

Research article

Sustainability and profitability in family firms: A distributional analysis of carbon emissions

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Abstract: Amid rising institutional pressure for corporate climate action, the alignment between environmental responsibility and financial success remains a critical debate. This article examines the relationship between family ownership, family-led management, greenhouse gas emissions, and firm profitability in the Spanish manufacturing sector between 2014 and 2023 using data from the Spain's carbon footprint registry. Drawing on the literature on socioemotional wealth, reputational concerns, and long-term orientation, we argue that family firms may be more committed to reducing emissions than their non-family counterparts. Using panel data models, we examine whether family firms, and particularly those managed by a family chief executive officer (CEO), exhibit lower levels of greenhouse gas (GHG) emissions and how environmental performance relates to profitability. Results show that family ownership is associated with significantly lower emissions, while the presence of a family CEO reinforces this effect, particularly among highly polluting firms. Regarding profitability, we find no evidence that year-to-year reductions in emissions generate immediate improvements in return on assets. However, family firms with lower carbon footprints tend to display higher profitability, suggesting that both outcomes may stem from underlying organizational characteristics such as long-term orientation, governance quality, and reputational concerns. This study contributes to the literature on family business sustainability by providing evidence that family ownership and family management play a significant role in climate-related corporate behavior. It also contributes to the debate on the relationship between environmental performance and profitability by showing that their coexistence in family firms is better explained by shared organizational attributes than by a direct causal effect.

Keywords: CO₂ emissions; family firms; sustainability; carbon footprint; profitability; family CEO; environmental responsibility

JEL Codes: G32, L60, M14, Q53, Q56

Abbreviations: CO₂: Carbon dioxide; CEO: Chief executive officer; EBIT: Earnings before interest and taxes; FE: Fixed-Effects; GHG: Greenhouse gas; SABI: Iberian Balance Sheet Analysis System; PSM: Propensity Score Matching; QR: Quantile Regression; RE: Random-Effects; RBV: Resource-based view; ROA: Return on assets; SMEs: Small and medium-sized enterprises; VIF: Variance Inflation Factor

1. Introduction

Climate change has become one of the most pressing challenges facing contemporary economies. Governments, investors, and society increasingly demand that firms reduce their environmental footprint and contribute to global decarbonization efforts (Filonchyk et al., 2024). In response, companies are facing growing pressure to adopt sustainable business practices, improve their environmental performance, and reduce greenhouse gas (GHG) emissions. As a result, understanding the organizational factors that influence firms' environmental behavior has become an important area of research in both sustainability and corporate governance (Valdivieso-Uvidia et al., 2025).

Among the various ownership structures, family firms constitute a particularly relevant organizational form. They represent a substantial proportion of businesses worldwide and play a dominant role in many economies, including Spain. Unlike non-family corporations, family firms frequently combine ownership, control, and management within the same family group, creating distinctive incentives that influence strategic decision-making. Recent evidence further suggests that ownership structure can condition the relationship between corporate governance and financial outcomes. Zheng et al. (2024), for example, show that ownership heterogeneity influences the relationship between bank capital and the cost of financial intermediation. Although their analysis focuses on the banking sector, their findings suggest that ownership structure may also shape firms' strategic decisions beyond purely financial outcomes, including environmental decision-making and carbon performance.

Previous research has increasingly examined the relationship between family ownership and environmental responsibility. Studies have shown that family firms often display stronger stakeholder orientation, greater commitment to sustainability, and superior environmental performance than their non-family counterparts (Fiorillo et al., 2025; Agostino and Ruberto, 2021). The socioemotional wealth perspective suggests that preserving family reputation and ensuring intergenerational continuity may encourage family owners to adopt more environmentally responsible practices (Borsuk et al., 2024). Nevertheless, the existing evidence remains fragmented, and several important questions remain unresolved (Citterio et al., 2024).

First, although numerous studies have analyzed corporate social responsibility and sustainability in family firms, relatively little evidence is available regarding their actual carbon emissions (Borsuk et al., 2024). Much of the existing literature relies on sustainability ratings, environmental disclosures, or broader environmental, social, and governance (ESG) indicators, which may not accurately reflect firms' environmental impact. Evidence based on direct measures of greenhouse gas emissions remains comparatively scarce Ginglinger (2026).

Second, the literature has devoted considerably less attention to the role of family management in shaping environmental outcomes. While family ownership and family management are often

examined jointly, the mechanisms through which family chief executive officers (CEOs) influence environmental behavior remain insufficiently understood (Kraiczy et al., 2015; Herrero et al., 2024). In particular, little is known about whether the environmental effect of family leadership varies according to firms' emission intensity, despite growing evidence that environmental challenges and sustainability strategies differ substantially across firms (Duong et al., 2024).

Third, the relationship between environmental performance and profitability remains controversial. While some studies suggest that environmental responsibility can generate competitive advantages and improve financial outcomes through enhanced reputation, stakeholder relationships, and operational efficiency (Läger et al., 2025; Garcés-Ayerbe et al., 2022), others argue that environmental investments may impose substantial costs and fail to generate immediate economic returns (Suharman, 2026). Consequently, existing evidence remains inconclusive regarding whether firms that achieve lower carbon emissions also obtain superior profitability. Importantly, this relationship may also be dynamic rather than contemporaneous. Bajwa et al. (2025) provide evidence that environmental and economic outcomes can evolve along different trajectories, suggesting that improvements in environmental performance do not necessarily translate into simultaneous economic gains. This perspective highlights the importance of considering the timing of financial effects when examining the carbon-profitability relationship.

To address these gaps, this study examines the relationship between family ownership, family management, GHG emissions, and profitability in Spanish manufacturing firms during the period 2014–2023. To ensure econometric rigor, our research design relies on direct, audited data from the Spanish Carbon Footprint Registry. Methodologically, our empirical strategy is precisely tailored to the distinct nature of each research question. To evaluate the impact of family governance on carbon performance, we employ generalized estimating equations (GEE) with Mundlak corrections to neutralize unobserved heterogeneity, complemented by panel quantile regressions (QRs) to map the non-linear trajectories of these effects across the emissions distribution. In contrast, to analyze the carbon performance-profitability nexus, we utilize within-firm fixed effects (FE) models alongside cross-sectional association specifications to isolate short-term variations from structural organizational traits. Finally, to ensure the validity of our main findings, the governance models are subjected to propensity score matching (PSM) counterfactual designs as a robust check against selection bias.

Our results indicate that family ownership is associated with significantly lower GHG emissions, a premium that remains robust under counterfactual controls. Moreover, the presence of a family CEO further strengthens this effect, particularly among firms facing greater environmental challenges. Finally, regarding the economic nexus, within-firm fixed effects confirm that short-term, year-to-year emission cuts are financially neutral regarding immediate operating returns. This finding is consistent with the dynamic perspective proposed by Choi et al. (2025), who highlight that financial relationships may emerge through lagged and interconnected processes rather than through immediate one-period effects. However, cross-sectional association models show a stable economic premium exclusively within the family firm cohort, suggesting that carbon performance may act as a visible manifestation of superior internal management quality and long-term organizational discipline rather than as a direct, exogenous cause of profitability.

This article contributes to the literature in several ways. First, it extends research on family business sustainability by focusing on direct measures of GHG emissions rather than broader sustainability indicators. Second, it advances the governance debate by proving that the environmental

impact of family management is non-linear. By introducing quantile methodologies, we reveal how internal executive discretion operates under acute operational and reputational pressures, an asymmetric reality that traditional mean-based models (e.g., ordinary least squares or standard fixed effects) structurally fail to capture. Third, it contributes to the debate on the relationship between environmental and economic performance by showing that the coexistence of lower emissions and higher profitability in family firms is better explained by shared organizational attributes, high management quality driven by socioemotional wealth (SEW) preservation, rather than by a direct causal effect of emission reductions.

The remainder of the paper is organized as follows. Section 2 develops the hypotheses and presents the research design. Section 3 reports the empirical results and robustness analyses. Finally, Section 4 concludes and discusses the implications of the findings.

2. Research design

This section develops the theoretical arguments underlying our study and presents the empirical strategy used to test the proposed hypotheses. We first derive the hypotheses concerning the relationship between family ownership, family management, GHG emissions, and firm profitability. We then describe the econometric models, variables, and data employed in the empirical analysis.

2.1. Hypothesis development

The relationship between family ownership and corporate environmental behavior has attracted growing attention in recent years (Aparicio and Iturralde, 2023; Gallizo-Larraz et al., 2024; Sun et al., 2024). Climate change and decarbonization have become central concerns for firms, regulators, and investors, increasing the importance of understanding the organizational factors that shape environmental performance. Family firms represent a particularly relevant setting because their objectives often differ from those of non-family corporations (Garcés-Ayerbe et al., 2022; Gómez-Mejía et al., 2007).

The family business literature offers two competing perspectives regarding environmental investments (Herrero et al., 2024; Bauweraerts et al., 2022). From an agency theory perspective, the concentration of ownership and control reduces traditional principal-agent conflicts and allows controlling families to pursue strategic objectives more effectively (Anderson and Reeb, 2003). However, family owners are frequently characterized as risk-averse and concerned with preserving family wealth, which may discourage investments with uncertain returns or long payback periods (Habbershon et al., 2003). Environmental initiatives aimed at reducing greenhouse gas (GHG) emissions often require substantial investments and may therefore be perceived as costly undertakings (De Massis et al., 2022).

In contrast, the SEW perspective argues that family firms pursue not only economic goals, but also non-financial objectives related to family reputation, social legitimacy, emotional attachment, and the preservation of the business for future generations (Gómez-Mejía et al., 2007). Because the family name is closely linked to the firm's public image, environmental misconduct may generate reputational damage that extends beyond purely financial consequences (Kets de Vries, 1993). Consequently, family owners may be particularly motivated to adopt environmentally responsible practices that reinforce stakeholder trust and ensure the long-term continuity of the business (Berrone et al., 2010).

A growing body of empirical evidence supports this latter view. Previous studies have documented that family firms tend to exhibit stronger environmental commitment, greater engagement in sustainability initiatives, and lower environmental risk exposure (Berrone et al., 2010; Dangelico et al., 2017; Dal Maso et al., 2020). Similarly, recent research suggests that the preservation of socioemotional wealth and reputational capital encourages family-controlled firms to adopt more sustainable business practices (Borsuk et al., 2024).

The desire to preserve the family's socioemotional wealth, safeguard the family name, and ensure the transfer of the business to future generations may outweigh the short-term costs associated with environmental investments and carbon mitigation strategies. Although the effectiveness of such incentives may be constrained in contexts requiring substantial technological transformations or large-scale capital expenditures, the long-term orientation and reputational concerns that characterize family ownership suggest that family firms should, on average, exhibit superior environmental performance. Therefore, we hypothesize:

H1. Family firms exhibit lower levels of GHG emissions than non-family firms.

Beyond ownership, managerial control may further influence corporate environmental behavior. The appointment of a family CEO represents a deep convergence of ownership and executive power. Family CEOs often internalize family objectives more strongly than external managers and may place greater emphasis on preserving the family's reputation, social legitimacy, and long-term legacy (Miller and Le Breton-Miller, 2006). Compared with non-family executives, they are generally less exposed to short-term labor market pressures and more closely aligned with the family's strategic vision (Co et al., 2024).

The stewardship perspective suggests that family managers frequently act as guardians of long-term organizational interests rather than as purely self-interested agents (Du and Cao, 2023). Consequently, they may be more willing to undertake environmental initiatives whose benefits materialize over extended periods. Previous research has linked family management to stronger stakeholder orientation, longer planning horizons, and greater commitment to sustainability-related objectives (Kraiczy et al., 2015).

Moreover, the influence of family management may not be uniform across firms. Environmental challenges vary substantially depending on the firm's emission profile. In firms with relatively low levels of pollution, environmental improvements may require only incremental operational adjustments. In contrast, highly polluting firms face greater environmental pressures and often require more intensive managerial intervention to achieve meaningful emission reductions (Duong et al., 2024). Under such circumstances, discretion, commitment, and long-term orientation associated with family leadership may become particularly relevant.

Accordingly, we propose:

H2a. Among family firms, those managed by a family CEO exhibit lower levels of GHG emissions than those managed by a non-family CEO.

H2b. The environmental effect of family management is stronger among highly polluting firms, where environmental challenges require more intensive managerial intervention and long-term strategic decision-making.

The relationship between environmental performance and profitability remains one of the most debated questions in the sustainability literature (Läger et al., 2025; Suharman, 2026). Traditional approaches emphasize the costs associated with environmental investments and argue that reducing emissions may adversely affect short-term profitability. In contrast, stakeholder theory and the resource-based view (RBV) suggest that environmental responsibility can generate competitive

advantages through enhanced reputation, improved stakeholder relationships, greater operational efficiency, and reduced regulatory risk. For example, Höck et al. (2020) show that firms with more advanced environmental strategies face lower regulatory exposure and greater adaptive capacity, while Lewandowski (2017) argues that sustainability investments may improve access to financing and strengthen firms' long-term economic stability.

Recent studies have produced mixed evidence regarding the economic consequences of environmental performance. While some authors report positive associations between sustainability initiatives and firm performance, others find that the benefits are highly contingent on organizational characteristics and industry context (Läger et al., 2025; Suharman, 2026). Family firms constitute an especially interesting setting because their long-term orientation may allow them to realize economic benefits from environmental investments over longer time horizons.

At the same time, the direction of causality remains unclear. More profitable firms may possess greater financial resources to invest in environmental improvements, while environmentally responsible firms may also benefit from enhanced stakeholder support and reputational advantages. Given these competing arguments, our objective is not to test a direct causal relationship but rather to examine whether environmental and the profitability are systematically associated.

Therefore, we hypothesize:

H3. Lower levels of GHG emissions are positively associated with firm profitability.

2.2. Model specification

Designing a robust empirical strategy to examine the environmental behavior of family firms and its financial consequences presents three major econometric challenges that a single estimation method cannot simultaneously resolve.

First, the condition of being a family firm is a structural, time-invariant characteristic in our sample. Standard fixed effects estimators are unfeasible because they eliminate all time-invariant variables through the within-transformation, while standard random effects (RE) models assume that unobserved firm heterogeneity is completely uncorrelated with corporate decisions, an assumption frequently violated in corporate sustainability literature. To overcome this, we adopt the Mundlak (1978) approach as our primary model, which allows us to isolate the consistent effect of family ownership while explicitly controlling for correlated unobserved heterogeneity.

Second, corporate environmental strategies and emission profiles are highly heterogeneous; the behavior of average polluters might differ substantially from that of extreme polluters. Relying solely on mean-based regressions could hide critical nuances. Therefore, we employ QR for panel data to capture how family influence varies across different points of the emission distribution.

Third, exploring the nexus between carbon reduction and profitability introduces potential reverse causality and simultaneity bias (i.e., whether eco-efficiency drives profitability or whether highly profitable firms simply have more resources to invest in green technologies). To address this, we operationalize the financial model using a strictly time-varying framework where we can exploit the within-firm variance through a FE setup to mitigate omitted variable bias.

Finally, the intrinsic asymmetry of our database (where 75% of the companies are family-owned in concordance with the Spanish business context) introduces a self-selection risk. To ensure that our comparison group is statistically equivalent, this entire multi-stage framework is also estimated using weights derived from a PSM procedure.

2.2.1. Family ownership and GHG emissions (Mundlak)

In line with the empirical framework outlined above, we begin by evaluating the baseline impact of family ownership on GHG emissions. Panel data methodologies have long been recognized as essential tools in social science research to track corporate behavior over time. In sustainability and environmental studies, such models have been widely applied to analyze how family firms differ from non-family firms in terms of GHG emissions, corporate social responsibility, or environmental performance (Berrone et al., 2010; Dangelico et al., 2017; Dal Maso et al., 2020). The general econometric specification is formulated as follows:

$$GHG\ Emissions_{it} = \alpha + \beta_1 Family_i + \beta_2 X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

where i represents each firm ($i = 1, 2, \dots, 912$), t denotes the time period ($t = 2014, 2015, \dots, 2023$), X_{it} is the vector of control variables, μ_i captures unobserved firm-specific effects, δ_t represents time fixed effects (included through annual dummy variables) to control for common macroeconomic shocks, such as those caused by the pandemic, and ε_{it} denotes the error term.

The choice of a panel data methodology aimed at obtaining a consistent estimate for the variable *Family* (time-invariant). Since the FE model removes such variables and the RE model requires the strict assumption of no correlation between unobserved effects (μ_i) and the covariates (X_{it}), the Mundlak (1978) model was adopted as the main specification.

The Mundlak model is an extension of the RE framework that addresses the correlation problem by explicitly including the time averages ($\bar{X}_i$) of the time-varying covariates as additional regressors:

$$GHG\ Emissions_{it} = \alpha + \beta_1 Family_i + \beta_2 X_{it} + \beta_3 \bar{X}_i + \mu_i + \delta_t + \varepsilon_{it} \quad (2a)$$

The statistical significance of the coefficients β_3 (the coefficients of the time averages) serves as a direct Wald test of endogeneity in the standard RE model (Mundlak test). Our empirical results confirmed that the time averages of some control variables (size and change in fixed assets) were highly significant ($p < 0.001$), which provides strong support for the use of the Mundlak Model to obtain consistent estimators of the average effect of family ownership.

Furthermore, this identical Mundlak framework is applied to the subsample of family firms to examine the average effect of internal governance characteristics on environmental performance. In this sub-estimation, the general family firm indicator is omitted (as it becomes a constant equal to 1 across all observations in the subsample) and is replaced by the *Family CEO* dummy variable. This allows us to evaluate whether having a member of the owning family at the helm of the corporation introduces distinct behavioral patterns regarding average GHG emissions, while maintaining identical controls and time-averages ($\bar{X}_i$) to ensure consistency and isolate unobserved heterogeneity. Consequently, for the family firm subsample, the empirical model is specified as follows:

$$GHG\ Emissions_{it} = \alpha + \beta_1 CEO\ Family_i + \beta_2 X_{it} + \beta_3 \bar{X}_i + \mu_i + \delta_t + \varepsilon_{it} \quad (2b)$$

2.2.2. Heterogeneity analysis: QR

To complement the average effect estimated through the Mundlak specification, panel QR is employed to examine whether the impact of family governance is homogeneous across the conditional

distribution of GHG emissions. For this heterogeneity analysis, the effects are estimated at three key quantiles of the emissions distribution: the 10th percentile ($\tau = 0.10$) representing low polluters, the 50th percentile ($\tau = 0.50$) representing the median, and the 90th percentile ($\tau = 0.90$) capturing high-polluting firms. Examining the variation in the coefficients across these quantiles is essential to determine whether family influence exerts a stronger influence among extreme polluters or among those with lower emission levels, thus capturing the underlying environmental heterogeneity within our sample.

This framework is estimated in two distinct phases. First, using the full sample of manufacturing firms, the quantile specification evaluates the impact of general family ownership ($Family_i$) as follows:

$$GHG\ Emissions_{it} = \alpha(\tau) + \beta_1(\tau)Family_i + \beta_2(\tau)X_{it} + \mu_i(\tau) + \delta_t(\tau) + \varepsilon_{it}(\tau) \quad (3a)$$

where $\beta_1(\tau)$ captures the specific impact of family ownership on the τ -th quantile of GHG emissions, X_{it} represents the identical vector of time-varying controls used in previous models, $\mu_i(\tau)$ denotes the firm-level unobserved effects at quantile τ , $\delta_t(\tau)$ accounts for time fixed effects, and $\varepsilon_{it}(\tau)$ is the idiosyncratic error term at quantile τ .

Second, we restrict the analysis to the subsample of family firms to explore internal family dynamics. In this phase, the general family dummy is omitted and replaced by the type of CEO ($CEOFamily_i$), yielding the following specification:

$$GHG\ Emissions_{it} = \alpha(\tau) + \beta_1(\tau)CEO\ Family_i + \beta_2(\tau)X_{it} + \mu_i(\tau) + \delta_t(\tau) + \varepsilon_{it}(\tau) \quad (3b)$$

2.2.3. GHG emissions and profitability (FE/RE)

Subsequently, to explore the environmental-financial nexus and understand the economic implications of corporate environmental strategies, additional models are estimated where the dependent variable is economic profitability (ROA). Rather than assuming a direct causal pathway, this specification examines the systematic association between a firm's carbon footprint and its accounting returns, while controlling for the direct effect of corporate governance characteristics. The baseline econometric specification for the profitability framework is formulated as follows:

$$ROA_{it} = \alpha + \beta_1 GHG\ Emissions_{it} + \beta_2 Family_i + \beta_3 X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (4)$$

where $GHG\ Emissions_{it}$ represents the primary time-varying independent variable of interest, and $Family_i$ is the time-invariant dummy capturing family ownership. The vector X_{it} contains the identical time-varying corporate control variables used in previous stages, μ_i denotes the unobserved firm-specific heterogeneity, δ_t controls for time fixed effects, and ε_{it} is the idiosyncratic error term.

Since both profitability and GHG emissions vary over time, the FE model was adopted to explicitly control for unobserved and time-invariant firm-specific factors (e.g., long-term reputation or organizational culture) that might simultaneously influence both emissions and performance. By removing this potential omitted-variable bias, the FE model isolates the strictly within-firm relationship, testing whether year-to-year changes in carbon emissions associate with immediate variations in ROA. Nonetheless, the RE specification is also estimated as a benchmark to capture cross-sectional variation, along with panel QR models to explore potential heterogeneity across different profitability boundaries. For the quantile framework, estimates were obtained for the quantiles $\tau = 0.1$, $\tau = 0.5$, and $\tau = 0.9$ to map the relationship across low, median, and high-profitability firms.

2.2.4. Estimation procedures and statistical inference

To ensure the statistical validity and integrity of our results across all stages of the empirical analysis, specific inference protocols are implemented. For all panel regression specifications (Mundlak, FE, and RE), we use robust standard errors clustered at the firm level. This approach relaxes the standard Gauss-Markov assumptions by correcting for potential heteroscedasticity and arbitrary within-unit temporal autocorrelation, which are common in long panel distributions.

For the panel QR models estimated in both phases of the study ($\tau = 0.10$, $\tau = 0.50$, and $\tau = 0.90$), standard analytical standard errors can be unreliable due to the non-smooth nature of the objective function. To overcome this limitation, empirical standard errors and confidence intervals are computed using a non-parametric bootstrapping procedure with 500 replications, ensuring consistent and robust statistical inference. All econometric estimations throughout this study were performed using the statistical software Stata 19.

2.2.5. Robustness strategy: PSM specification

A potential econometric concern in evaluating the impact of family ownership on both carbon emissions and profitability is endogeneity arising from self-selection bias. Family and non-family firms often differ systematically in observable characteristics, such as firm size, age, and capital structure, which simultaneously affect environmental strategies and profitability. Consequently, a direct comparison between these two groups could yield biased estimates if treatment assignment (i.e., being a family firm) is non-random.

To mitigate this selection bias and ensure a robust causal interpretation, we employ a PSM approach as a robustness check in Section 3.4. The PSM framework constructs a synthetic control group of non-family firms that mirror the treatment group of family firms across all relevant baseline covariates. First, we estimate a conditional probability model (probit) to calculate the propensity scores (the probability of a firm being family-owned) conditioned on key financial and operational characteristics:

$$\Pr(\text{Familiar}_{it} = 1) = \Phi(X_{it}\gamma + \delta_t) \quad (5)$$

where X_{it} represents the vector of matching covariates, and δ_t controls for time-specific shocks. Based on these estimated scores, we implement a Kernel matching algorithm restricted to the region of common support to ensure optimal overlap between groups. This method uses weighted averages of all individuals in the control group to construct the counterfactual, maximizing sample efficiency while reducing conditional variance.

Finally, following a “doubly robust” estimation strategy, the generated matching weights (pweight) are integrated into our primary econometric specifications, the Mundlak approach for the emission models and the FE/RE estimators for the profitability models.

This combination effectively controls for both selections on observables (via PSM weighting) and unobserved time-invariant heterogeneity (via panel data specifications), ensuring the structural integrity of our baseline findings.

2.3. Variables and data

2.3.1. Data sources and sample selection

Data on CO₂ emissions for the organizations analyzed were obtained from the *Carbon footprint registration, offsetting and carbon dioxide absorption projects*, a voluntary public registry administered by the Spanish Ministry for Ecological Transition and Demographic Challenge (MITECO). This instrument, established under Royal Decree 163/2014, forms part of Spain's national strategy for climate change mitigation and aims primarily to promote the measurement, reduction, and offsetting of greenhouse gas (GHG) emissions. Carbon footprint calculation enables the identification of the total amount of emissions generated by an economic activity, as well as their specific sources, facilitating the adoption of effective mitigation strategies (Ministerio Español para la Transición Ecológica y Cambio Demográfico, 2020).

Companies registered in the system receive an official certificate and the right to use an accreditation seal, which reflects their level of participation and progress in emission reductions. Consequently, inclusion in this registry serves as an indicator of corporate environmental commitment, as it is a voluntary process (Gallizo-Larraz et al., 2024). At the beginning of 2025, the registry included 5,431 companies, 1,155 of which belonged to the manufacturing sector, which constitutes the main focus of the present study.

Economic and financial data, along with information on ownership and management structures, were obtained from the SABI database (Iberian Balance Sheet Analysis System), produced by Bureau van Dijk, one of the most reputable sources of business information in Spain and Portugal. This database is widely used in academic research on family firms and financial analysis (Casillas et al., 2024; Escamilla-Solano et al., 2024).

It should be noted that SABI does not include information on sole proprietors or self-employed individuals; therefore, these entities were excluded from the analysis. Likewise, companies lacking sufficient information on ownership or management, preventing their classification as family or non-family firms, as well as those without available economic data for some of the years in which they reported emissions, were removed. Observations with inconsistent or extreme values were also eliminated, particularly firms with negative equity, as these were considered indicative of financially distressed situations.

After applying the filtering criteria described, the final sample consisted of 912 firms, generating an unbalanced panel of 2,087 observations for the period 2014–2023. The temporal distribution of observations is not homogeneous, with a progressive increase in the number of records over time, reflecting heightened environmental awareness among Spanish companies.

2.3.2. Variable definitions and operationalization

This section details the operationalization and theoretical justification of the variables embedded within our econometric specifications to evaluate both the impact of family governance on corporate carbon emissions and the subsequent financial returns of emission mitigation strategies. For synthesis and immediate reference, Table 1 provides a comprehensive overview of the definitions, algebraic formulas, and primary data sources for all metrics used in this study.

Dependent variables

Total GHG emissions (measured in tons of CO₂)

This variable captures the comprehensive environmental footprint of the firm, aggregating direct emissions from sources owned or controlled by the company, such as fossil fuel combustion and heating systems (Scope 1); indirect emissions derived from electricity purchased and consumed by the organization (Scope 2); and other indirect emissions occurring along the firm's value chain (Scope 3). All values are derived from the official MITECO registry, ensuring high reporting standards. Due to the highly skewed distribution and large variance of absolute emission metrics across manufacturing sectors, this variable is transformed using its natural logarithm to ensure normality and stabilize conditional variance. In the second phase of our empirical design (Equation 4), this metric serves as the primary time-varying independent regressor.

Economic profitability (ROA)

Corporate economic performance is operationalized through the return on assets (ROA) ratio. Following standard accounting literature, it is calculated as:

$$ROA_{it} = \frac{\text{Earnings Before Interest and Taxes (EBIT)}_{it}}{\text{Total Assets}_{it}}$$

We deliberately use EBIT in the numerator instead of net income to isolate the true operational efficiency of the firm's asset base, preventing distortionary effects stemming from heterogeneous corporate tax strategies or distinct financial leverage structures. Its implementation as a robust proxy for economic performance is very common in corporate environmental performance literature (Álvarez, 2012; Dixon-Fowler et al., 2013; Garcés-Ayerbe et al., 2022; Gallizo-Larraz et al., 2024).

Independent variables

Family firm

A time-invariant dichotomous variable equal to 1 if the firm is family owned and 0 otherwise. Family ownership has been previously employed in carbon emissions research (Garcés-Ayerbe et al., 2022; Gallizo-Larraz et al., 2024). The classification into family and non-family firms follows the definition proposed by the Instituto de la Empresa Familiar (2015). While this definition is based on the proportion of equity held by the owning family, it also accounts for the fact that firms with more dispersed ownership structures may require smaller ownership stakes to exert control (Sánchez-Pulido et al., 2022).

According to this framework:

- **Dispersed ownership structure (no shareholder owns more than 50% of capital):** A firm is considered family-owned if an individual or family holds more than 5% individually or more than 20% collectively and the individual shareholder sits on the Board of Directors, or if shareholders holding more than 20% are also managers. Otherwise, the firm is classified as non-family.

- **Concentrated ownership structure (a shareholder owns more than 50%):**

A firm is family-owned when the family shareholder controls at least 50.01% of equity or when shareholder-managers hold more than 50.01%. Firms that do not meet this criterion are classified as non-family.

Family CEO

Applied exclusively within the family firm subsample to capture internal agency dynamics, this dummy variable equals 1 if the CEO belongs to the owning family, and 0 otherwise. The identification protocol involved matching executive names against the main shareholders' lineages, verified through surname commonalities, and completed via case-by-case corporate registry lookups to identify hidden family ties (e.g., spouses or maternal surnames).

Control variables

To isolate the true effect of family governance and mitigate omitted variable bias, a comprehensive vector of time-varying corporate control variables (X_{it}) is incorporated:

Firm size (Ln sales)

Operationalized as the natural logarithm of total annual sales revenue. Larger manufacturing entities face intensified regulatory scrutiny, higher public visibility, and greater stakeholder pressure, which typically forces them to adopt proactive environmental management routines (Wulansari et al., 2023; Ng and Hamilton, 2024).

Change in fixed assets

Calculated as the annual percentage change in net property, plant, and equipment: $(\text{Fixed Assets}_{it} - \text{Fixed Assets}_{i,t-1}) / \text{Fixed Assets}_{i,t-1}$. This metric acts as a proxy for net capital expenditures (CapEx). Modern environmental investments in clean technologies or energy-efficient infrastructure are reflected here, allowing us to capture whether heavy physical re-investment directly structuralizes carbon footprint contractions (World Resources Institute, 2023). Smaller firms, particularly family SMEs, often rely more heavily on self-financing due to limited credit access (Hernando et al., 2014), which may constrain their capacity to invest in emission-reducing technologies.

Sales growth (change in sales)

Measured as the annual percentage change in sales revenue: $(\text{Sales}_{it} - \text{Sales}_{i,t-1}) / \text{Sales}_{i,t-1}$. Firms adopting sustainable practices such as circular economy principles or eco-design may benefit from increased demand stemming from improved reputation and corporate image (Science Based Targets, 2018), making this control essential to separate general market expansions from eco-efficiency returns.

Firm age (years since incorporation)

The number of years elapsed since the firm's official legal incorporation. Older firms are often more willing to disclose environmental information and show stronger commitment to environmental management due to their need to maintain legitimacy and reputation (Solikhah et al., 2021). Over time, firms accumulate knowledge, routines, and internal capabilities, enabling them to develop more effective sustainability policies (Argote and Miron-Spektor, 2011).

Leverage

Operationalized as the ratio of total liabilities to total shareholders' equity ($\text{Total Liabilities}_{it} / \text{Total Equity}_{it}$). Highly leveraged firms face greater financial obligations and default risk; however, adopting sustainable practices may mitigate these risks by reducing regulatory exposure and enhancing adaptation capacity (Höck et al., 2020). Although high leverage can be associated with greater financial vulnerability, investments in environmental sustainability can reduce exposure to regulatory and reputational risks, thereby promoting long-term stability (Dorfeitner et al., 2015). Investments in environmental initiatives may therefore support long-term financial stability (Dorfeitner et al., 2015).

Thus, firms with higher debt levels may be incentivized to adopt emission-reduction strategies to meet regulatory requirements and protect financial stability.

Together, these control variables are incorporated to isolate the effect of structural and financial factors that may influence the relationship between GHG emissions and profitability. Their inclusion enhances the accuracy and validity of the empirical analysis, offering a more comprehensive understanding of how firms' internal characteristics shape their environmental behavior and profitability.

Table 1. Summary of variable definitions and measurement.

Variable Type	Variable Name	Operationalization/Measurement Formula	Source
Dependent/Independent	Total GHG emissions	Natural logarithm of total greenhouse gas emissions (tons of CO ₂ , Scopes 1, 2, and 3). Acts as the dependent variable in Equation (1)–(3) and as the main independent variable in Equation (4).	MITECO
Dependent	ROA	EBIT _{it} /Assets _{it} (Return on Assets based on operational returns in Equation (4).	Own calculation based on data from SABI
Independent	Family firm	Dummy variable: 1 if family-owned according to Instituto de la Empresa Familiar (2015) multi-criteria; 0 otherwise.	Own classification according to data from SABI
	Family CEO	Dummy variable: 1 if the CEO belongs to the owning family; 0 otherwise.	Own classification according to data from SABI
Control	Firm size	Natural logarithm of total annual sales revenue.	SABI
	Change in fixed assets	Annual net variation: $(\text{Fixed Assets}_{it} - \text{Fixed Assets}_{i,t-1}) / \text{Fixed Assets}_{i,t-1}$	SABI
	Growth sales	Annual revenue growth rate: $(\text{Sales}_{it} - \text{Sales}_{i,t-1}) / \text{Sales}_{i,t-1}$	SABI
	Firm age	Number of calendar years since the firm's official incorporation.	SABI
	Leverage	Capital structure ratio: $\text{Total Liabilities}_{it} / \text{Total Equity}_{it}$	SABI

3. Empirical analysis

3.1. Descriptive statistics

To contextualize the operational, financial, and institutional profiles of the manufacturing organizations under analysis, we begin our empirical exploration with a comprehensive descriptive assessment.

Table 2 reports the baseline descriptive statistics comprising mean values, standard deviations, and range minimums and maximums for the full unbalanced panel spanning 2,087 observations across

912 distinct firms during the 2014–2023 period. This matrix allows for an initial exploration of the structural characteristics of the data before applying formal econometric transformations.

Table 2. Descriptive statistics.

Variable	Mean	Std. Dev.	Min	Max
Total GHG emissions (in tons of CO ₂)	173,106	3,261,891	0.23	86,158,033
Economic profitability (ROA)	0.0803	0.1000	−0.3820	0.9422
Family firm	0.7547	0.4304	0	1
Family CEO	0.7270	0.4457	0	1
Firm size (sales in thousands of euros)	110,052	1,051,247	33	27,371,242
Change in fixed assets	0.2148	2.8488	−0.8657	119.4479
Sales growth	0.1592	0.5662	−0.8121	17,3505
Firm age (years since incorporation)	31.20	17.44	1	121
Leverage	1.9671	3.5248	0.0271	66.0183

The raw data presented in Table 2 reveals critical economic insights that strongly justify our subsequent econometric design.

First, absolute GHG emissions exhibit a massive scale disparity, with a sample mean of 173,106 tons of CO₂ but a substantial standard deviation of over 3.26 million tons, stretching from a micro-polluter (0.23 tons) to an extreme industrial emitter (86.15 million tons). From an economic and methodological standpoint, this extreme variance provides double justification: first, it necessitates the natural log transformation of the environmental footprint variable to prevent extreme outliers from biasing our linear estimates; second, it confirms that mean-based regression models (like standard OLS, RE, or Mundlak) are insufficient on their own, thereby empirically validating our deployment of Panel Quantile Regressions to examine whether family influence acts differently at the boundaries of the emission distribution.

Second, the sample displays a robust average economic profitability of 8.03%. Because registration in the MITECO carbon registry is entirely voluntary and carries non-negligible carbon accounting, verification, and administrative costs, this high average return suggests that proactive corporate environmental strategies do not erode competitive advantages. Instead, it signals that manufacturing firms in Spain can successfully reconcile commercial viability with voluntary climate disclosures, a pattern highly consistent with win-win hypotheses and previous empirical evidence (Orlitzky et al., 2003; Dixon-Fowler et al., 2013; Gallizo-Larraz et al., 2024).

Third, regarding governance architectures, 75.47% of the observations correspond to firms operating under a family ownership regime. Within this family subsample, 72.70% are also managed by a family leader (family CEO). This heavy concentration reflects the structural reality of the Spanish manufacturing fabric but introduces a significant statistical asymmetry. This structural imbalance provides the explicit economic rationale for implementing the PSM protocol, ensuring that our counterfactual comparison group of non-family firms is statistically equivalent across all observable covariates.

The control variables show a mature sample (average firm age of 31.20 years, with some legacy corporations reaching 121 years) that has experienced parallel expansions in physical infrastructure investment (change in fixed assets = 21.48%) and market demand (sales growth = 15.92). However,

the average leverage ratio of 1.9671 indicates that debt nearly doubles equity. This capital structure implies that manufacturing firms are operating under notable external financial commitments, which could economically constrain or shape their ability to deploy heavy capital expenditures toward long-term green transitions due to immediate debt-servicing pressures (Höck et al., 2020).

Following our data evaluation, we conduct a rigorous multicollinearity diagnostic before running the core panel regressions. Table 3 presents the pairwise Pearson correlation matrix across all variables embedded in Equations (1) to (5), accompanied by their respective variance inflation factors (VIF) to confirm the structural independence of the estimators.

Table 3. Pairwise correlation matrix and VIF.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	VIF
(1) ROA	1									
(2) GHG emissions	−0.0259	1								1.66
(3) Family firm	0.0157	−0.1966*	1							1.07
(4) Family CEO	−0.0332	−0.3045*		1						
(5) Size	0.1103*	0.6164*	−0.1897*	−0.3414	1					1.73
				*						
(6) Δ Fixed assets	0.0380	−0.0350	0.0207	0.0329	−0.0485	1				1.03
(7) Sales growth	0.1489*	−0.0186	−0.0231	0.0342	0.0236	0.1045*	1			1.03
(8) Firm age	−0.0302	0.2160*	0.0544	−0.1813	0.3028*	−0.1337	−0.1312*	1		1.22
				*		*				
(9) Leverage	−0.1515*	0.0522	−0.0617*	0.0306	−0.0555	0.0278	0.0539	−0.2415*	1	1.08

* Significant at the 1% level.

Consistent with basic industrial economics, a positive and statistically significant correlation is observed between firm size (LnSales) and absolute GHG emissions ($r = 0.6164$, $p < 0.01$). This strong linear relationship is intuitive: a larger operational scale translates into higher production volumes, greater energy throughput, and consequently, a larger absolute environmental footprint. This connection aligns perfectly with previous manufacturing sector studies in Spain (Gallizo-Larraz et al., 2024), reinforcing why controlling for size is mathematically mandatory to avoid omitted variable bias when evaluating the true net effect of family governance. Beyond this expected scale relationship, the correlation coefficients across the remaining corporate determinants are remarkably low, with none exceeding 0.35. More importantly, the VIF analysis provides conclusive evidence regarding the absence of multicollinearity. All individual VIF metrics remain exceptionally low, ranging from a minimum of 1.03 to a maximum of 1.73, which falls well below the conservative econometric ceiling of 5. From an econometric perspective, these low VIF scores mean that the standard errors of our linear coefficients in the Mundlak, FE, and QR will not be artificially inflated due to linear redundancies among the regressors. Each chosen control variable captures a distinct, non-redundant economic

dimension of the firm, ensuring that our subsequent multi-stage estimations are statistically stable, efficient, and reliable for causal inference.

3.2. Influence of family ownership and management on GHG emissions

To evaluate the formal relationship between family ownership governance and absolute corporate carbon footprint profiles, we implement a progressive multi-stage panel data estimation.

Table 4 presents the comprehensive empirical results derived from six econometric specifications. We begin by estimating baseline static panels using standard RE and FE setups (Columns 1 and 2). To correct for potential omitted variable bias stemming from unobserved firm-level heterogeneity correlated with our regressors, we deploy our primary specification, the generalized estimating equations (GEE) Mundlak model (Column 3). Finally, to explore whether the effect of family governance is uniform or heterogeneous across different pollution regimes, we estimate QR at the 10th ($\tau = 0.1$), 50th ($\tau = 0.5$), and 90th ($\tau = 0.9$) conditional percentiles of the GHG emission distribution (Columns 4, 5, and 6).

Initial exploratory diagnostics validate our progressive econometric approach. While the standard FE framework (Column 2) isolates unobserved time-invariant heterogeneity, it mathematically omits our primary variable of interest (family firm) due to its time-invariant nature in the medium term. Conversely, the RE model (Column 1) yields a negative and highly significant family effect ($\beta = -0.959$, $p < 0.01$). However, the underlying assumption that unobserved firm-level characteristics are strictly orthogonal to the explanatory variables is rejected.

This friction is formally resolved by the Mundlak specification (Column 3). The statistical significance of the within-firm cluster means, specifically for operational scale (mean size = 0.938, $p < 0.01$) and infrastructure expansion (mean Δ fixed assets = 0.042, $p < 0.01$), confirms that unobserved structural effects are correlated with corporate characteristics. Consequently, the Mundlak model successfully purges the correlated random effects bias, providing a cleaner and more efficient average estimate of the family governance effect.

Under the baseline Mundlak framework (Column 3), the family firm regressor exhibits a negative and highly statistically significant relationship with corporate environmental footprints ($\beta = -0.548$, $p < 0.01$). In terms of economic magnitude, since the dependent variable is log-transformed (GHG Emissions), this coefficient behaves as a semi-elasticity. Holding all operational, lifecycle, and financial indicators constant, family-controlled manufacturing firms achieve an average carbon footprint reduction of 42.2% [calculated as $(e^{-0.548} - 1) \times 100$] relative to non-family organizations. This substantial gap confirms a pronounced environmental premium driven by family governance architectures, validating previous findings in the Spanish industrial context (Gallizo-Larraz et al., 2024). This result would therefore support our Hypothesis 1, which holds that family-owned firms have lower emissions than non-family-owned firms.

Table 4. Influence of family ownership on GHG emissions.

GHG emissions	(1)RE	(2)FE	(3) Mundlak	(4)QR (0.1)	(5)QR (0.5)	(6)QR (0.9)
Independent variable						
Family firm	−0.959***	omitted	−0.548***	−0.491***	−0.451***	0.1343
Control variables						
Sales	0.349***	0.051	0.054*	0.659***	0.988***	1.163***
Δ Fixed assets	−0.007	−0.009**	−0.009**	−0.039	0.015	−0.001
Sales growth	−0.083***	−0.029	−0.031	−0.255*	−0.204	−0.227
Firm age	0.223***	−0.220	−0.007	0.129	0.125*	0.446**
Leverage	0.027***	0.019*	0.019*	0.075***	0.072***	0.142***
Mundlak variables						
(bias correction)						
Mean sales			0.938***			
Mean Δ fixed assets			0.042***			
Mean sales growth			−0.223			
Mean firm age			0.065			
Mean leverage			0.024			
Year dummies						
2015	0.099	0.125	0.116	0.203	−0.144	−0.114
2016	−0.100	−0.028	−0.041	−0.450	−0.491	−0.064
2017	−0.057	0.246	0.003	−0.641*	−0.115	0.048
2018	−0.190	−0.095	−0.130	−1.032***	−0.320	−0.203
2019	−0.362**	−0.238	−0.279	−0.699**	−0.696*	−0.743
2020	−0.647***	−0.557***	−0.594***	−1.285***	−0.721**	−0.186
2021	−0.428**	−0.308	−0.342*	−1.159***	−0.630*	0.216
2022	−0.361**	−0.168	−0.209	−0.829***	−0.590*	−0.497
2023	−0.403**	−0.165	−0.237	−0.806***	−0.643*	−1.301*
Constant	2.972***	5.848***	−3.021***	−1.706***	−3.193***	−3.991***
N (N groups)	2,087(912)	2,087(912)	2,087(912)	2,087	2,087	2,087
Pseudo R ²	0.3401	0.1044	0.4416	0.1549	0.2523	0.2647

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Quantile Regression models are estimated via non-parametric bootstrapping with 500 replications.

However, the panel QR (Columns 4–6) reveal that this mitigating effect is highly heterogeneous across emission distribution thresholds. For cleaner and moderate industrial polluters, the family environmental premium remains highly potent and statistically stable. In the lower tail ($\tau = 0.1$), family firms emit 38.8% less carbon than their non-family counterfactuals ($\beta = -0.491$, $p < 0.01$). This reduction remains steady at the conditional median ($\tau = 0.5$) at 36.3% ($\beta = -0.451$, $p < 0.01$). This empirical pattern provides strong support for the Socioemotional Wealth (SEW) paradigm and non-economic utility models (Berrone et al., 2010). Family owners are highly risk-averse regarding reputational damage and legal environmental non-compliance, which could tarnish the family name within local communities. Consequently, their long-term stewardship orientation, deeply intertwined with the preservation of emotional assets and cross-generational business legacy (Borsuk et al., 2024), manifests in structurally

superior environmental performance. In sharp contrast, for extreme industrial polluters in the upper tail ($\tau = 0.9$), the family coefficient shifts to a positive sign ($\beta = 0.1343$) and completely loses statistical significance ($p = 0.564$). From an economic and technological standpoint, this loss of efficacy indicates that for the top 10% most carbon-intensive manufacturing operations, socioemotional non-economic utilities become subordinate to structural economic forces. In heavy-emitting environments, achieving carbon reductions requires radical, capital-intensive eco-innovations and structural re-engineering of production lines. The high financial costs, combined with severe technical abatement barriers, overwhelm family non-economic motivations, causing the family governance premium to evaporate. This finding is also consistent with Duong et al. (2024), who emphasize the role of eco-innovation capabilities in achieving substantial environmental improvements. While family ownership appears to strengthen environmental commitment, our results suggest that its influence weakens among the most polluting firms, where meaningful emission reductions require costly technological transformations.

The behavior of the control variables yields additional insights into the structural drivers of industrial carbon emissions. Operational scale displays a positive and statistically dominant effect across almost all specifications. In the QR models, the size coefficient increases systematically along the distribution, rising from a semi-elasticity of 0.659 ($p < 0.01$) at $\tau = 0.1$ to an elasticity of 1.163 ($p < 0.01$) at the extreme pollution boundary ($\tau = 0.9$). Economically, this means that for heavy polluters, a 1% expansion in market turnover drives a compounding 1.16% increase in absolute greenhouse gases. This finding aligns with scale effect frameworks (Wulansari et al., 2023), confirming that larger manufacturing operations inherently multiply environmental impacts due to higher production volumes. It also supports recent literature suggesting that large industrial corporations often rely heavily on external “carbon offsetting” strategies rather than direct internal mitigation, allowing their absolute operational emissions to scale alongside market growth (Wright and Nyberg, 2024; Trouwloon et al., 2023).

In the primary Mundlak model, changes in physical infrastructure yield a negative and statistically significant impact on carbon output ($\beta = -0.009$, $p < 0.05$). This indicates that modern capital expenditure trends promote energy efficiency. Corporate investment in physical asset renewal acts as a practical mechanism for decarbonization, facilitating the replacement of legacy systems with cleaner technologies and modern, energy-efficient machinery (Horbach, 2008; De Marchi, 2012).

Firm age remains statistically neutral across the lower and median pollution thresholds but develops a positive and significant impact at the extreme boundary ($\tau = 0.9$: $\beta = 0.446$, $p < 0.05$). This implies that among heavy polluters, older firms face much greater difficulties in decarbonization. This pattern reflects structural and technological lock-in, where legacy industrial installations suffer from organizational inertia and high switching costs. This result highlights the complexity of corporate lifecycles, adding nuance to the inconclusive findings of earlier studies, such as Haner et al. (2025), who found a positive linear tie between longevity and climate strategy development.

Across all six models, leverage displays a consistently positive and statistically significant relationship with emissions, peaking at the heavy polluter threshold ($\tau = 0.9$: $\beta = 0.142$, $p < 0.01$). This dynamic points to a clear financial constraint effect. Highly leveraged manufacturing firms face severe debt-servicing commitments that absorb free cash flow. Consequently, high debt loads restrict managerial capacity to undertake proactive green capital investments, which typically feature long payback periods and high upfront costs. This constraint effect aligns with the evidence from Clarkson et al. (2013), confirming that restrictive financial conditions and high capital costs limit a firm’s ability to improve its environmental performance.

Finally, the temporal indicators capture an explicit downward structural shift from 2019–2020 onwards across the RE, FE, and Mundlak specifications (e.g., Mundlak, 1978: $\beta = -0.594$, $p < 0.01$). This general contraction reflects the combined impact of exogenous macroeconomic shocks (primarily the COVID-19 production disruptions) and a tightening European and Spanish climate regulatory landscape, which accelerated baseline industrial carbon efficiency regardless of specific corporate governance structures.

Table 5. Influence of a family CEO on GHG emissions in family firms.

Variable / Model	(1) RE	(2) FE	(3) Mundlak	(4) QR ($\tau = 0.1$)	(5) QR ($\tau = 0.5$)	(6) QR ($\tau = 0.9$)
Independent variable						
Family CEO	−0.999***	omitted	−0.344**	−0.261	−0.418***	−1.359***
Control variables						
Sales	0.282	0.050	0.050	0.527***	0.889***	0.982***
Δ Fixed assets	−0.006	−0.009*	−0.009**	−0.003	0.020	−0.005
Sales growth	−0.100**	−0.049	−0.050	−0.118	−0.339**	−0.272*
Firm age	0.309***	0.130	0.136	0.372**	0.292***	0.142
Leverage	0.018*	0.018	0.018	0.041	0.073***	0.067
Mundlak variables (bias correction)						
Mean sales			0.090***			
Mean Δ fixed assets			0.049***			
Mean sales growth			−0.183			
Mean firm age			0.003			
Mean leverage			0.002			
Year dummies						
2015	0.047	0.075	0.065	0.047	−0.126	−0.553
2016	−0.160	−0.097	−0.109	−0.519	−0.430	−0.846
2017	−0.169	−0.106	−0.137	−0.786**	−0.165	−0.880
2018	−0.241	−0.170	−0.207	−1.108***	−0.400	−0.884
2019	−0.375**	−0.283	−0.321*	−0.833***	−0.536	−1.398**
2020	−0.724***	−0.668***	−0.690***	−1.364***	−0.727	−0.717
2021	−0.527***	−0.454**	−0.478***	−1.234***	−0.600	−0.250
2022	−0.406**	−0.299	−0.319*	−0.875***	−0.599	−0.951
2023	−0.461**	−0.301	−0.355*	−0.960***	−0.624	−1.373**
Constant	3.217***	5.204***	−2.961***	−1.467**	−2.969***	0.307
N (N groups)	1,575(710)	1,575(710)	1,575(710)	1,575	1,575	1,575
Pseudo R ²	0.3096	0.1288	0.4085	0.1406	0.2220	0.2753

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Quantile Regression models are estimated via non-parametric bootstrapping with 500 replications.

To disentangle whether the responsible behavior is driven purely by capital allocation or by direct executive leadership, we restrict our focus to the subsample of family-controlled

organizations ($N = 1,575$ observations across 710 distinct firms). This allows us to isolate the specific effect of having a family member occupying the executive suite (family CEO).

Table 5 details the econometric estimations for this internal governance mechanism across six alternative models. Following our established empirical path, we report standard RE and FE baselines (Columns 1 and 2), our primary GEE Mundlak specification to purge time-invariant correlated bias (Column 3), and the panel QR layout at the 10th, 50th, and 90th percentiles to map executive discretion across different pollution intensities (Columns 4, 5, and 6).

As can be seen in Table 5 the GEE Mundlak framework (Column 3) once again demonstrates superior empirical fitness for the family firm subsample. The unobserved within-firm averages for scale (Mean Size = 0.090, $p < 0.01$) and physical infrastructure changes (Mean Δ Fixed assets = 0.049, $p < 0.01$) are highly significant. This statistical pattern confirms that unobserved structural variance remains correlated with corporate covariates inside the family enterprise cluster, rendering uncorrected RE (Column 1) biased and validating the Mundlak strategy as the mathematically consistent framework to isolate executive effects.

Under the primary Mundlak baseline (Column 3), the presence of a Family CEO yields a negative and statistically significant impact on absolute carbon footprints ($\beta = -0.344$, $p < 0.05$). Translating this coefficient into economic magnitude, the appointment of an internal family executive is associated with an average 29.1% reduction in greenhouse gas emissions $[(e^{-0.344}-1)*100]$ compared to family firms managed by an external, non-family professional. This result, therefore, supports our Hypothesis 2a, which posited that among family firms, those managed by a family CEO exhibit lower levels of GHG emissions than those managed by a non-family CEO.

Crucially, contrasting this with our full-sample results reveals an important institutional nuance: the executive coefficient ($\beta = -0.344$) is smaller in absolute magnitude than the generic family ownership coefficient ($\beta = -0.548$ from Table 4). This economic differential implies that decarbonization in family firms is not exclusively an operational mandate imposed top-down by family executives. Instead, a substantial portion of the associated effect stems from broader institutional factors, such as embedded organizational culture, cross-generational stewardship values, and collective family board oversight, that constrain or guide managerial actions regardless of the specific CEO identity.

Finally, the most striking empirical revelation emerges from the panel QR (Columns 4–6), which indicate that the environmental efficacy of a family CEO is highly asymmetric:

- For clean or low-emitting family enterprises ($\tau = 0.1$), the executive coefficient is negative but fails to reach statistical significance ($\beta = -0.261$, $p = 0.125$).
- At the conditional median ($\tau = 0.5$), the effect becomes statistically binding, proving that a family CEO drives a 34.2% carbon contraction ($\beta = -0.418$, $p < 0.01$).
- At the extreme pollution boundary ($\tau = 0.9$), the family CEO coefficient drops to a massive -1.359 ($p < 0.01$). In terms of real economic magnitude, this implies an outstanding 74.3% reduction $[(e^{-1.359}-1)*100]$ in absolute carbon emissions for the heaviest polluters when a family member leads the executive suite.

From an economic and agency theory perspective, this extreme behavior demonstrates that family CEOs use their superior managerial discretion and lower alignment costs to execute sweeping, costly, and structurally complex environmental turnarounds, primarily when the firm faces an environmental crisis or heavy regulatory exposure. This pattern strongly confirms the frameworks of Kraiczy et al. (2015): when family wealth concentration matches internal executive execution, firms avoid the classic principal-agent friction, facilitating aggressive capital deployment toward eco-innovations.

Conversely, when a non-family CEO is introduced into a high-pollution family firm, agency conflicts often surface; external managers, focused on short-term financial performance metrics, are less willing to sacrifice immediate liquidity for long-term carbon mitigation investments, which aligns with the governance frictions described by Borsuk et al. (2024). These results, therefore, also support our Hypothesis 2b, which posited that the environmental effect of family management is stronger among highly polluting firms, where environmental challenges require more intensive managerial intervention and long-term strategic decision-making.

The behavior of the corporate controls inside the family firm subsample highlights distinct operational challenges. Unlike the full sample where age was mostly neutral, inside family firms, age exerts a positive and highly significant effect on emissions at the lower ($\tau = 0.1$, $\beta = 0.372$, $p < 0.05$) and median percentiles ($\tau = 0.5$, $\beta = 0.292$, $p < 0.01$). Economically, this indicates that older family firms suffer from a structural carbon penalty during normal operations. This dynamic reflects technological lock-in and traditionalist inertia. As family firms mature across generations, their internal routines often become rigid, creating strong resistance to altering legacy manufacturing practices or updating operational frameworks. This pattern supports the evidence from Liu et al. (2017), who found that high family involvement in aging organizations can constrain proactive innovation, leading to a larger environmental footprint due to delayed capital modernization. Furthermore, this lifecycle inertia is structurally reinforced by financial constraints. Long-established family firms frequently maintain conservative, closed capital structures to avoid dilution of family control, relying heavily on internal cash generation or restrictive banking lines. This capital configuration makes it much harder to fund heavy, long-term sustainability investments (Serrasqueiro et al., 2016). This dynamic is empirically confirmed by the positive and significant effect of Leverage at the median threshold ($\tau = 0.5$, $\beta = 0.073$, $p < 0.01$), indicating that high debt burdens actively drain the free cash flow required to execute green transitions, leaving managers economically constrained.

3.3. Nexus between GHG emissions and profitability

To examine the economic-environmental nexus and explore the potential alignment between eco-efficiency and accounting returns, we evaluate the systematic association between GHG emissions and profitability (ROA). Table 6 reports the empirical estimates for the full sample across five distinct specifications. Columns 1 and 2 present the baseline static panel models using RE and FE setups. Furthermore, to explore whether this relationship exhibits distributional heterogeneity across different performance boundaries, Columns 3, 4, and 5 present the panel QR estimates at the 10th ($\tau = 0.1$), 50th ($\tau = 0.5$), and 90th ($\tau = 0.9$) conditional percentiles of the distribution.

Although the formal Hausman specification test ($p = 0.6348$) does not statistically reject the consistency of the RE estimator, we select the FE model (Column 2) as our primary baseline for causal inference. This choice is guided by the severe divergence in the core carbon coefficient between the RE ($\beta = -0.004$, $p < 0.01$) and FE ($\beta = 0.001$, non-significant) setups. This empirical discrepancy reveals that cross-sectional RE estimates suffer from omitted variable bias driven by unobserved time-invariant firm factors, which are properly neutralized within the FE design.

The non-significant coefficient under the primary FE model provides a critical economic insight: within-firm variations in carbon emissions do not exert an immediate financial penalty or premium on short-term operating returns. Economically, this neutrality suggests that the capital expenditure required to execute carbon reductions features a long gestation period, meaning their accounting

returns do not manifest immediately in current-year ROA. Short-term compliance costs are balanced by structural efficiencies, resulting in a net neutral operational impact.

Table 6. The nexus between GHG emissions and economic profitability.

ROA	(1)RE	(2)FE	(4)QR (0.1)	(5)QR (0.5)	(6)QR (0.9)
Independent variable					
GHG emissions	−0.004***	0.001	−0.003***	−0.003***	−0.004***
Control variables					
Family firm	0.008	omitted	0.005***	0.005	−0.001
Sales	0.012***	0.014***	0.009***	0.010***	0.012***
Δ Fixed assets	0.001	0.001	0.001	−0.000	0.004
Sales growth	0.022**	0.019**	0.019*	0.039***	0.056***
Firm age	−0.013***	0.001	−0.004	−0.019***	−0.020***
Leverage	−0.005***	−0.005***	−0.002**	−0.004***	−0.006***
Year dummies					
2015	0.007	−0.000	0.012	0.012	0.023
2016	−0.013	0.006	0.009	0.019	0.063***
2017	−0.006	−0.012	−0.001	0.010	0.037***
2018	0.005	−0.003	−0.009	0.015	0.047***
2019	0.003	−0.004	0.007	0.012	0.042***
2020	−0.004	−0.010	−0.002	0.012	0.035***
2021	−0.004	−0.014	−0.000	0.005	0.037***
2022	0.002	−0.012	0.002	0.017*	0.046***
2023	0.023*	0.010	0.013	0.033***	0.074***
Constant	0.028	−0.051	−0.025*	0.036**	0.074**
N (N groups)	2,087(912)	2,087(912)	2,087	2,087	2,087
Pseudo R ²	0.0803	0.0459	0.0346	0.0564	0.0792

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Quantile Regression models are estimated via non-parametric bootstrapping with 500 replications.

Conversely, the panel QR (Columns 3–5) reveal a consistently negative and highly significant carbon coefficient ($\beta = -0.003$ to -0.004 , $p < 0.01$) across all profitability thresholds. In terms of economic magnitude, since emissions are log-transformed and are expressed as a ratio, a 10% reduction in absolute GHG emissions is associated with a stable cross-sectional increase of approximately 0.03 to 0.04 percentage points in ROA across the entire profitability distribution.

Rather than indicating a direct short-term causal mechanism, this homogeneous negative association reflects a structural “managerial capability” effect. Cross-sectionally, inherently well-managed, highly disciplined manufacturing firms possess both organizational resources to optimize operational efficiency (leading to lower carbon footprints) and the strategic capacity to maximize commercial returns (leading to higher ROA) simultaneously, supporting win-win frameworks (Orlitzky et al., 2003; Gallizo-Larraz et al., 2024).

Regarding the explanatory power of our models (R^2) we acknowledge that it is relatively low. However, this pattern is highly standard when modeling corporate profitability ratios (ROA) via panel

data, where short-term accounting variance is heavily driven by unobserved competitive shocks, specific asset mixes, and qualitative strategic shifts. Our primary focus remains on obtaining consistent, unbiased within-firm estimators, which the FE model achieves by eliminating unobserved firm-level heterogeneity.

Finally, the control vectors behave in strict alignment with corporate finance theory: commercial scale (sales) and market demand expansions (sales growth) act as positive drivers of profitability due to economies of scale and operational leverage. Conversely, financial risk (Leverage) exerts a consistent negative drag on ROA across all models, reflecting how debt-servicing outlays compress operating margins.

To uncover the governance mechanisms driving the carbon-profitability nexus, we replicate our baseline estimations by splitting the sample into two distinct institutional clusters: family-controlled firms ($N = 1,575$) and non-family firms ($N = 512$).

Tables 7 and 8 report the empirical outcomes for the family and non-family cohorts, respectively. For both subsamples, Columns 1 and 2 present the static baseline models (RE and FE), while Columns 3, 4, and 5 outline the panel QR trends across the 10th, 50th, and 90th percentiles of the respective ROA distributions

Table 7. The nexus between GHG emissions and economic profitability in family firms.

ROA	(1)RE	(2)FE	(4)QR (0.1)	(5)QR (0.5)	(6)QR (0.9)
Independent variable					
GHG emissions	-0.005***	0.001	-0.003***	-0.004***	-0.004**
Control variables					
Sales	0.013***	0.015***	0.010***	0.010***	0.010***
Δ Fixed assets	0.001	0.001	0.001	0.001	0.002
Sales growth	0.037***	0.034***	0.026***	0.045***	0.062***
Firm age	-0.0175***	0.004	-0.008**	-0.020***	-0.025***
Leverage	-0.006***	-0.005**	-0.003**	-0.006***	-0.008***
Year dummies					
2015	0.004	-0.000	-0.005	0.008	0.005
2016	0.007	0.002	-0.003	0.009	0.044*
2017	-0.001	-0.004	-0.013	0.003	0.024
2018	0.001	-0.006	-0.015	0.007	0.032*
2019	0.013	0.008	-0.007	0.008	0.038**
2020	0.010	0.008	-0.008	0.016*	0.032**
2021	-0.001	-0.006	-0.013	0.003	0.029*
2022	0.009	-0.002	-0.006	0.017**	0.040***
2023	0.031***	-0.021	-0.001	0.034***	0.072***
Constant	0.037*	-0.081	-0.008	0.046***	0.090***
N (N groups)	1,575(710)	1,575(710)	1,575(710)	1,575(710)	1,575(710)
Pseudo R ²	0.1191	0.0624	0.0450	0.0707	0.0897

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Quantile Regression models are estimated via non-parametric bootstrapping with 500 replications.

Table 8. The nexus between GHG emissions and economic profitability in non-family firms.

ROA	(1)RE	(2)FE	(4)QR (0.1)	(5)QR (0.5)	(6)QR (0.9)
Independent variable					
GHG emissions	−0.002	0.001	−0.001	−0.002	−0.002
Control variables					
Sales	0.009***	0.009*	0.006**	0.009***	0.013***
Δ Fixed assets	−0.018	−0.035**	0.005	−0.003	0.013
Sales growth	0.008	0.007	0.001	0.020	0.035
Firm age	0.001	0.004	0.000	−0.010	−0.015*
Leverage	−0.003*	−0.005*	−0.002	−0.003*	−0.004**
Year dummies					
2015	0.007	−0.004	0.016	0.039	0.052
2016	0.026	0.021	0.021	0.038	0.048
2017	−0.017	−0.023	0.006	0.030	−0.006
2018	0.014	0.012	0.002	0.032	0.023
2019	−0.018	−0.020	0.002	0.025	0.002
2020	−0.038	−0.044	−0.004	0.009	−0.013
2021	−0.009	−0.027	0.004	0.023	0.028
2022	−0.014	−0.033	−0.009	0.017	0.021
2023	0.001	−0.015	0.018	0.032	0.028
Constant	0.013	−0.001	−0.022	0.001	0.035
N (N groups)	512(204)	512(204)	512(204)	512(204)	512(204)
Pseudo R ²	0.0566	0.0431	0.0311	0.0376	0.0772

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Quantile Regression models are estimated via non-parametric bootstrapping with 500 replications.

Methodological diagnostics confirm that omitted variable bias affects the sub-cohorts differently. For family-controlled enterprises (Table 7), the statistical shift in the carbon footprint coefficient between the RE model ($\beta = -0.005$ $p < 0.01$) and the primary FE setup ($\beta = 0.001$, non-significant) indicates that unobserved time-invariant characteristics (e.g., family values, stewardship culture) are strongly correlated with both carbon strategies and profitability. In contrast, non-family firms (Table 8) show no statistical sensitivity across any baseline specification, with the carbon coefficient remaining consistently flat and non-significant in both RE ($\beta = -0.002$) and FE ($\beta = 0.001$) settings.

The empirical comparison across Tables 7 and 8 yields two critical insights into how governance shapes environmental economics:

- **Universal Short-Term Neutrality:** Under the primary within-firm FE specifications (Column 2 in both tables), the carbon footprint coefficient is completely non-significant for both family and non-family sub-samples. This result confirms that short-term, year-to-year changes in carbon emissions do not mechanically alter current operating returns (ROA). This short-term neutrality applies regardless of the corporate governance structure.

- **The Cross-Sectional Contrast:** The QRs (Columns 3–5) reveal a striking institutional divide. For non-family firms, carbon performance captures zero statistical association with profitability at any point across the performance distribution. Conversely, family firms exhibit a

negative and highly significant carbon coefficient across the entire ROA distribution, from the lowest tier ($\tau = 0.1$: $\beta = -0.003$, $p < 0.01$) to the median ($\tau = 0.5$: $\beta = -0.004$, $p < 0.01$) and upper performance boundaries ($\tau = 0.9$: $\beta = -0.004$, $p < 0.05$).

In terms of economic magnitude, inside the family cohort, a 10% cross-sectional decrease in absolute carbon output maps to a stable increase of approximately 0.04 to 0.05 percentage points in profitability. The fact that this premium is statistically potent only within family firms confirms that carbon reduction is not an independent driver of short-term profitability. Instead, it serves as a visible symptom of superior internal management quality and long-term organizational discipline that is unique to family governance systems.

This asymmetrical pattern is highly consistent with the socioemotional wealth (SEW) framework (Berrone et al., 2010; Gómez-Mejía et al., 2010). Family owners are deeply committed to non-economic utilities, such as protecting the family reputation, building ties with local communities, and ensuring cross-generational continuity. These stewardship priorities incentivize family firms to build superior operational structures that naturally optimize resources. As a result, sustainability emerges as a structural characteristic of high-quality family management rather than an independent cause of profitability.

Over longer horizons, these proactive configurations generate real operational advantages. As argued by Homroy and Slechten (2019), systematic carbon reductions strengthen corporate reputation, build customer loyalty, lower compliance risk, and enhance long-term resource efficiency. These factors support structural profitability over time, even if they do not register in short-term, year-to-year ROA accounting variations. Consequently, our findings support hypothesis 3, which posited that lower levels of GHG emissions are positively associated with firm profitability.

3.4. Robustness checks: Propensity Score Matching procedure

To evaluate the structural integrity of our baseline empirical findings and mitigate potential endogeneity stemming from self-selection bias, this section implements a “doubly robust” estimation technique. We pair a PSM framework with our primary panel data specifications, forcing treated (family-governed) and control (non-family) organizations to be strictly comparable across observable dimensions.

Prior to estimating the regression models, the diagnostic properties of the Kernel matching procedure were verified. The probit model successfully estimated propensity scores within a well-defined region of common support. The global balancing tests (pctest) confirmed the high quality of the matching architecture (see Table A1 in the Supplementary Material for full variable-by-variable diagnostics), as the mean standardized bias was drastically reduced from 15.5% in the unmatched sample to a mere 4.3% in the matched sample, well below the conservative 5% threshold recommended in the econometrics literature. Furthermore, Rubin’s B statistic dropped from 39.9% to 9.2% (safely below the 25% critical limit), and the Pseudo- R^2 collapsed from 0.036 to 0.003. Crucially, the joint likelihood-ratio test of all covariates became completely statistically insignificant after matching (LR $\chi^2 = 5.86$, $p = 0.320$), indicating that systematic differences between the treatment and control groups were effectively eradicated. At the individual level, key confounding variables such as firm size (Ln Sales) and leverage exhibited a substantial bias reduction of 88.5% and 88.0%, respectively, with their post-matching t-tests confirming no significant differences between family and non-family counterparts ($p = 0.335$ and $p = 0.683$).

Table 9 outlines the empirical results derived from the PSM-weighted sample. Column 1 implements the Mundlak specification to test absolute GHG emissions. Columns 2 and 3 evaluate corporate economic profitability (ROA) using matched RE (via GEE) and FE panel setups, respectively.

Table 9. Robustness checks using PSM Kernel weights.

Variables	(1) GHG Emissions Mundlak	(2) ROA Random Effects	(3) ROA Fixed Effects
Independent variable			
Family firm			
GHG emissions	−0.384**	−0.003**	−0.002
Control variables			
Sales	0.065**	0.011***	0.010***
Δ Fixed assets	−0.008	0.000	0.000
Sales growth	−0.043	0.031**	0.027**
Firm age	−0.002	−0.000	0.001
Leverage	0.032**	−0.005***	−0.007***
Mundlak means	Included	Not Applicable	Not Applicable
Year fixed effects	Included	Included	Included
Constant	−2.770***	0.017	0.020
N (N groups)	2,087 (912)	2,087 (912)	2,087 (912)

Notes: Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Column 1 uses GEE with a Gaussian family and identity link to estimate the Mundlak specification with PSM probability weights. Column 2 uses GEE with an exchangeable correlation matrix and robust standard errors. Column 3 utilizes the fixed-effects panel estimator with PSM analytical weights.

In terms of economic magnitude, treating this matched parameter as a semi-elasticity reveals that family ownership drives a net 31.9% absolute carbon reduction $[(e^{-0.384}-1) \times 100]$. This confirms that even when forcing family and non-family firms to be strictly comparable in terms of size, age, and capital structure, and after controlling for unobserved time-invariant heterogeneity through the Mundlak framework, family ownership exerts a significant mitigating effect on corporate carbon footprints. Regarding the control variables, firm size and leverage display positive and significant coefficients, suggesting that larger scale and higher debt levels are structurally associated with greater emission volumes.

Columns 2 and 3 confirm the asymmetric, non-causal nature of our carbon-profitability nexus under strict matching conditions. In the matched RE GEE framework (Column 2), which balances inter-firm and intra-firm variance, the total carbon footprint retains a negative and significant relationship with profitability ($\beta = -0.003$, $p = 0.049$). This indicates that a 10% lower cross-sectional carbon footprint maps to a 0.03 percentage point advantage in baseline ROA, validating that overall eco-efficiency tracks structural competitive advantages. Crucially, when shifting to the matched within-firm FE specification (Column 3), the carbon performance coefficient drops in magnitude and completely loses statistical significance ($\beta = -0.002$, $p = 0.677$).

This consistent lack of significance in the matched within-estimator confirms our baseline narrative. Short-term, year-over-year operational drops in carbon emissions do not yield immediate accounting rewards or cash penalties in current ROA. Instead, corporate carbon performance acts as a

long-term structural differentiator. It reflects underlying management quality and strategic discipline rather than serving as an exogenous tool to manipulate short-term profitability.

Therefore, the results allow us to corroborate all our working hypotheses.

Finally, for methodological consistency, subsample analyses (disaggregating family firms by CEO type) were excluded from the PSM framework. Because the family firm variable becomes a constant within these subsamples, matching on ownership structures is mathematically redundant. The baseline sub-estimations are therefore considered robust under their original specifications.

4. Conclusions

This study examines how family ownership, family management and carbon emissions jointly shape the environmental and financial performance of manufacturing firms. By using advanced panel methodologies, specifically GEE Mundlak corrections and panel QR across an exhaustive dataset from Spain's carbon footprint registry, the findings contribute to the literature by explaining why governance structures influence corporate decarbonization and why environmental improvements do not necessarily translate into immediate accounting returns.

Building on this contribution, the study advances the green finance literature in three main respects. First, it demonstrates that ownership heterogeneity influences not only financial outcomes but also corporate carbon performance. Second, it shows that family CEOs exert their strongest environmental influence precisely among the highest-emitting firms. Third, it reconciles the apparent contradiction between environmental improvement and profitability by distinguishing between short-term within-firm dynamics and long-term cross-sectional organizational capabilities.

First, our findings validate the existence of a substantial environmental advantage embedded within family governance structures.

Family-controlled firms exhibit substantially lower carbon footprints than comparable non-family firms, and this relationship remains robust across alternative specifications, including PSM.

Our evidence complements Zheng et al. (2024), who show that ownership structure moderates financial relationships in the banking sector. Unlike their study, which focuses on financial intermediation, our findings show that ownership heterogeneity also shapes corporate decarbonization strategies in manufacturing firms, thereby extending the ownership literature to the domain of carbon emissions and environmental performance.

The stronger environmental performance of family firms can be interpreted through the socioemotional wealth perspective. Families have stronger incentives to preserve transgenerational reputation, maintain legitimacy within local communities, and protect the long-term survival of the business. These objectives reduce short-term managerial pressures and facilitate investments in cleaner technologies despite their long payback periods.

Second, this study uncovers the critical role of executive identity as an internal catalyst. Within the family firm cohort, direct executive leadership by a family member drives an additional average 29.1% contraction in carbon footprints relative to family enterprises managed by external professionals. Crucially, our quantile profiles reveal that the environmental efficacy of a family CEO is highly asymmetric: the effect is negligible among low-emission firms but becomes substantially stronger, reaching a 74.3% reduction in emissions among the highest-emitting firms.

From an agency perspective, this reveals that when heavy environmental exposures or reputational crises threaten the organization, family CEOs effectively use their superior managerial

discretion, long-term operational horizons, and lower principal-agent alignment frictions to execute sweeping, capital-intensive eco-innovations that external, short-term oriented managers are structurally hesitant to undertake.

Third, our analysis of the carbon-profitability nexus calls for a more nuanced understanding. Within-firm FE designs confirm that short-term, year-to-year operational reductions in GHG emissions exhibit no contemporaneous effect on ROA. This indicates that environmental capital allocations feature extended gestation periods that do not distort current-year accounting margins. This apparent neutrality does not imply that environmental investments lack economic value; rather, it suggests that their benefits unfold over longer time horizons.

Our findings are consistent with Bajwa et al. (2025), who argue that environmental improvements and economic performance should not be expected to evolve simultaneously. While they document that environmental and economic outcomes may follow different trajectories, our firm-level evidence shows that reductions in GHG emissions do not generate immediate improvements in economic profitability. This supports the view that decarbonization involves investments whose financial benefits materialize over longer horizons rather than within the current accounting period.

The absence of contemporaneous profitability effects is also compatible with the dynamic perspective proposed by Choi et al. (2025). Their analysis highlights that financial outcomes frequently emerge through lagged and interconnected causal processes rather than through immediate one-period responses. In this context, investments aimed at reducing emissions should be interpreted as long-term strategic decisions whose economic returns may only become observable after several years.

Several mechanisms may explain this result. First, environmental investments usually require substantial upfront expenditures that are recognized immediately, whereas efficiency gains, reputational benefits, and market advantages accumulate gradually. Second, accounting profitability captures only short-term operating performance and may therefore underestimate the longer-term value created through improved environmental practices.

Family ownership and family management not only influence firms' environmental behavior but also determine how environmental investments translate into financial outcomes over time. These results provide robust evidence that ownership heterogeneity is a key mechanism linking sustainability and corporate performance. Taken together, the evidence reinforces the importance that corporate decarbonization cannot be fully understood without considering governance structures.

These insights carry direct practical implications for multiple corporate stakeholders. For regulators and policymakers, the results demonstrate that generic environmental mandates should account for internal corporate governance structures. Since family firms possess natural socioemotional incentives to lower emissions, public policies should focus on providing technical support to overcome the structural, cross-generational technological lock-in observed in aging family organizations. While for institutional investors and ESG analysts, our findings warn against using simple, cross-sectional ESG metrics without deep governance context. A low carbon footprint should be interpreted not as an isolated operational victory, but as an indicator of robust, long-term management quality, particularly when backed by family governance stability.

Despite the econometric rigor applied, certain limitations pave the way for future scholarly inquiries. The dataset draws from a voluntary carbon footprint registry, which may introduce a self-selection bias toward environmentally conscious organizations. While our PSM architecture neutralized structural imbalances, future studies should evaluate these dynamics under fully mandatory disclosure regimes, such as the gradual roll-out of the European Sustainability Reporting Standards (ESRS). Although our

quantitative framework captures ownership and executive titles but leaves out rich, unobserved qualitative dynamics, including specific family generational successions, emotional family attachment levels, and exact internal compensation metrics. Finally, the empirical focus is restricted to Spanish manufacturing firms. Expanding the geographical scope to other European institutional frameworks or contrasting these patterns with capital-intensive service sectors would greatly enhance the generalizability of the proposed frameworks.

Author contributions

Jordi Moreno-Gené: Conceptualization, Methodology, Data Curation, Formal analysis, Validation, Writing-original draft, Writing-review & editing.

Laura Sánchez-Pulido: Conceptualization, Data Curation, Writing-original draft, Writing-review & editing.

José Luis Gallizo-Larraz: Writing-original draft, Writing-review & editing, Supervision, Funding acquisition.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflict of interest

All authors declare no conflicts of interest in this paper.

Data Availability Statement

Data available upon reasonable request.

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