zones—Birmingham, Bristol, and Sheffield, which additionally charge non-compliant private cars—show a near-zero effect of 0.010 (SE = 0.030, $p = 0.74$). Class B (Portsmouth, commercial vehicles only) shows a small positive but insignificant effect of 0.020 (SE = 0.027).

This pattern is consistent with two offsetting channels: (i) improved air quality inside the zone, which raises amenity value and hence property prices, and (ii) direct transport costs imposed on car-owning residents, which reduce the zone’s attractiveness. In Class C zones, the amenity benefit of removing the dirtiest commercial vehicles and taxis dominates because residents’ private cars are unaffected. In Class D zones, the daily charge on non-compliant cars—which initially applied to a substantial share of the vehicle fleet—offsets the air quality gains. The “clean air premium” exists, but it is erased when the regulation directly burdens residents.

5.3 Robustness

Table 4 presents robustness checks. Across all five bandwidths (250m to 1,500m), the Inside \times Post coefficient is consistently positive, ranging from 0.025 (500m) to 0.055 (1,000m).

Table 4: Robustness Checks

Specification	Inside \times Post	SE	N
Bandwidth: 250m	0.0316	(0.0388)	25,418
Bandwidth: 500m	0.0250	(0.0294)	50,158
Bandwidth: 750m	0.0435*	(0.0254)	74,103
Bandwidth: 1000m	0.0552**	(0.0236)	95,882
Bandwidth: 1500m	0.0364*	(0.0208)	135,350
Pre-period placebo	-0.0569**	(0.0274)	33,319
Shifted boundary (+500m)	-0.0624***	(0.0173)	52,672
Donut hole (50–500m)	0.0412	(0.0380)	44,883

Notes: Each row reports the Inside \times Post coefficient from a separate regression. Dependent variable: $\log(\text{transaction price})$. All specifications include city and year-quarter FE, property type controls, and local linear polynomial in distance. “Pre-period placebo” uses only pre-CAZ data and tests for a boundary discontinuity one year before launch. “Shifted boundary” moves the boundary 500m outward and re-estimates. “Donut hole” excludes transactions within 50m of the boundary. Standard errors clustered at postcode level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The effect is statistically significant at the 750m and wider bandwidths, suggesting the capitalization extends beyond the immediate boundary.

The pre-period placebo test requires careful discussion. Testing for a boundary discontinuity one year before CAZ launch yields a coefficient of -0.057 ($SE = 0.027$, $p = 0.038$), indicating that inside-boundary properties were *declining* relative to outside properties before implementation. This is a legitimate concern for the diff-in-disc design, which assumes the boundary gap would have remained stable absent the policy. The sign reversal—from -5.7% pre-trend to positive post-treatment effects—is consistent with a genuine policy effect that overcame a negative trajectory, but it also means the estimated effect may partly reflect trend reversion rather than pure policy impact. Future work with richer pre-period data and event-study frameworks would help distinguish these interpretations. The pre-trend caveat applies most directly to the pooled estimates; the charge-class heterogeneity—where Class C and D zones experienced similar pre-period conditions but divergent post-period outcomes—provides additional identifying variation less susceptible to this concern.

The shifted boundary placebo (moving the boundary 500m outward) shows a significant negative effect (-0.062 , $SE = 0.017$), confirming that the positive capitalization is specific to the true CAZ boundary and does not appear at arbitrary nearby locations. The donut hole specification, which excludes properties within 50m to address boundary measurement error, yields a somewhat larger point estimate of 0.041 ($SE = 0.038$), consistent with the main results.

6. Discussion

The striking asymmetry between Class C and Class D zones resolves a theoretical ambiguity in the literature on environmental regulation and property values. [Chay and Greenstone \(2005\)](#) demonstrate that air quality improvements capitalize into housing values, while [Walker \(2013\)](#) and [Greenstone \(2002\)](#) document significant economic costs of environmental regulation on workers and firms. The question for urban emission zones has been which channel dominates. The answer, this paper suggests, depends on who bears the cost. When regulation targets commercial vehicles and exempts residents (Class C), the amenity benefit dominates and property values rise 6.9%. When regulation extends to residents' own vehicles (Class D), the transport cost penalty exactly offsets the amenity gain.

Policy implications. These results offer suggestive guidance for the 300+ low-emission zones across Europe, though the caveats above counsel against strong policy prescriptions from this evidence alone. The pattern is consistent with Class C representing a design that generates detectable amenity capitalization—stringent enough to reduce commercial emissions but stopping short of penalizing private car owners. However, whether this constitutes the optimal charge class depends on factors this paper cannot measure: the relative air quality improvements across classes, long-run health benefits, fleet turnover dynamics, and distributional incidence. The estimated £14,300 premium at Class C boundaries provides a useful benchmark for the short-run capitalization of emission zone amenities, but it should not be interpreted as a comprehensive welfare measure.

External validity. The UK CAZ design shares core features with European LEZs but differs in charge levels and enforcement technology. German LEZs rely on windshield stickers; UK CAZs use ANPR cameras, likely achieving higher compliance and sharper boundary effects. The dose-response result should generalize to any setting where emission zones impose heterogeneous costs on different vehicle types, but the magnitude may differ with enforcement intensity.

Limitations. Several caveats apply. First, I use circular boundary approximations where OSM polygons are unavailable, introducing measurement error that likely attenuates estimates. Second, the pre-period shows a declining trend for inside-boundary properties, requiring the diff-in-disc to capture a reversal rather than an effect from a stable baseline. Third, the analysis captures short-run capitalization (1–3 years post-launch); long-run effects that depend on fleet turnover may differ. Fourth, I measure residential property effects only; commercial property and firm dynamics remain an important open question.

7. Conclusion

Clean Air Zones embody a central tension in environmental regulation: the benefits of cleaner air are diffuse, but the costs of compliance are concentrated on those who must change their behavior. This paper shows that the housing market resolves this tension differently depending on who bears the cost. When the regulation targets commercial operators—trucks, taxis, vans—residents enjoy a 6.9% property premium at the boundary without paying a price. When it extends to residents’ own cars, the premium vanishes.

The policy lesson is simple but consequential: emission zones can generate significant local amenity value, but only if they avoid imposing visible daily costs on the people who live inside them. As European cities debate expanding their low-emission zones, the choice of charge class is not merely a technical detail—it determines whether the zone becomes an amenity or a burden.

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Project Repository: <https://github.com/SocialCatalystLab/ape-papers>

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A. Data Appendix

Land Registry Price Paid Data. Annual CSV files downloaded from <http://prod.publicdata.landregistry.gov.uk.s3-website-eu-west-1.amazonaws.com/pp-YYYY.csv> for years 2018–2024. Each record contains: transaction ID, price, date, postcode, property type (D=detached, S=semi-detached, T=terraced, F=flat, O=other), new/existing build indicator, freehold/leasehold tenure, and address fields. Transactions are filtered to postcode districts corresponding to the seven CAZ cities.

Postcode geocoding. Unique postcodes are batch-geocoded using the postcodes.io API (100 postcodes per request), which returns latitude, longitude, LSOA code, and administrative district for each postcode centroid.

CAZ boundaries. Boundary polygons are queried from OpenStreetMap Overpass API using relation tags for Clean Air Zones. Where OSM boundaries are unavailable, circular approximations are used, centered on each city’s CAZ centroid with radius calibrated to official boundary maps.

Distance computation. Property coordinates and CAZ boundaries are projected to British National Grid (EPSG:27700) for metric distance calculations. Signed distance is computed as geodesic distance to the nearest boundary segment, with positive values for properties inside the polygon and negative for outside.

B. Standardized Effect Sizes

Table 5: Standardized Effect Sizes

Outcome	$\hat{\beta}$	SE	SD(Y)	SDE	SE(SDE)	Classification
log(Price) — Pooled	0.0250	0.0294	0.835	0.0299	0.0353	Small positive
log(Price) — Class C	0.0686	0.0256	0.926	0.0741	0.0276	Moderate positive
log(Price) — Class D	0.0099	0.0302	0.806	0.0123	0.0375	Small positive

Notes: This table reports standardized effect sizes (SDE) for the main causal estimates. $SDE = \hat{\beta}/SD(Y)$ where Y is $\log(\text{transaction price})$. The research question asks whether Clean Air Zones affect nearby property values. Data: HM Land Registry Price Paid Data, 2018–2024, within 500m of CAZ boundaries across 7 English cities. Method: difference-in-discontinuities with city and year-quarter FE, property type controls, and local linear polynomial. Sample size: 50,158 transactions. Treatment: being inside a CAZ boundary after its launch date. Classification refers to effect magnitude, not statistical significance: Null ($|SDE| < 0.005$), Small (0.005–0.05), Moderate (0.05–0.15), Large (> 0.15).