Where Firms Retire Carbon Offsets: Operational Footprints and Offset Quality*

Alvaro Pedraza† Tomas Williams‡ Federica Zeni§

Abstract

Although the climate benefit of carbon abatement does not depend on where it occurs, firms do not treat carbon offsets as geographically fungible. Using data on corporate retirements in voluntary carbon markets, we show that firms retire a disproportionate share of offsets in countries where they operate. We compare two explanations for this pattern: local operations may help firms identify better projects, or they may make offsets especially valuable in countries where firms seek to build goodwill with local stakeholders. The evidence supports the second view. Offsets retired in countries where foreign firms operate are of systematically lower quality than those the same firms retire elsewhere. This quality gap declines with firm experience, consistent with learning, but is stronger where local visibility is likely to be more valuable: in countries with higher climate ambition and in weaker-governance environments. We further show that in countries with more concentrated demand from operating firms, prices are less closely aligned with project quality. These patterns suggest that firms' choices among offset projects are shaped more by local stakeholder visibility than by environmental integrity across locations.

JEL Codes: F18, L14, Q54, Q58, G32.

Keywords: Voluntary carbon markets, Operational footprint, Local Goodwill, Carbon offset quality.

1 Introduction

Carbon dioxide is the canonical global externality: the climate impact of a ton of emissions is invariant to its geographic source. By extension, carbon offsets should be perfectly fungible. In a frictionless market, a verified unit of CO_2 removal or avoidance in Brazil should be a perfect substitute for an identical unit in Indonesia. However, this paper documents a stark departure from this benchmark. Using a transaction-level dataset of global voluntary carbon market (VCM) retirements—where firms permanently cancel offset credits to claim them against their own emissions—we show that corporate

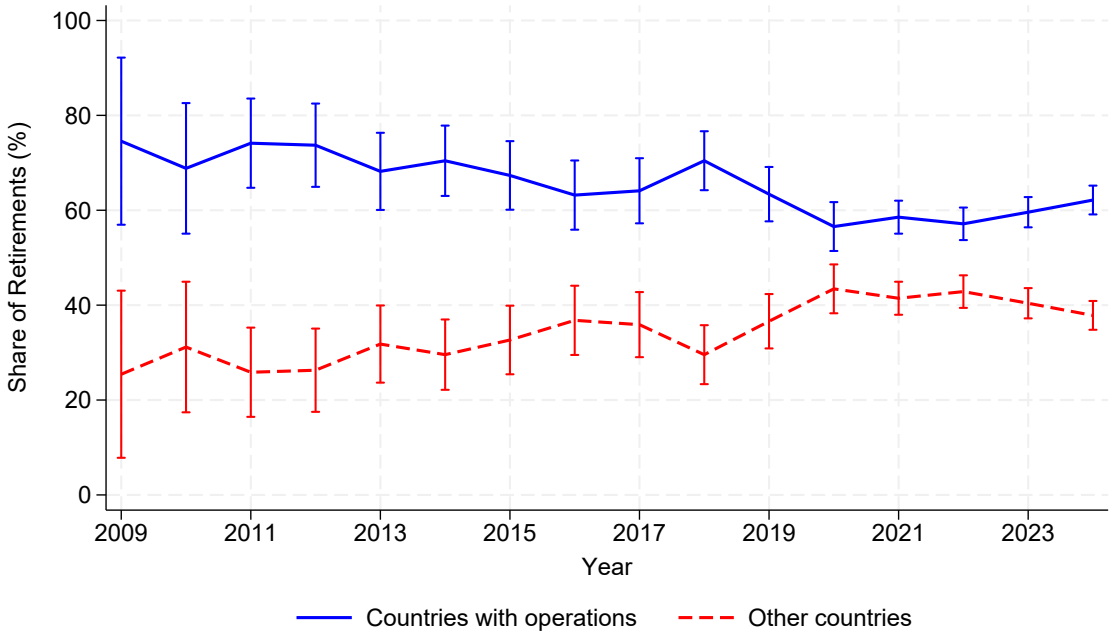
*We would like to thank Deeksha Gupta and Tarun Ramadorai for valuable comments.

†World Bank. Email: apedrazamorales@worldbank.org

‡George Washington University. Email: tomaswilliams@gwu.edu

§Ecole Politechnique Federale de Lausanne and Swiss Finance Institute (SFI). Email: federica.zeni@epfl.ch

Figure 1: Retirements by Geographical Presence



Note: The figure shows the estimated annual mean share of carbon offsets retired in countries where the firm operates (solid blue line) and in countries where it does not (dashed red line). Means are obtained from year-specific regressions with country, project-type, and industry fixed effects. Error bars denote 95% confidence intervals.

demand is systematically correlated with firms' operational geography. More importantly, we find that this geographic concentration is associated with systematically lower-quality offset projects, suggesting that non-pecuniary motives lead firms to prioritize local visibility over climate impact.

The voluntary carbon market has emerged as a key vehicle for corporate decarbonization, yet it remains characterized by pervasive informational asymmetries and quality uncertainty. Critics frequently point to the lack of additionality and permanence in many offset projects, raising concerns that the market facilitates "greenwashing" rather than genuine abatement (e.g., Schneider et al., 2019; West et al., 2023; Gill-Wiehl et al., 2024; Calel et al., 2025). These concerns create invalidation risk: credits retired today may later be viewed as environmentally ineffective or reputationally damaging. In such environment, the geographic composition of a firm's portfolio should, in principle, reflect its ability to screen for quality.

We document that firms allocate a disproportionate share of their retirements to countries where they maintain a physical operational presence (Figure 1). Crucially, because these retirements occur within the voluntary carbon market rather than compliance regimes, this concentration is not driven by regulatory mandates. Unlike cap-and-trade systems that may require domestic sourcing (see, e.g., Shapiro and Walker, 2025), firms in our sample face no formal obligation to align their offset portfolios with their

operational geography. This suggests that the observed spatial distribution reflects a strategic choice rather than a regulatory constraint.[1]

To rationalize this "local bias," we consider two countervailing mechanisms. The *Information Channel* suggests that operational presence facilitates screening of project quality through local knowledge and proximity. The *Goodwill Channel* instead posits that firms derive non-pecuniary benefits from local visibility, such as securing a "social license to operate" or managing stakeholder relationships.[2]

To distinguish between these mechanisms, we develop a conceptual framework of offset choice under asymmetric information and non-pecuniary payoffs. While both channels rationalize geographic concentration, they imply opposing predictions for equilibrium quality. Under the *Information Channel*, operational presence enhances screening, leading to a positive quality gradient: offsets retired in a firm's country of operations should exhibit higher environmental integrity than those retired abroad. If instead the *Goodwill Channel* dominates, local visibility alters marginal incentives. The reputational payoff from local sourcing reduces firms' sensitivity to project quality, as part of the retirement's value is decoupled from its underlying climate impact. In this regime, firms are willing to accept lower-quality offsets in exchange for local visibility, generating a negative quality gradient within their portfolios.

We test these predictions by merging the universe of retirement records from major VCM registries with firm-level geographic revenue data and ex-post project ratings. Our empirical strategy employs firm-by-year fixed effects, allowing us to compare the quality of offsets the same firm retires in countries where it operates to those retired elsewhere.

Our analysis yields three main results. First, foreign firms concentrate retirements within their operational footprints, rejecting geographic fungibility. Second, we document a significant negative *quality gradient*: conditional on observable project characteristics and firm-by-year fixed effects, foreign firms retire lower-quality offsets in host countries where they maintain operations relative to the offsets the same firms retire elsewhere. This pattern is consistent with non-pecuniary motives outweighing informational advantages in shaping offset demand.

Third, these demand distortions have equilibrium pricing implications. Projects whose buyer base is dominated by foreign firms with operations in the host country exhibit lower average prices and a

[1] While some jurisdictions have introduced hybrid systems—most notably Colombia's 2017 carbon tax, which permits tax neutralization via domestic offsets—we explicitly exclude these compliance-linked transactions from our primary analysis to ensure our results capture purely voluntary corporate demand.

[2] A large literature in non-market strategy and corporate social responsibility formalizes these forces. Locally salient environmental initiatives help firms build legitimacy, strengthen community relationships, and secure operational continuity (Gunningham et al., 2004; Owen and Kemp, 2013). Such actions reduce political and operational risks and are empirically associated with fewer disruptions and higher project value (Henisz et al., 2014). Environmental initiatives can also provide insurance-like protection against reputational and financial downside risk, generating what has been described as goodwill capital (Godfrey et al., 2009; Lins et al., 2017; Albuquerque et al., 2019). Relatedly, Bertrand et al. (2020) show that corporations geographically target philanthropic giving for strategic purposes, while Broccardo et al. (2022) show how stakeholder pressure can induce voluntary environmental actions even in the absence of regulation.

weaker relationship between prices and objective quality ratings. While prices in segments dominated by other foreign buyers reflect a sharp premium for higher-rated credits, this relationship is attenuated in markets where local goodwill substitutes for environmental efficacy. This systematic *price-quality decoupling* suggests that prices become less informative about project integrity when a larger share of buyers value other attributes of local offsetting.

Beyond average effects, we document systematic heterogeneity that sheds light on the mechanisms behind the negative quality gradient for foreign firms operating in host countries. The gradient attenuates with firm experience—both overall market participation and country-specific familiarity—consistent with informational frictions playing a partial role. It strengthens when offsets constitute a larger share of a firm's emissions strategy, as measured by retirement intensity, and is most pronounced among low-emission-intensity firms, for whom local signaling may dominate the marginal value of credible abatement. We further show that these patterns are not driven by mechanical matching with international developers but instead reflect active demand-side reallocation by foreign firms across locations.

Additional evidence reinforces the goodwill interpretation. The local allocation effect and the negative quality gradient are concentrated in countries with higher climate ambition, where climate action is likely to be more visible to stakeholders. The quality gradient is also stronger in low-governance environments, where local engagement may carry greater non-pecuniary returns. Finally, using subsidiary filings for U.S.-listed firms, we show that firms increase offset retirements after establishing subsidiaries in a country, and that these entry-country retirements are lower quality than the same firms' retirements elsewhere.

These findings have important welfare and policy implications. When corporate demand for local visibility sustains lower-quality projects, prices may fail to fully reflect environmental integrity. If the social cost of carbon exceeds the private reputational gains from local offsetting, the resulting allocation of climate finance is inefficient.[3] Moreover, because demand follows operational footprints, capital may be diverted away from regions with the highest abatement potential and toward those with greater multinational presence.

Contribution to the Literature. This paper contributes to an emerging literature on strategic offsetting and the quality of corporate decarbonization. While earlier work has emphasized supply-side integrity concerns—such as additionality, leakage, and permanence (Schneider et al., 2019; Calel et al., 2025)—a growing body of research highlights the role of demand-side incentives in shaping firms' use of carbon offsets.

[3]Related theoretical work shows that with imperfect certification, adverse selection can weaken voluntary carbon markets. When some buyers value non-carbon attributes (e.g., co-benefits), trade may persist despite quality uncertainty, potentially weakening the link between transactions and climate effectiveness (Manshadi et al., 2025).

Recent studies show that firms adjust offsetting behavior in response to capital-market pressures, using offsets strategically to manage ESG assessments and investor scrutiny (Kim et al., 2023), as well as to product-market pressures, where firms signal environmental responsibility to downstream customers through offset purchases rather than operational abatement (Beck and Pedraza, 2026).

In line with our findings, evidence on offsets pricing suggests that non-pecuniary attributes play an important role in carbon credit valuation. Berg et al. (2025) show that credits from projects with high *emotional tangibility* – like household-level interventions and deforestation avoidance projects, command price premia despite offering lower climate reliability, indicating that reputational value may outweigh objective carbon integrity for some buyers. Consistent with this, Heeb et al. (2023) find that investors exhibit substantial willingness-to-pay for sustainable assets but do not pay more for greater actual impact, suggesting that demand responds to sustainability labels rather than underlying environmental effectiveness.

We extend this literature by identifying geographic operational footprint as a central dimension organizing these strategic choices. We contrast an *Information Channel*, where local presence facilitates project screening (drawing on the logic of Coval and Moskowitz, 1999, 2001), with a *Goodwill Channel*, where foreign firms prioritize projects in host countries to manage stakeholder relationships and secure a "social license to operate"—building a reservoir of social capital that enhances local legitimacy and mitigates operational and political risks (Gunningham et al., 2004; Lins et al., 2017). This emphasis on geography connects to evidence that multinationals spatially allocate both pollution (Ben-David et al., 2021) and philanthropy (Bertrand et al., 2020, 2021) in ways that reflect strategic rather than efficiency-driven motives.

Finally, we contribute to the literature on the equilibrium effects of ESG preferences (Pástor et al., 2025) by showing how non-market motives can weaken the information content of prices in voluntary carbon markets. Our evidence adds a spatial dimension to this literature: when offset demand is tied to where firms operate rather than where abatement is most valuable, market prices become less effective at screening project quality.

2 Conceptual Framework

In this section, we present a stylized model that disciplines our empirical tests.

Information structure and timeline. The economy features three periods, $t \in \{0,1,2\}$, two carbon offset–producing countries, and two otherwise identical firms, each operating in one of the two countries. In each country, there are two offset projects that differ in quality: a high-quality project, indexed by $k = H$, and a low-quality project, indexed by $k = L$. Each project $k = \{H,L\}$ delivers a benefit θ_k from each unit of offsets q_k retired. For simplicity, we set the low quality to $\theta_L = 0$ and the high

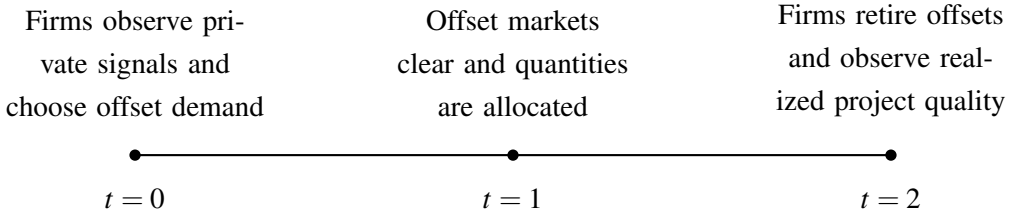
quality to $\theta_H = \theta$. In addition, firms receive a local marginal benefit $\beta \geq 0$ when purchasing offsets in the country where they operate ($j = l$). This benefit is independent of the project quality and reflects reputational or stakeholder advantages associated with sourcing offsets domestically.

Firms differ in their information about offsets quality depending on their operational exposure to the country where offsets are produced. Firms operating in the same country as the offset projects (*local firms, l*) are differently informed about which project is high quality than firms operating abroad (*foreign firms, f*).

Formally, at time $t = 0$, in each country, each firm $j \in \{l, f\}$ receives a private signal about the project believed to be high quality, denoted by $s_j \in \{H, L\}$. The signal is correct with probability

$$\Pr(k = H \mid s_j = H) = 1 - \Pr(k = L \mid s_j = H) = \rho_j \in (1/2, 1).$$

After observing their signals, firms simultaneously choose the quantity of offsets to purchase from each project, taking prices as given. At time $t = 1$, each offset market clears and quantities are allocated. Finally, at time $t = 2$, the true quality of each project is realized. The model timeline is illustrated below.



Firm problem. Conditional on signal $s_j \in \{H, L\}$, firm $j \in \{l, f\}$ chooses quantities $\{q_{k,j}(s_j)\}_{k \in \{H,L\}}$ to maximize:

$$\max_{\{q_{k,j}(s_j)\}} \sum_{k \in \{H,L\}} \left[B_{k,j}(s_j)\, q_{k,j}(s_j) - p_{k,j}\, q_{k,j}(s_j) - \frac{\gamma}{2} \mathrm{Var}(\theta_k \mid s_j)\, q_{k,j}(s_j)^2 \right], \tag{1}$$

where beliefs are given by:

$$\mathbb{E}[\theta_k \mid s_j] = \begin{cases} \rho_j \theta & \text{if } k = s_j, \\ (1 - \rho_j)\theta & \text{if } k \neq s_j, \end{cases} \tag{2}$$

and variance:

$$\mathrm{Var}(\theta_k \mid s_j) = \rho_j (1 - \rho_j) \theta^2, \qquad \forall k \in \{H, L\}. \tag{3}$$

The expected benefits per unit of purchased offset are:

$$B_{k,j}(s_j) = \left[(\beta \mathbf{1}\{j = l\})^{\sigma} + (\mathbb{E}[\theta_k \mid s_j])^{\sigma}\right]^{1/\sigma}, \qquad \sigma \leq 1. \tag{4}$$

Thus, a firm's marginal willingness to pay for an offset reflects two components: (i) the expected climate benefit implied by its private signal, and (ii) any non-pecuniary benefit associated with sourcing offsets locally. The relative weight of these two components determines how sensitive demand is to project quality. The CES specification captures diminishing marginal gains from retiring additional offsets, consistent with the idea that regulatory or reputational advantages may saturate beyond a certain level.

From the first order conditions, the optimal demand for each project satisfies:

$$q^*_{k,j}(s_j) = \frac{B_{k,j}(s_j) - p_{k,j}}{\gamma \mathrm{Var}(\theta_k \mid s_j)}, \qquad k \in \{H, L\}. \tag{5}$$

Offset producers. In each country, offset producers of type $k \in \{H, L\}$ sell competitively to both firms $j \in \{l, f\}$ and face convex production costs. Each offset market is segmented by the signal received by the local and foreign firm, (s_l, s_f), with prices adjusting so that supply equals demand in each segment.[4] Specifically, each producer k chooses quantities to sell to foreign and local firms, $q_{k,j}$, to maximize profits:

$$\max_{q_{k,j}} \sum_{j \in \{l,f\}} \left[p_{k,j}\, q_{k,j} - \frac{\phi_k}{2} q^2_{k,j} \right], \tag{6}$$

where ϕ_k is the production cost parameter, which we assume $\phi_L = \phi_H = \phi$.

The first-order condition with respect to each $q_{k_j,j}$ yields

$$q^*_{k,j} = \frac{p_{k,j}}{\phi}, \qquad j \in \{l, f\}, \quad k = \{H, L\}. \tag{7}$$

Equilibrium. Equilibrium prices and quantities are determined by market clearing.

Formally, an equilibrium is a set of prices and quantities such that (i) Firms choose offset quantities to maximize expected utility (1) given prices; (ii) Producers choose offset quantities to maximize profit (6) given prices; (iii) Each market clears: the quantity demanded by firms equals the quantity supplied

[4] This structure reflects the decentralized and project-based nature of voluntary carbon markets, where transactions are typically negotiated bilaterally and prices vary by project characteristics, certification standard, and vintage. See, among others, Hamilton et al. (2010) and Hamilton et al. (2012), State of the Voluntary Carbon Markets (Ecosystem Marketplace), which documents the OTC and project-specific pricing structure of voluntary offsets.

by producers for all k and j. Specifically, equilibrium prices are signal-contingent and pinned down by

$$p^*_{k,j}(s_j) = \frac{\phi}{\phi + \gamma \mathrm{Var}(\theta_k \mid s_j)} B_{k,j}(s_j). \tag{8}$$

Formally, an equilibrium is a collection of prices and quantities such that: (i) firms choose offset quantities to maximize expected utility (1) given prices and their signal; (ii) producers choose quantities to maximize profits (6) given prices; and (iii) markets clear, so that for each project type $k \in \{H, L\}$ and firm $j \in \{l, f\}$, supply equals demand.

Given the linear-quadratic structure, equilibrium prices are signal-contingent and given by

$$p^*_{k,j}(s_j) = \frac{\phi}{\phi + \gamma \mathrm{Var}(\theta_k \mid s_j)} B_{k,j}(s_j), \qquad k \in \{H, L\},\ j \in \{l, f\}. \tag{9}$$

2.1 Model Implications

Since the signal is correct with probability ρ_j, ex-post prices are obtained by averaging over signal realizations. For each project type $k \in \{H, L\}$, the expected price charged to firm j is:

$$p^*_{H,j} = \rho_j\, p^*_{H,j}(H) + (1-\rho_j)\, p^*_{H,j}(L), \qquad p^*_{L,j} = \rho_j\, p^*_{L,j}(L) + (1-\rho_j)\, p^*_{L,j}(H), \tag{10}$$

with $p^*_{k,j}(s_j)$ as in (9). Furthermore, using the supply relation in (7), expected quantities are:

$$q^*_{H,j} = \rho_j \frac{p^*_{H,j}(H)}{\phi} + (1-\rho_j) \frac{p^*_{H,j}(L)}{\phi}, \qquad q^*_{L,j} = \rho_j \frac{p^*_{L,j}(L)}{\phi} + (1-\rho_j) \frac{p^*_{L,j}(H)}{\phi}. \tag{11}$$

We prove the model's testable implications in Appendix B.

Proposition 1 (Local bias)**.** *Let $\phi > 0$, $\gamma > 0$, $\theta > 0$, $\sigma \in (0, 1]$, and $\rho_f, \rho_l \in (0.5, 1)$. If the local benefit β satisfies*

$$\beta > \kappa(\rho_f, \rho_l)\, \theta, \tag{12}$$

where $\kappa_{\rho_f}(\rho_f, \rho_l) > 0$ and $\kappa_{\rho_l}(\rho_f, \rho_l) < 0$, then the total share of offset retirements exhibits a local bias:

$$\frac{Q^*_l}{Q^*_l + Q^*_f} > \frac{1}{2}, \tag{13}$$

with total average quantities in each country defined as

$$Q^*_j = q^*_{H,j} + q^*_{L,j}, \qquad j \in \{l, f\}.$$

Proposition 1 provides a sufficient condition for the equilibrium share of surrendered offsets to exhibit a local bias. In particular, condition (12) sets a lower bound on the local benefit β necessary to generate this outcome in equilibrium.

Since $\kappa_{\rho_f}(\rho_f, \rho_l) > 0$ and $\kappa_{\rho_l}(\rho_f, \rho_l) < 0$, the larger the information gap between local and foreign firms (i.e., $\rho_l - \rho_f > 0$), the more slack the condition becomes. Intuitively, when firms are more informed about the quality of local offsets, they are more inclined to purchase domestically even without additional non-pecuniary gains.

Proposition 2 (Quality gradient)**.** *Let $\phi > 0$, $\gamma > 0$, $\theta > 0$, $\sigma \in (0,1]$, and $\rho_f, \rho_l \in (0.5, 1)$. If the local benefit β satisfies*

$$\beta > \nu(\rho_f, \rho_l)\,\theta, \tag{14}$$

where $\nu_{\rho_f}(\rho_f, \rho_l) < 0$ and $\nu_{\rho_l}(\rho_f, \rho_l) > 0$, then the fraction of high-quality offsets retired from local countries is strictly lower than that from foreign countries:

$$\frac{q^*_{H,l}}{Q^*_l} < \frac{q^*_{H,f}}{Q^*_f}. \tag{15}$$

Proposition 2 characterizes how local benefits distort the composition of retirements. When β exceeds the threshold in (14), the marginal valuation of local offsets becomes less sensitive to expected quality. As a result, the equilibrium share of high-quality offsets is lower in local markets than in foreign markets.

Unlike Proposition 1, the information gap now works in the opposite direction. Since $\nu_{\rho_f}(\rho_f, \rho_l) < 0$ and $\nu_{\rho_l}(\rho_f, \rho_l) > 0$, the condition becomes more binding as local firms become better informed relative to foreign firms (i.e., as $\rho_l - \rho_f$ increases). Intuitively, when local firms have more precise information about project quality, quality differences are more salient in their marginal valuation. In that case, a larger non-pecuniary benefit β is required to offset the importance of quality and generate a lower share of high-quality offsets locally. Conversely, when informational frictions are more severe or foreign firms are relatively better informed, non-pecuniary motives more easily dominate quality considerations, and the condition becomes slack.

Proposition 3 (Price-quality decoupling)**.** *Let $\phi > 0$, $\gamma > 0$, $\theta > 0$, $\sigma \in (0,1]$, and $\rho_f, \rho_l \in (0.5, 1)$. When $\sigma < 1$, If the local benefit β satisfies*

$$\beta > \theta \left(\frac{\mu(\rho_l)}{\mu(\rho_f)} \right)^{\frac{1}{1-\sigma}}, \tag{16}$$

where $\mu(\rho_j) = \rho_j^2 + (1-\rho_j)^2$, then the sensitivity of local offset prices to quality is lower than that of foreign prices:

$$\frac{\partial p^*_{k,l}}{\partial \theta} < \frac{\partial p^*_{k,f}}{\partial \theta}, \qquad k \in \{H, L\}. \tag{17}$$

When $\sigma = 1$, the CES aggregator becomes linear and local benefits affect prices only through a level shift rather than through substitution patterns. In this case, there exists a finite threshold $\bar{\beta}_1(\theta, \rho_l, \rho_f, \gamma, \phi)$ such that

$$\beta > \bar{\beta}_1 \quad \Rightarrow \quad \frac{\partial p^*_{k,l}}{\partial \theta} < \frac{\partial p^*_{k,f}}{\partial \theta}, \qquad k \in \{H, L\}. \tag{18}$$

Proposition 3 links buyer composition to equilibrium price formation. Quality-driven climate benefits and local non-pecuniary gains are imperfect substitutes. Thus, an increase in β reduces the marginal contribution of quality to total willingness to pay in local markets. As a result, equilibrium prices in segments with stronger local demand respond less to improvements in underlying project quality. In other words, the sensitivity of prices to θ is lower in markets where non-pecuniary motives constitute a larger share of marginal valuation.

When preferences are strictly convex in aggregation ($\sigma \in (0,1)$), this dampening effect arises through CES substitution: local non-pecuniary benefits directly crowd out the marginal weight of quality in willingness to pay, generating a nonlinear attenuation of price sensitivity that strengthens in β. In the limiting linear case ($\sigma = 1$), this substitution channel disappears and β affects equilibrium prices only as a level shifter. Nonetheless, even in this benchmark, sufficiently large local benefits still reduce the relative responsiveness of local prices to quality changes by amplifying the baseline wedge between local and foreign demand compositions.

3 Testable Hypotheses

The conceptual framework yields three predictions that guide the empirical analysis. We examine whether the data are consistent with an environment in which local non-pecuniary benefits meaningfully influence firms' offset demand, even after accounting for informational differences across markets.

Specifically, we test the following three hypotheses:

Hypothesis 1 (Local Bias). *Firms allocate a larger share of their carbon offset retirements to countries where they maintain an operational footprint.*

Under geographic fungibility, a firm's offset portfolio should be independent of its revenue geography. Systematic concentration of retirements in operationally relevant countries indicates that location-specific factors enter firms' demand.

Hypothesis 2 (Negative Quality Gradient). *Offsets retired in a firm's country of operations exhibit lower average environmental integrity than those retired in foreign jurisdictions.*

If local non-pecuniary benefits are independent of project integrity, operational presence reduces the marginal valuation of quality in domestic markets, generating a negative quality gradient within firms.

The framework further implies that the magnitude of this gradient depends on the relative importance of environmental integrity and local signaling in firms' objective. When the marginal value of true emissions reductions is high, or when informational frictions are limited, the negative quality gradient should attenuate. Conversely, when local signaling benefits are relatively more important, the gradient should strengthen.

Hypothesis 3 (Price–Quality Decoupling). *The relationship between offset prices and environmental integrity is weaker in jurisdictions with greater local operational demand.*

When non-pecuniary motives constitute a larger share of marginal willingness to pay, prices become less responsive to differences in project quality. As a result, prices in markets with stronger local operational demand are less tightly aligned with underlying environmental integrity.

4 Data and aggregate patterns

To examine how corporate participation in voluntary carbon markets is linked to firms' operational footprint, we construct a comprehensive database that combines project-level offset retirement data, firm-level operational and emissions data, and project quality assessments.

4.1 Carbon Offsets

Voluntary carbon offsets do not have centralized transaction-level purchase data; offset use becomes observable only when credits are formally retired. We therefore assemble project-level retirement data from the four largest voluntary carbon registries: Verra, Gold Standard, the American Carbon Registry, and the Climate Action Reserve, using data compiled by the Berkeley Carbon Trading Project (Berkeley Carbon Trading Project, 2025). The resulting dataset covers 3,565 distinct offset projects and more than 350,000 retirement transactions between 2009 and 2024, corresponding to a total of 759 million tons of CO_2 retired over the period (Table 1, Panel A).

To identify corporate users of offsets, we extract and standardize information from unstructured text fields describing the retirement beneficiary. We use large-language-model-assisted text processing to harmonize beneficiary names, resolve spelling and formatting inconsistencies, and map retirements to ultimate parent companies. Retirements attributed to subsidiaries are assigned to the parent firm, and all retirements are aggregated at the headquarters (parent-company) level. We do not attempt to distinguish

between direct subsidiary purchases and centralized corporate procurement. This procedure identifies 1,582 publicly listed firms that retire offsets from 1,889 distinct projects across 88 countries. Projects used by listed firms account for approximately 87% of total retired volume in the full sample, or 659 million tons of CO_2 (Table 1, Panel A).

Offset quality ratings. To measure offset quality, we match projects to MSCI's Carbon Project Ratings (MSCI, 2024), which provide ex-post assessments of project additionality, permanence, leakage risk, and monitoring credibility. MSCI covers 2,549 projects in our sample and assigns each project both a letter grade—ranging from *AAA* (highest integrity) to *CCC* (lowest integrity)—and an associated numerical integrity score, where higher values denote higher environmental quality. As shown in Table 1, the average numerical rating is 2.99 in the full sample and 2.98 among projects used by listed firms. The distribution reflects a meaningful quality spread; the interquartile range spans from a numerical score of 2.69 (corresponding to a letter grade of *B*) at the 25th percentile to 3.24 (*BBB*) at the 75th percentile.

We complement MSCI ratings with project assessments from BeZero Carbon and Sylvera, two independent analytics providers that specialize in evaluating the environmental integrity and risk profile of carbon offset projects, which together cover 375 and 358 projects in our sample, respectively. These ratings provide additional standardized evaluations of project credibility and permanence. A key feature of all three rating datasets is that, over our sample period, they are largely ex post. MSCI released its ratings in bulk only in late 2024 for projects that had already issued and retired credits, while BeZero Carbon and Sylvera began assigning ratings only after 2021, often after projects had already begun issuing credits and retirements had taken place. As a result, these ratings generally do not reflect the information available to firms at the time of offset purchase or retirement.

Carbon offset prices. Information on carbon offset prices is drawn from Sylvera, which compiles transaction-level data and broker-quoted information from voluntary carbon markets and reports average prices at the project-vintage level. Sylvera aggregates observed trades and indicative quotes into weekly average prices for each project and vintage, reflecting prevailing market conditions rather than contract-specific terms. Coverage is most comprehensive from 2020 onward, coinciding with the rapid expansion of trading activity and price reporting in voluntary carbon markets. We aggregate these weekly data to the annual level by project and vintage to align with the timing of observed retirements. Price information is available for 1,049 projects in the full sample and 750 projects used by listed firms (Table 1, Panel A).

These prices should be interpreted as indicative measures of the market value of a credit from a given project and vintage around the time of retirement, rather than as the exact prices paid by the retiring firm. We do not observe the purchase date, so realized acquisition costs may differ from the price observed at retirement if firms acquired credits earlier and held them in inventory. At the same time, each retirement is linked to the issuance date of the retired credits, which allows us to observe the gap

between issuance and retirement. In our sample, that gap is relatively short: the median is about 0.9 years, and 80 percent of retired CO_2 tonnes are retired within two years of issuance. Since purchase must occur no earlier than issuance and no later than retirement, these patterns imply that retirement-year prices are likely to be reasonably close to the market conditions prevailing when firms acquired the credits. In the analysis, prices are therefore used as comparative measures of the opportunity cost and market value of retiring credits across projects and vintages, rather than as exact transaction prices faced by firms.

As shown in Panel B, average offset prices are similar across samples, with a mean price of $6.35 per ton in the full sample and $6.34 among projects used by listed firms. Price dispersion is substantial, with standard deviations exceeding the mean and prices ranging from less than a dollar to over $115 per ton. This wide variation reflects heterogeneity in project type, location, vintage, and perceived quality, as well as thin trading and episodic transactions in voluntary carbon markets.

4.2 Firms' Geographical Footprint, Emissions, and Financial Data

To characterize firms' global operations, we merge our carbon offset retirement data with *FactSet GeoRevenue*, a database that provides a granular breakdown of publicly listed firms' revenues by country. GeoRevenue uses firms' segment disclosures, regulatory filings, and proprietary text analysis to assign, for each firm-year, the percentage of consolidated revenue generated in each country of operation. This allows us to construct a consistent and time-varying measure of firms' geographical footprint across markets.

Our matched sample includes 1,450 publicly listed firms domiciled in 54 countries that retired at least one metric ton of CO_2 to offset emissions at some point between 2009 and 2024. The largest headquarters locations are the United States (325 firms), the United Kingdom (128), Japan (94), and Australia (81). Publicly listed firms account for approximately 40% of all carbon offset retirements observed in the combined registry dataset over the sample period. For each firm-year, we observe the full distribution of revenues across countries, which we use to identify whether a firm has an operational presence—defined as positive revenue—in a given country at the time offsets are retired.

Table 2 highlights a striking asymmetry between the geographic origin of firms retiring offsets and the location of the underlying carbon offset projects. While the majority of listed firms using carbon offsets are domiciled in high-income countries, most carbon offset projects are located in low- and middle-income countries, including India, China, Indonesia, Brazil, and several countries in Sub-Saharan Africa. This pattern underscores the role of voluntary carbon markets as a channel through which firms headquartered in advanced economies direct resources toward mitigation projects in developing countries. As such, voluntary carbon markets are often viewed as a potential source of private climate finance for emissions-reduction projects in low- and middle-income countries, where abate-

ment opportunities may be relatively inexpensive and financing constraints more binding (World Bank, 2025).

Firm emissions and financial characteristics. Firm carbon emissions and financial information are obtained from ISS STOXX. We use Scope 1 and Scope 2 emissions, total sales, and balance-sheet characteristics, all reported at the annual frequency. Emission intensity is constructed as total emissions divided by revenue, providing a standardized measure of firms' baseline carbon exposure that is comparable across industries and over time.

Climate targets. Information on firms' climate commitments is obtained from the Carbon Disclosure Project (CDP). CDP is a global non-profit platform through which firms voluntarily report standardized information on greenhouse gas emissions, climate risks, and mitigation strategies to investors and other stakeholders. Using these data, we construct an indicator for whether a firm has an approved Science Based Targets initiative (SBTi) emissions-reduction target in a given year. This variable captures the formal adoption of externally validated decarbonization commitments and allows us to distinguish firms with explicit climate targets from those without.

Table 3 reports summary statistics for firm characteristics and carbon offset retirements at the firm-year level. Panel A summarizes overall firm attributes and aggregate offset activity. The average firm in our sample reports annual sales of $20.35 billion and emits approximately 3.36 million metric tons of CO_2 per year. Roughly 30% of firm-year observations occur after a firm has obtained SBTi target approval. On average, firms retire offsets from 4.7 distinct projects across 2.6 countries, and the share of firm revenue generated in these retirement countries averages 7.5

Offset usage is economically meaningful but modest relative to firms' scale. The average firm retires about 7,500 metric tons of CO_2 annually through carbon credits, with an average credit price of $6.73 and an average MSCI project rating of 2.96 (both measures value-weighted across projects).

Panels B and C split offset retirements based on whether credits are sourced from countries where the firm has an operational presence (positive revenue) or from countries where it does not. Two stylized facts emerge. First, firms retire a larger share of offsets in countries where they operate. Second, offsets retired in these operational countries are, on average, of lower MSCI-rated quality and lower price than offsets retired in other countries. This pattern is consistent with the mechanisms emphasized in our conceptual framework, in which local presence can increase the attractiveness of nearby projects through information advantages or non-pecuniary (e.g., goodwill or reputational) considerations, potentially weakening incentives to select the highest-quality available offsets.

4.3 Aggregate patterns

Figures 1 and 2 characterize the geographic concentration of carbon offset retirements. As shown in Figure 1, firms allocate a significantly larger share of their portfolio to countries within their operational

footprint throughout the sample period. While the share of offsets sourced from countries without a revenue footprint has increased over time, retirements remain predominantly concentrated in countries where firms maintain a physical presence.

Figure 2 explores the intensity of this preference by relating retirement location to the scale of local operations. Excluding a firm's home country to ensure the results are not driven solely by domestic bias, we sort firm-country pairs into quartiles based on their revenue share. We find a monotonic relationship: the mean operational retirement share rises from 68% in the lowest revenue quartile to 83% in the highest quartile. This evidence suggests that the tilt toward local offsets is not merely binary but scales with the intensity of a firm's local economic activity. Together, these aggregate patterns reject the benchmark of geographic fungibility and provide initial support for the local bias predicted by Hypothesis 1.

We next examine whether the quality of retired offsets varies systematically with firms' geographic presence, using MSCI project ratings. Figure 3 reports the distribution of offset retirements across rating quartiles, disaggregated by firms' operational presence in the country where the offset project is located.

Panel A contrasts firms with and without an operational presence in the host country. For each MSCI rating quartile, the figure reports the share of corporate offset retirements accounted for by the two groups; by construction, these shares sum to one within each quartile, so differences in levels partly reflect overall participation in voluntary carbon markets. The salient pattern lies in the quality gradient. Firms with an operational presence account for roughly two-thirds of retirements in the lowest quality quartile (Q1) and less than one-third in the highest quality quartile (Q4). Firms without local operations exhibit the opposite pattern: they account for about one-third of retirements in Q1 but nearly two-thirds in Q4, indicating a pronounced tilt toward higher-rated projects.

Panel B zooms in on firms with an operational presence and further disaggregates them by the intensity of their local footprint and by firm domicile. Foreign firms with a high revenue footprint in the host country (above the sample median revenue share) display the strongest quality gradient, with retirements concentrated in intermediate and lower-rated projects: over 40 percent of their retirements are in Q2 projects, while less than 15 percent are allocated to the highest-rated offsets. In contrast, foreign firms with a low revenue footprint exhibit a relatively balanced allocation across the quality spectrum, with shares in each quartile ranging between roughly 14 and 18 percent. Domestic firms—those headquartered in the same country as the offset project—retire substantially fewer offsets overall, and their allocations are also tilted toward lower-rated projects; the relatively flat profile across rating categories reflects the smaller scale of domestic retirements rather than the absence of a quality gradient.

Taken together, these descriptive patterns indicate that the geographic bias in offset retirements is accompanied by systematic differences in the quality composition of firms' offset portfolios. While

carbon offsets are, in principle, fungible across locations, firms with a local operational footprint—particularly those with substantial revenue exposure—tend to concentrate their retirements in lower-rated projects in the countries where they operate. By contrast, firms without local operations disproportionately retire higher-quality credits.

5 Empirical Methodology

To examine how firms' operational presence relates to the location and quality of carbon offset retirements, we estimate regressions that compare offset choices across projects and locations within the same firm over time.

Firms retiring offsets in countries where they operate may differ systematically from those that do not in size, sector, emissions profile, or sustainability strategy. Similarly, countries attracting more foreign retirements may differ in project availability or baseline quality. To isolate firms' location-specific preferences, our empirical approach conditions on observable firm and project characteristics and exploits within-firm variation in offset choices across destinations.

Our baseline specification is:

$$S_{kiy} = \beta_1 \text{Operation}_{ij} + \beta_2 \text{Rating}_k + \beta_3 \left(\text{Operation}_{ij} \times \text{Rating}_k\right) + \mathbf{X}'_{iy}\gamma + \text{Fixed Effects} + \varepsilon_{kiy}, \quad (19)$$

where S_{kiy} denotes the share of carbon offsets retired by firm i from project k in year y, defined as the volume of credits retired from project k divided by the firm's total retirements in that year. The indicator Operation_{ij} equals one if firm i has an operational presence in country j, where project k is located. Rating_k captures the ex-post quality rating assigned to project k.

Equation (19) directly tests Hypotheses 1 and 2. The coefficient β_1 captures geographic concentration (Local Bias). The interaction term β_3 identifies the quality gradient by measuring whether the allocation of retirements across projects differs by quality within firms' operational footprints.We also distinguish among different forms of exposure to the country of operations, separating domestic firms, foreign firms with more salient host-country operations, and foreign firms with more limited exposure.

The vector $\mathbf{X}_{iy}$ includes firm-level controls such as emissions, revenue, and SBTi target status. All specifications include project classification, vintage, and country-of-retirement-by-year fixed effects to account for supply-side variation. This absorbs time-varying factors common to projects available in the same country-year, including changes in project entry, exit, registry composition, and the local distribution of ratings, and therefore addresses the concerns that firms with operations may simply retire offsets in country-years where the available project menu is systematically different. We report specifications with firm fixed effects as well as our most restrictive specification with firm-by-year fixed

effects, which absorb all time-varying firm characteristics and compare offset quality choices within the same firm and year across locations.

Standard errors are clustered at the firm level to account for serial correlation in retirement choices.

Hypothesis 3, which concerns the relationship between prices and project quality, is tested separately using project-level price regressions described in Section 8.

6 Results

Table 4 reports baseline estimates using MSCI project ratings. We begin by documenting the overall relationship between offset quality and retirement shares. Across specifications, the coefficient on *Rating* is positive and statistically significant, indicating that, on average, firms allocate a larger share of their offset retirements to higher-rated projects. In the absence of location-specific incentives, environmental integrity is an important determinant of demand.

We next examine whether retirement choices vary systematically with firms' operational presence in the project country. Consistent with the theory, we begin with a broad definition of operational footprint that includes both domestic firms and foreign firms with revenues in the project country, and then compare across different margins of exposure. Columns (1)-(2) define *Operation* broadly to include domestic and foreign firms with positive revenues in the project country. Columns (3)-(4) narrow this definition to foreign firms whose revenue footprint in the project country is above the median, while columns (5)-(6) define *Operation* using foreign firms with below-median revenue exposure. Under the above-median definition, the coefficient on *Operation* is positive and economically large: projects located in countries where firms have a salient foreign operational presence receive about 24 percentage points more of the firm's annual retirements. This result provides direct support for Hypothesis 1 and points to a pronounced geographic concentration of offset retirements around firms' most important foreign operating markets.

We then turn to the interaction between operational presence and project quality. In columns (3)–(4), the coefficient on *Operation* $\times$ *Rating* is negative and precisely estimated, indicating that firms allocate relatively larger retirement shares to lower-rated projects in countries where their foreign revenue footprint is more salient. Quantitatively, a one-standard-deviation increase in the MSCI rating (about 0.53 points) is associated with a 4.2 percentage point decline in the retirement share allocated to projects in countries where foreign firms have an above-median revenue footprint (-0.079×0.53). In column (4), which includes firm-by-year fixed effects, this comparison is made within the same firm and year across countries with high versus low operational exposure, and the negative interaction remains. This suggests that the quality gradient is not driven by cross-firm composition or time-varying firm characteristics, and is consistent with Hypothesis 2.

In contrast, columns (5)-(6) show that foreign firms with below-median revenue exposure exhibit neither significant geographic concentration nor a statistically detectable quality gradient. The interaction term is small and imprecisely estimated, suggesting that limited local exposure does not generate systematic shifts in portfolio quality. This contrast helps sharpen the interpretation of the results. Although the conceptual framework is written in terms of operational footprint more generally, the negative quality gradient in the data is concentrated among foreign firms with more salient host-country exposure, rather than among domestic firms or foreign firms with only limited exposure. This pattern is consistent with a goodwill channel, since the strongest effects appear precisely for firms that must build or maintain local stakeholder relationships outside their home country.

These patterns are robust to alternative measures of project quality. Appendix Table A1 replicates the analysis using binary indicators based on BeZero and Sylvera ratings. Despite the smaller sample size, the qualitative results remain unchanged: firms with substantial operational exposure concentrate retirements locally and exhibit a weaker alignment between operational presence and project quality.

Because project integrity is not directly observed at the time firms retire offsets—MSCI released its ratings only in late 2024, and the BeZero and Sylvera coverage is also largely recent—our baseline regressions use ex-post ratings as an econometric proxy for underlying project quality. From the econometrician's perspective, these realized ratings summarize dimensions of integrity such as additionality, permanence, leakage risk, and monitoring credibility. Firms, however, did not observe the later MSCI ratings when making retirement decisions and instead had to rely on their own due diligence and on project characteristics that were plausibly visible at the time of choice.

This distinction matters for interpretation. The negative interaction in Table 4 should therefore be read first as a realized integrity gradient: projects retired in foreign firms' operational footprints later receive lower ex-post quality ratings. To assess whether this pattern is also visible in information available ex ante, we construct an observable quality proxy based only on harmonized project type (for example, renewable energy, cookstoves, or REDD+), developer status (that is, whether the developer operates only locally or across multiple countries), and registry (such as Verra, Gold Standard, CAR, or ACR). Specifically, for each (p, d, r) bucket, we compute the retired-volume-weighted share of projects classified as high quality under the MSCI measure and assign that score back to each project.

Re-estimating Table 4 with this ex-ante observable proxy yields a similar pattern (see Appendix Table A2). In particular, for foreign firms with an above-median revenue footprint in the project country, the interaction between operational presence and ex-ante quality remains negative and statistically significant. Thus, the negative quality gradient is not solely an artifact of ex-post ratings released in 2024; it is also visible across project categories defined by characteristics firms could plausibly observe at the time of retirement.

One additional concern with the project-level specification in Equation (19) and Table 4 is that the dependent variable is defined at the firm-project level rather than at the level of aggregate firm allocations across exposure and quality groups. In principle, the estimates could therefore be influenced by portfolio fragmentation. For example, a firm could spread retirements across many small low-quality projects while concentrating in a few large local high-quality projects, potentially affecting the project-level coefficients even if its aggregate allocation across quality and exposure categories were unchanged. In our setting, however, this concern appears limited. As shown in Table 3, the median firm-year involves retirements in only one country and two projects; even at the 75th percentile, firms retire in only three countries and five projects. This leaves relatively little scope for the main results to be driven mechanically by firms splitting a given country allocation across many small projects. To assess whether the main pattern survives in a more aggregated setting, we also collapse retirements into firm-year cells defined jointly by exposure and quality buckets.

The aggregated firm-year-cell results, reported in Table 5, confirm the main pattern. Relative to foreign countries where the firm has no operations, firms allocate a significantly larger share of retirements to foreign countries where they do operate: the retirement share is about 11.6 percentage points higher in the firm $\times$ year specification. At the same time, the interaction with project quality shows a clear negative gradient within foreign operational markets. The coefficient on *Foreign with Ops* $\times$ *High Quality* is negative and statistically significant, implying that, conditional on operating there, firms allocate relatively less to above-median MSCI-rated projects in those foreign countries than in foreign countries where they have no operations. In column (2), this differential is about 14.3 percentage points. These results are consistent with Hypotheses 1 and 2, but they also suggest that, although our conceptual framework is about operational footprint more broadly, the empirical relationship is concentrated among foreign firms operating in host countries.

While the aggregated results are informative, we prefer the project-level specification as our main design because it allows us to condition directly on project characteristics and absorb supply-side heterogeneity more finely. Taken together, the evidence points to a consistent pattern: firms concentrate retirements in foreign countries where they have an operational presence, and within those locations the composition of retirements shifts toward lower-rated projects. These findings reinforce both the geographic concentration result and the negative quality gradient within firms.

7 Mechanism Heterogeneity and Comparative Statics

The baseline results document a negative quality gradient associated with firms' operational presence. We now examine how the strength of this gradient varies across environments where the marginal benefits of integrity or local signaling plausibly differ.

7.1 Experience in Carbon Markets

We first examine whether the negative relationship between operational presence and offset quality attenuates when informational frictions are likely to be lower. Although project transparency is not directly observable, we proxy for information acquisition using firms' experience in carbon offset markets. Experience is defined in two ways: overall participation in offset markets and repeated activity within a specific country.

Figure 4 illustrates the role of country-level experience. The figure separates retirements by foreign firms with an operational footprint into those occurring during the first two years of activity in a country and those occurring after at least two years. In early years, retirement shares decline steeply with project quality, indicating a pronounced negative gradient. After firms accumulate country-level experience, this gradient becomes noticeably flatter.

Table 6 confirms this attenuation in regression form. Across both definitions of experience, the interaction between *Operation* and *Rating* remains negative but declines meaningfully in magnitude with experience. For example, comparing columns (2) and (4), which differ only in firms' overall offset experience, the interaction coefficient is substantially smaller once firms have accumulated several years of participation. A similar pattern emerges when experience is defined at the firm-country level. These results indicate that greater familiarity with offset markets mitigates, though does not eliminate, the negative quality gradient.

7.2 Retirement Intensity

The conceptual framework implies that the strength of the quality gradient depends on the marginal value firms attach to local offset sourcing relative to environmental integrity. When offsetting represents a larger share of a firm's emissions management strategy, the non-pecuniary benefits associated with the geographic allocation of retirements may carry greater weight in portfolio choice. In such cases, operational presence should exert a stronger influence on the composition of offsets.

To examine this idea, we measure firms' reliance on offsets using *retirement intensity*, defined as the ratio of total offset retirements to total Scope 1 and 2 emissions. The sample is split at the median level of retirement intensity (Table 7, Columns 1-4).

Among firms with low retirement intensity, operational presence has limited predictive power for either geographic concentration or portfolio quality. In contrast, firms with high retirement intensity exhibit both strong local concentration and a substantially steeper negative quality gradient. The interaction coefficient between *Operation* and *Rating* is larger in magnitude and statistically significant for this group. This pattern indicates that the quality gradient strengthens when offsets represent a more central component of the firm's emissions management strategy.

7.3 Emission Intensity

Finally, we consider heterogeneity by emission intensity. Firms with higher emissions per unit of revenue plausibly face a higher marginal benefit from credible abatement. When splitting firms at the median of emission intensity (Table 7, Columns 5-8), the negative quality gradient is strongest among low-emission-intensity firms and substantially attenuated among high-emission-intensity firms.

For firms with greater emissions exposure, portfolio quality is more uniform across locations, whereas firms with lower emissions intensity exhibit a sharper tilt toward lower-rated projects within their operational footprints. This heterogeneity suggests that the relative valuation of environmental integrity versus local signaling varies with the firm's underlying emissions profile.

Overall, these comparative statics indicate that the magnitude of the negative quality gradient varies systematically with proxies for informational frictions and with the relative importance of offsetting within the firm's emissions strategy.

7.4 Supply-Side Matching and Developer Access

A remaining concern is that the negative quality gradient reflects mechanical matching between firms and project developers rather than strategic allocation across projects. In the voluntary carbon market, some international developers operate across multiple jurisdictions and tend to implement larger projects with higher average integrity. If firms without local operations disproportionately source from these developers, observed quality differences could arise from supply-side access rather than location-specific demand.

To address this concern, we re-estimate the baseline specification including an indicator for international developer status and its interaction with operational presence (Table 7, Columns 9-10). The coefficient on international developer status is statistically insignificant, and its interaction with *Operation* is economically small. Crucially, the negative interaction between *Operation* and *Rating* remains quantitatively similar to the baseline and highly significant.

These results indicate that the quality gradient is not driven by differential access to international versus domestic developers. Instead, firms reallocate retirement shares across projects conditional on geography, consistent with demand-side portfolio choices rather than mechanical supply matching.

8 Price Implications and the Decoupling of Prices from Quality

We next examine whether the allocation patterns documented above extend to price formation in the voluntary carbon market. Table 8 reports project-level regressions of average offset prices on project quality (ratings), the share of retirements by firms with a local operational footprint, and their interac-

tion. This analysis directly tests Hypothesis 3, which predicts that the relationship between prices and environmental integrity weakens in markets dominated by firms with local operational exposure.

Across all specifications, project ratings are positively and significantly associated with prices. Higher-rated projects command a premium, indicating that environmental integrity remains an important determinant of valuation.

We then examine whether this price-quality relationship varies with the composition of demand. Columns (2), (5), and (8) show that projects with a larger share of retirements by firms with a local operational footprint tend to have lower average prices. This pattern is consistent with the allocation results, which show that local demand is tilted toward lower-rated projects.

The central test lies in the interaction between project ratings and the share of retirements by firms with local operations. In Columns (4), (7), and (10), this interaction is negative and statistically significant. While higher ratings are associated with higher prices overall, the sensitivity of prices to ratings is weaker for projects whose demand is dominated by firms with an operational presence in the host country. In other words, the sensitivity of prices to project ratings declines in markets where local operational demand is more prominent.

This attenuation is strongest when local demand is driven by foreign firms with high revenue exposure in the project country and is negligible for firms with low exposure (Columns 11-13). The heterogeneity mirrors the allocation results and indicates that the strength of the price-quality relationship depends on the intensity of operational presence.

Taken together, these findings indicate that the association between prices and environmental integrity varies systematically with the composition of buyers. In markets characterized by stronger local operational demand, prices are less tightly aligned with project ratings.

9 Local visibility and the strength of the goodwill channel

The preceding results show that firms disproportionately retire offsets in countries where they operate, but that these local retirements are tilted toward lower-quality projects. This pattern is consistent with the goodwill channel: operational presence raises the private value of supporting local projects, even when they offer weaker environmental integrity. This section provides three additional pieces of evidence on the strength of this channel. First, the local allocation effect and the negative quality gradient are concentrated in countries with higher climate ambition, where climate action is likely to be more visible to stakeholders. Second, the quality gradient is also stronger in weaker-governance environments, where firms may place greater value on local engagement. Third, using subsidiary filings for U.S.-listed firms, we show that offset retirements increase after firms establish subsidiaries in a country, and that these entry-country retirements are lower quality than the same firms' retirements elsewhere.

9.1 Climate ambition and the quality gradient

We measure country-level climate ambition using the Climate Change Performance Index (CCPI), an annually published index produced by Germanwatch. The CCPI evaluates countries' climate mitigation performance on a 0–100 scale, combining indicators on greenhouse gas emissions, renewable energy, energy use, and climate policy.[5] We merge the CCPI overall score to the retirement-level data at the country-year level and classify project countries into high- and low-climate-ambition groups based on the year-specific median CCPI score. The CCPI covers 63 countries, which account for about 90% of global emissions. In our sample, 29 of the 88 project countries where firms retire offsets have CCPI coverage, and these countries account for roughly two-thirds of retirement observations. The 59 countries without CCPI scores are predominantly developing countries that supply offsets but where listed firms have limited operational presence; nearly half are in Sub-Saharan Africa. This coverage limitation makes the CCPI exercise a more demanding test, since it excludes many arm's-length offset-supplying countries that would otherwise sharpen the contrast between local and non-local sourcing.

Table 9 reports the results. The evidence points to two related patterns. First, the allocation effect is concentrated in high-CCPI countries. In columns (1)–(2), foreign firms with operational presence allocate a larger share of retirements to projects in high-CCPI countries where they operate. The coefficient on Operation is 0.327 in the firm fixed effects specification. In low-CCPI countries, by contrast, the corresponding coefficient is smaller and statistically insignificant. Firms therefore do not simply retire offsets wherever they operate; they do so disproportionately in countries where climate action is more salient.

Second, the negative quality gradient is also concentrated in high-CCPI countries. In columns (1)–(2), the coefficient on Operation $\times$ Rating is negative and statistically significant: -0.097 with firm fixed effects and -0.081 with firm-by-year fixed effects. In low-CCPI countries, the corresponding estimates are small and statistically insignificant. The quality gradient is therefore strongest precisely where local climate visibility is likely to be most valuable.

Columns (5)–(6) estimate a pooled specification that interacts operational presence and quality ratings with the standardized CCPI score. The continuous results confirm the allocation pattern. The coefficient on Operation $\times$ CCPI is positive and significant in the firm fixed effects specification, indicating that firms allocate more retirements to countries where they operate when those countries have higher climate ambition. The triple interaction, Operation $\times$ Rating $\times$ CCPI, is negative but not statistically significant at conventional levels. Its sign is nevertheless consistent with the split-sample evidence: the quality gradient becomes more negative as climate ambition rises.

Taken together, the CCPI results support the goodwill interpretation. Firms source offsets locally more intensively in countries where climate action is more visible to stakeholders, and in those same countries

[5] Recent economics and finance research uses the CCPI to capture differences in national climate performance and policy ambition; see, for example, Bolton and Kacperczyk (2023) and Demirgüç-Kunt et al. (2024).

local sourcing is associated with lower project quality. This pattern is difficult to reconcile with a pure information channel. If local operations primarily improved project screening, the quality gradient should be weaker in high-CCPI countries, where monitoring and environmental information are likely to be stronger. Instead, the evidence suggests that local visibility raises the private value of offsetting within the firm's operational footprint, even when this comes at a cost to environmental integrity.

9.2 Governance and the goodwill channel

We next examine whether the quality gradient also varies with broader institutional quality. The goodwill channel should be stronger in environments where firms may rely more heavily on visibility, local engagement, and relationship management to maintain stakeholder support. In such settings, the reputational value of supporting local projects may be especially high.

To examine this implication, we measure country-year governance using the World Bank Worldwide Governance Indicators and classify project countries into "low governance" and "high governance" groups based on the sample median in each year. Figure 5 reports the distribution of retirement shares across MSCI rating quartiles, separately for firms with and without operational presence in the project country.

The contrast is sharp. In low-governance project countries (Panel A), firms with an operational presence allocate a substantially larger share of retirements to lower-rated projects and a smaller share to higher-rated projects relative to firms without local operations. The negative quality gradient is pronounced. In high-governance countries (Panel B), by contrast, these differences are markedly attenuated, and the allocation of retirements across rating quartiles is more similar across firms.

This heterogeneity is consistent with the goodwill channel. The link between operational presence and lower-quality offset sourcing is strongest in environments where stakeholder engagement plausibly carries greater value. Combined with the CCPI evidence, the governance patterns suggest that firms' operational footprints shape not only where offsets are retired, but also the integrity of the projects they choose.

9.3 Subsidiary entry and local offset sourcing

The main analysis measures operational presence using the geographic distribution of firm revenue. This measure has broad coverage, but it may not fully capture the strength of a firm's local engagement. Firms can generate revenue in a country through exports, distributors, or intermediaries without having a meaningful physical presence. To address this concern, we complement the baseline results with an alternative measure of operational footprint based on subsidiary locations.

We identify subsidiary entry events using Exhibit 21 filings from U.S.-listed firms. Exhibit 21, filed with annual 10-K reports, lists a firm's significant subsidiaries and their jurisdictions of incorporation.

By tracking the first year in which a country appears in a firm's subsidiary filings, we identify new country-entry events. We collect Exhibit 21 filings for 322 U.S.-listed firms in our offset sample over 2010–2024 and obtain subsidiary information for 308 firms. After standardizing jurisdiction names and excluding tax havens, we identify 2,248 country-entry events across 219 firms and 130 countries. Restricting the sample to countries with voluntary carbon offset projects yields 1,299 firm-country entry pairs across 206 firms.

This setting provides a useful validation exercise for the goodwill channel. Establishing a subsidiary represents a discrete increase in the firm's legal and physical presence in a country. If local offset sourcing reflects visibility and stakeholder engagement, retirement behavior should shift toward newly entered countries after subsidiary entry. Moreover, if this motive weakens the link between offset demand and environmental integrity, entry-country retirements should be lower quality than the same firm's retirements elsewhere.

Figure 6 examines the timing of retirement behavior around subsidiary entry. The unit of observation is firm by entry-country group by year, where all entry countries for a firm are pooled into a single group. The event study includes unit and year fixed effects, with the year before entry as the omitted category. The pre-entry coefficients are close to zero, providing little evidence of differential pre-trends. Retirement behavior changes sharply after entry. The probability that a firm retires any offsets in entry countries increases by 9.7 percentage points in the entry year and rises to 21.3 percentage points four or more years after entry. The intensive margin evolves more gradually: the share of firm-year retirements allocated to entry countries rises over the post-entry period and reaches 9.9 percentage points by year four.

We next examine whether offsets retired in entry countries are of lower quality. Because relatively few firms retire offsets in the same country both before and after subsidiary entry, this exercise is not designed as a difference-in-differences test. Instead, we compare the quality of offsets retired in countries where the firm has recently established a subsidiary with the quality of other offsets retired by the same firm in other countries. This within-firm comparison holds fixed the firm's overall offsetting strategy and asks whether the local component of its portfolio is tilted toward lower-quality projects.

Table 10 reports the quality results. Offsets retired in entry countries are of lower quality than other offsets retired by the same firm elsewhere. This pattern appears both when quality is measured by the share of retirements going to above-median MSCI projects and when it is measured by the average MSCI rating. The gap is largest in the first two years after entry and becomes smaller over time, suggesting that the tilt toward lower-quality local projects is strongest when the firm first establishes a local presence.

Panels B and C address a potential composition concern. The negative quality gradient could arise if firms enter countries where the available offset supply is generally of lower quality. To examine this

possibility, we split project countries by their average MSCI quality. The quality gap is concentrated in above-median-quality countries: even in countries where the local offset supply is relatively strong, firms entering through subsidiaries retire lower-quality projects than their own retirements elsewhere. In below-median-quality countries, the estimates are smaller and statistically insignificant. This pattern suggests that the result is not simply driven by firms entering low-quality offset markets.

These results reinforce the interpretation of the baseline findings. The local offset bias and the negative quality gradient are not specific to a revenue-based measure of operational presence; they also emerge when operational footprint is measured by subsidiary entry. After entry, firms are more likely to source offsets from the entry country, but those offsets are lower quality than the same firm's retirements elsewhere. Consistent with the goodwill channel, local presence increases the private value of visible local sourcing, especially when firms first enter a country, without necessarily directing demand toward higher-integrity projects.

10 Conclusion

This paper investigates the geographic composition of corporate carbon-offset portfolios and how firms' retirement behavior departs from the benchmark of geographic fungibility implied by the global nature of carbon emissions. While a ton of carbon reduced should, in principle, deliver identical climate benefits regardless of its origin, we document a systematic and persistent "local bias" in corporate offset retirements. A conceptual framework that contrasts informational advantages with non-pecuniary goodwill incentives helps explain why firms may deviate from environmentally efficient allocations and favor projects within their operational footprints.

Our analysis yields three central findings. First, foreign firms retire a disproportionately large share of offsets in countries where they maintain an operational presence. Second, offsets retired in these locations are, on average, of lower project quality than those retired elsewhere, generating a negative local quality gradient. This pattern is consistent with non-pecuniary motives—such as securing a "social license to operate" through local visibility—reducing the marginal valuation of quality.The gradient is stronger in countries with higher climate ambition and weaker governance, where local visibility and stakeholder engagement are likely to be more valuable. Third, we document equilibrium price-quality decoupling: in jurisdictions where demand is dominated by local buyers, prices are less responsive to project quality, indicating that reputational considerations weaken the informational content of prices.

Taken together, these results highlight the role of demand-side incentives in shaping the functioning of voluntary carbon markets. Geographic concentration emerges as a channel through which firms trade off climate integrity against non-pecuniary benefits, potentially sustaining demand for lower-quality projects. If the social value of emissions reductions exceeds the private returns from local signaling,

such behavior may entail welfare losses by diverting climate finance away from high-abatement opportunities.

More broadly, the cross-country allocation of voluntary climate finance appears to reflect the operational footprints of multinational firms as much as underlying mitigation potential. For market designers, this underscores the importance of credible and transparent quality benchmarks that preserve the link between prices and environmental performance. Strengthening the informational foundations of voluntary carbon markets may therefore be essential to ensuring that they channel capital toward projects with the greatest global impact.

References

Albuquerque, R., Koskinen, Y., and Zhang, C. (2019). Corporate social responsibility and firm risk: Theory and empirical evidence. *Management Science*, 65(10):4451–4469.

Beck, A. and Pedraza, A. (2026). Deep and shallow decarbonization in supply chains. *Policy Research Working Paper World Bank*.

Ben-David, I., Jang, Y., Kleimeier, S., and Viehs, M. (2021). Exporting pollution: Where do multinational firms emit CO2? *Economic Policy*, 36(107):377–437.

Berg, F., Ceccarelli, M., Heeb, F., Ivashchenko, A., Rigobón, R., and Zwinkels, R. C. (2025). The market for voluntary carbon offsets. Technical report, SAFE Working Paper.

Berkeley Carbon Trading Project (2025). Voluntary registry offsets database. https://gspp.berkeley.edu/berkeley-carbon-trading-project/offsets-database. Accessed January 3, 2024.

Bertrand, M., Bombardini, M., Fisman, R., Hackinen, B., and Trebbi, F. (2021). Hall of mirrors: Corporate philanthropy and strategic advocacy. *Quarterly Journal of Economics*, 136(4):2413–2465.

Bertrand, M., Bombardini, M., Fisman, R., and Trebbi, F. (2020). Tax-exempt lobbying: Corporate philanthropy as a tool for political influence. *American Economic Review*, 110(7):2065–2102.

Bolton, P. and Kacperczyk, M. (2023). Global pricing of carbon-transition risk. *The Journal of Finance*, 78(6):3677–3754.

Broccardo, E., Hart, O., and Zingales, L. (2022). Exit versus voice. *Journal of Political Economy*, 130(12):3101–3145.

Calel, R., Colmer, J., Dechezleprêtre, A., and Glachant, M. (2025). Do carbon offsets offset carbon? *American Economic Journal: Applied Economics*, 17(1):1–40.

Coval, J. D. and Moskowitz, T. J. (1999). Home bias at home: Local equity preference in domestic portfolios. *The Journal of Finance*, 54(6):2045–2073.

Coval, J. D. and Moskowitz, T. J. (2001). The geography of investment: Informed trading and asset prices. *Journal of political Economy*, 109(4):811–841.

Demirgüç-Kunt, A., Pedraza, A., Pulga, F., and Ruiz-Ortega, C. (2024). Global bank lending under climate policy. *IMF Economic Review*, 72(2):858–901.

Gill-Wiehl, A., Kammen, D. M., and Haya, B. K. (2024). Pervasive over-crediting from cookstove offset methodologies. *Nature Sustainability*, 7(2):191–202.

Godfrey, P. C., Merrill, C. B., and Hansen, J. M. (2009). The relationship between corporate social responsibility and shareholder value: An empirical test of the risk management hypothesis. *Strategic Management Journal*, 30(4):425–445.

Gunningham, N., Kagan, R. A., and Thornton, D. (2004). Social license and environmental protection: why businesses go beyond compliance. *Law & Social Inquiry*, 29(2):307–341.

Hamilton, K., Sjardin, M., Marcello, G., and Xu, J. (2012). State of the voluntary carbon markets 2012.

Hamilton, K., Sjardin, M., Shapiro, A., and Marcello, G. (2010). State of the voluntary carbon markets 2010.

Heeb, F., Kölbel, J. F., Paetzold, F., and Zeisberger, S. (2023). Do investors care about impact? *Review of Financial Studies*, 36(5):1737–1787.

Henisz, W. J., Dorobantu, S., and Nartey, L. J. (2014). Spinning gold: The financial returns to stakeholder engagement. *Strategic Management Journal*, 35(12):1727–1748.

Kim, S., Li, T., and Wu, Y. (2023). Carbon offsets: Decarbonization or transition-washing? *Review of Financial Studies*, 36(11):4585–4630.

Lins, K. V., Servaes, H., and Tamayo, A. (2017). Social capital, trust, and firm performance: The value of corporate social responsibility during the financial crisis. *Journal of Finance*, 72(4):1785–1824.

Manshadi, V., Monachou, F., and Morgenstern, I. (2025). Offsetting carbon with lemons: Adverse selection and certification in the voluntary carbon market. *Available at SSRN 5792202*.

MSCI (2024). Carbon project ratings. https://www.msci.com/data-and-analytics/carbon-markets/carbon-project-ratings. Accessed December 20, 2024.

Owen, J. R. and Kemp, D. (2013). Social licence and mining: A critical perspective. *Resources Policy*, 38(1):29–35.

Pástor, L., Stambaugh, R. F., and Taylor, L. A. (2025). Sustainable investing. *Annual Review of Financial Economics*, 17.

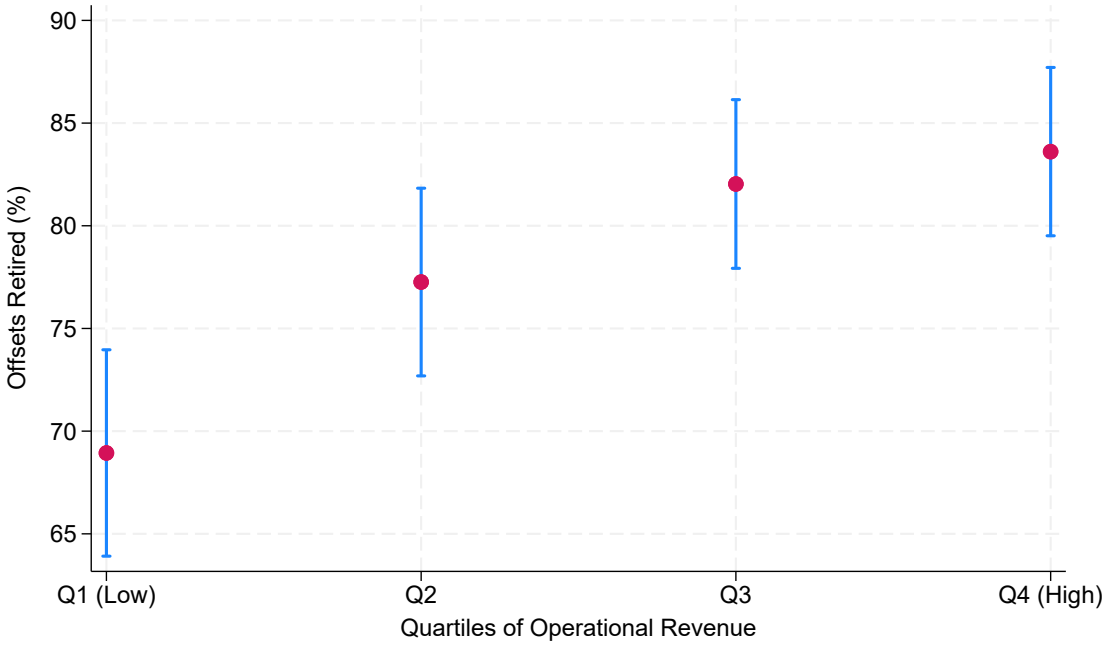
Schneider, L., La Hoz Theuer, S., Broekhoff, D., Füssler, J., Kizzier, K., Korberg, M., Lazarus, M., and Howard, A. (2019). Environmental integrity of international carbon market mechanisms under the paris agreement. *Climate Policy*, 19(3):386–400.

Shapiro, J. S. and Walker, R. (2025). Is air pollution regulation too lenient? Evidence from US offset markets. *American Economic Review*, 115(9):3058–3080.

West, T. A., Wunder, S., Sills, E. O., Börner, J., Rifai, S. W., Neidermeier, A. N., Frey, G. P., and Kontoleon, A. (2023). Action needed to make carbon offsets from forest conservation work for climate change mitigation. *Science*, 381(6660):873–877.

World Bank (2025). *State and Trends of Carbon Pricing 2025*. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO.

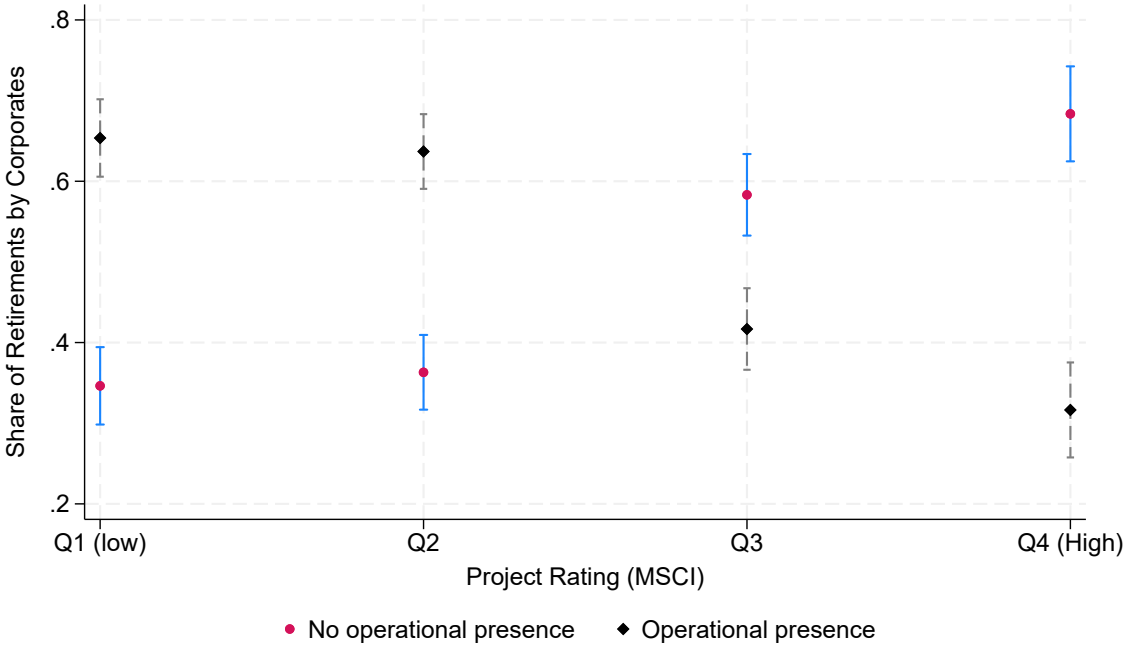
Figure 2: Revenue Exposure and Concentration of Offset Retirements



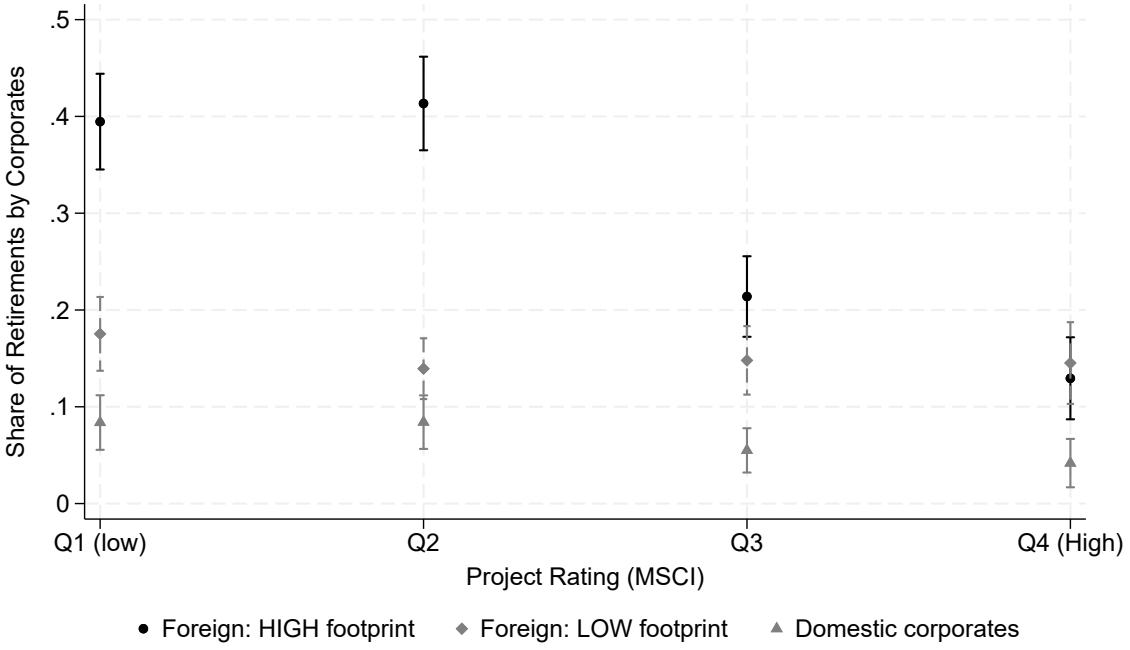
Note: This figure plots the mean share of carbon offsets retired in countries where the firm has an operational presence, by quartiles of the firm's operational revenue share across countries. Points denote quartile means and vertical bars indicate 95% confidence intervals. Operational presence is defined as positive revenue in a country. The figure shows a monotonic increase in the share of offsets retired in operational countries as firms' operational revenue exposure rises.

Figure 3: Carbon offset retirements by project quality and firm presence

Panel A: Operational presence vs. no operational presence

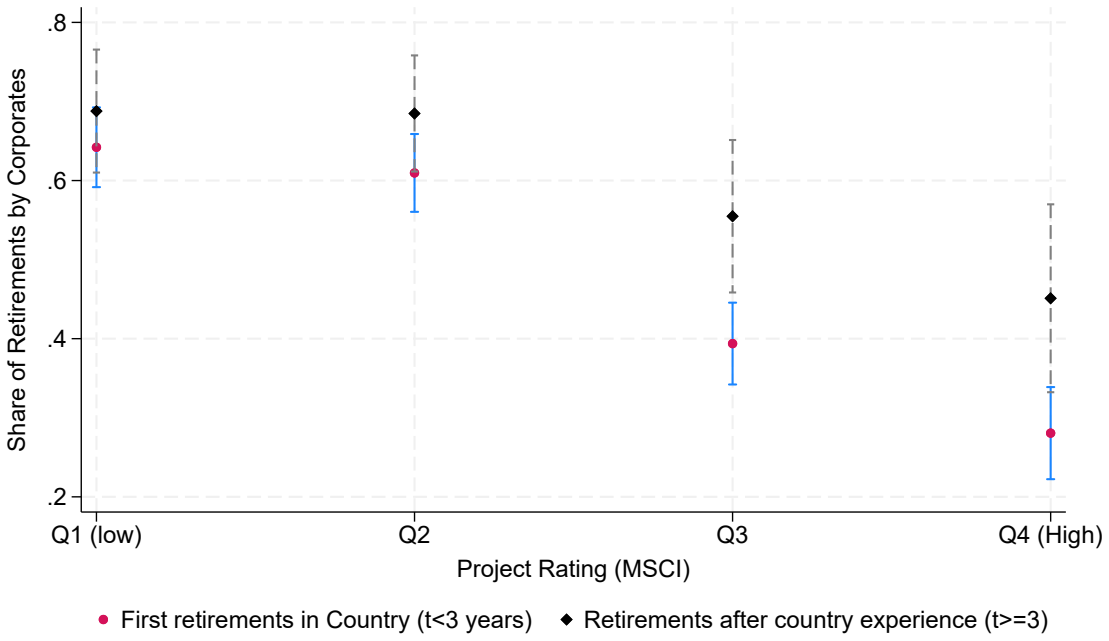


Panel B: Disaggregation among firms with operational presence



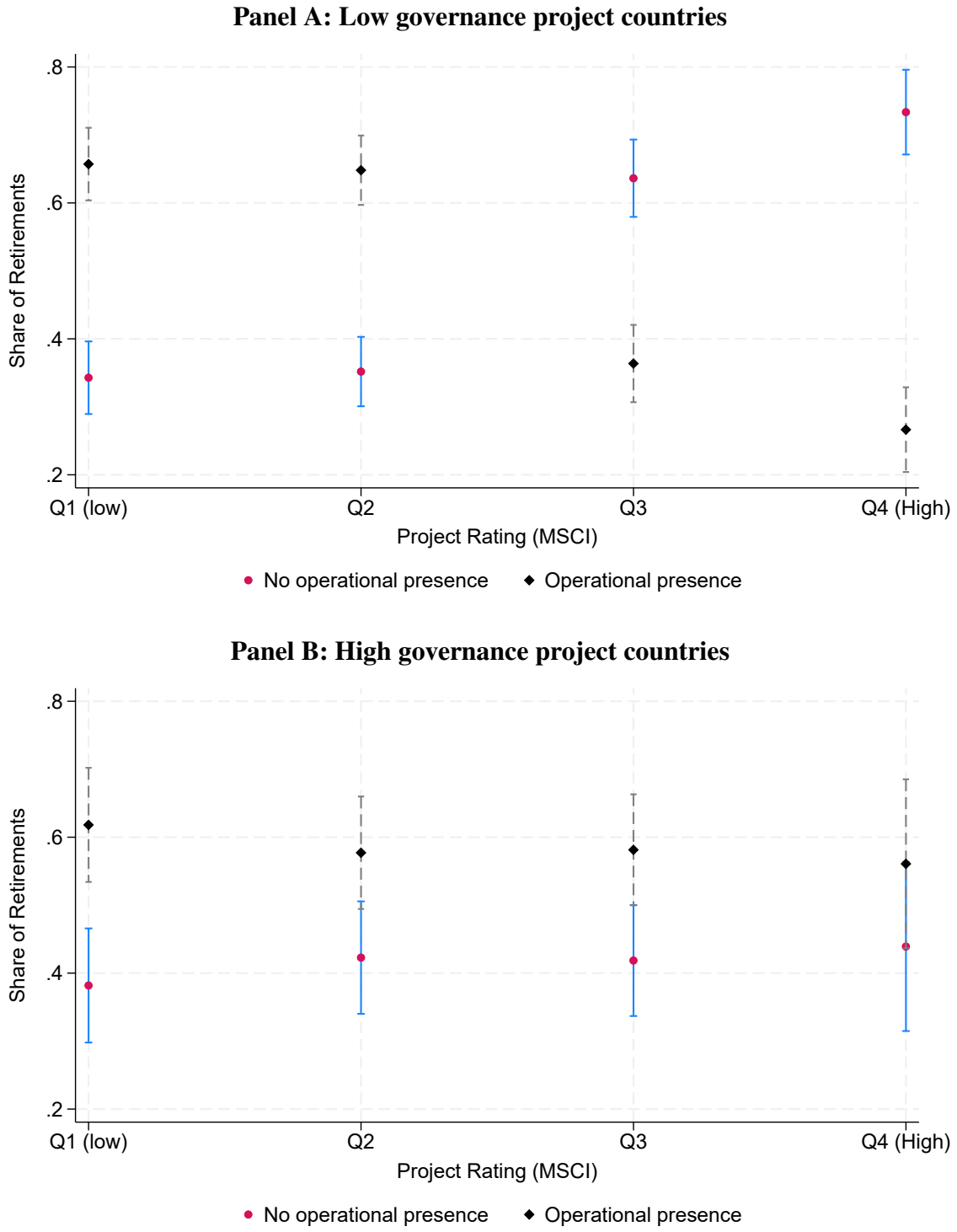
Notes: Panel A reports the share of carbon offset retirements by publicly listed firms across quartiles of project quality, as measured by MSCI project ratings. Firms are classified based on whether they have an operational presence in the country where the offset project is located, defined as positive firm revenues in that country at the time of retirement. Panel B focuses on the subset of firms with an operational presence and further disaggregates them into foreign firms with a high revenue footprint, foreign firms with a low revenue footprint (relative to the sample median), and domestic firms domiciled in the project country. In both panels, markers represent mean shares within each rating quartile, and vertical bars denote 95% confidence intervals.

Figure 4: Offset Quality and Firm Experience within Project Countries



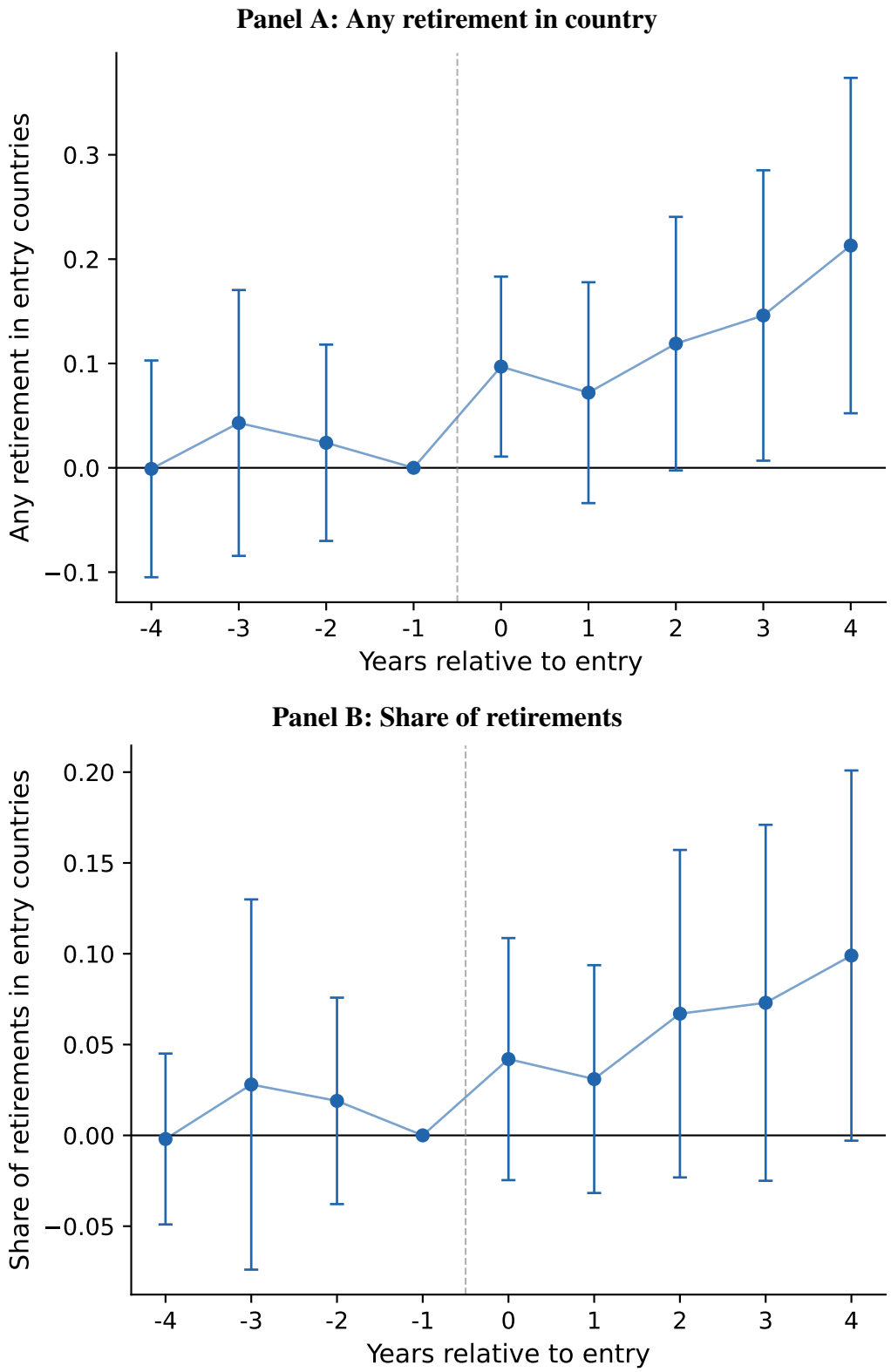
Note: The figure reports the share of carbon offset retirements by foreign firms with an operational presence in a country, disaggregated by project quality (MSCI rating quartiles) and by firm experience in that country. “First retirements" correspond to offsets retired within the first two years in which a firm retires any project in a given country. “Later retirements" correspond to offsets retired after at least two years of country-level experience. Points represent mean shares within each rating quartile, and vertical bars indicate 95% confidence intervals.

Figure 5: Carbon offset retirements by project quality and firm presence: High vs. Low governance countries



Notes: Share of carbon offset retirements by publicly listed firms across quartiles of project quality, as measured by MSCI project ratings. Firms are classified based on whether they have an operational presence in the country where the offset project is located, defined as positive firm revenues in that country at the time of retirement. Panel A is the sample of countries with below median WGI indicator and Panel B above median. In both panels, markers represent mean shares within each rating quartile, and vertical bars denote 95% confidence intervals.

Figure 6: Offset use after subsidiary presence



Notes: Event study: retirement behavior in subsidiary entry countries. Panel (a) plots the probability of any retirement in entry countries; Panel (b) plots the share of firm-year retirements allocated to entry countries. $N = 1{,}047$, 206 treated firms. Unit and year FE; SE clustered at firm level. Error bars show 95% confidence intervals..

Table 1: Carbon Offset Projects: Summary Statistics

Data are from the Voluntary Registry Offsets Database developed by the Berkeley Carbon Trading Project. The sample includes projects with retirements between 2009 and 2024 from four major voluntary carbon registries: American Carbon Registry, Climate Action Reserve, Gold Standard, and Verra. The full sample comprises the universe of retirement transactions reported in the database over this period. "Used by listed firms" refers to projects from which at least one ton of CO_2 was retired by a publicly listed company. Panel A reports the number of unique projects and countries, as well as data coverage across rating agencies and prices. Panel B reports project-level means, standard deviations, minimums, and maximums.

	Full Sample				**Used by Listed Firms**			
Panel A. Number of projects and sample size								
Projects	3,565				1,889			
Countries	103				88			
Projects with MSCI ratings	2,549				1,395			
Projects with BeZero ratings	375				303			
Projects with Sylvera ratings	358				295			
Projects with price data	1,049				750			
Total credits retired (million tons)	759				659			
	Mean	Std.	Min	Max	Mean	Std.	Min	Max
Panel B. Summary statistics by project								
MSCI rating	2.99	0.58	1.4	4.4	2.98	0.56	1.4	4.4
Price (USD)	6.35	6.68	0.11	115.10	6.34	7.20	0.11	115.10
Credits retired (1,000 tons)	213	847	0	24,454	349	1,136	0	24,454

Table 2: Top Countries by Corporate Origin and Carbon Project Location

The table reports the top 15 countries by total carbon offset retirements, measured in million tons of CO_2 ($MtCO_2$). The left panel ranks countries by the headquarters location of parent firms retiring offsets, while the right panel ranks countries by the location of carbon offset projects. Firm counts refer to the number of listed firms headquartered in each country, and project counts refer to the number of distinct offset projects located in each country.

	Parent Company HQ			Carbon Project		
Rank	Country	Firms	Retirements ($MtCO_2$)	Country	Projects	Retirements ($MtCO_2$)
1	United States	325	74.55	India	306	34.64
2	Germany	74	26.97	United States	331	32.24
3	United Kingdom	128	22.64	China	282	32.14
4	Japan	94	22.25	Indonesia	15	20.72
5	Australia	81	15.52	Brazil	105	13.94
6	Italy	34	13.77	Peru	18	13.23
7	France	56	8.78	Colombia	25	10.30
8	Switzerland	36	6.59	Congo	2	8.27
9	China	48	5.86	Turkey	130	6.70
10	Brazil	61	5.86	Zambia	6	6.18
11	Colombia	8	3.78	Kenya	39	5.17
12	Canada	43	2.99	South Korea	5	4.51
13	Hong Kong	24	2.53	Zimbabwe	2	3.17
14	Sweden	51	1.87	Cambodia	6	2.77
15	Spain	39	1.27	Tanzania	5	2.57

Table 3: Listed companies retiring carbon credits: Summary statistics

This table reports summary statistics for firm-level characteristics and carbon offset retirements. Panel A summarizes firm characteristics and overall offset use. Panels B and C report statistics separately for credits retired in countries where firms operate and in other countries. All variables are reported at the firm–year level.

	Mean	Std.	Min	P25	Median	P75	Max
Panel A. Firms' summary statistics							
Sales (billion USD)	20.35	44.41	0.00	1.48	5.36	18.58	588.37
Emissions (million tons)	3.36	12.29	0.00	0.01	0.08	0.78	120.70
Emission intensity	198.75	519.80	0.07	3.45	17.93	102.61	3188.17
SBTi target approved	0.30	0.44	0.00	0.00	0.00	0.88	1.00
Number of countries	2.62	2.84	1.00	1.00	1.00	3.00	30.00
Number of projects	4.71	8.50	1.00	1.00	2.00	5.00	118.00
Share of revenue (%)	7.51	14.63	0.10	0.78	2.21	7.42	100.00
Retired offsets (1,000 tons)	152.80	835.86	0.00	0.20	3.00	29.16	12,982.65
MSCI rating	2.96	0.46	1.60	2.69	2.92	3.24	4.30
Price (USD)	6.73	5.12	0.32	3.50	6.03	8.04	115.10
Panel B. Carbon credits retired in countries with operations							
Share of retirements (%)	41.61	45.44	0.00	0.00	7.41	100.00	100.00
MSCI rating	2.90	0.46	1.60	2.60	2.84	3.14	4.30
Price (USD)	6.13	6.80	0.35	2.66	5.25	7.03	115.10
Panel C. Carbon credits retired in other countries							
Share of retirements (%)	38.15	44.67	0.00	0.00	3.71	100.00	100.00
MSCI rating	3.03	0.46	1.60	2.71	3.00	3.30	4.30
Price (USD)	7.45	5.97	0.32	3.42	6.60	9.08	46.00

Table 4: Operational Presence, Revenue Footprint, and Offset Quality

This table reports estimates from the following specification:

$$S_{kiy} = \beta_1 \,\text{Operation}_{ij} + \beta_2 \,\text{Rating}_k + \beta_3 \left(\text{Operation}_{ij} \times \text{Rating}_k\right) + \mathbf{X}'_{iy}\boldsymbol{\gamma} + \text{Fixed Effects} + \varepsilon_{kiy}.$$

The dependent variable S_{kiy} is the share of firm i's annual carbon offset retirements allocated to project k in year y. Operation_{ij} is a dummy equal to one if firm i has operations in the country j where project k is located. In columns (1)-(2), Operation_{ij} equals one for firms with operations in the project country, including both foreign firms with positive revenues and domestic firms headquartered in that country. In columns (3)-(4), Operation_{ij} equals one for foreign firms with a revenue footprint above the sample median in the project country. Columns (5)-(6) analogously define Operation_{ij} for foreign firms with a revenue footprint below the sample median. Rating_p denotes the project's MSCI rating. All specifications include project classification, vintage, and country-of-retirement-by-year fixed effects. Standard errors are clustered at the firm level and reported in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Operational Presence Domestic + Foreign		Foreign Above median revenue		Foreign Below median revenue	
	(1)	(2)	(3)	(4)	(5)	(6)
OPERATION	0.143*	0.048	0.244***	0.234***	0.052	-0.075
	(0.076)	(0.063)	(0.045)	(0.05)	(0.099)	(0.051)
RATING	0.07***	0.042***	0.061***	0.048***	0.042**	0.021
	(0.018)	(0.015)	(0.01)	(0.018)	(0.017)	(0.021)
OPERATION × RATING	-0.051**	-0.026	-0.085***	-0.079***	-0.021	0.014
	(0.024)	(0.023)	(0.014)	(0.017)	(0.032)	(0.018)
Log(Emissions)	0.008		0.008		0.007	
	(0.01)		(0.01)		(0.01)	
Log(Revenue)	-0.05***		-0.052***		-0.05***	
	(0.015)		(0.015)		(0.015)	
Target Approved	-0.016		-0.016		-0.018	
	(0.03)		(0.03)		(0.03)	
Observations	6268	5206	6268	5206	6268	5206
R-squared	0.55	0.477	0.55	0.478	0.549	0.477
Firm FE	Yes	No	Yes	No	Yes	No
Firm × Year FE	No	Yes	No	Yes	No	Yes

Table 5: Aggregated Firm-Year-Cell Results: Three-Category Exposure Buckets

This table reports estimates from the following firm-year-cell specification:

$$S_{iqcy} = \beta_1 \mathbb{1}(c=1) + \beta_2 \mathbb{1}(c=2) + \beta_3 q + \beta_4 (\mathbb{1}(c=1) \times q) + \beta_5 (\mathbb{1}(c=2) \times q) + \text{Fixed Effects} + \varepsilon_{iqcy}.$$

The dependent variable S_{iqcy} is the share of firm i's annual carbon offset retirements in year y allocated to cell (q,c). The quality indicator q equals one if the project is above the median MSCI rating and zero otherwise. The exposure variable c is defined using three mutually exclusive categories: $c=0$ for foreign countries where the firm has no operations, $c=1$ for the firm's domestic country, and $c=2$ for foreign countries where the firm has operations. Each firm-year contributes up to six cells: $(q,c) \in \{0,1\} \times \{0,1,2\}$. The omitted category is $c=0$. Standard errors are clustered at the firm level and reported in parentheses. Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

	(1)	(2)
Domestic (c=1)	0.003	-0.024
	(0.066)	(0.105)
Foreign with Ops (c=2: any operational presence)	0.12***	0.116***
	(0.029)	(0.039)
High Quality (q=1: above-median MSCI rating)	0.009	-0.006
	(0.026)	(0.032)
Domestic x High Quality (c=1 x q)	0.056	0.1
	(0.068)	(0.121)
Foreign with Ops x High Quality (c=2 x q)	-0.125***	-0.143***
	(0.035)	(0.044)
Observations	3486	1826
R-squared	0.38	0.107
Firm FE	Yes	No
Year FE	Yes	No
Firm $\times$ Year FE	No	Yes

Table 6: Operational Presence, Experience, and Offset Quality

This table reports estimates from the following specification:

$$S_{kiy} = \beta_1 \,\text{Operation}_{ij} + \beta_2 \,\text{Rating}_k + \beta_3 \left(\text{Operation}_{ij} \times \text{Rating}_k\right) + \mathbf{X}_i'\gamma + \text{Fixed Effects} + \varepsilon_{kiy}.$$

The dependent variable S_{kiy} is the share of firm i's annual carbon offset retirements allocated to project k in year y. Operation_{ij} is a dummy equal to one if firm i has operations in the country j where project k is located. Columns (1)-(4) split the sample based on firms' overall experience using carbon offsets, regardless of location. Firms are classified as inexperienced if they have retired offsets for fewer than three years and as experienced if they have retired offsets for three or more years. Columns (5)-(8) define experience at the firm-country level, based on whether firm i has retired offsets in country j for fewer than three years or for three or more years. Rating_p denotes the project MSCI rating. All specifications include firm log sales, log emissions, an indicator if the firm has SBTi target approved as controls, and project classification, vintage, and country-of-retirement-by-year fixed effects. Standard errors are clustered at the firm level and reported in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Firm experience using offsets				Firm–country experience using offsets			
	$t < 3$ years		$t \geq 3$ years		$t < 3$ years		$t \geq 3$ years	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
OPERATION	0.273***	0.307***	0.207***	0.152**	0.255***	0.225***	0.126	0.115
	(0.063)	(0.090)	(0.039)	(0.065)	(0.064)	(0.054)	(0.121)	(0.177)
RATING	0.073***	0.076***	0.050***	0.022	0.057***	0.060***	0.055	0.024
	(0.018)	(0.027)	(0.013)	(0.013)	(0.014)	(0.018)	(0.036)	(0.026)
OPERATION × RATING	-0.103***	-0.115***	-0.061***	-0.049*	-0.090***	-0.084***	-0.033	-0.036
	(0.020)	(0.032)	(0.014)	(0.024)	(0.019)	(0.020)	(0.047)	(0.062)
Constant	0.675*	0.028	0.189	0.112***	0.516**	0.037	0.800*	0.105
	(0.357)	(0.080)	(0.233)	(0.039)	(0.203)	(0.055)	(0.418)	(0.076)
Observations	2,936	2,399	3,300	2,908	5,048	4,123	1,248	1,003
R-squared	0.620	0.453	0.482	0.446	0.546	0.471	0.555	0.427
Year FE	Yes	No	Yes	No	Yes	No	Yes	No
Firm FE	Yes	No	Yes	No	Yes	No	Yes	No
Firm × Year FE	No	Yes	No	Yes	No	Yes	No	Yes

Table 7: Retirement Intensity, Operational Presence, and the Quality Gradient

This table reports estimates from variants of the following specification:

$$S_{piy} = \beta_1 \,\text{Operation}_{ij} + \beta_2 \,\text{Rating}_p + \beta_3 \left(\text{Operation}_{ij} \times \text{Rating}_p\right) + \mathbf{X}_i'\gamma + \text{FE} + \varepsilon_{piy}.$$

The dependent variable S_{piy} is the share of firm i's carbon offset retirements in year y allocated to project p. Operation_{ij} is an indicator equal to one if firm i has an operational presence in country j, where project p is located. Rating_p denotes the environmental quality rating of project p. Control variables include indicators for international project developers, firm sales, emissions, and target commitments. All specifications include classification fixed effects, project vintage fixed effects, and country-of-retirement fixed effects. Columns alternate between year and firm fixed effects and firm-by-year fixed effects, as reported. Standard errors are clustered at the country-of-retirement level. In columns (1)-(4), firms are split by *retirement intensity*, defined as total carbon offset retirements divided by total emissions at the firm level. In columns (5)-(8), firms are split by *emission intensity*, defined as yearly emissions divided by firm revenue. Columns labeled "Low" ("High") report estimates for firms below (above) the median of each measure. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	Retirement Intensity				Emission Intensity					
	Low		High		Low		High		All Firms	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
OPERATION	0.059	0.205***	0.344***	0.275***	0.364***	0.347***	0.069	0.129***	0.222***	0.235***
	(0.070)	(0.055)	(0.054)	(0.088)	(0.109)	(0.122)	(0.048)	(0.044)	(0.042)	(0.040)
RATING	0.013	0.031	0.077***	0.059***	0.052***	0.055***	0.054***	0.040*	0.051***	0.046***
	(0.017)	(0.021)	(0.011)	(0.019)	(0.019)	(0.019)	(0.014)	(0.020)	(0.010)	(0.014)
OPERATION × RATING	−0.015	−0.057**	−0.124***	−0.111***	−0.123***	−0.134***	−0.025	−0.037*	−0.076***	−0.084***
	(0.022)	(0.023)	(0.017)	(0.032)	(0.035)	(0.040)	(0.022)	(0.019)	(0.013)	(0.015)
International Developer									0.001	0.010
									(0.010)	(0.013)
OPERATION × Int. Developer									−0.015	0.001
									(0.022)	(0.029)
Constant	0.901**	0.100	0.405***	0.049	0.750***	0.074	0.010	0.068	0.546***	0.071*
	(0.411)	(0.063)	(0.146)	(0.054)	(0.210)	(0.058)	(0.327)	(0.058)	(0.133)	(0.041)
Observations	2,709	2,210	3,654	3,094	3,082	2,555	3,275	2,752	6,371	5,316
R^2	0.557	0.462	0.510	0.448	0.493	0.441	0.562	0.467	0.519	0.443
Year FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Firm FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Firm × Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Table 8: Prices, Buyer Composition, and Project Quality

This table reports estimates from the following specification:

$$P_{ky} = \alpha + \beta_1 \,\text{Rating}_k + \beta_2 \,\text{Share}_{ky} + \beta_3 \left(\text{Rating}_k \times \text{Share}_{ky}\right) + \mu_{c(k)} + \lambda_y + \varepsilon_{ky}.$$

The dependent variable P_{ky} is the average transaction price of carbon offsets for project k in year y. Rating_k denotes the environmental quality rating of project k. The variable Share_{ky} measures the share of total offset retirements in project country j and year y accounted for by different groups of firms. In columns (2)–(4), Share_{ky} is computed using all firms with operations in the project country, including both domestic firms headquartered in that country and foreign firms with positive revenues there. In columns (5)–(7), Share_{ky} is computed using only domestic firms. In columns (8)–(10), Share_{ky} is computed using only foreign firms whose revenue footprint in the project country is above the sample median. In columns (11)–(13), Share_{ky} is computed using only foreign firms whose revenue footprint in the project country is below the sample median.. All specifications include classification fixed effects $\mu_{c(k)}$ and year fixed effects λ_y. Standard errors are clustered at the project level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

		Operation (Domestic + Foreign)			Domestic Firms			Foreign: High Revenue			Foreign: Low Revenue		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Rating	1.962***		2.032***	3.167***		1.962***	2.165***		2.034***	2.728***		1.962***	1.501***
	(0.722)		(0.722)	(0.894)		(0.721)	(0.764)		(0.722)	(0.861)		(0.717)	(0.576)
Share		-0.736*	-0.846**	4.795*	-1.298*	-1.830***	5.352	-0.790***	-0.875***	7.375***	0.301	0.322	-4.811
		(0.398)	(0.374)	(2.667)	(0.684)	(0.561)	(3.411)	(0.297)	(0.320)	(2.580)	(0.423)	(0.431)	(4.066)
Share × Rating				-1.946**			-2.465**			-2.852***			1.789
				(0.986)			(1.238)			(0.943)			(1.512)
Constant	-0.208	6.067***	0.037	-3.264	5.749***	-0.088	-0.674	5.827***	-0.243	-2.251	5.573***	-0.292	1.045
	(2.051)	(0.317)	(2.075)	(2.491)	(0.201)	(2.043)	(2.160)	(0.218)	(2.033)	(2.422)	(0.200)	(2.084)	(1.647)
Observations	713	845	713	713	845	713	713	845	713	713	845	713	713
R^2	0.436	0.373	0.442	0.448	0.372	0.443	0.447	0.372	0.440	0.451	0.369	0.437	0.441

Table 9: Country Climate Ambition and Firms' Retirements

This table reports estimates from variants of the following specification:

$$S_{kijy} = \beta_1 \,\text{Operation}_{ij} + \beta_2 \,\text{Rating}_k + \beta_3 \left(\text{Operation}_{ij} \times \text{Rating}_k\right) + \mathbf{X}'_{iy}\gamma + \text{FE} + \varepsilon_{kijy}.$$

The dependent variable S_{kijy} is the share of firm i's carbon offset retirements in year y allocated to project k located in country j. Operation_{ij} is an indicator equal to one if firm i has above-median revenue in country j. Rating_k denotes the MSCI numerical quality rating of project k. Columns (1)–(2) restrict the sample to project countries above the year-specific median of the Climate Change Performance Index (CCPI), while columns (3)–(4) restrict the sample to project countries below the year-specific median. Columns (5)–(6) use the pooled sample and interact operational presence and project quality with the standardized CCPI score of the project country. Control variables include log emissions, log revenue, and an indicator for whether the firm has a net-zero target. All specifications include country-of-retirement-by-year fixed effects. Columns alternate between firm fixed effects and firm-by-year fixed effects, as reported. Standard errors are clustered at the firm level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	High CCPI		Low CCPI		CCPI Interaction	
	(1) Firm	(2) Firm×Year	(3) Firm	(4) Firm×Year	(5) Firm	(6) Firm×Year
Operation (high)	0.327***	0.208	0.117	−0.062	0.233***	0.167*
	(0.124)	(0.139)	(0.113)	(0.097)	(0.082)	(0.087)
Quality rating	0.056*	0.080**	0.028	−0.047	0.050**	0.037*
	(0.031)	(0.036)	(0.037)	(0.031)	(0.023)	(0.022)
Operation × Rating	−0.097**	−0.081*	−0.037	0.022	−0.078***	−0.058*
	(0.041)	(0.048)	(0.039)	(0.037)	(0.028)	(0.032)
Operation × CCPI					0.190**	0.090
					(0.093)	(0.102)
Rating × CCPI					0.019	0.011
					(0.023)	(0.021)
Operation × Rating × CCPI					−0.051	−0.029
					(0.034)	(0.036)
Observations	2,253	1,691	1,625	1,222	4,066	3,215
R-squared	0.562	0.460	0.632	0.538	0.541	0.439
Firm FE	Yes	No	Yes	No	Yes	No
Firm × Year FE	No	Yes	No	Yes	No	Yes

Table 10: Subsidiary Entry and Offset Qualitys

This table examines the quality of offsets retired in countries where firms establish new subsidiaries. Panel A reports estimates from the following specification:

$$Q_{ict} = \beta_1 \mathbf{1}\{\text{Entry}_{ic}, \text{0–2 years}\} + \beta_2 \mathbf{1}\{\text{Entry}_{ic}, \text{3–5 years}\} + \beta_3 \mathbf{1}\{\text{Entry}_{ic}, 6+ \text{ years}\} + \mu_{it} + \varepsilon_{ict}.$$

Panels B and C report estimates from the following specification:

$$Q_{ict} = \beta\, \text{NewEntry}_{ic} + \mu_{it} + \varepsilon_{ict}.$$

The dependent variable Q_{ict} denotes the quality of offsets retired by firm i in country c in year t, measured either as an indicator for above-median MSCI quality, *High Quality*, or as the continuous MSCI rating, *Avg MSCI*. NewEntry_{ic} is an indicator equal to one if country c is a subsidiary-entry country for firm i. The omitted category is countries in which firm i retires offsets but has no operations; countries with established operations are excluded from the comparison. μ_{it} denotes firm-by-year fixed effects. Panels B and C estimate the specification separately for above- and below-median-quality countries, where country quality is measured using the country-level average MSCI rating and the sample median. Standard errors are clustered at the firm level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	High Quality (1)	Avg MSCI (2)
Panel A: By years since entry		
Entry, 0–2 years	−0.340**	−0.474**
	(0.135)	(0.217)
Entry, 3–5 years	−0.239**	−0.187
	(0.104)	(0.127)
Entry, 6+ years	−0.069	−0.092
	(0.103)	(0.129)
N	2,238	2,238
Panel B: Above-median quality countries		
New entry	−0.283*	−0.387**
	(0.147)	(0.175)
N	784	784
Panel C: Below-median quality countries		
New entry	−0.134	−0.091
	(0.093)	(0.186)
N	1,030	1,030

A Appendix Tables

Table A1: Operational Presence, Revenue Footprint, and Offset Quality (Sylvera and BeZero ratings)

This table reports estimates from the following specification:

$$S_{kiy} = \beta_1 \,\text{Operation}_{ij} + \beta_2 \,\text{Rating}_k + \beta_3 \left(\text{Operation}_{ij} \times \text{Rating}_k\right) + \mathbf{X}_i'\gamma + \text{Fixed Effects} + \varepsilon_{kiy}.$$

The dependent variable S_{kiy} is the share of firm i's annual carbon offset retirements allocated to project k in year y. Operation_{ij} is a dummy equal to one if firm i has operations in the country j where project k is located. In columns (1)-(2), Operation_{ij} equals one for firms with operations in the project country, including both foreign firms with positive revenues and domestic firms headquartered in that country. In columns (3)-(4), Operation_{ij} equals one for foreign firms with a revenue footprint above the sample median in the project country. Columns (5)-(6) analogously define Operation_{ij} for foreign firms with a revenue footprint below the sample median. Rating_p is a binary indicator equal to one if the project is rated BB or higher based on the combined letter ratings from BeZero and Sylvera, and zero otherwise. The sample is restricted to projects rated at least one of these agencies. All specifications include project classification, vintage, and country-of-retirement-by-year fixed effects. Standard errors are clustered at the firm level and reported in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Operational Presence Domestic + Foreign		Foreign Above median revenue		Foreign Below median revenue	
	(1)	(2)	(3)	(4)	(5)	(6)
OPERATION	0.009	-0.024	0.057**	0.025	-0.030	-0.029
	(0.022)	(0.018)	(0.023)	(0.031)	(0.023)	(0.024)
RATING	0.053*	0.037	0.054**	0.052*	0.023	0.042
	(0.030)	(0.025)	(0.021)	(0.028)	(0.020)	(0.043)
OPERATION × RATING	-0.031	0.012	-0.105***	-0.041	0.029	0.006
	(0.027)	(0.025)	(0.032)	(0.061)	(0.030)	(0.038)
Log Emissions	-0.013		-0.012		-0.014	
	(0.014)		(0.013)		(0.013)	
Log Sales	-0.034*		-0.038*		-0.034*	
	(0.019)		(0.019)		(0.020)	
Target Approved	0.020		0.021		0.019	
	(0.040)		(0.039)		(0.041)	
Constant	0.811***	0.227***	0.815***	0.208***	0.829***	0.222***
	(0.172)	(0.010)	(0.165)	(0.007)	(0.167)	(0.014)
Observations	4,158	3,244	4,158	3,244	4,158	3,244
R-squared	0.505	0.417	0.506	0.417	0.505	0.417
Firm FE	Yes	No	Yes	No	Yes	No
Firm × Year FE	No	Yes	No	Yes	No	Yes

Table A2: Operational Presence, Revenue Footprint, and Ex-Ante Quality

This table reports estimates from the following specification:

$$S_{kiy} = \beta_1 \,\text{Operation}_{ij} + \beta_2 \, Q_{pdr} + \beta_3 \left(\text{Operation}_{ij} \times Q_{pdr}\right) + \mathbf{X}_i'\gamma + \text{Fixed Effects} + \varepsilon_{kiy}.$$

The dependent variable S_{kiy} is the share of firm i's annual carbon offset retirements allocated to project k in year y. Operation_{ij} is a dummy equal to one if firm i has operations in the country j where project k is located. In columns (1)–(2), Operation_{ij} equals one for firms with operations in the project country, including both foreign firms with positive revenues and domestic firms headquartered in that country. In columns (3)–(4), Operation_{ij} equals one for foreign firms with a revenue footprint above the sample median in the project country. Columns (5)–(6) analogously define Operation_{ij} for foreign firms with a revenue footprint below the sample median. Q_{pdr} is an ex-ante observable quality proxy constructed using observable characteristics at the time of retirement. For each bucket (p,d,r),

$$Q_{pdr} = \frac{\sum_{k\in(p,d,r)} \text{Volume}_k \cdot \mathbf{1}[\text{HighQuality}_k]}{\sum_{k\in(p,d,r)} \text{Volume}_k},$$

where p denotes harmonized project type, d developer status (local-only versus operating in multiple countries), and r registry (VCS, Gold Standard, ACR, or CAR). HighQuality_k equals one if project k's MSCI rating is above the sample median, and zero otherwise. Weights are total retired volume. The classification variable p contains 9 categories, yielding 72 (p,d,r) buckets in total. All specifications include project classification, vintage, and country-of-retirement-by-year fixed effects. Standard errors are clustered at the firm level and reported in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

	Operational Presence Domestic + Foreign		Foreign Above median revenue		Foreign Below median revenue	
	(1)	(2)	(3)	(4)	(5)	(6)
OPERATION	0.023	-0.015	0.03	0.041***	0.001	-0.034**
	(0.022)	(0.013)	(0.019)	(0.012)	(0.022)	(0.016)
QUALITY	0.069*	0.024	0.052*	0.024	0.044	0.009
	(0.038)	(0.039)	(0.031)	(0.035)	(0.028)	(0.038)
OPERATION x QUALITY	-0.051*	-0.025	-0.061*	-0.076***	-0.011	0.011
	(0.029)	(0.026)	(0.031)	(0.023)	(0.034)	(0.024)
Log(Emissions)	0.006		0.006		0.005	
	(0.008)		(0.008)		(0.008)	
Log(Revenue)	-0.049***		-0.05***		-0.048***	
	(0.015)		(0.015)		(0.015)	
Target Approved	-0.033		-0.033		-0.033	
	(0.027)		(0.026)		(0.027)	
Observations	7881	6733	7881	6733	7881	6733
R-squared	0.545	0.487	0.545	0.487	0.545	0.487
Firm FE	Yes	No	Yes	No	Yes	No
Firm × Year FE	No	Yes	No	Yes	No	Yes

B Model Appendix

Proposition 1 (proof). We want to determine the conditions under which the share of offsets purchased locally is larger than that from the foreign country. This amounts to verify

$$\frac{q^*_{H,l}+q^*_{L,l}}{q^*_{H,l}+q^*_{L,l}+q^*_{H,l}+q^*_{L,l}} > \frac{1}{2}, \tag{20}$$

with equilibrium average quantities $\{q^*_{H,j}, q^*_{L,j}\}_{j=l,f}$ from (11). This is equivalent to verifying that

$$q^*_{H,l}+q^*_{L,l} > q^*_{H,f}+q^*_{L,f}. \tag{21}$$

Substituting the explicit expressions from the first order conditions, we get

$$q^*_{H,j}+q^*_{L,j} = \frac{1}{\phi+\theta^2\gamma\rho_j(1-\rho_j)}\Big(\rho_j B_{H,j}(H)+(1-\rho_j)B_{H,j}(L)+\rho_j B_{L,j}(L)+(1-\rho_j)B_{L,j}(H)\Big) \tag{22}$$

since $\phi_L=\phi_H=\phi$, we have that $B_{L,j}(L)=B_{H,j}(L)=B_{L,j}$ and $B_{H,j}(H)=B_{L,j}(H)=B_{H,j}$, thus the expression in (21) simplifies to

$$\Big(B_{H,l}+B_{L,l}\Big) > \Big(\frac{\gamma\rho_l(1-\rho_l)\theta^2+\phi}{\gamma\rho_f(1-\rho_f)\theta^2+\phi}\Big)\Big(B_{H,f}+B_{L,f}\Big) \tag{23}$$

where substituting the benefits terms and rearranging, we get

$$\Big(\big[(\beta)^\sigma+(\rho_l\theta)^\sigma\big]^{\frac{1}{\sigma}}+\big[(\beta)^\sigma+((1-\rho_l)\theta)^\sigma\big]^{\frac{1}{\sigma}}\Big) > \Big(\frac{\gamma\rho_l(1-\rho_l)\theta^2+\phi}{\gamma\rho_f(1-\rho_f)\theta^2+\phi}\Big)\theta. \tag{24}$$

When $\sigma=1$, condition (24) can be rearranged to obtain a lower bound on the local benefit β:

$$\beta > \kappa(\rho_f,\rho_l)\,\theta, \tag{25}$$

where

$$\kappa(\rho_f,\rho_l) = \frac{1}{2}\left(\frac{\gamma\rho_l(1-\rho_l)\theta^2+\phi}{\gamma\rho_f(1-\rho_f)\theta^2+\phi}-1\right).$$

If $\rho_l>\rho_f$, then $\kappa(\rho_f,\rho_l)<0$, so the lower bound is slack: even $\beta=0$ is sufficient to generate a local bias. Conversely, if $\rho_f>\rho_l$, then $\kappa(\rho_f,\rho_l)>0$, and local benefits must be sufficiently large to overturn the information disadvantage.

When $\sigma<1$, we use the property of the CES aggregator that for $0<\sigma<1$ and $a,b\geq 0$,

$$(a^\sigma+b^\sigma)^{1/\sigma} \geq a+b.$$

This implies that a sufficient condition for (21) to hold is again

$$\beta > \kappa(\rho_l,\rho_f)\,\theta. \tag{26}$$

Therefore, when $\sigma < 1$, the same threshold as in the linear case $\sigma = 1$ is sufficient. Moreover, since for $\sigma < 1$ the CES aggregator is strictly convex, the true lower bound on β is weakly smaller than in the linear benchmark.

Proposition 2 (proof). We seek conditions under which the firm holds a larger share of low-quality offsets locally, that is

$$\frac{q^*_{H,l}}{q^*_{H,l}+q^*_{L,l}} < \frac{q^*_{H,f}}{q^*_{H,f}+q^*_{L,f}}. \tag{27}$$

with equilibrium average quantities $\{q^*_{H,j}, q^*_{L,j}\}_{j=l,f}$ from (11). From the previous argument, the local high-quality share, $\frac{q^*_{H,l}}{q^*_{H,l}+q^*_{L,l}}$, can be written as

$$f(\beta,\sigma) = \frac{\rho_l A(\beta,\sigma) + (1-\rho_l)B(\beta,\sigma)}{A(\beta,\sigma)+B(\beta,\sigma)}, \tag{28}$$

where

$$A(\beta,\sigma) = [\beta^\sigma + (\rho_l\theta)^\sigma]^{1/\sigma}, \qquad B(\beta,\sigma) = [\beta^\sigma + ((1-\rho_l)\theta)^\sigma]^{1/\sigma}. \tag{29}$$

The foreign high-quality share simplifies to

$$f_f = \rho_f^2 + (1-\rho_f)^2. \tag{30}$$

As $\beta \to \infty$, both $A(\beta,\sigma)$ and $B(\beta,\sigma)$ become asymptotically linear in β, implying

$$\lim_{\beta\to\infty} f(\beta,\sigma) = \frac{1}{2},$$

independently of ρ_l. Since $f_f > \frac{1}{2}$ whenever $\rho_f > \frac{1}{2}$, the inequality is eventually satisfied for sufficiently large β. The problem therefore reduces to characterizing the threshold level of β above which $f(\beta,\sigma) < f_f$.

Consider first the benchmark case $\sigma = 1$. The CES aggregator becomes linear and the inequality reduces to

$$\frac{\beta/\theta + \rho_l^2 + (1-\rho_l)^2}{2\beta/\theta + 1} < \rho_f^2 + (1-\rho_f)^2. \tag{31}$$

Let $s(\rho) = \rho^2 + (1-\rho)^2 > \frac{1}{2}$. Rearranging yields

$$\beta > \nu(\rho_l,\rho_f)\theta, \tag{32}$$

where

$$\nu(\rho_l,\rho_f) = \frac{s(\rho_l) - s(\rho_f)}{2s(\rho_f) - 1}, \tag{33}$$

and $s(\rho_j) = \rho_j^2 + (1-\rho_j)^2 > \frac{1}{2}$. If $\rho_l < \rho_f$, then $s(\rho_l) < s(\rho_f)$ and the lower bound is negative, implying that even $\beta = 0$ generates a negative quality gradient. If instead $\rho_l > \rho_f$, then $\nu(\rho_l,\rho_f) > 0$ and local goodwill must be sufficiently large to overturn the informational advantage.

For the general case $\sigma < 1$, the function $f(\beta,\sigma)$ is continuous and strictly decreasing in β. Moreover,

$$f(0,\sigma) = \rho_l^2 + (1-\rho_l)^2, \qquad \lim_{\beta\to\infty} f(\beta,\sigma) = \frac{1}{2}.$$

Hence, whenever $\rho_l > \rho_f$, there exists a unique cutoff $\underline{\beta}(\sigma)$ such that $f(\beta,\sigma) < f_f$ for all $\beta > \underline{\beta}(\sigma)$. Furthermore, since the CES aggregator is convex for $\sigma < 1$, one has

$$A(\beta,\sigma) \geq \beta + \rho_l\theta, \qquad B(\beta,\sigma) \geq \beta + (1-\rho_l)\theta, \tag{34}$$

which implies

$$f(\beta,\sigma) \leq f(\beta,1), \qquad \forall \beta > 0. \tag{35}$$

Therefore, the linear benchmark in (32) provides a sufficient condition for the inequality to hold, namely

$$\beta > \nu(\rho_l,\rho_f)\theta \quad \Longrightarrow \quad f(\beta,\sigma) < f_f. \tag{36}$$

Proposition 3 (proof). We show that the presence of the local benefit β reduces price sensitivity to quality. Formally, we want to establish

$$\frac{\partial p_{k,l}^*}{\partial\theta} < \frac{\partial p_{k,f}^*}{\partial\theta}, \qquad k \in \{H,L\}. \tag{37}$$

with $p_{k,j}^*$ average equilibrium prices from (10). Fix for simplicity $k = H$. Using the equilibrium price formula, local and foreign prices can be written as

$$p_l^* = \Big(\rho_l A(\beta,\sigma) + (1-\rho_l)B(\beta,\sigma)\Big)\frac{\phi}{\gamma\rho_l(1-\rho_l)\theta^2+\phi}, \tag{38}$$

where

$$A(\beta,\sigma) = [\beta^\sigma + (\rho_l\theta)^\sigma]^{1/\sigma}, \qquad B(\beta,\sigma) = [\beta^\sigma + ((1-\rho_l)\theta)^\sigma]^{1/\sigma},$$

while foreign prices simplify to

$$p_f^* = \theta\left(\rho_f^2 + (1-\rho_f)^2\right)\frac{\phi}{\gamma\rho_f(1-\rho_f)\theta^2+\phi}. \tag{39}$$

Consider first the benchmark case $\sigma = 1$. The CES aggregator becomes linear, so that

$$\rho_l A + (1-\rho_l)B = \beta + \theta\left(\rho_l^2 + (1-\rho_l)^2\right).$$

Hence,

$$p_l^* = \Big(\beta + \theta\mu(\rho_l)\Big)\frac{\phi}{\gamma\rho_l(1-\rho_l)\theta^2+\phi}, \qquad \mu(\rho) = \rho^2 + (1-\rho)^2. \tag{40}$$

The marginal derivative of the local price with respect to θ thus becomes

$$\frac{\partial p_l^*}{\partial\theta} = \frac{\partial}{\partial\theta}\Big[\frac{\phi\theta\mu(\rho_l)}{\gamma\rho_l(1-\rho_l)\theta^2+\phi}\Big] - 2\beta\phi\Big[\frac{\gamma\rho_l(1-\rho_l)\theta}{(\gamma\rho_l(1-\rho_l)\theta^2+\phi)^2}\Big] \tag{41}$$

whereas for the foreign price,

$$\frac{\partial p_f^*}{\partial \theta} = \frac{\partial}{\partial \theta}\Big[\frac{\phi\,\theta\,\mu(\rho_f)}{\gamma\rho_f(1-\rho_f)\theta^2+\phi}\Big] \tag{42}$$

Note that the term in first brackets in (41) is strictly increasing in ρ, whereas the second term is decreasing in β. Thus if $\rho_f > \rho_l$, the inequality in (37) holds necessarily for any β. However, for any given $\beta > 0$, local price sensitivity to quality may dampened even if $\rho_l > \rho_f$. Specifically, solving the derivatives and rearranging, one has that the inequality in (37) holds if and only if

$$\beta > \frac{1}{2\gamma\rho_l(1-\rho_l)\theta}\Big[\phi(\mu(\rho_l)-\mu(\rho_f)) - \gamma\theta^2(\mu(\rho_l)\rho_l(1-\rho_l)-\mu(\rho_f)\rho_f(1-\rho_f))\Big]. \tag{43}$$

When $\sigma < 1$, local benefits partially substitute quality thereby dampening price sensitivity further. As before, we establish a sufficient lower bound on β such that the inequality in (37) holds even when $\rho_l > \rho_f$. Equilibrium prices can be written in the form

$$p_j(\theta) = M_j(\theta,\beta)\,D_j(\theta), \tag{44}$$

$$D_j(\theta) = \frac{\phi}{\gamma\rho_j(1-\rho_j)\theta^2+\phi}, \tag{45}$$

$$M_l(\theta,\beta) = \rho_l A(\beta,\sigma) + (1-\rho_l)B(\beta,\sigma), \tag{46}$$

$$M_f(\theta) = \theta\,\mu(\rho_f), \qquad \mu(\rho) = \rho^2+(1-\rho)^2, \tag{47}$$

with

$$A(\beta,\sigma) = [\beta^\sigma + (\rho_l\theta)^\sigma]^{1/\sigma}, \qquad B(\beta,\sigma) = [\beta^\sigma + ((1-\rho_l)\theta)^\sigma]^{1/\sigma}. \tag{48}$$

Noting that $D_j^{'}(\theta) < 0$, and thus

$$\frac{\partial p_l}{\partial \theta} = \frac{\partial M_l(\theta,\beta)}{\partial \theta}D_l(\theta) - M_l(\theta,\beta)\frac{\partial D_l(\theta)}{\partial \theta} < \frac{\partial M_l(\theta,\beta)}{\partial \theta}D_l(\theta), \tag{49}$$

a sufficient condition for (37) is therefore that

$$\frac{\partial M_l(\theta,\beta)}{\partial \theta} < \frac{\partial M_f(\theta)}{\partial \theta}. \tag{50}$$

Differentiating A with respect to θ gives

$$\frac{\partial A}{\partial \theta} = \rho_l\left(\frac{(\rho_l\theta)^\sigma}{\beta^\sigma+(\rho_l\theta)^\sigma}\right)^{\frac{1-\sigma}{\sigma}}, \tag{51}$$

and analogously for B. Define

$$\omega_l(\beta,\theta) = \left(\frac{(\rho_l\theta)^\sigma}{\beta^\sigma+(\rho_l\theta)^\sigma}\right)^{\frac{1-\sigma}{\sigma}} \in (0,1), \tag{52}$$

so that

$$\frac{\partial M_l}{\partial \theta} = \rho_l^2\omega_l + (1-\rho_l)^2\tilde{\omega}_l < \mu(\rho_l), \tag{53}$$

while

$$\frac{\partial M_f}{\partial \theta} = \mu(\rho_f). \tag{54}$$

As $\beta \to \infty$, the local sensitivity term satisfies

$$\frac{\partial M_l}{\partial \theta} \sim \mu(\rho_l) \left(\frac{\theta}{\beta}\right)^{1-\sigma}, \tag{55}$$

so that the marginal effect of θ on local prices shrinks at rate $\beta^{-(1-\sigma)}$, while the foreign marginal effect remains independent of β.

A sufficient condition for (50) is therefore

$$\frac{\partial M_l}{\partial \theta} < \mu(\rho_f), \tag{56}$$

which using (55) implies

$$\mu(\rho_l) \left(\frac{\theta}{\beta}\right)^{1-\sigma} < \mu(\rho_f). \tag{57}$$

Solving for β yields the lower bound

$$\beta > \theta \left(\frac{\mu(\rho_l)}{\mu(\rho_f)}\right)^{\frac{1}{1-\sigma}}. \tag{58}$$

Thus, even when $\rho_l > \rho_f$, sufficiently large local goodwill β reduces the sensitivity of local prices to quality and ensures the inequality (37).