Socially Responsible Investing and Multinationals' Environmental Harm

Evidence from Global Remote Sensing Data*

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This paper examines how Socially Responsible Investment (SRI) capital affects the environmental footprint of multinational firms. Using the inverse relationship between industrial pollution and satellite-based vegetation health measured by the Normalized Difference Vegetation Index (NDVI), we combine NDVI with SRI ownership data for 52,806 facilities operated by 911 multinationals across 124 countries from 2006 to 2020. Higher SRI ownership improves nearby vegetation, a result corroborated using mergers as plausibly exogenous ownership shocks. However, improvements at OECD facilities coincide with deterioration at non-OECD sites, indicating pollution displacement that intensifies with stronger investor engagement.

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1. Introduction

Assets managed according to environmental, social, and governance (ESG) principles are large and expanding rapidly, with institutional investors widely viewed as key drivers of firms' environmental and social performance (Stroebel and Wurgler, 2021). These investors emphasize engagement rather than divestment as a means to address externalities such as climate risk (Krueger et al., 2020). Firms, in turn, frequently highlight in their sustainability disclosures environmental initiatives related to waste management, hazardous-waste reduction, recycling, on-site treatment, and water stewardship.[1] Yet rigorous evidence on whether this large-scale reallocation of ESG-aligned capital and investor pressure translate into real environmental improvements remains limited. Most measures of corporate environmental impact are self-reported, aggregated, and geographically incomplete, especially outside the richest economies. Furthermore, improvements in one jurisdiction may be offset elsewhere if firms reallocate activity in response to differences in regulation, bargaining power, or marginal abatement costs (Ben-David et al., 2021; Yang et al., 2022). These concerns are particularly salient for multinational enterprises (MNEs), which account for a substantial share of global environmental harm (Tanaka et al., 2022; Levinson, 2009; Noack et al., 2025).[2] Even if socially responsible investors matter, it remains unclear where firms adjust and whether these adjustments do improve their environmental footprint.

This paper provides new evidence on how Socially Responsible Investors (SRI) capital relates to multinational firms' environmental harm. We address longstanding challenges in measuring firms' environmentally harmful activity and tracing its displacement across borders by introducing a globally consistent, high-frequency, and spatially granular approach based on satellite data. Specifically, we exploit the well-established inverse relationship between environmental harm and the Normalized Difference Vegetation Index (NDVI), a satellite-derived measure of

[1] See e.g. Dow's 2023 Intersections Progress Report (https://corporate.dow.com/content/dam/corp/documents/about/066-00469-01-2023-progress-report.pdf), Lear's 2023 Sustainability Report (https://ir.lear.com/node/24541/pdf), Baxter's ESG disclosures (https://investor.baxter.com/investors/ESG--Corporate-Responsibility/), Newell Brands' 2024 Corporate Citizenship Report (https://www.newellbrands.com).

[2] The Environmental Protection Agency (EPA) estimates that the manufacturing sector, dominated by multinationals, produces about 60% of hazardous waste in the United States and is a major source of chemical discharges and air pollutants. Levinson (2009) further shows that U.S. manufacturing firms account for roughly 20% of global sulfur dioxide (SO_2), 15% of nitrogen oxides (NO_x), and 12% of carbon dioxide (CO_2).

vegetation health.[3] The NDVI offers three key advantages to track environmental harm: it is (i) available worldwide, including regions lacking formal environmental monitoring; (ii) less susceptible to manipulation than disclosures; and (iii) fine-grained enough to detect local changes around individual facilities. Put differently, the NDVI is not subject to atmospheric transport or source-attribution challenges and can be mapped directly to production sites. Furthermore, capturing multispectral pollution dominates a focus on individual pollutants like CO_2 or $PM_{2.5}$ because we know that firms emit multiple regulated and unregulated substances and can substitute across them in response to incentives (Gibson, 2019; Tanaka et al., 2022; Bartram et al., 2022).

While NDVI does not directly measure pollution levels, our approach relies on the premise that increases in local environmental harm reduce NDVI on average, holding other factors constant (including for example vegetation type, weather fluctuations, climate trends, or industrial presence). A stable negative relationship between *changes* in environmentally harmful behavior and *changes* in NDVI is sufficient for our purposes. We build on a growing body of evidence in environmental science documenting NDVI's sensitivity to pollutant exposure (e.g., Dean et al., 2024; Clevers et al., 2004; Zhang et al., 2022; Vashold et al., 2025). Furthermore, we validate this relationship at scale in Section 3 by showing that local NDVI decreases following facility-level toxic releases and chemical spills in U.S.-wide panels. To our knowledge, this is the first paper to employ satellite-based vegetation health data to systematically monitor global firms' environmental footprint.

Our empirical analysis combines four main datasets to cover 13,651 grid cells in 124 countries containing over 52,000 production facilities owned by 911 parent companies. First, we obtain from Dun & Bradstreet Worldbase geolocated facility-level information for the universe of production facilities of publicly listed U.S. multinationals operating in polluting sectors.[4] We then match these facilities to parent-company institutional ownership from FactSet. We measure exposure to responsible investing by identifying institutional owners that are signatories of the

[3]The NDVI is calculated from reflected red and near-infrared light. Higher NDVI values indicate denser, more photosynthetically active vegetation.

[4]Namely Agriculture, Forestry, and Fishing (SIC code 01-09), Mining (10-14), Construction (15-17), and Manufacturing (20-39). These sectors account for the majority of toxic pollutants released into land and water, and about 30% of total toxic air pollutants in the U.S.A. Source: U.S. Environmental Protection Agency (2024). *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, and *Toxics Release Inventory (TRI) National Analysis*. Available at: `https://www.epa.gov/ghgemissions/industry-sector-emissions` and `https://www.epa.gov/trinationalanalysis`.

Principles for Responsible Investment (PRI), the largest ESG initiative in the asset-management industry (Kim and Yoon, 2023; Gibson Brandon et al., 2022). Our main explanatory variable is the time-varying share of the parent's equity held by PRI signatories. Finally, we overlay the facility network with NDVI measured on a $0.1^\circ \times 0.1^\circ$ grid of cells (about 11×11 km at the equator), observed biweekly from 2006 to 2020.

Our empirical design exploits two dimensions of variation in exposure to SRI capital: time, and the relationship between each facility and its parent company. We relate NDVI around facility locations to the parent firm's quarterly exposure to ownership by PRI signatories, conditioning on high-dimensional fixed effects, weather, and built-environment controls. The fixed effects absorb, among others, time-invariant facility and firm characteristics, local seasonal patterns, and heterogeneous climate trends across agroclimatic zones.

Identification comes from within-firm changes in socially responsible ownership over time, comparing how the NDVI evolves around the firm's facilities, conditional on controls and fixed effects. For intuition, consider two facilities in neighboring grid cells owned by different parent firms. Differences in socially responsible ownership across parents are related to differences in NDVI around these facilities over time.

A remaining concern is that inflows from socially responsible investors could coincide with broader changes in firms' economic or environmental attractiveness. We address this in two ways. First, we control for time-varying local activity using night-time lights to separate environmental changes from production-driven shifts. Second, we can explicitly control for overall institutional ownership to separate the role of PRI signatories from that of institutional investors at large. Last but not least, we exploit a fundamentally different source of variation in SRI exposure by leveraging mergers in which a PRI signatory acquires a non-signatory asset manager, generating discrete and plausibly exogenous increases in socially responsible ownership for the target's portfolio firms.

We first find that increases in socially responsible ownership improve local environmental conditions on average. A one percentage point increase in responsible ownership is associated with a reduction of roughly 85 tons of toxic releases per facility. To put this estimate in perspective, 85 tons of releases exceed three times the U.S. Environmental Protection Agency's minimum reporting threshold under the Toxic Release Inventory and are equivalent to the combined annual

releases of more than three facilities operating at that threshold. Responsible ownership varies meaningfully in the data, with a standard deviation of eight percentage points. A one standard deviation increase therefore corresponds to a reduction of approximately 680 tons of toxic releases per facility-year, an amount comparable to eliminating the entire annual toxic output of more than 50 threshold-level facilities. These results are robust when we exploit alternative sources of variation, including facility-level specifications and quasi-experimental variation from mergers. Taken together, the findings indicate that ownership structure shapes firm behavior and suggest that socially responsible investors exert meaningful governance pressure in environmental domains.

To discipline the interpretation of NDVI as an outcome measure, we implement a falsification test in the United States, where the data allow us to distinguish facilities with and without production. Applying the baseline design to non-producing U.S. facilities owned by the same multinationals, we find no systematic relationship between socially responsible ownership and NDVI. The absence of effects in this natural comparison group rules out the concern that changes in NDVI reflect broader firm expansion, local economic development, or non-environmental investment, such as increased activity, infrastructure, or land use, rather than changes in harmful releases. Instead, it supports interpreting NDVI responses around production facilities as capturing environmental impacts associated with industrial activity.

At the same time, the analysis reveals systematic displacement of environmental harms from OECD to non-OECD countries. OECD economies are typically richer and exhibit greater investment in pollution monitoring and environmental oversight.[5] We find that vegetation health improvements are concentrated around facilities in OECD countries, whereas environmental degradation intensifies around facilities in non-OECD regions. Quantitatively, a one–percentage point increase in responsible ownership is associated with an average reduction of approximately 70 tons of toxic releases per OECD facility, but an increase of more than 200 tons per non-OECD facility. Because most facilities are located in OECD countries, the average global effect remains positive, roughly 90 tons per firm per year for the median multinational enterprise.

[5]The Organisation for Economic Co-operation and Development (OECD) presents itself as "an international organisation that works to build better policies for better lives. [...] We work closely with policy makers, stakeholders and citizens to establish evidence-based international standards and to find solutions to social, economic and environmental challenges." Source: https://www.oecd.org/en/about.html, October 28, 2025.

This uneven distribution across countries highlights a tension between local improvements and global environmental justice. Put differently, using facility-level outcomes allows us to observe not only whether pollution reductions occur but also where harms are relocated, patterns that are invisible in firm-level ESG ratings or portfolio-level emissions. Our results call for greater attention to cross-border enforcement.

The final part of the paper shows that investor stewardship matters. Using information extracted from mandatory self-reported fillings submitted by signatories to the PRI, we construct a novel measure of intensity of investors engagement that classifies signatories as Basic, Moderate, or Advanced.[6] We find that improvements are concentrated among firms owned by the most engaged institutions. However, displacement abroad is also strongest in these cases. The evidence is consistent with firms responding to strong investor pressure by improving outcomes in well-monitored regions while relocating harms elsewhere, underscoring the need for international monitoring.

This paper contributes to four strands of literature. First, we advance research on pollution displacement, showing that firms may shift harmful externalities toward jurisdictions with weaker enforcement (Dai et al., 2021). This vibrant literature typically exploits differences in regulatory stringency to document the outsourcing of environmental harm across borders (Ben-David et al., 2021; Burgess et al., 2012; Cust et al., 2023; Kundu and Ruenzi, 2024; Lipscomb and Mobarak, 2016; Tanaka et al., 2022). Conceptually closer to our focus on the role of investors, ongoing work by Berg et al. (2023) demonstrates that investor pressure can induce geographically targeted divestment from environmentally intensive assets. We build on and extend this literature by introducing a novel global measure of environmental impact based on satellite-derived vegetation health, which allows us to map where sustainability-oriented investors reduce or relocate harmful activity. We find that improvements are concentrated around facilities in OECD countries, while environmental degradation intensifies in non-OECD regions, particularly where ownership stems from highly engaged investors. Even committed stewardship appears insufficient to eliminate displacement in the absence of globally coordinated monitoring.

Second, we contribute to the growing empirical literature examining how socially responsible

[6]We use a large language model (LLM) to analyze unstructured PRI disclosure text and show that self-reported engagement labels correspond to substantively different stewardship practices. Advanced signatories often mention leadership roles and collaborative engagements, Moderates emphasize collaboration without leadership, and Basics provide brief, heterogeneous responses.

institutional investors affect firms' environmental outcomes. Building on seminal work showing that ownership structure shapes firm behavior (Shleifer and Vishny, 1986, 1997), recent evidence suggests that SRI ownership can reduce firms' environmental footprints when measured through firm-level GHG or CO_2 emissions (Azar et al., 2021; Kahn et al., 2023) or composite ESG scores (Dyck et al., 2019), although Heath et al. (2023) or Cust et al. (2023) find no significant changes in observable firm actions. The work of Naaraayanan et al. (2021) zooms in on a panel of U.S. facilities and documents that an increase in investor activism reduces firms' toxic releases at the national level. We extend this literature along several dimensions. Exploiting a facility-level analysis in a global panel, we show that changes in responsible ownership translate, on average, into measurable improvements in local environmental conditions, both in fixed-effects regressions and in a quasi-experimental setting. Furthermore, consistent with recent theory (Heinkel et al., 2001; Berk and van Binsbergen, 2021; Broccardo et al., 2022; De Angelis et al., 2023; Oehmke and Opp, 2024), we document that the direction and magnitude of these effects depend systematically on the regulatory context and the intensity of investor stewardship.

Third, we contribute to recent research on institutional stewardship (Ceccarelli et al., 2024; Dimson et al., 2025; Gibson Brandon et al., 2022; Kim and Yoon, 2022; Lowry et al., 2025). We use PRI disclosures to construct a novel text-based measure that distinguishes passive signatories from active stewards. Not every signatory is equally committed: only 13% classify themselves as Advanced and 21% as Moderate. These differences in self-reported engagement are reflected in the impact investors have on portfolio firms, consistent with evidence in Gibson Brandon et al. (2022) that PRI signatory status is a noisy proxy for responsible ownership and that stewardship intensity varies widely across institutions. However, we also show that even strong institutional engagement does not fully prevent the displacement of environmental harm. This pattern of results suggests that engagement alone is insufficient if country- or customer-level monitoring quality is weak: the real effects of responsible investment are conditional on credible oversight.

Finally, this paper contributes to a growing literature that uses satellite data to measure economic activity and externalities globally. This approach is particularly valuable when ground data are limited or distorted (Donaldson and Storeygard, 2016; Kundu and Ruenzi, 2024). For example, recent research uses satellite data to document strategic misreporting of GDP growth

by autocracies (Martinez, 2022), or strategic timing of polluting production outside monitored days in the US (Zou, 2021). Here, we show that vegetation indices such as NDVI, so far widely used to assess ecosystem health (Alix-Garcia et al., 2015; Asher and Novosad, 2020; Girard et al., 2025), provide a scalable tool to monitor firms' multispectral pollution footprints. By capturing the consequences of multispectral pollution, our approach also links firm behavior to broader outcomes such as biodiversity loss (Giglio et al., 2023; Garel et al., 2024) and aligns with a policy shift toward outcome-based environmental assessment, as reflected in European Sustainability Reporting Standards (ESRS), the International Sustainability Standards Board (ISSB), and the Global Reporting Initiative (GRI) frameworks.

2. Data and Identification Strategy

We assemble a panel of cells that combines establishments' locations and ownership with satellite-based vegetation health at biweekly (16-day) frequency from 2006 to 2020. Our baseline unit is a global grid of cells of $0.1° \times 0.1°$ (approximately 11×11 km at the equator) that host at least one facility. This resolution provides fine spatial detail, as most cells contain a single establishment, while remaining computationally tractable.[7] The key variables for our final analysis are, at the cell-date level, the presence of U.S.-owned facilities, quarterly institutional ownership of the parent company, and the biweekly NDVI measure.

2.1 Data sources

U.S. public multinationals' facilities. We obtain the global network of establishments for publicly listed U.S. multinationals from Dun & Bradstreet (D&B) WorldBase. D&B offers globally consistent coverage of establishment-level activities, which is essential for linking responsible ownership to environmental conditions around actual production facilities. The extract is a cross-sectional snapshot (2023 vintage). Our analysis therefore relies on the persistence of multinational production networks, which adjust slowly given sunk entry and exit costs (Dixit, 1989). We confirm this stability in the U.S. sample, where we can test it.[8] The

[7] As a robustness check, we replicate key results on alternative cell sizes and in a facility-level panel. Appendix Table B-1 presents descriptive statistics by cell size.

[8] To gauge the stability of facility networks, we use the U.S. EPA Toxic Release Inventory (TRI), which lists facilities annually when they exceed reporting thresholds. For TRI parents with an identifier (`parentcodbnum`) observed in both 2006 and 2020, we compute, for each parent, the Jaccard similarity

main implication is measurement error in the timing of openings and closures, adding noise to estimated effects.

The use of the D&B data rather than the widely known Orbis data stems from the important distinction between establishment-level and legal-entity-level data. Orbis focuses on corporate ownership structures and financial reporting units: it does not provide systematic global coverage of production facilities (Sonno (2025)). In contrast, D&B WorldBase identifies the physical locations where production occurs. Its establishment-level coverage allows scholars interested in MNEs networks to map facilities locations across more than 100 countries, or to construct spatial measures of industrial activity, which cannot be derived from Orbis alone (Alfaro and Chen, 2014).

We restrict attention to SIC codes 01–39, which are major contributors to environmentally harmful releases and where investor pressure is most likely to affect environmental outcomes (Hartzmark and Shue, 2022). These SIC codes correspond to Agriculture, Forestry and Fishing (01–09), Mining (10–14), Construction (15–17), and Manufacturing (20–39). According to the U.S. Environmental Protection Agency (2024), these sectors account for the majority of toxic substances released into land and water, and about 30% of total toxic air releases.

Crucially for the purpose of this study, the D&B data allows us to precisely locate all establishments and therefore match them to satellite measurements of vegetation health. We geolocate establishments using latitude/longitude provided by D&B for U.S. sites and ArcGIS World Geocoding for non-U.S. addresses. The raw D&B file includes 57,961 establishments in 124 countries, mapped to 985 parent companies. Panel (a) of Figure 1 plots facility locations.

Institutional ownership. Quarterly institutional ownership at the parent-company level comes from FactSet Ownership (Ferreira and Matos, 2008). Our measure of socially responsible investing is the proportion of a company's shares held by signatories of the PRI. The PRI is the only global stewardship initiative in asset management with mandatory reporting and an

between the sets of reporting facilities in 2006 and 2020. The mean similarity is 0.76 (median = 1.00), indicating strong persistence. As TRI entries and exits can reflect threshold crossings as well as true openings and closures, three-quarters stability over 14 years underscores strong hysteresis in production networks. A remaining concern is that firms may restructure networks in response to responsible ownership (for example, outsourcing more polluting activities to suppliers not covered by our facility data). If pervasive, such shifts could bias effects. We revisit this question in Section 4.; the pattern we document, with reductions at OECD facilities coupled with increases at non-OECD facilities, is consistent with intra-network reallocation rather than wholesale divestment or network restructuring (Duchin et al., 2024).

external accountability framework. It is also the largest, encompassing more than 5,000 signatories and roughly $121 trillion in assets under management as of September 2022 (Kim and Yoon, 2023). Signatories include investment managers (76%), asset owners (14%), and service providers (10%), with Europe and North America accounting for most participants. We collect signatory names and joining dates from PRI publications and hand-match them to FactSet institutions.

We refer to the resulting institutional ownership share as "PRI ownership"; in tables this appears as *PRI IO*. PRI signatories commit to six principles stressing integration of ESG considerations in investment decisions, active ownership, disclosure, and annual public reporting (UN PRI Association, 2024).[9] These obligations make the PRI the only globally adopted, externally monitored framework for responsible ownership.

In the final part of the paper, we use PRI's Transparency Reports to move beyond a binary signatory indicator. Between 2014 and 2020, signatories reported their level of ESG engagement (Basic, Moderate, or Advanced) as part of their mandatory disclosure. This information, contained in module SG09 of the Transparency Reports,[10] allows us to decompose *PRI IO* into ownership held by basic, moderate, and advanced signatories and to capture heterogeneity in commitment levels.

[Figure 1 about here.]

Vegetation health. To assess whether responsible ownership affects firms' local environmental conditions, we track vegetation health around facilities using the Normalized Difference Vegetation Index (NDVI) (Didan, 2015; Alix-Garcia et al., 2015; Asher and Novosad, 2020; Girard et al., 2025). Figure 1 shows a snapshot of the 0.05° 16-day composites, which we area-average to our grid of $0.1° \times 0.1°$ cells.[11] The NDVI captures "greenness" from red and near-infrared

[9] Principle 1: incorporate ESG issues into investment analysis and decision-making. Principle 2: be active owners and incorporate ESG issues into ownership policies and practices. Principle 3: seek appropriate disclosure on ESG issues by investee entities. Principle 4: promote acceptance and implementation of the Principles within the investment industry. Principle 5: work together to enhance implementation effectiveness. Principle 6: report on activities and progress. Noncompliance may lead to delisting.

[10] We retrieved the 2014–2020 Public Transparency Reports from `https://www.unpri.org/signatories/reporting-and-assessment/public-signatory-reports`. The engagement-intensity question appears in modules OA10 (2014–2015), SG08 (2016), and SG09 (2017–2020); we refer to it as SG09 for brevity. The reports were removed from the website after 2020, but the PRI continues to make them available to academics upon request. Appendix G-7 provides an example of the relevant section.

[11] Data source: `https://www.earthdata.nasa.gov/data/catalog/lpcloud-mod13c1-061/`.

reflectance of leafy vegetation and ranges from -1 to 1 (values < 0 typically correspond to water or snow; values near zero to bare ground or built-up areas; 0.1–0.5 to sparse vegetation; and ≥ 0.6 to dense vegetation). NDVI varies systematically across space and seasons; our empirical specifications absorb local idiosyncrasies and weather-driven variation, and control for economic activity.

Section 3. documents NDVI's responsiveness to industrial releases. Importantly, the NDVI renders multispectral pollution rather than focusing on one specific pollutant, as we know firms can substitute across substances when under scrutiny (Gibson, 2019; Tanaka et al., 2022; Bartram et al., 2022). Exploiting NDVI data also allows to overcome many of the measurement challenges which persist even for heavily regulated pollutants: carbon dioxide emissions for example are largely self-reported, while methane emissions are substantially underestimated due to intermittent super-emitter events missed by inventories, and particulate matter are dominated by transportation rather than industrial production (McDuffie et al., 2021). Efforts such as Climate TRACE and satellite products from Copernicus and NASA's OCO-2 and OCO-3 represent important advances but remain constrained in coverage, resolution, or historical depth. Finally, unlike pollutant-specific satellite products, such as fine particulate matter ($PM_{2.5}$) concentrations (van Donkelaar et al., 2016), NDVI is not subject to atmospheric transport or source-attribution challenges and can be mapped directly to production sites.

Controls. We include three main sets of controls. (i) Weather: we capture weather-related variability in vegetation health through monthly temperature and precipitation from the Climatic Research Unit (CRU) at $0.5° \times 0.5°$ resolution (Harris et al., 2020), entering levels and squares to allow nonlinear responses (see Dell et al., 2014). (ii) Local economic activity: development and settlement patterns that may affect vegetation independently of firms' releases. We consider night-time lights harmonized by Li et al. (2020) for the period 2006-2018,[12] alongside population and building counts from the EU Global Human Settlement Layer (GHSL).[13] (iii) Ecological heterogeneity: we consider agroclimatic-zone-by-year fixed effects based on the World Bank's Köppen–Geiger classification to capture ecological boundaries and allow zone-specific annual responses.

[12] A well-established proxy of local economic activity and GDP (Donaldson and Storeygard, 2016; Henderson et al., 2012; Martinez, 2022), we interpolate the missing data.

[13] GHSL: `https://ghsl.jrc.ec.europa.eu/download.php`. The GHSL is available every five years, we interpolate it to annual frequency.

2.2 Sample and summary statistics

We start from 57,961 facilities linked to 985 parents in D&B data. We drop 572 establishments with insufficient address information and match 911 parents to FactSet institutions by name, yielding 52,806 facilities, 4,353 of which are in non-OECD countries. Panel A of Table 1 summarizes the final sample. The average parent operates 58 facilities (median 18), and 493 parents have at least one facility in a non-OECD country. Most facilities are in North America (40,222), followed by Europe (7,020), Asia (3,934), Latin America (1,407) and Africa (223).

Our final panel comprises 13,651 grid cells that host these 52,806 facilities. A cell-date observation enters the panel if it contains at least one establishment whose parent has recorded quarterly institutional ownership. The distribution of facilities per cell is highly skewed: the median cell-date contains a single establishment, with a small mass of multi-facility cells (Panel B of Table 1). The mean number of facilities per cell is 3.74. We show in section 4. that our findings are robust to trimming cells with more than one facility.

To relate cell-level NDVI to socially responsible ownership over time, when a cell hosts multiple facilities, we compute cell-level socially responsible ownership ($PRI\ IO$) as the simple average across establishments in that cell-date. The mean of $PRI\ IO$ is 9%. Although NDVI ranges in principle from -1 to 1, we do not observe polar regions: in our sample the cell-level mean NDVI spans from -0.18 to 0.95, with an overall mean of 0.50 and a standard deviation of 0.20.

[Table 1 about here.]

2.3 Identification strategy

Our baseline analysis examines how socially responsible ownership relates to firms' environmental harm, measured via NDVI, in a global panel. Before turning to these results, Section 3. validates that NDVI responds to local industrial pollution in a large-N U.S. setting. Both analyses share a common panel framework; here we present the specification for the main relation of interest:

$$NDVI_{i,t,y} = \beta \text{PRI IO}_{i,q-1,y} + \theta' \text{Weather}_{i,m-1,y} + \kappa' \text{X}_{i,y-1} + \gamma_{m\times y} + \delta_{i\times m} + \alpha_{z\times y} + \varepsilon_{i,t,y}, \quad (1)$$

where i indexes grid cells, t denotes 16-day NDVI periods, m the calendar month, q the calendar quarter, y the year, and z the agroclimatic zone. The outcome $NDVI_{i,t,y}$ measures vegetation health in cell i at time t, y. The regressor of interest, PRI $\text{IO}_{i,q-1,y}$, is the previous-quarter share of parent equity held by PRI signatories for the facility or facilities located in cell i. We lag ownership by one quarter so that vegetation reflects prior shifts in ownership composition; this timing also matches the adjustment window documented in the spill event study (Appendix E).

Fixed effects and controls. The specification includes high-dimensional fixed effects. Cell×month fixed effects ($\delta_{i\times m}$) absorb all time-invariant cell characteristics and local seasonality, including land cover, persistent weather patterns, and time-invariant facility or firm characteristics.[14] Year×month fixed effects ($\gamma_{m\times y}$) capture global shocks at a given point in time. Agroclimatic-zone×year fixed effects ($\alpha_{z\times y}$) absorb yearly shocks and allow their effects to vary across ecological zones.

The specification includes a set of lagged controls designed to capture the main confounders that influence both vegetation and firm activity. Weather controls include monthly temperature and precipitation (levels and squares), which account for short-run shocks to plant growth. To capture local economic conditions, we include lagged night-time lights, building counts, and population, which jointly proxy for changes in economic activity, land use, and settlement patterns at a fine spatial scale. These measures have become standard proxies for local growth, infrastructure, and development intensity in settings where traditional economic statistics are unavailable at comparable resolution. By conditioning on these time-varying local factors, together with the cell×month fixed effects, the specification absorbs shifts in activity around facilities, such as expansions in employment, traffic, or built structures, that could affect vegetation independently of industrial releases. This allows the coefficient on responsible ownership to be interpreted as the association with vegetation changes beyond those correlated with local economic dynamics. Our sensitivity analysis also confirms that, although total institutional ownership and PRI ownership are highly correlated in recent years, their estimated effects are empirically distinct.

[14] For cells that host a single facility, cell-month fixed effects coincide with facility-month fixed effects; for the minority of multi-facility cells, these fixed effects absorb time-invariant characteristics shared by co-located plants. We also show that restricting the sample to single-facility cells yields similar estimates.

Panel structure and inference. NDVI is observed at a biweekly frequency, which provides a rich outcome series. Identification, however, does not rely on high-frequency movements. The cell×month and month×year fixed effects absorb all persistent and seasonal variation, so the identifying variation comes from changes in responsible ownership rather than from the number of NDVI readings within a month. Standard errors are clustered at the cell level, allowing for arbitrary serial correlation within each cell. While NDVI exhibits spatial dependence, spatial HAC is unwarranted when only the outcome – rather than both the outcome and the regressor – displays spatial correlation (Colella et al., 2019) (Online Appendix C). Appendix F shows that inference is similar when using alternative approaches, including two-way clustering by cell and parent, clustering at the firm level, and aggregating the outcome to quarterly or annual frequency. We also report estimates for the sample restricted to single-facility cells, which yields nearly identical coefficients. These features ensure that the panel structure does not overstate precision.

Interpretation. Identification comes from within-cell changes in responsible ownership after absorbing all time-invariant heterogeneity and common shocks. Intuitively, we compare how vegetation around a given facility evolves as its responsible ownership changes, holding fixed local seasonality, the firm and facility intrinsic characteristics, global month–year shocks, and ecological-zone trends.

We complement this cell-level design with two additional approaches. First, we estimate facility-level specifications with explicit firm fixed effects and firm-level controls.[15] Second, we exploit mergers in which PRI signatories acquire non-signatory asset managers, generating discrete increases in responsible ownership for portfolio firms.

[15] A facility-level panel allows us to include firm (parent) fixed effects and firm-level controls similar to Dyck et al. (2019). The rest of the specification follows Equation 1.

3. NDVI Response to Facilities' Environmental Damages or Improvements

3.1 Case studies

The contribution of this paper hinges on the proposition that vegetation health, as measured by the NDVI, responds to changes in facilities' environmental harm. The sensitivity of NDVI to pollutants is well documented in environmental science (e.g., Amer et al., 2017; Clevers et al., 2004; Garty, 2001; Sridhar et al., 2007). NDVI can decline due to soil contamination (Dean et al., 2024); water pollution that alters nutrient uptake (Resende Vieira and Christofaro, 2024); and atmospheric pollutants that induce oxidative stress in plants (Lim et al., 2004).[16] The recent study of Li et al. (2023) also show symmetry: NDVI improves when release falls. Appendix A reviews this literature. While these studies provide valuable evidence in controlled settings, they typically cover limited geographies. We therefore provide below two large-N validations at a geographic scale relevant for our ultimate analysis.

3.2 NDVI reaction to U.S. firms' toxic releases (TRI)

In this section, we exploit U.S.-wide data to ask whether NDVI around facilities is negatively associated with facility-level toxic releases.

The U.S. Environmental Protection Agency's (EPA) Toxics Release Inventory (TRI) provides plant-level annual releases for more than 600 substances, distinguishing on-site and off-site releases and reporting precise facility coordinates. The TRI's nationwide coverage allows us to test the NDVI–pollution link across diverse agroclimatic zones.

Two well-known challenges to using the TRI data are changes in the chemical list over time and reporting thresholds that introduce artificial entry/exit. We mitigate these by restricting to facilities that report consistently for at least nine consecutive years, reducing noise from threshold effects and arbitrary churn.[17] Furthermore, we focus on 2006-2020, which is our SRI

[16] We should note that the relationship between NDVI and CO_2 is more ambiguous: some work finds adverse effects on vegetation health (Lim et al., 2004), while other evidence points the other way (Ainsworth and Long, 2005). Following the literature in using a "bundle" of toxic releases, we find that their relation to the NDVI is unaffected by by hyperlocal CO_2 emissions.

[17] Facilities report only when chemical- and industry-specific thresholds are exceeded. Roughly 40% of the unrestricted sample meets the nine-year criterion. See https://www.epa.gov/

sample period, and a period with a stable list of chemicals.

The resulting dataset covers 5,027 cells containing 7,696 reporting facilities in the U.S. 25% of the cell–year observations host two or more facilities reporting releases; for these, we aggregate plant-level releases to the cell–year by summation. We consider the measure of total releases across chemicals as provided by the EPA as a measure of industrial pollution (the most common approach in the literature, e.g. Andrikogiannopoulou et al., 2025; Currie et al., 2015; Gibson, 2019; Li et al., 2025; Naaraayanan et al., 2021; Xu and Kim, 2021). The large majority of reported releases take place on-site (mean 74%, median 100%, Appendix Table B-3).

We estimate the NDVI response to toxic releases using a modified version of Equation (1), introducing the regressor of interest total toxic releases, $\text{TotRelease}_{i,y}$, aggregated from plant-level TRI to the cell-year and assigned to all 16-day observations within year y. Accordingly, we omit the institutional ownership term (PRI IO). The fixed effects and local controls are unchanged:

$$NDVI_{i,t,y} = \beta\,\text{TotRelease}_{i,y} + \theta'\text{Weather}_{i,m-1,y} + \kappa'\text{X}_{i,y-1} + \gamma_{y\times m} + \delta_{i\times m} + \alpha_{z\times y} + \varepsilon_{i,t}.$$

This specification asks whether NDVI declines when total toxic releases rise in the same cell-year, relative to cells under the same seasonal and agroclimatic trends and global month–year shocks.

[Table 2 about here.]

Table 2 reports a precisely estimated negative association between total releases and NDVI in all specifications. Columns (1) and (2) show the stability of results to the introduction of controls for local economic conditions. Columns (2) and (3) compare annual and biweekly designs; we favor biweekly because cell×month fixed effects more flexibly absorb local seasonality. Column (4) tests symmetry by restricting to cells with monotonically declining releases ($\text{release}_y \leq \text{release}_{y-1}$), and finds similar magnitudes, suggesting that NDVI responses are symmetric to improvements and deteriorations. Column (5) restricts to single-facility cells and yields comparable effects. Finally, Column (6) allows zone-specific vegetation trends via agroclimatic-zone×year fixed effects, with stable estimates.

`toxics-release-inventory-tri-program/basics-tri-reporting`.

Columns (7)–(8) probe the importance of the intensity and proximity of the industrial pollution. Using the EPA's Risk-Screening Environmental Indicators (RSEI),[18] Column (7) shows larger NDVI declines for releases with above-mean toxicity per unit mass. Column (8) splits releases into on-site and off-site: NDVI responds to on-site releases, whereas those off-site have no discernible effect–a placebo-style result consistent with exposure to local releases being the only one that affects vegetation health.[19]

We address several additional confounds in the Appendix D. We confirm results robustness to alternative grid definitions, ruling out spatial aggregation artifacts (Table D-5). Results are qualitatively unchanged when we lag toxic releases by 12 months; although some specifications lose precision, consistent with NDVI primarily capturing contemporaneous environmental harm (Table D-7) and in line with our toxic spill event study (next Section). We also find that the TRI-NDVI association is orthogonal to these facilities' CO_2 emissions (Appendix Table D-8).[20] Finally, Table D-6 demonstrates stability across alternative error structures. Taken together, these results confirm that NDVI reacts systematically to localized industrial pollution.

3.3 NDVI reaction to accidental toxic spills

As a complementary validation, we study vegetation responses to major toxic chemical spills in an event-study design using the U.S. Coast Guard's National Response Center data. These acute shocks allow us to trace short-run stress and recovery (see Appendix E for the full analysis). We document a sharp and statistically significant increase in the probability of observing abnormally low NDVI in the month of the incident (event time $t = 0$). The effect is spatially localized: the increase is largest in the immediate vicinity of the accident site and attenuates steadily with distance. Importantly, we also find a gradual recovery, with the probability of abnormal NDVI returning to its pre-incident baseline within roughly four months ($t \approx +4$).

[18] The EPA's RSEI model adjusts reported releases by chemical toxicity, exposure pathways, and potential population exposure. We allow the relation between total releases and NDVI to differ depending on whether a cell's releases have an above- or below-mean RSEI toxicity score. Coverage is limited (post-2013) and excludes some chemicals. We impute zeros for missing RSEI values to preserve comparability.

[19] Put differently, if NDVI reflects localized environmental harm from firms, it should respond to on-site releases occurring within the grid cell where vegetation is measured, but not to off-site releases that are transferred or managed elsewhere.

[20] Interestingly, the correlation between emissions and total releases is limited, at 0.006. When considering both variables together in the equation, we find a small positive association between the facilities' emissions and the NDVI.

Taken together, the tests in this and the previous subsections support the view that NDVI responds to industrial toxic releases. Two features are especially relevant for what follows. First, the response is symmetric: NDVI declines when toxic releases increase and improves when they fall, including within a short time window after acute spill events. Second, the response is local: NDVI loads on on-site releases and is strongest in directly affected cells, attenuating sharply with distance, with no discernible effect for off-site transfers.

4. The average effect of responsible ownership

4.1 Levels of PRI ownership

Table 3 reports the main estimates. Columns 1-3 use the full sample and show a consistent, positive, and precisely estimated association between lagged socially responsible (PRI) ownership and vegetation health (NDVI). Across specifications, the coefficient on lagged PRI ownership is stable in the range 0.003–0.004 and is significant at the 1% level. The relationship remains robust as we sequentially add controls for built environment, population, and night-time lights, and as we introduce increasingly demanding fixed effects (year×month and agroclimatic-zone×year).

[Table 3 about here.]

To assess economic significance, we benchmark the PRI–NDVI coefficient against the relationship between toxic releases and NDVI reported in Table 2, using column (6), which incorporates the EPA's Risk-Screening Environmental Indicators (RSEI) and is our preferred specification. A one standard deviation increase in toxic releases (12.67 million pounds) is associated with a 0.003 decline in NDVI, implying that a one-unit change in NDVI corresponds to approximately 4.22 billion pounds (2.11 million tons) of toxic releases. The estimated PRI–NDVI coefficient is 0.004 when PRI ownership is measured on a 0–1 scale, so a one percentage point increase in PRI ownership raises NDVI by 0.00004. Applying the conversion above, this increase corresponds to a reduction of roughly 85 tons of toxic releases. This effect is economically meaningful: it exceeds three times the U.S. EPA's minimum reporting threshold and amounts to more than half of the average facility's annual toxic output in our TRI validation sample. In the TRI validation sample (0.1° grid, yearly), the average facility releases approximately 159 tons of

toxic chemicals per year. Given that responsible ownership exhibits substantial variation, with a standard deviation of 8 percentage points, a one standard deviation increase in PRI ownership implies a reduction of roughly 680 tons of toxic releases per facility-year. This reduction is equivalent to eliminating the entire annual toxic output of more than 50 facilities operating at the EPA's 25,000 lb reporting threshold.[21]

Taken together, these magnitudes indicate that even modest, empirically observed changes in responsible ownership generate economically meaningful improvements in local environmental conditions, comparable in scale to substantial reductions in industrial pollution at the facility level.

Columns 4–5 examine two potential concerns related to the study sample. First, facility clustering within cells could complicate identification if facilities owned by different parents face simultaneous ownership shocks. We confirm that restricting to single-facility cells (Column 4) yields indistinguishable coefficients. Second, global scope may matter if multinationals with non-OECD exposure adjust differently. Restricting to "global" firms (meaning here firms with at least one non-OECD facility; Column 5) again leaves the PRI coefficient essentially unchanged. International scope does not materially alter the relationship between responsible ownership and environmental conditions.

Column 6 reports estimates separately for placebo cells, which host only non-producing establishments. In placebo cells, the estimated coefficient on lagged PRI ownership is close to zero, at approximately -0.001, and statistically insignificant, indicating that PRI ownership is not associated with vegetation changes in locations where firms do not engage in environmentally relevant production activity. This placebo result supports an environmental interpretation of the baseline findings. The absence of any effect in non-producing locations, combined with a robust and economically meaningful effect in polluting cells, suggests that the relationship between PRI ownership and NDVI is not driven by generic shifts in firm presence or activity, but instead reflects changes in environmentally harmful production attributable to treated facilities.

The results are robust to alternative specifications. Firstly, although total institutional ownership and PRI ownership are highly correlated in recent years, the effects are empirically

[21] See `https://www.epa.gov/trinationalanalysis/tri-data-considerations`.

distinct: controlling for lagged total institutional ownership leaves the PRI coefficient essentially unchanged (Appendix Table F-10). We also consider clustering schemes that address spatial and temporal dependence, including clustering by country, agroclimatic zone, their interaction, and two-way clustering by cell and year–month (Table F-12). Table F-13 further shows that the findings are unaffected by accounting for temporal dependence, including specifications with lagged NDVI, extensions to twelve biweekly lags, and differencing at the quarterly frequency.[22] Appendix Table F-11 further confirms that the results are stable across alternative spatial resolutions, ranging from 0.5×0.5 degrees to 0.05×0.05 degrees.

4.2 M&A Shocks as Identification

[Table 4 about here.]

We exploit mergers in the asset-management industry to obtain plausibly exogenous variation in responsible ownership, following recent work that uses M&A events as ownership shocks (e.g., Evans et al., 2025, 2020). We focus on transactions in which a PRI signatory acquires a non-signatory asset manager, generating discrete increases in PRI ownership across the target's portfolio firms. Because these changes are induced by corporate control events in asset management rather than firm-level portfolio rebalancing, they are plausibly orthogonal to investee firms' environmental trajectories.

Treated parents are those held by the target in the quarter preceding the announcement and present in our MNE sample. Treatment intensity is measured by the target's pre-announcement equity share in the parent (*PreDealShare*). Starting from all SDC Platinum M&A deals between 2008 and 2020 (516,170), we restrict to acquire–target pairs linked to Compustat (Ewens et al., 2024) (5,572), then to asset-manager transactions (662). Hand-matching acquirers to PRI signatories and requiring PRI membership prior to announcement yields 20 deals, of which three involve targets that match to FactSet and are themselves non-signatories. In all three cases, the ownership change is induced by asset-manager consolidation and is unrelated to the environmental performance or expected environmental trajectory of portfolio firms.[23]

[22] Dynamic OLS with lagged NDVI is appropriate in this long-T panel. Nickell bias is negligible, and GMM estimators such as Arellano–Bond are not well suited here: they assume short T, rely on moment conditions that are rejected in our data, and in large-T panels risk instrument proliferation that undermines identification.

[23] The three qualifying transactions are: (i) GE Asset Management Inc, the in-house asset manager of General Electric and a non-PRI signatory, acquired by State Street Corp in 2016. State Street was

Despite the small number of events, exposure is broad. Prior to announcement, the three targets collectively hold equity in 76, 271, and 434 multinationals, corresponding to 8,781, 28,589, and 40,880 facilities. A cell is treated if it contains at least one facility of a multinational held by the target in the pre-announcement quarter. For each merger, we draw an equal number of untreated cells and construct a stacked event-time panel spanning ten quarters before and after the announcement.

Table 4 reports stacked difference-in-differences estimates. We interact post-event year indicators with a treated-cell indicator and, alternatively, scale effects by *PreDealShare*. We find no systematic effect in year +1, but a clear and economically meaningful increase in NDVI by year +2, consistent across specifications. These dynamics align with a gradual post-merger integration of stewardship practices. Taken together, the merger results reinforce the baseline findings by showing that exogenous increases in responsible ownership are followed by improvements in local environmental outcomes.

Overall, the two identification strategies are complementary. The baseline design exploits cross-sectional and time-series variation in PRI ownership across multinational enterprises, allowing us to use the full global sample of firms and locations. The merger-based design instead leverages discrete ownership shocks generated by asset manager consolidation, providing a cleaner source of exogenous variation at the cost of a smaller number of events. The convergence of results across these two approaches strengthens our interpretation that responsible ownership has real effects on local environmental quality.

4.3 Alternative Mechanisms: Carbon Emission and Fertilization Effects

One might read the positive effects of SRI on NDVI as reflecting a CO_2 fertilization mechanism. If SRI increased output and, in turn, CO_2 emissions, higher local CO_2 concentrations could mechanically raise NDVI.

a PRI signatory prior to the deal, mechanically converting GE Asset Management's pre-existing equity holdings into PRI-owned capital. (ii) E*TRADE Financial Corp's asset management business, a non-PRI signatory, acquired by Morgan Stanley in 2020 as part of a broader expansion into wealth and asset management; Morgan Stanley had joined the PRI prior to the acquisition. (iii) Eaton Vance Corp, a large active asset manager and non-PRI signatory, acquired by Morgan Stanley in 2021, generating the largest ownership shock in our sample due to Eaton Vance's extensive pre-deal equity holdings.

The data do not support this CO_2 fertilization interpretation. First, in the U.S. validation, vegetation health responds to toxic releases independently of facilities' CO_2 emissions (Table D-8). Second, facility-level CO_2 emissions and toxic releases are only weakly correlated when jointly observed (Pearson $r = 0.02$), making it unlikely that they capture the same underlying variation in environmental load. Third, our specifications control for local economic activity (night-time lights, population, built environment), and cell-specific ambient trends are absorbed by high-dimensional fixed effects. Overall, the NDVI improvements under greater SRI ownership are unlikely to be CO_2-driven greening.

4.4 Alternative Explanations: Cosmetic Corporate Actions

An alternative interpretation is "superficial greening," whereby firms plant vegetation to appear responsible without meaningfully reducing their environmental footprint. While such landscaping may yield limited benefits relative to bare surfaces, it is not the objective of responsible investing.

Several considerations make this explanation unlikely to drive our results. First, firms are not aware that they are being monitored through satellite-based vegetation indices such as NDVI, which are constructed from remote sensing data rather than corporate disclosures or regulatory reporting. This substantially weakens incentives to undertake targeted cosmetic actions aimed at influencing our outcome measure. Second, purely cosmetic greening is difficult to reconcile with the heterogeneity we document across contexts in Section 5.1, including sharp differences across regulatory environments.

Moreover, to affect our estimates, greening would need to occur within the $0.1^\circ \times 0.1^\circ$ analysis cell (approximately 11×11 km) and at a scale large enough to materially shift cell-level NDVI. Small ornamental plantings are too limited, whereas larger initiatives, such as sponsoring a city park or participating in programs like *1% for the Planet*, are unlikely to be spatially concentrated within the facility's cell. While some landscaping may occur, it is implausible that such actions account for the global patterns we document.

5. Heterogeneity Across Locations and Investor Types

5.1 Geographic Asymmetries in Sustainable Investment Impact

[Table 5 about here.]

In this section, we examine whether the effect of socially responsible ownership on vegetation health varies with facility location. Specifically, we explore how socially responsible investing impact differs between OECD and non-OECD countries.[24] The typical OECD country is richer and exhibits greater interest and investment in environmental oversight.

Multinationals could respond to responsible ownership in two opposite ways. On the one hand, stricter regulation and monitoring in OECD economies may induce firms to reduce harmful activity where scrutiny is greatest (Cust et al., 2023), potentially displacing environmental harm toward jurisdictions with weaker enforcement (a logic documented, for example, in the context of battery recycling by Tanaka et al., 2022). On the other hand, if baseline industrial pollution is higher in non-OECD regions, the scope for improvement may be larger there, yielding greater gains outside the OECD.

To distinguish these channels, in Table 5 we interact PRI ownership with an indicator for non-OECD location. As in the baseline, socially responsible ownership is positively and significantly associated with NDVI. The coefficient on lagged PRI ownership is approximately 0.005 per unit of ownership, corresponding to 0.00005 per one percentage point increase. Using the calibration from Table 2 based on column (6), where a one-unit change in NDVI corresponds to roughly 2.1 million tons of toxic releases, a one percentage point increase in PRI ownership in OECD countries implies a reduction of about 105 tons of toxic releases per facility. This magnitude is equivalent to the combined annual releases of roughly eight facilities operating at the EPA's Toxic Release Inventory reporting threshold. By contrast, the interaction between responsible ownership and the non-OECD indicator is negative. The implied effect in non-OECD countries ranges from -0.00009 to -0.00023 NDVI per one percentage point increase in PRI ownership, corresponding to an increase of approximately 190 to 490 tons of toxic releases per facility

[24] We set OECD membership as of 2006, the start of our sample. That list includes: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, Czech Republic, New Zealand, Republic of Korea.

under the same calibration. This magnitude is equivalent to the annual releases of roughly 15 to 40 facilities operating at the TRI reporting threshold. A back-of-the-envelope aggregation suggests that for the average firm in our sample, which operates about 58 facilities including roughly six outside the OECD, the net effect of a one percentage point increase in responsible ownership remains positive, with an overall reduction on the order of 2,500 to 4,300 tons of toxic releases per year. For the median firm, which operates approximately 18 facilities with one to two outside the OECD, the implied average reduction ranges from roughly 700 to 1,300 tons per year. The gains from responsible ownership are therefore positive on net but geographically unevenly distributed

To assess whether these geographic asymmetries are driven by cross-firm sorting or by within-firm responses to ownership changes, we estimate a facility-level specification with parent-company fixed effects and time-varying firm controls (Table 6). This design exploits within-firm variation in PRI ownership over time while holding constant all time-invariant firm characteristics. As a result, the estimates isolate how a given firm's facilities respond to changes in responsible ownership across locations, rather than reflecting differences between firms that operate in different institutional environments.[25]

The firm fixed effects results confirm that the positive relationship between responsible ownership and vegetation health is not driven by cross-sectional differences between firms that choose to locate in OECD versus non-OECD countries. Even within the same parent company, increases in PRI ownership are associated with improvements in local vegetation conditions at the facilities it operates. This finding strengthens the interpretation that the baseline effects reflect an ownership channel rather than compositional sorting across firms or locations.

[Table 6 about here.]

As a robustness check, we replace the OECD split with a continuous measure of institutional quality using the World Bank's Regulatory Quality Index from the Worldwide Governance

[25]Implementing this design requires two modifications to model (1). First, we maintain the panel at the facility level rather than collapsing to the cell level. The key explanatory variable becomes lagged PRI ownership of the facility's parent, while NDVI remains measured at the cell level. If multiple facilities of the same parent are located in the same cell, we retain a single parent–cell observation. Second, to absorb location-specific seasonality while also including parent fixed effects, we residualize NDVI with respect to cell-month fixed effects and use the residuals as the dependent variable. Firm-level controls follow Dyck et al. (2019) and include log total assets, leverage, profitability, tangibility, and Tobin's Q.

Indicators (WGI).[26] This index captures perceptions of the government's ability to formulate and implement sound policies and regulations that support private sector development. We match country-year index scores to facilities and estimate heterogeneous effects across quintiles of regulatory quality. Appendix Table F-14 shows that PRI ownership is positively associated with NDVI only in the upper two quintiles of regulatory quality; in contrast, the interaction is negative and statistically significant in the lowest quintile. These results hold in the full sample, in the single-facility cell subsample, and among multinationals with at least one non-OECD facility. Furthermore, in Table 6, we confirm that the results hold when introducing parent-company fixed effects and time-varying firm-level controls in a facility-level panel.

These heterogeneous effects align with the classic view that ownership influences corporate behavior within the constraints imposed by legal and institutional environments (Shleifer and Vishny, 1997; La Porta et al., 1998). In jurisdictions with weaker regulatory enforcement and investor protection, socially responsible investors appear less able to constrain harmful industrial pollution, resulting in displacement toward non-OECD regions where governance pressures are less binding.

Overall, these findings highlight the importance of institutional and regulatory contexts for the effectiveness of sustainable finance. PRI signatories appear able to improve environmental performance where monitoring and enforcement are strong, but their influence weakens in low-governance environments, where risks of environmental displacement persist. These results point to a need for cross-border accountability mechanisms to ensure that ESG-driven improvements are not geographically uneven or regressive in their environmental consequences.

5.2 Engagement Intensity and the Power of Stewardship

[Table 7 about here.]

A common concern with using PRI signatory status as a proxy for responsible ownership is that it may be a weak signal of actual stewardship, given monitoring frictions and potential for greenwashing (Gibson Brandon et al., 2022; Kim and Yoon, 2022). We therefore test whether the PRI–NDVI relationship varies with the *intensity* of investors' self-reported engagement.

[26] Worldwide Governance Indicators, 2024 Update, World Bank (`www.govindicators.org`), accessed on October 2, 2025.

We exploit PRI transparency documentation to construct a novel, simple, and replicable measure of investors' engagement. PRI Transparency Reports include a standardized module (SG09) in which signatories classify their engagement intensity as *Basic*, *Moderate*, or *Advanced*. Reports are available annually from 2014 through 2020, providing a consistent scale over that period.[27] Panel A of Table 7 shows that 60% of signatories report *Basic* engagement, 23% report *Moderate*, and 16% report *Advanced*. Panel B documents high persistence: the probability of remaining in the same category year-over-year is 89% for Basic, 79% for Moderate, and 91% for Advanced; among Moderates, upgrades to Advanced (13%) outnumber downgrades to Basic (8%).

[Table 8 about here.]

Because these labels are self-reported, we also analyze the optional open-ended justification text that signatories provide to elaborate on their selection. We use a large language model (ChatGPT) to extract and classify recurring themes from this unstructured text. Appendix Figure G-8 summarizes reported themes by engagement level, and Appendix G details the LLM-based classification methodology and validation.

Advanced signatories are far more likely to reference collaborative stewardship, and in particular leadership roles, than other groups: approximately 80% explicitly mention leadership, consistent with agenda-setting and coalition-building. *Moderate* signatories emphasize collaboration but less frequently cite leadership. *Basic* signatories provide shorter and more heterogeneous responses; they rarely mention leadership and are roughly thirteen times more likely than *Advanced* signatories to simply note signatory status. Overall, stronger self-reported engagement is characterized by participation and leadership in collaborative initiatives, consistent with the "Leader" concept in Ceccarelli et al. (2024), who show that only a small subset of institutions drives improvements in firms' ESG scores.

For each parent-quarter, we construct three ownership shares–*Basic PRI IO*, *Moderate PRI IO*, and *Advanced PRI IO*–by summing equity held by signatories in each tier. For years prior to 2014, we backfill engagement levels to 2006 or to the year in which the institution first became a PRI signatory, whichever occurs later, leveraging the high persistence documented in Table 7

[27] After 2020, PRI revised its questionnaire and removed the SG09 engagement-intensity question; earlier reports were publicly accessible via the UN PRI Reporting and Assessment portal.

Panel B.

Table 8 presents the results. Column (1) reproduces the baseline PRI effect on the subsample with engagement information; a 1 pp increase in overall PRI ownership is associated with an NDVI increase of about 0.00004, consistent with Table 3 results. Columns (2)–(4) replace overall PRI ownership with the three tier-specific shares. All three tiers load positively, with a clear gradient in magnitude: effects rise from *Basic* to *Moderate*/*Advanced*. In Column (5), we include the three shares jointly. The *Moderate* and *Advanced* coefficients remain positive and statistically significant, whereas the *Basic* coefficient is small and not significant. Thus, the PRI-NDVI relationship is not uniform across signatories: measurable environmental gains are concentrated among institutions that undertake at least structured, moderate-level stewardship, with little evidence that minimal "box-ticking" engagement translates into on-the-ground improvements. These results are consistent with a mechanism in which active stewardship drives real environmental changes at the facility level, consistent with stewardship-oriented investors fostering green capital expenditures by firms (Wiedemann, 2025).

5.3 Engagement does not prevent the displacement of environmental harm

[Figure 2 about here.]

Combining the approaches from the previous sections, Figure 2 plots coefficients from regressions of cell-level NDVI on lagged PRI ownership interacted with investor engagement intensity (Basic/Moderate/Advanced) and an indicator for facilities located outside the OECD. The figure reveals sharp asymmetries. Within the OECD, higher PRI ownership is associated with improvements in vegetation health, with effects that strengthen with engagement intensity. Outside the OECD, PRI ownership is consistently associated with lower NDVI–even for highly engaged investors. This set of results extends the heterogeneity in Table 5: engagement matters, but engagement intensity alone does not deliver improvements when country-level enforcement is weak.

This pattern aligns with theories in which investor pressure is effective only under credible enforcement and strong monitoring. In the presence of regulatory arbitrage and strategic compliance, we would expect displacement to weaker jurisdictions when oversight is unreliable (Baron,

2001); and shareholder monitoring frameworks stress credible oversight as a precondition for real effects (Admati and Pfleiderer, 2009; Edmans, 2009). Consistent with these predictions, PRI ownership –especially by more engaged investors– coincides with better environmental outcomes where governance is strong, but with declines in vegetation health outside the OECD, suggestive of significant displacement. To our knowledge, this is the first evidence that the real effects of ESG engagement systematically diverge with countries' institutional quality, improving under strong governance and reversing under limited enforcement.

6. Conclusion

This paper studies the real environmental consequences of sustainable investing by asking whether–and where–socially responsible institutional ownership translates into measurable improvements in local ecological conditions around industrial facilities worldwide.

Leveraging high-frequency satellite data on vegetation health (NDVI), we provide a spatially and temporally detailed measure of environmental quality that is independent of firms' self-reports and available globally. We first validate NDVI as an indicator of environmentally harmful industrial activity. Using U.S.-wide data, we show that vegetation health deteriorates when toxic releases increase and improves when releases decline, with stronger responses to more hazardous and on-site discharges and placebo-like null effects for off-site transfers. We also find that NDVI exhibits short-run deterioration and recovery around accidental toxic spills.

Building on this foundation, we examine how social responsible ownership relates to changes in local environmental quality. Our results show a positive and statistically significant association: higher levels of sustainable institutional ownership are associated with improved vegetation health, suggesting that social responsible capital may help reduce environmental harm. A falsification test confirms that the impact of socially responsible ownership on NDVI comes from facilities with production activities.

Our identification strategy supports a causal interpretation. Our main specification relies on high-dimensional fixed effects and rich local controls to isolate within-cell and within-firm variation over time. As a complementary approach, we exploit mergers in which a PRI signatory acquires a non-signatory asset manager, creating an exogenous shock to responsible ownership.

Although such events are relatively rare, they lead to measurable increases in NDVI around treated facilities two years after the merger. The positive effects are stronger where pre-merger ownership stakes were larger.

However, these environmental gains are highly uneven. Geographically, they are concentrated in OECD countries, while effects in non-OECD regions are negative, consistent with the displacement of environmentally harmful activity when enforcement is limited.

We also find that investor stewardship matters. Building a novel measure of engagement based on PRI transparency reports, we find a clear gradient: improvements are concentrated among institutions reporting structured, moderate-to-advanced-level engagement. Yet this effect is again highly asymmetric across geographies. Outside the OECD, even high-intensity engagement does not prevent displacement.

Two broader implications follow. First, the effectiveness of sustainable finance is jointly determined by investor stewardship and countries' institutions. Active ownership complements strong enforcement; without enforcement, pressure risks shifting part of the environmental harm rather than reducing it. Second, NDVI offers a scalable complement to traditional disclosures, enabling monitoring of localized environmental outcomes across borders.

Sustainable investing can deliver tangible environmental benefits, especially when paired with meaningful engagement from institutional investors. Ensuring that these gains are not offset by cross-border displacement would require harmonized, facility-level disclosure, stronger international enforcement, and accountability mechanisms that travel with global production networks. Aligning private stewardship with public oversight is essential for durable and equitable environmental progress.

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Table 1: NDVI and the multinational facilities network – summary statistics. Descriptive statistics on international establishments of public U.S. multinationals from Dun & Bradstreet (D&B) WorldBase. Our sample consists of industrial multinationals with SIC codes 01 to 39, representing Agriculture, Forestry and Fishing (01–09), Mining (10–14), Construction (15–17), and Manufacturing (20–39). Establishments are mapped to 0.1° latitude–longitude grid cells, which serve as the unit of observation in the analysis. Variable definitions and data sources are provided in Appendix Table B-2.

	N	Mean	Std	Min	p10	p25	p50	p75	p90	Max
A. MNEs facilities network										
Nr Facilities	52,806									
(outside OECD)	4,353									
Nr Parents	911									
(with facilities outside OECD)	493									
Facilities per parent	911	57.96	115.22	1.00	3.00	6.00	18.00	58.00	140.00	982.00
B. Cell-level panel										
Nr Cells	13,651									
Nr DB Facilities in cell	4,756,407	3.74	8.86	1.00	1.00	1.00	1.00	3.00	8.00	485.00
Average NDVI	4,756,407	0.50	0.20	-0.18	0.23	0.38	0.52	0.66	0.75	0.95
Average SRI ownership	4,756,407	0.09	0.08	0.00	0.01	0.02	0.06	0.16	0.21	0.53
Average Institutional ownership	4,756,407	0.79	0.16	0.00	0.59	0.72	0.81	0.89	0.97	1.00

Table 2: NDVI reaction to toxic releases. Results from OLS estimations. The dependent variable is the Normalized Difference Vegetation Index (NDVI), the explanatory variables come from the Toxic Release Inventory (TRI) database. All specifications include weather controls (average temperature and its square, total precipitation and its square) and economic controls (night-time lights, buildings in the cell, and population). The unit of observation is a $0.1° \times 0.1°$ cell. Appendix Table D-4 reports the full specification. Column (6) incorporates EPA's Risk-Screening Environmental Indicators (RSEI) model. This allows us to test whether vegetation responds more strongly to hazardous releases. Variable definitions and data sources are provided in Appendix Table B-2. * significant at 10%; ** at 5%; *** at 1%. Standard errors are clustered at the cell level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. var.				NDVI				
Sample		Full		TRI down	One plant		Full	
Tot. releases	-0.005***	-0.005***	-0.001**	-0.006*	-0.002**	-0.003**		
	(0.002)	(0.001)	(0.001)	(0.003)	(0.001)	(0.002)		
Tot. releases X RSEI above mean toxicity							-0.004***	
							(0.001)	
Tot. releases X RSEI below mean toxicity							-0.002	
							(0.001)	
Tot. on-site releases								-0.003**
								(0.002)
Tot. off-site releases								0.001
								(0.001)
Lights		-0.060***	-0.051***	-0.054***	-0.048***	-0.042***	-0.042***	-0.042***
		(0.005)	(0.003)	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)
Population		-0.078**	-0.048***	-0.074**	-0.058***	-0.044***	-0.044***	-0.044***
		(0.031)	(0.018)	(0.032)	(0.022)	(0.016)	(0.016)	(0.016)
Build		0.149***	0.072***	0.164***	0.082***	0.064***	0.064***	0.064***
		(0.028)	(0.016)	(0.029)	(0.019)	(0.015)	(0.015)	(0.015)
Nb. facilities		0.006**	0.003*	0.007**	0.003*	0.004***	0.004***	0.004***
		(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Cell FE	Yes	Yes	No	No	No	No	No	No
Cell X month FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	No	No	No	No	No	No
Year X month FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Year X agroclimatic FE	No	No	No	No	No	Yes	Yes	Yes
Frequency	Yearly	Yearly	Bi-weekly	Bi-weekly	Bi-weekly	Bi-weekly	Bi-weekly	Bi-weekly
Observations	98088	98029	2255922	1692631	1890168	2248494	2248494	2248494

Table 3: NDVI and PRI ownership. Results from OLS estimations of model (1). The unit of observation is a $0.1^\circ \times 0.1^\circ$ cell. The dependent variable is the Normalized Difference Vegetation Index (NDVI). The main explanatory variable is $PRI\ IO$, which measures socially responsible ownership of establishments in a cell in the previous quarter. Global firms are those with at least one facility outside the OECD. Placebo establishments are defined as plants operating in service-sector industries (NAICS 51–56 and 61–62) that are not plausibly associated with local environmental externalities, while treated cells contain only polluting establishments. The placebo sample is restricted to U.S. plants with reliably identified establishment-level location and production status. All columns include weather controls. Variable definitions and data sources are provided in Appendix Table B-2. * significant at 10%; ** at 5%; *** at 1%. Standard errors are clustered at the cell level and reported in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable				NDVI		
Split:			Full sample		One plant	Global firm	Placebo cell
Lagged PRI IO	0.004***	0.004***	0.004***	0.003**	0.004***	-0.001
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.007)
Builts		-0.002*	-0.001	0.000	-0.001	0.016
		(0.001)	(0.001)	(0.002)	(0.001)	(0.015)
Population		-0.125***	-0.070**	-0.252***	-0.070**	-3.512
		(0.039)	(0.034)	(0.053)	(0.034)	(3.262)
Lights		-0.725***	-0.450***	-0.450***	-0.457***	-0.244**
		(0.020)	(0.018)	(0.025)	(0.019)	(0.123)
Cell-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-Agroclimat FE	No	No	Yes	Yes	Yes	Yes
Observations	4,445,313	3,782,638	3,774,182	1,868,951	3,394,504	66,157

Table 4: NDVI and mergers and acquisitions. Stacked difference-in-differences estimates around three mergers where a PRI signatory acquired a non-signatory asset manager. *Treated cells* contain at least one facility of a multinational held by the target in the pre-announcement quarter; control cells are randomly sampled in equal number. *Pre-DealShare* The event-time panel spans ten quarters before and after each announcement. The dependent variable is cell-level NDVI. All specifications include cell–month–cohort, event-time–cohort fixed effects, and weather controls. Variable definitions are in Appendix Table B-2. * significant at 10%; ** at 5%; *** at 1%. Standard errors clustered at the cell-cohort level.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable			NDVI			
Sample:	— Full sample —		Global firm	— Full sample —		Global firm
year +1 × Treated=1	0.001*	0.000	0.000			
	(0.000)	(0.000)	(0.000)			
year +2 × Treated=1	0.005***	0.004***	0.004***			
	(0.001)	(0.001)	(0.001)			
year +1 × Portfolio Weight				0.000	0.000	0.000
				(0.002)	(0.002)	(0.002)
year +2 × Portfolio Weight				0.341***	0.277***	0.277***
				(0.079)	(0.067)	(0.067)
Population		-0.000**	-0.000**		-0.000**	-0.000**
		(0.000)	(0.000)		(0.000)	(0.000)
Builts		-0.000***	-0.000***		-0.000***	-0.000***
		(0.000)	(0.000)		(0.000)	(0.000)
Lights		-0.001***	-0.001***		-0.001***	-0.001***
		(0.000)	(0.000)		(0.000)	(0.000)
CellMonth-Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes
Weather controls	Yes	Yes	Yes	Yes	Yes	Yes
ET-Cohort FE	No	No	Yes	No	No	Yes
Observations	2,302,040	2,302,040	2,302,040	2,302,040	2,302,040	2,302,040

Table 5: NDVI and PRI ownership – inside versus outside the OECD. Results from OLS estimations. The unit of observation is a 0.1° × 0.1° cell. The dependent variable is the Normalized Difference Vegetation Index (NDVI). The main explanatory variable is *PRI IO*, which measures average PRI ownership of establishments in a cell in the previous quarter. *Non-OECD* equals one for cells outside the OECD. All columns include weather controls. Variable definitions and data sources are provided in Appendix Table B-2. * significant at 10%; ** at 5%; *** at 1%. Standard errors are clustered at the cell level and reported in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Variable			NDVI			
Split:		Full sample			One plant	Global firm
Lagged PRI IO	0.005***	0.005***	0.005***	0.005***	0.004***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
outsideOECD × Lagged PRI IO	-0.013***	-0.009***	-0.023***	-0.022***	-0.018***	-0.022***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Builts		-0.005***	-0.001	-0.001	0.001	-0.001
		(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Population		0.006	-0.076**	-0.038	-0.209***	-0.038
		(0.013)	(0.036)	(0.034)	(0.060)	(0.034)
Lights			-0.713***	-0.439***	-0.440***	-0.444***
			(0.020)	(0.018)	(0.025)	(0.019)
Cell-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-Agroclimat FE	No	No	No	Yes	Yes	Yes
Observations	4,445,313	4,445,313	3,782,638	3,774,182	1,868,951	3,394,504

Table 6: NDVI and PRI ownership – plant-level analysis with parent fixed effects. Results from OLS estimations. The unit of observation is the facility. The dependent variable is the residualized Normalized Difference Vegetation Index (NDVI), obtained from a regression of NDVI on cell-month fixed effects, measured in the 0.1° × 0.1° cell containing the facility. The main explanatory variable is *PRI IO*, which represents the lagged PRI ownership of the facility's parent company. *Non-OECD* equals one for facilities outside the OECD. Out of a total number of 52,806 facilities, 4,353 are outside the OECD. All columns include weather controls. Variable definitions and data sources are provided in Appendix Table B-2. * significant at 10%; ** at 5%; *** at 1%. Standard errors are clustered at the cell level and reported in parentheses.

	(1)	(2)	(3)	(4)
Dep. Variable	NDVI resid			
PRI IO	0.002***	0.003***	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Outside OECD			0.005***	0.004***
			(0.001)	(0.001)
Outside OECD × PRI IO			-0.033***	-0.028***
			(0.003)	(0.003)
Log Assets	-0.000**	-0.000	-0.000***	-0.000*
	(0.000)	(0.000)	(0.000)	(0.000)
Tangibility	-0.003***	-0.001*	-0.003***	-0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
Leverage	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Profitability	0.001**	0.000	0.001**	0.000
	(0.001)	(0.000)	(0.001)	(0.000)
Tobin's Q	-0.000	-0.000**	-0.000*	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
Year-month FE	Yes	Yes	Yes	Yes
Parent FE	Yes	Yes	Yes	Yes
Year-Agroclimat FE	No	Yes	No	Yes
Observations	10,775,584	10,752,850	10,775,584	10,752,850

Table 7: NDVI and signatories' self-reported involvement with PRI. Summary statistics of PRI signatories' reported level of involvement, as disclosed in module SG09 of the PRI's Public Transparency Reports (see Appendix Figure G-7 for an example of the form). Panel A presents the annual distribution of signatories across the three engagement categories (Basic, Moderate, and Advanced) over the 2014–2020 period. Panel B reports the row-normalized transition matrix of engagement roles, showing the year-over-year probabilities that a signatory remains in, or moves between, levels.

Panel A: Share of signatories by involvement level

Obs (signatory-year)	Basic (%)	Moderate (%)	Advanced (%)
6721	60.36	23.51	16.13

Panel B: Transition matrix

	Basic (t+1)	Moderate (t+1)	Advanced (t+1)
Basic (t)	0.89	0.09	0.02
Moderate (t)	0.08	0.79	0.13
Advanced (t)	0.02	0.07	0.91

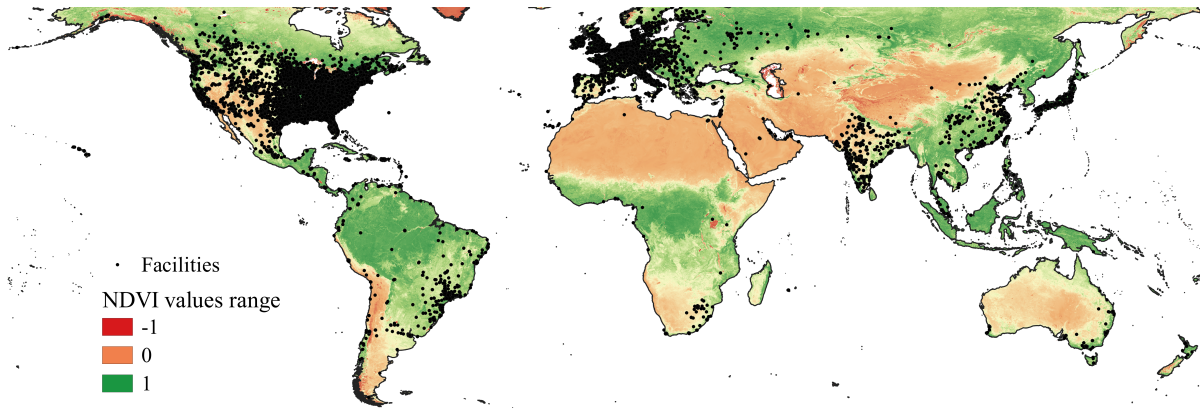
Table 8: NDVI and PRI ownership – by engagement intensity. Results from OLS estimations extending equation (1), disaggregating PRI ownership by engagement intensity. The unit of observation is a 0.1° × 0.1° cell. The dependent variable is the Normalized Difference Vegetation Index (NDVI), with ownership variables lagged by one quarter. All regressions include weather controls. Variable definitions and data sources are provided in Appendix Table B-2. * significant at 10%; ** at 5%; *** at 1%. Standard errors are clustered at the cell level and reported in parentheses.

	(1) ndvi	(2) ndvi	(3) ndvi	(4) ndvi	(5) ndvi
Lagged PRI IO	0.004***				
	(0.001)				
Lagged Basic PRI IO		0.004**			0.003
		(0.002)			(0.002)
Lagged Moderate PRI IO			0.006**		0.006**
			(0.003)		(0.003)
Lagged Advanced PRI IO				0.006*	0.005*
				(0.003)	(0.003)
Builts	-0.001	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Population	-0.070**	-0.070**	-0.071**	-0.071**	-0.070**
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Lights	-0.450***	-0.451***	-0.450***	-0.451***	-0.450***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
Cell-month FE	Yes	Yes	Yes	Yes	Yes
Year-month FE	Yes	Yes	Yes	Yes	Yes
Year-Agroclimat FE	Yes	Yes	Yes	Yes	Yes
Observations	3774182	3774182	3774182	3774182	3774182
Adjusted R^2	0.90	0.90	0.90	0.90	0.90

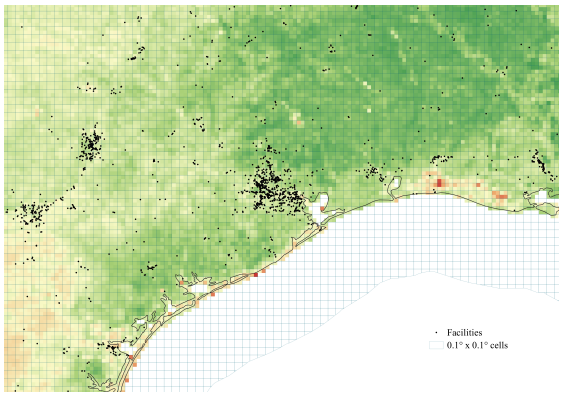
Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

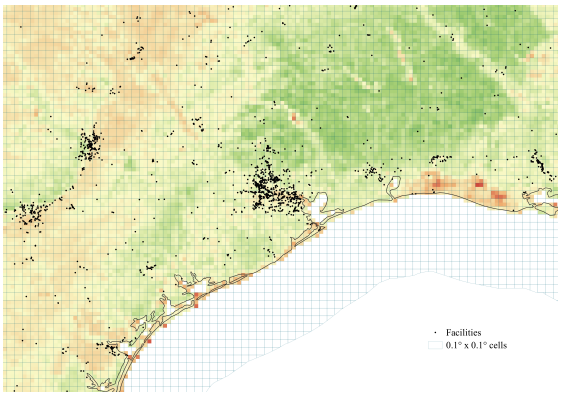
Figure 1: NDVI and production plants owned by U.S. multinationals. Panel (a) shows the international establishments of public U.S. multinationals in SIC codes 01-39, obtained from D&B WorldBase overlayed with the gradient of NDVI value in June 2006. Panel (b) zooms on the surrounding of Houston and adds the grid of cells of 0.1×0.1 degrees (our baseline level of analysis). Panel (c) repeats the image of Panel b for January 2006.



(a) The global network of U.S.-owned facilities and NDVI values in June



(b) Houston with 0.1°×0.1°cells in June



(c) Houston with 0.1°×0.1°cells in January

Figure 2: NDVI and PRI ownership – by engagement intensity and OECD location. The figure plots the coefficient estimates from a single regressions for the levels of Basic, Moderate, and Advanced PRI IO, as well as their interaction terms with *Outside OECD*. The average firm comprises about 58 facilities, including 6 outside the OECD. Controls include weather controls (temperature, precipitation and their squares), economic controls (nighttime lights, buildings, population), and fixed effects by cell–month, year–month, and agroclimatic-zone–year. Error bars show the 95% confidence interval. Variable definitions and sources are provided in Appendix Table B-2.

