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PDO certification and profitability in Spanish olive oil: a firm-level analysis

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Abstract

In an increasingly competitive global market, Protected Designation of Origin (PDO) quality schemes serve as vital strategic tools for product differentiation and regional economic sustainability. This study examines the impact of PDO certification on firm profitability by analyzing a unique panel dataset of 202 Spanish olive oil mills over the 2014–2022 period. Using the DuPont model and a random-effects regression, the analysis investigates how these quality labels influence financial performance and whether this effect varies according to firm size. The results show that PDO certification does not universally improve profitability; its benefits are most significant for smaller mills that leverage the label to achieve premium pricing and enhance consumer trust. Conversely, the positive effects diminish when certification is used primarily for volume-based competition without a clear quality signaling strategy. These findings provide critical insights for mill managers and regulatory councils, suggesting that the economic value of a PDO depends on its integration into a coherent, quality-focused marketing strategy. Furthermore, the results inform policymakers on the effectiveness of quality schemes as instruments for the economic sustainability of small-scale producers within rural development and Common Agricultural Policy frameworks.

Keywords: PDO certification, Olive oil industry, Firm profitability, Market differentiation, DuPont analysis, Panel data analysis

Introduction

Olive oil, one of the most emblematic products of Spanish agriculture, is facing increasing competition in the global market, exacerbated by globalization and the rise in product adulteration (Yang *et al.*, 2022). To differentiate themselves, producers increasingly rely on the Protected Designation of Origin (PDO) label, a certification that not only guarantees product quality but also links its characteristics to a specific geographic origin and local production conditions (Crupi, 2025). PDO Regulatory Councils play a crucial role in this process, as their mission is to ensure product authenticity, guarantee originality, proximity, and quality for consumers, while protecting against counterfeiting. Additionally, these bodies aim to enhance the international trade of certified products by increasing their market value (EUIPO, 2024).

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Despite these advantages, PDO certification is not without challenges. While the PDO label can enhance perceived value and improve access to competitive markets (Carrquiry & Bruce 2007; Suter et al. 2021), the number of Spanish olive mills affiliated with PDOs has shown a downward trend in recent years. Between 2017 and 2022, the absolute number of registered mills declined by 5.5%, reflecting growing reluctance to participate in PDO schemes despite their associated benefits (MAPA 2023a, b). This data contrast with the number of active oil mills in the sector, which increased during the same period (3,10%). Although PDO products could command higher prices than non-certified ones, some mills, particularly smaller ones, choose not to join these collective labels due to the associated costs or the perception that the certification does not provide a significant competitive advantage (Bhandari & Rodgers 2017; Barbosa et al. 2024). Therefore, the data reflect both the exit of some previously registered oil mills and the refusal of new companies to register.

Against this backdrop, the aim of this study is to assess whether PDO affiliation contributes to the profitability of Spanish olive oil mills. To this end, we conduct an empirical analysis combining the DuPont model with a random-effects model estimated via feasible generalized least squares (FGLS) applied to highly granular panel dataset of 202 olive mills for the period 2014–2022, both PDO-certified and non-certified, affiliated with nine of the most commercially relevant PDOs in Spain. The analysis also examines whether the impact of PDO certification differs by firm size, based on the hypothesis that smaller mills may benefit more from certification due to their limited capacity to build and promote their own brand identity. The results reveal that while no overall significant differences in profitability were found between PDO and non-PDO mills, some PDOs exhibit a positive effect on firm performance, particularly among smaller enterprises. These mills appear to benefit from the visibility and reputation associated with the PDO label, suggesting that in such cases, PDO certification may represent a valuable strategy to enhance competitiveness.

Although previous studies have explored the profitability of PDO schemes in other sectors (Sellers-Rubio & Más-Ruiz 2013; Moreno-Gené et al. 2026), research on the specific impact of PDO certification on olive oil mills remains limited (Iotti & Bonazzi 2023; García-Moral et al., 2025). This paper aims to fill this gap by providing a comprehensive analysis that contributes to the existing literature in three significant ways. First, it leverages an unprecedented level of granularity by using a unique longitudinal dataset of 202 individual firms over a nine-year period, moving beyond the aggregate regional data or qualitative case studies common in the field. Second, it systematically addresses the ‘size-effect gap’ by testing firm size as a moderating factor in the relationship between PDO affiliation and profitability. This provides crucial evidence for European policy-making, particularly regarding the economic sustainability of small-scale producers facing global price volatility. Third, by focusing on the world’s leading producer (Spain) the study applies the DuPont model to formally decompose the drivers of profitability (margin vs. turnover). This represents a methodological refinement that to the best of our knowledge, has not been previously explored in the context of olive oil PDOs, allowing us to identify the specific strategic mechanisms through which these quality schemes create economic value.

The remainder of the paper is structured as follows: Sect. “[Background](#)” reviews the background literature, highlighting the relevance and complexities of PDOs in the olive oil sector and establishing the context for the study. Sect. “[Methods](#)” describes the sample and methodology. Sect. “[Results and discussion](#)” presents the empirical results, and Sect. “[Conclusions](#)” discusses the conclusions and implications for olive oil producers.

Background

Olive oil, a fundamental product of agricultural activity, has traditionally been considered a low-technology sector (Barbosa et al. [2024](#)). However, in recent years, it has come under increasing scrutiny due to the rise in adulteration and fraud in global trade (International Olive Council [2021](#)). This phenomenon, combined with growing global competition, has pushed producers not only to anticipate market demand but also to adopt more innovative marketing and differentiation strategies (Skuras & Vakrou [2002](#); Sáiz & Zofío, [2022](#)). In this context, effective brand management has become one of the key strategies for market differentiation (Sellers-Rubio & Más-Ruiz [2013](#); Sáiz & Fernández [2012](#)). Producers can generally pursue two paths: investing in technological innovation or focusing on differentiation through specific product attributes that appeal to consumers (Skuras & Vakrou [2002](#)).

In 1992, the European Union enacted Regulation (EEC) No. 2081/92, establishing the legal framework for Protected Designations of Origin (PDOs) and Protected Geographical Indications (PGIs). These quality schemes constitute intellectual property rights that group together producers within a specific geographical area, aiming to guarantee the authenticity of agri-food products originating from the EU. Both labels ensure that certified products meet predefined quality standards. The key difference between a PDO and a PGI lies in the production process: While a PDO requires that all stages (production, transformation, and processing) occur within the designated area, a PGI only requires that at least one of these stages takes place in that region (Parra-López et al. [2015](#)).

Spain is the world leader in olive oil production, producing a total of 1,493,008 tons in the 2021–2022 season, representing approximately 28% of the country’s PDO-cultivated area (MAPA [2023a](#)). Despite this, the number of mills registered under a PDO has decreased from 385 in 2017 to 364 in 2022, representing a 5.5% decline in recent years. In terms of commercialization, only 2% of the olive oil produced in Spain is marketed under a PDO label (MAPA [2023b](#)), indicating that a significant share of producers opts not to participate in these collective schemes, despite their associated benefits.

Globally, olive oil ranks among the most protected products, with 127 PDOs and 29 PGIs registered worldwide (e-Ambrosia [2025](#)). Spain is the second country with the highest number of PDOs in the sector. In 2022, Spanish olive oil PDOs marketed 32,119 tons of oil, with an economic value of €157.51 million (MAPA [2023a](#)). The average market price of PDO-certified oils can significantly exceed that of non-certified oils, reinforcing the argument that PDOs can provide substantial added value to a product (Pappu et al. [2006](#); Ramón-Muñoz, [2020](#)).

Geographical origin labels have become essential tools for both consumer information and product differentiation, especially within the framework of the European Union’s agri-food promotion policies. Their strategic value, however, extends beyond the EU’s internal market. Menapace et al. ([2011](#)) analyze consumer preferences in the Canadian

olive oil market and find that willingness to pay increases not only with the product's country of origin but also with the presence of PGIs. Oils labeled with PDOs or protected PGIs command higher premiums compared to uncertified products from the same country. Although the evidence that consumers favor PDOs over PGIs is relatively weak, the findings nonetheless underscore the added value that origin certification can generate in international markets.

However, PDO membership is not uniformly valued by all producers. Some studies suggest that small firms benefit more from PDO affiliation, as it enables them to position their products in the market without having the resources to build a strong brand of their own (Benavente 2013; Deluze & Lanotte 2010; Sellers-Rubio et al. 2021). In contrast, larger companies often prefer to focus on developing and promoting their own brands, thereby reducing the relative impact of PDO membership on their profitability (Sáiz & Fernández 2012).

In line with this, Parra-López et al. (2015) argue that PDO adoption in the Andalusian olive oil sector is driven more by commercial strategy and territorial contagion effects than by differences in industrial practices or managerial profiles. Based on structured interviews with mill managers, their study concludes that while optimal industrial standards are already widely implemented in the region, PDO certification primarily serves as a market differentiation mechanism rather than a tool for operational improvement. This perspective supports the idea that the true value of PDOs lies in their strategic use as marketing instruments, particularly in contexts where product quality is already ensured.

However, some authors suggest that increasing globalization has led some producers to avoid PDO schemes due to the shared reputation risk that can be damaged by negative consumer perceptions (Bhandari & Rodgers 2017). A notable example is the PDO "Aceite de la Comunidad Valenciana", which decided to cease operations in 2022 due to difficulties in meeting its product specifications and was officially deregistered in 2024 (Navarro 2024). This case has fueled skepticism regarding the effectiveness and utility of PDOs for producers.

García-Moral et al. (2023) confirm that PDO certification adds value to olive oil products and boosts exports. However, they also note that the Spanish olive oil sector has not fully capitalized on the potential of this quality label, as a substantial portion of extra virgin olive oil (EVOO) is still marketed without PDO certification. This indicates a missed opportunity for the sector, where the link between certification and economic performance remains underexploited.

Methods

Sample

To analyze the impact of Protected Designations of Origin (PDOs) on the profitability of olive oil mills, a specific subsample was constructed for each selected PDO. This subsample incorporates economic and financial variables extracted from the SABI database (Iberian Balance Sheet Analysis System), developed by Bureau Van Dijk. SABI is recognized as one of the most authoritative sources of business information in Spain and is frequently used in academic research on Spanish firms (Casillas et al. 2024; Escamilla-Solano et al. 2024; Moreno-Gené et al. 2026).

To identify the active PDOs for olive oil in Spain, we consulted the annual report on PDOs, PGIs (Protected Geographical Indications), and TSGs (Traditional Specialties Guaranteed) for agri-food products, published by the General Sub-Directorate for Food Quality Control and Agro-food Laboratories of the Ministry of Agriculture, Fisheries and Food (MAPA 2023a), corresponding to the year 2022. According to this report, there were 28 PDOs and 2 PGIs in force for virgin olive oil in that year. Based on this information, the 10 most economically significant PDOs were selected using two objective criteria: the highest economic value in the destination market and the highest commercialized volume. These PDOs, listed in descending order by sales volume, are: Baena, Siurana, Estepa, Sierra de Cazorla, Sierra Mágina, Priego de Córdoba, Les Garrigues, Aceite del Bajo Aragón, Sierra de Segura, and Aceite de Lucena.

However, upon querying the SABI database, it was found that there were insufficient observations for the Sierra de Segura PDO to allow for robust estimations; thus, it was excluded from the analysis. The final study focused on 9 PDOs, which together represented 82.94% of the total Spanish economical value and 80.33% of the volume of PDO-certified olive oil marketed in 2022, underlining their relevance in the Spanish olive oil sector. The exclusion of the remaining smaller PDOs was necessary to ensure statistical robustness, as the limited number of registered firms in those regions did not provide sufficient observations for reliable econometric estimation. Consequently, the selection was driven by market representativeness and data feasibility, avoiding potential selection bias based on performance.

The identification of olive mills registered under each PDO was carried out through the websites of their respective Regulatory Councils, from which the tax identification number of each registered company was obtained. In total, 177 olive mills were identified across the 9 selected PDOs: 43 corporations, 130 cooperatives, and 4 individual proprietors. As the SABI database does not provide financial information on individuals, these were excluded, resulting in a target population of 173 companies.

Of these 173 companies, financial information was available in SABI for 131. It is worth noting that many cooperatives are not listed in this database, which explains main part of the discrepancy.

To identify mills not affiliated with any PDO, the relevant filters in SABI were applied to select all corporations and cooperatives whose main activity corresponds to olive oil production (CNAE code 1043). A total of 1,342 companies were retrieved. Subsequently, those registered under any of the 28 existing PDOs in Spain were excluded by cross-referencing with the records from all the Regulatory Councils. In parallel, an analysis of the territories covered by the 9 selected PDOs was conducted, identifying 132 companies that were not registered but were located in regions eligible for PDO inclusion.

As a result, the sample was composed of two groups:

Companies registered under one of the 9 selected PDOs.

Companies located within the geographical scope of those PDOs but chose not to register.

For each firm, data were collected for the 2014–2022 period. Outliers, such as companies with highly negative equity, were removed to avoid distortions in the results. The

final sample was structured as an unbalanced panel dataset, comprising a total of 1,067 observations corresponding to 202 companies: 105 registered under a PDO and 97 not registered.

Table 1 presents the number of registered olive mills per PDO, their legal form, the number of PDO and non-PDO companies included in each territorial subsample, as well as the representation percentage of each PDO within the overall sample. Almost all subsamples include data on over 50% of registered mills, with no case falling below 45%, ensuring adequate representativeness both globally and for each individual PDO. The PDOs with the highest representation in the sample are Baena and Sierra de Cazorla (each with more than 80% of their registered mills), followed by Les Garrigues (with 70%), further strengthening the empirical foundation of the study.

DuPont decomposition of Return on Assets

To assess the profitability of olive oil mills operating under different Protected Designations of Origin (PDOs) and to analyze the mechanisms through which profitability is generated, this study employs the DuPont decomposition of Return on Assets (ROA). Although originally developed within financial statement analysis, the DuPont framework has been increasingly adopted in applied economic research as a tool to disentangle the drivers of firm performance, particularly in empirical studies focused on efficiency, resource allocation, and competitive strategy (Fraser & Ormiston 2013; Soliman 2004; Altahtamouni et al. 2022).

Table 1 Distribution of companies registered under each PDO and their presence in the sample

| PDO | Total no. of registered mills ¹ | Legal form of registered mills | | | No. of registered mills in the sample | No. of non-registered mills in the sample | % of registered mills represented in the sample ² |
|------------------------|--|--------------------------------|--------------|------------------|---------------------------------------|---|--|
| | | Capital companies | Cooperatives | Sole proprietors | | | |
| Baena | 19 | 6 | 13 | | 17 | 8 | 89.47% |
| Siurana | 33 | 3 | 30 | | 17 | 9 | 51.52% |
| Estepa | 18 | 0 | 18 | | 10 | 14 | 55.56% |
| Sierra de Cazorla | 10 | 4 | 6 | | 8 | 8 | 80.00% |
| Sierra Mágina | 24 | 6 | 18 | | 11 | 10 | 45.83% |
| Priego de Córdoba | 18 | 13 | 5 | | 9 | 10 | 50.00% |
| Les Garrigues | 20 | 1 | 19 | | 14 | 9 | 70.00% |
| Aceite del Bajo Aragón | 28 | 9 | 15 | 4 | 15 | 5 | 53.57% |
| Aceite de Lucena | 7 | 1 | 6 | | 4 | 24 | 57.14% |
| Total | 177 | 43 | 130 | 4 | 105 | 97 | 59.32% |

¹ According to information from the respective Regulatory Councils

² Calculated as: (No. of registered mills in the sample/Total registered mills) × 100

Definition of ROA

Return on Assets is defined as the ratio of operating earnings to the total asset base of the firm. In line with the literature, ROA is computed using earnings before interest and taxes (EBIT), which isolates operating performance from financing and tax decisions:

$$ROA_i = \frac{EBIT_i}{A_i}$$

where $EBIT_i$ denotes operating earnings of firm i and A_i represents total assets.

ROA provides a comprehensive measure of firm profitability by capturing how efficiently a firm transforms its asset base into operating profits, and it is widely used in both economic and financial performance analyses (Moreno-Gené et al. 2026).

DuPont decomposition

Following the DuPont identity, ROA can be algebraically decomposed into two multiplicative components by multiplying and dividing by sales:

$$ROA_i = \frac{EBIT_i}{Sales_i} \times \frac{Sales_i}{A_i}$$

This decomposition yields:

$$ROA_i = Margin_i \times Turnover_i$$

where

$$Margin_i = \frac{EBIT_i}{Sales_i}$$

$$Turnover_i = \frac{Sales_i}{A_i}$$

The first component, **operating margin**, captures the firm's ability to generate operating profits from its sales and reflects pricing power, cost efficiency, and product differentiation. The second component, **asset turnover**, measures the efficiency with which the firm uses its asset base to generate revenue and is closely related to operational efficiency, scale, and resource utilization (Block et al. 2014; Fraser & Ormiston 2013).

Economic interpretation

From an economic perspective, the DuPont decomposition allows distinguishing between alternative sources of firm performance. Higher ROA may result either from superior margins—associated with differentiation strategies, branding, and value-added activities—or from higher asset turnover, reflecting efficiency-based strategies focused on scale, throughput, and rapid asset utilization. This distinction is particularly relevant in agro-food industries, where firms often face trade-offs between quality differentiation and cost efficiency (Burja & Mărginean 2014).

In the olive oil sector, previous studies have documented that commercialization strategies strongly influence these two dimensions. Montegut et al. (2002) show that a large share of olive oil mills sells their output in bulk, which tends to depress prices

and operating margins. Conversely, Sepúlveda et al. (2020) find that the olive oil sector exhibits relatively high asset turnover compared to the broader food industry, indicating efficient use of productive assets.

Application to PDO certification

Applying the DuPont framework in this study enables an explicit assessment of whether PDO certification is associated with a shift in the underlying drivers of profitability. PDO affiliation may encourage firms to adopt differentiation-oriented strategies, such as bottled, branded, and direct-to-consumer sales, which are expected to positively affect operating margins. At the same time, PDO-related investments may alter asset structures and operational processes, with ambiguous effects on asset turnover.

Prior research suggests that differences between PDO and non-PDO firms are not necessarily structural in terms of production technology, but rather stem from more advanced marketing, positioning, and value-creation strategies (Parra-López et al. 2015). The DuPont decomposition provides an appropriate empirical framework to test this hypothesis by examining whether PDO membership is associated with higher margins, improved asset turnover, or both.

Overall, the DuPont model offers a parsimonious yet economically meaningful approach to analyzing firm profitability, allowing the identification of the specific channels through which PDO certification may influence performance in the olive oil sector.

Regression model

To analyze the effect of PDO affiliation—both in general and for each specific PDO—on firm profitability, the following regression model has been estimated. This model has been applied both to the full sample and to each individual subsample.

Dependent variable

The selected dependent variable is the firm's economic profitability, measured through the Return on Assets (ROA), calculated as earnings before interest and taxes (EBIT) divided by total assets. This ratio reflects how efficiently a firm uses its resources to generate earnings and is particularly useful for analyzing productivity and competitiveness, both longitudinally and comparatively (Wahlen et al. 2022). ROA has been widely used in studies on the agri-food sector (Grau & Reig 2015; Gallizo et al. 2019; Neves et al. 2022; Moreno-Gené et al. 2026; Zikovic et al. 2025), reinforcing its suitability as the central indicator in this analysis.

Explanatory variable

The main explanatory variable is a binary dummy (PDO), taking the value 1 if the firm is registered under one of the nine selected PDOs, and 0 otherwise. Given that the Spanish olive oil sector shows relatively low profitability compared to other sectors, it is relevant to investigate whether PDO certifications contribute to improving these results. According to Sepúlveda et al. (2020), distributing companies, often associated with PDO registration due to the requirement of selling bottled and labeled products, tend to have higher ROA than exporters. Various studies indicate that certification may raise the product's selling price due to higher perceived value among consumers (Ribeiro &

Santos 2004; Sáiz & Fernández 2012). Consequently, a positive relationship between PDO affiliation and ROA is expected.

However, previous research in other sectors has shown that not all PDOs yield the same impact on profitability (Sellers-Rubio & Más-Ruiz 2013; Moreno-Gené et al. 2026), justifying the need to examine each PDO individually.

Control variables

- **Cooperative:** A binary variable that equals 1 if the firm is legally organized as a cooperative, and 0 if it is a capital company (either public or limited). This variable captures potential profitability differences related to governance structure. According to Property Rights Theory, cooperatives pursue different objectives in terms of profit distribution compared to capital firms, typically favoring a more collectively oriented market logic (Marcos et al., 2013). Empirical evidence from other agri-food sectors suggests that this governance structure may be associated with lower levels of economic profitability. However, there is limited empirical evidence on whether these patterns hold in the olive oil sector, making its inclusion particularly relevant in this context.
- **Firm Size:** Measured through total assets of the previous year. The use of total assets as a proxy for firm size in profitability models based on ROA is common in the economic literature (Demsetz & Lehn 1985; Goddard et al. 2005; Lee 2009), and has been widely applied in empirical studies analyzing firm performance in the agri-food sector (Grau & Reig 2015; Gallizo et al. 2019; Zikovic et al. 2025). However, to prevent any potential mechanical correlation or endogeneity, since ROA includes total assets in its denominator, we use the lagged value of total assets ($Assets_{i,t-1}$) instead of the contemporaneous one. This ensures that the independent variable and the denominator of the dependent variable do not belong to the same period, effectively breaking the algebraic identity. This approach is a standard procedure in empirical corporate finance and agricultural economics to mitigate simultaneity bias and mechanical correlation between performance ratios and their components (Reed 2015; Wooldridge 2010).

To ensure comparability across the study period and to account for inflationary effects, all monetary values were deflated and expressed in real terms (constant prices) using the Spanish Consumer Price Index (CPI) provided by the National Statistics Institute (INE), with 2021 as the base year (2021=100). This specification addresses both potential endogeneity by definition and ensures that firm size reflects the real economic scale of olive oil mills. Due to its highly skewed distribution, reflecting the coexistence of small and large mills, the variable has been log-transformed to reduce dispersion and enhance econometric interpretability.

The relationship between firm size and profitability has been widely debated in the economic literature, mainly in sectors other than olive oil, where firms differ substantially in terms of scale, resources, and market orientation. On the one hand, the Theory of Economies of Scale suggests that larger firms may benefit from cost reductions, stronger bargaining power, and greater capacity to access external markets or invest

in innovation (Sellers & Alampi-Sottini 2016; Hirsch & Hartmann 2014). On the other hand, empirical evidence from various industries indicates that size does not always translate into higher profitability, particularly in traditional or highly regulated agri-food sectors (Sepúlveda et al. 2020; Inga et al., 2017; Zouaghi et al. 2017). In the case of the olive oil industry, and especially in Spain, empirical analyses addressing this relationship remain scarce, which reinforces the exploratory and contributive nature of this control variable within the present study.

- **Age:** Calculated as the difference between the year of observation and the firm's founding year, and log-transformed to reduce skewness. Age is a common control variable in agri-food profitability studies (Neves et al. 2022; Cardil et al. 2023; Moreno-Gené et al. 2026). Older firms may benefit from market consolidation, operational experience, and organizational efficiency, along with enhanced reputation. However, older firms may also be less adaptable to dynamic environments like the olive oil industry, potentially limiting innovation and profitability (Loderer et al. 2016).
- **Growth:** Firm growth is measured as the annual rate of sales growth, calculated as the percentage change in operating revenues between two consecutive years. This variable captures the firm's expansion dynamics and reflects changes in market penetration, production capacity, and commercial strategy. Growth is frequently included as a control variable in profitability models (Grau & Reig 2015; Gallizo et al. 2019; Cardil et al. 2025; Zikovic et al. 2025), as expansion processes may have heterogeneous effects on firm performance depending on managerial capabilities, organizational structure, and sectoral characteristics.

From a theoretical perspective, firm growth can have ambiguous effects on profitability. On the one hand, growth may enhance profitability if it allows firms to exploit economies of scale, increase market power, or improve capacity utilization. On the other hand, poorly managed or excessively rapid growth may generate inefficiencies, increasing operational complexity, coordination costs, and financial pressure, particularly in traditional agri-food industries where production is subject to seasonal constraints and price volatility (Misangyi et al. 2006). Moreover, growth often requires upfront investments in working capital, marketing, or distribution channels, whose returns may materialize only in the medium or long term, thereby exerting a short-run negative effect on accounting profitability measures such as ROA.

In the olive oil sector, these trade-offs may be especially pronounced due to the coexistence of small, locally oriented mills and larger firms engaged in national or international markets. Expansion strategies, such as increasing bottled sales, entering new distribution channels, or scaling up production, may temporarily reduce profitability if they are not accompanied by proportional efficiency gains. Consequently, no a priori directional hypothesis is proposed for the Growth variable, and its inclusion as a control variable allows the empirical assessment of whether expansion dynamics are associated with higher or lower ROA, as well as whether this relationship differs between PDO and non-PDO firms.

Moderating variable: PDO × Firm size

This interaction term is constructed by multiplying the PDO dummy by the lagged firms size ($\text{LnAssets}_{i,t-1}$). It aims to capture a moderating effect of firm size on the relationship between PDO affiliation and ROA. In other words, it examines whether the impact of PDO certification on profitability varies according to the initial scale of the firm. By using the lagged value for this interaction, we ensure that the moderating effect is estimated independently of the contemporaneous components of the ROA, thus avoiding the risk of mechanical correlation pointed out in the econometric literature.

The theoretical rationale rests on the differential behavior of firms depending on their financial capacity and market positioning (Benavente 2013). In agri-food markets, especially for experience goods like olive oil, brand reputation and advertising play a key role in consumer decision-making (Sellers-Rubio et al. 2021). PDO firms often collaborate in promotion and marketing, using the collective mark as a shared visibility tool (Loureiro & McCluskey, 2000; Maratte, 2005). However, the extent to which this collective mark is leveraged depends on firm size. Smaller firms, with limited resources, rely more heavily on the PDO for differentiation, whereas larger firms complement it with strong individual branding (Deluze & Lanotte, 2010). As firm reputation increases, dependence on the PDO decreases (Sellers-Rubio et al. 2021).

Thus, the positive effect of PDO affiliation on profitability is expected to be more pronounced for smaller firms, who benefit more from the collective brand's added value. In contrast, for larger firms, the marginal benefit may be lower due to existing strategic assets. This variable allows for the evaluation of whether PDO certification serves as an especially effective profitability lever for small olive oil mills, an insight with significant implications for rural development policies and support strategies targeting small producers.

Table 2 presents all explanatory variables included in the econometric models, along with their definitions, nature, and expected relationship with the dependent variable (ROA).

Consequently, the proposed econometric model takes the following form:

$$\text{ROA}_{it} = \alpha + \beta_1 \text{PDO}_{it} + \beta_2 \text{Cooperative}_{it} + \beta_3 \text{Firm Size}_{it} + \beta_4 \text{Age}_{it} + \beta_5 \text{Growth}_{it} + \beta_6 \text{PDO}_{it} * \text{FirmSize}_{it} + \varepsilon_{it}$$

where “ i ” corresponds to the respective olive mill ($i = 1, 2, 3 \dots$ total number of mills in each subsample), “ t ” represents the time period ($t = 2014, 2015, \dots, 2022$); $\beta_1, \beta_2, \dots, \beta_6$ are the parameters to be estimated, and ε_{it} represents the error term.

Table 2 Variables included in the econometric model

| Variable | Description | Expected sign |
|-----------------|---|---------------|
| PDO | Dummy variable that takes the value 1 if the olive mill is registered under a designation of origin, and 0 otherwise | + |
| Cooperative | Dummy variable that takes the value 1 if the company is a cooperative, and 0 if it is a corporation (limited or public) | – |
| Firm size | Natural logarithm of total assets of previous year in current prices | + / – |
| Age | Natural logarithm of the number of years since the company was founded | + / – |
| Growth | (Current period sales/previous period sales)-1 | + / – |
| PDO × Firm size | Interaction between PDO membership and the logarithm of total assets | – |

The relationship between ROA and the set of independent variables has been estimated using a panel data methodology, which is widely used in empirical research to control for unobservable heterogeneity and to exploit both temporal and cross-sectional variation (Firebaugh et al. 2013). The data were structured as an unbalanced panel, as the number of observations per firm varies over the 2014–2022 period due to firm entries, exits, or gaps in financial reporting. The chosen estimation methods are designed to handle such unbalanced structures efficiently without introducing bias, provided the missing data are not correlated with the error term.

In order to determine the most appropriate estimation technique, the Breusch–Pagan Lagrange Multiplier test was applied to both the full sample and the subsamples. In all cases, the test rejected the null hypothesis of constant variance ($p < 0.05$), suggesting that the random-effects model (REM) is more efficient than the ordinary least squares (OLS) model. Furthermore, we performed the Hausman test to compare REM and FEM; the results failed to reject the null hypothesis, indicating that REM provides consistent and more efficient estimates. It is also important to note that the fixed-effects model (FEM) would be unsuitable for this study's primary objective, as the main independent variable (PDO certification) is time-invariant and would be omitted in a fixed-effects specification. Consequently, the models were estimated using REM via Feasible Generalized Least Squares (FGLS).¹ The statistical processing was carried out using Stata software.

Results and discussion

DuPont analysis

Table 3 presents the average values of economic profitability (EBIT/Assets), operating margin (EBIT/Sales), and asset turnover (Sales/Assets) for each subsample, distinguishing between firms registered under each of the Protected Designations of Origin (PDOs) analyzed and those not registered but located within the same designated geographical area. Additionally, the statistical significance of the observed differences between both groups is indicated.

Following the DuPont analysis approach, profitability is broken down into its two key components (margin and turnover), allowing for the identification of whether differences in profitability are due to value generation strategies (margin) or efficiency in asset utilization (turnover).

The average levels of economic profitability across the various groups range from a minimum of –3% to a maximum of 6.5%, reflecting generally low profitability. This finding aligns with previous studies that highlight how the olive oil sector in Spain tends to show lower profitability levels than the food industry as a whole (Sepúlveda et al. 2020).

In aggregate terms, the profitability differences between registered mills (average of 2.41%) and non-registered mills (2.33%) are relatively small, although not consistent across all PDOs. This points to a high degree of heterogeneity in the impact of certification on profitability. Such variability highlights the relevance of specific factors, such as

¹ The variance components of the Random Effects model were estimated using the Swamy–Arora method (Swamy & Arora 1972), which is particularly suitable for unbalanced panels. This method provides consistent estimates of the idiosyncratic (σ_e^2) and individual-specific (σ_u^2) variance components by using the residuals from the within and between estimators to construct the variance–covariance matrix (Ω) for the FGLS procedure.

Table 3 Comparison of means for ROA, margin, and turnover

| PDO | Obs | ROA | | Margin | | Assets turnover | | €/kg (MAPA. 2023a) |
|-------------------------------|-----|---------|---------|---------|---------|-----------------|----------|-----------------------|
| | | Mean | t | Mean | t | Mean | t | |
| <i>Baena</i> | | | | | | | | |
| Inside the PDO | 99 | 0,0378 | −0,13 | 0,0214 | −0,61 | 1,3123 | 0,98 | 5.75 |
| Outside the PDO | 49 | 0,0361 | | 0,0055 | | 1,5062 | | |
| <i>Siurana</i> | | | | | | | | |
| Inside the PDO | 94 | 0,0124 | 0,063 | 0,0159 | −0,48 | 0,7660 | 1,31 | 5 |
| Outside the PDO | 48 | 0,0127 | | 0,0082 | | 0,9150 | | |
| <i>Estepa</i> | | | | | | | | |
| Inside the PDO | 34 | 0,0070 | 1,44 | 0,0060 | 0,36 | 1,7064 | −3,00*** | 3.17 |
| Outside the PDO | 60 | 0,0372 | | 0,0227 | | 0,9359 | | |
| <i>Sierra de Cazorla</i> | | | | | | | | |
| Inside the PDO | 40 | 0,0240 | −0,97 | 0,0160 | −2,11** | 1,4083 | 0,23 | 3.85 |
| Outside the PDO | 41 | 0,0041 | | −0,1041 | | 1,4626 | | |
| <i>Sierra Mágina</i> | | | | | | | | |
| Inside the PDO | 66 | 0,0188 | −2,11** | 0,0274 | −1,22 | 1,1700 | −0,90 | 5.88 |
| Outside the PDO | 61 | −0,0037 | | −0,0210 | | 1,0478 | | |
| <i>Priego de Córdoba</i> | | | | | | | | |
| Inside the PDO | 59 | 0,0620 | 0,17 | 0,0374 | 0,22 | 1,8691 | 1,17 | 8.50 |
| Outside the PDO | 50 | 0,0651 | | 0,0410 | | 2,1475 | | |
| <i>Les Garrigues</i> | | | | | | | | |
| Inside the PDO | 59 | 0,000 | −1,42 | −1,2254 | 1,54 | 1,4157 | −2,45** | 4.61 |
| Outside the PDO | 36 | −0,0333 | | −0,1536 | | 0,8912 | | |
| <i>Aceite del Bajo Aragón</i> | | | | | | | | |
| Inside the PDO | 75 | 0,0270 | −1,00 | 0,0317 | −1,12 | 1,1049 | −4,76*** | 5.50 |
| Outside the PDO | 33 | 0,0193 | | −0,0488 | | 0,5176 | | |
| <i>Aceite de Lucena</i> | | | | | | | | |
| Inside the PDO | 26 | 0,0108 | 1,93* | 0,0156 | 0,16 | 0,6819 | 1,61 | 4.30 |
| Outside the PDO | 137 | 0,0350 | | 0,0380 | | 1,0583 | | |
| <i>Total</i> | | | | | | | | |
| Inside the PDO | 552 | 0,0241 | −0,16 | −0,1105 | 1,61 | 1,2462 | −1,28 | |
| Outside the PDO | 515 | 0,0233 | | −0,0065 | | 1,1634 | | |

Significance levels: 1% (***); 5% (**); 10% (*)

the market reputation of each PDO, the adopted commercial strategy, and the individual operational efficiency of each mill.

For instance, the subsample corresponding to Priego de Córdoba stands out with an average ROA above 6%, indicating a profitable utilization of certification. In contrast, other PDOs with significant market presence, such as Estepa or Les Garrigues, show average profitability levels below 1%, suggesting an uneven capture of the added value provided by the PDO label.

As for the non-registered mills, similarly, marked differences are observed: while those located in the Priego de Córdoba PDO area reach an average profitability close to 6.5%, those in the Les Garrigues region show a negative average return of around −3%.

Overall, these results indicate that neither being part of a PDO nor being outside of it is, by itself, a determining factor of economic performance. Rather, the impact of certification depends on multiple strategic and operational factors. The DuPont analysis

therefore allows us to refine the generalized view that joining a PDO automatically leads to improved profitability, opening the door to a more nuanced examination of the underlying causes behind these differences.

From an economic profitability standpoint, measured through Return on Assets (ROA), the differences between firms certified under Protected Designations of Origin (PDOs) and those operating outside such certifications are not statistically significant in most cases. Exceptions are found in two PDO regions: In Aceite de Lucena, certified olive mills exhibit lower profitability compared to non-certified firms, whereas in Sierra Mágina, PDO-certified firms perform significantly better, while non-certified firms record negative average returns. For the remaining PDOs analyzed: Baena, Siurana, Estepa, Sierra de Cazorla, Priego de Córdoba, Les Garrigues and Aceite del Bajo Aragón, no significant differences in ROA were detected.

When decomposing profitability into its core components, no clear pattern emerges across the sector, with differences observed between PDOs, reflecting the different commercial strategies adopted by each. In some PDOs, certified firms tend to operate with higher commercial margins than their non-certified counterparts. This can be seen in Baena, Siurana, Sierra Mágina, Aceite del Bajo Aragón and Sierra de Cazorla, with statistically significant differences in the last one. In these PDOs average margins for certified firms range from 1.6 to 3.2%, while non-certified firms in these PDOs often exhibit negative margins or close to 0%. These results suggest that market recognition associated with PDO labeling enables firms to command premium prices, effectively transferring added value to consumers.

Nevertheless, there are noteworthy deviations from this trend. In Estepa, Les Garrigues, Priego de Córdoba and Aceite de Lucena PDOs, non-certified firms outperform certified ones in terms of margins, potentially indicating inefficiencies in cost management or shortcomings in the collective branding strategy, although the differences are not statistically significant in any case.

These findings align with data from the MAPA (2023a) report, which indicates that PDOs able to secure higher market prices typically achieve better margins. This is the case for Baena, Aceite del Bajo Aragón, Sierra Mágina, and Siurana, regions where prices exceed €5/kg and average margins approach 2–3%. In contrast, PDOs such as Estepa, Sierra de Cazorla, and Aceite de Lucena, which operate around the €3/kg price point, achieve notably lower margins, generally near 1.5%.

The differences between PDOs can also be observed when analyzing asset turnover. In Estepa, Les Garrigues, Sierra Mágina and Aceite del Bajo Aragón, certified firms demonstrate higher turnover ratios (≥ 1.1) compared to non-certified firms (≤ 1). Statistically significant differences are found in Estepa, Les Garrigues and Aceite del Bajo Aragón. Conversely, the reverse is true in Baena, Siurana, Aceite de Lucena, Sierra de Cazorla and Priego de Cordoba where certified firms exhibit lower asset turnover, although the differences are not statistically significant in any of these cases.

Taken together, these findings point to diverse strategic approaches across PDO regions. For example, in Estepa and Les Garrigues, certified firms prioritize volume, achieving higher asset turnover at the expense of operating margins. In contrast, firms in the Sierra de Cazorla, Siurana, and Baena PDOs adopt premium positioning strategies, securing higher margins while accepting lower sales volumes.

The cases of Aceite del Bajo Aragón and Sierra Mágina stand out, as certified firms in both PDOs achieve higher operating margins and significantly greater asset turnover than their non-certified counterparts, suggesting a successful combination of premium positioning and market penetration strategies. However, the underlying mechanisms driving this outcome appear to differ across regions.

In the case of Aceite del Bajo Aragón, this performance can be explained by the industrial structure of the region. According to MAPA (2023a), Aceite del Bajo Aragón is characterized by a large number of olive mills and a relatively limited number of bottling facilities, which implies a higher degree of vertical integration among certified firms. In this context, PDO-certified mills benefit from economies of scope by performing bottling and packaging in-house within certified facilities, whereas non-certified firms often outsource these stages, incurring higher costs. This operational advantage translates into both higher margins and greater asset turnover, making PDO certification in this region a strategy closely linked to productive efficiency and cost reduction.

By contrast, although certified firms in Sierra Mágina also outperform non-certified mills in both dimensions of profitability, the available data do not allow for the identification of a similarly clear structural explanation. This suggests that other factors, such as a stronger collective reputation, more effective PDO governance, or superior marketing and commercialization strategies, may be at play. Further research incorporating qualitative evidence or more detailed information on commercialization practices would be required to disentangle these mechanisms.

In summary, the DuPont analysis reveals that Spanish olive oil PDOs pursue heterogeneous commercial and financial strategies. While some PDOs rely on premium pricing to transfer added value to consumers, others emphasize market penetration through higher product turnover. Despite their differences, both models represent viable growth paths and contribute to the broader objective of strengthening the competitiveness of Spanish olive oil in domestic and international markets.

Regression

The DuPont analysis highlights substantial heterogeneity across PDOs in the way certification is translated into profitability, revealing that higher economic performance may stem from different combinations of operating margins and asset turnover. While these descriptive results provide valuable insights into the strategic profiles of certified and non-certified mills, they do not allow for isolating the specific effect of PDO membership from other firm-level characteristics that may simultaneously influence profitability.

To address this limitation and formally test whether PDO certification has an independent impact on profitability, once differences in size, age, legal structure, growth, and financial structure are taken into account, we proceed with a multivariate regression analysis. This approach allows us to assess both the average effect of PDO membership and its heterogeneity across regions and firm sizes.

Descriptive analysis

Table 4 presents the descriptive statistics of the variables included in the regression models for the period 2014–2022. The table reports mean values, standard deviations, and the minimum and maximum observed values for each variable. These statistics

provide an overview of the distribution and variability of the key firm-level characteristics considered in the econometric analysis and serve as a preliminary step prior to estimating the regression models.

During the study period, the average profitability (ROA) across firms was 2.3%, a figure consistent with the historically lower profitability of the olive oil sector compared to the broader agri-food industry (Sepúlveda et al. 2020). The dispersion is notable, with ROA values ranging from a minimum of -75.1% to a maximum of 48.2% . Notably, the worst-performing firms were not PDO-certified; in fact, the three lowest ROA values were recorded by firms located in the PDO areas of Les Garrigues, Sierra de Cazorla and Stepa, though neither was certified.

Regarding legal structure, 29.6% of the observations correspond to cooperatives, 79% of which are PDO-certified. In contrast, only 31% of capital-based companies hold PDO certification. This suggests a stronger inclination among cooperatives to pursue PDO labeling. Overall, 51.86% of the observations in the sample correspond to firms certified under one of the nine PDOs analyzed.

The average total assets during the period was approximately €33.6 million, although there is significant variability. The smallest firm reported total assets of just €14,277 (located in Sierra de Cazorla and not PDO-certified), while the largest is located and certified in Baena). Among the top revenue-generating firms are also those certified under the Baena and Lucena PDOs. As can be seen in Fig. 1, there is a greater tendency among larger firms to obtain certification compared to smaller entities that show a greater tendency to remain uncertified.

Regarding firm age, the average age of olive mills is 32 years, with a wide range from newly established firms (1 year) to those with over a century of history (122 years). As illustrated in Fig. 2, companies are more likely to obtain PDO certification as they become more established, whereas younger firms tend to operate outside of the PDO framework.

The high dispersion observed in firm age is also reflected in other firm-level characteristics, particularly total assets, as younger firms tend to operate at a smaller scale than more established companies. A similar pattern emerges with respect to the growth variable. Over the study period, firms in the sample exhibit an average annual sales growth of approximately 33%, suggesting a phase of significant expansion within the sector.

However, this figure should be interpreted with caution. A substantial share of the sample consists of relatively young firms that started from very low initial sales levels. As a result, even moderate absolute increases in revenues translate into very large

Table 4 Descriptive statistics of the model variables

| Variable | Observations | Mean | SD | Min | Max |
|--------------------------------|--------------|-----------|-----------|--------|-----------|
| ROA | 1,067 | 0.023 | 0.755 | -0.751 | 0.482 |
| PDO (certified) | 1,067 | 0.517 | 0.499 | 0 | 1 |
| Cooperative | 1,067 | 0.296 | 0.456 | 0 | 1 |
| Firm size (thousands of euros) | 1,067 | 33,622.33 | 264,778.2 | 14.277 | 3,559,842 |
| Age (years) | 1,067 | 32.701 | 23.998 | 1 | 122 |
| Sales growth rate | 1,067 | 32.981 | 1,065.923 | -0.936 | 34,819 |

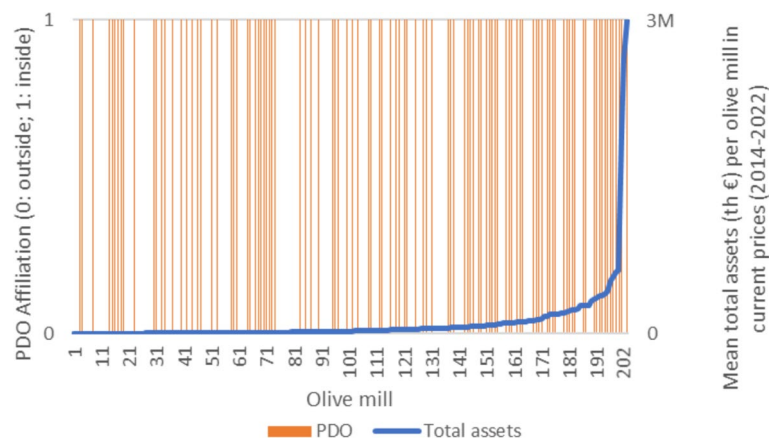


Fig. 1 Average total assets by company and PDO certification status (2014–2022)

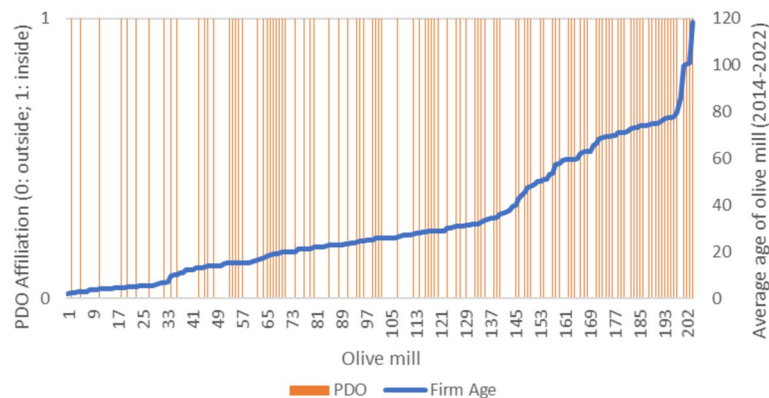


Fig. 2 Average firm age by PDO certification status (2014–2022)

percentage growth rates, which tend to inflate the sample mean. This feature is common in firm-level growth analyses and reflects the heterogeneous stages of development present in the olive oil industry rather than uniformly high growth across all firms. Consequently, the high average growth rate primarily captures the strong dispersion and skewness of the growth distribution, reinforcing the need to control for growth dynamics when analyzing profitability differences between PDO and non-PDO firms.

Table 5 shows the annual evolution of economic profitability. The year 2015 recorded the highest average profitability of the period (4.19%). However, since then, ROA steadily decreased, reaching its lowest point in 2019 (1.02%). Profitability remained low in 2020, coinciding with the pandemic. Starting in 2021, the recovery in olive oil prices boosted profitability, doubling within a year and maintaining levels similar to those at the beginning of the period in 2022. This trend aligns with the findings reported by ACCID (2022).

Two key moments stand out in this analysis: the start of the 2017–2018 campaign, which marked the beginning of the decline in olive oil prices, with a negative impact on economic results; and 2020–2021 campaign, with the recovery of prices, which represented a turning point in profitability and revenue for the sector (MAPA 2019; 2020; 2023b). Although the COVID-19 pandemic affected the overall economy, its impact on the olive oil sector was limited. The price surge in 2021 facilitated a quick recovery.

Table 5 Annual evolution of ROA

| Year | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|------|--------|--------|--------|-------|--------|--------|--------|--------|--------|
| ROA | 0.0276 | 0.0419 | 0.0191 | 0.026 | 0.0192 | 0.0122 | 0.0144 | 0.0275 | 0.0277 |

Table 6 Pairwise correlation matrix and VIF values

| | (1) | (2) | (3) | (4) | (5) | (6) | VIF |
|-----------------|------------|-----------|-----------|-----------|---------|-----|------|
| (1) ROA | 1 | | | | | | |
| (2) PDO | 0.0005 | 1 | | | | | 1.21 |
| (3) Cooperative | −0.1046*** | 0.4006*** | 1 | | | | 1.82 |
| (4) Firm Size | 0.0588* | 0.1996*** | 0.3240*** | 1 | | | 1.24 |
| (5) Age | 0.0007 | 0.3250*** | 0.5385*** | 0.4519*** | 1 | | 1.88 |
| (6) Growth | −0.0068 | 0.0295 | 0.0472 | −0.0390 | 0.0527* | 1 | 1.01 |
| Mean VIF | | | | | | | 1.43 |

Significance levels: 1% (***); 5% (**)

To assess potential multicollinearity among the variables included in the model, Table 6 presents the pairwise correlation matrix along with the variance inflation factor (VIF). The correlations between variables are generally low, with none exceeding an absolute value of 0.50, suggesting a weak linear association among them. This result rules out the presence of severe collinearities that could distort the model's estimates.

In addition, the VIF analysis supports this conclusion: In all cases, the values remain below 2, which is well below the commonly accepted critical threshold of 5, as noted by Akinwande et al. (2015). Overall, the results indicate that there are no multicollinearity issues that could compromise the validity or accuracy of the estimated regression coefficients.

Regression results

Table 7 reports the results of the random-effects regression models estimated for the full sample and for each of the nine PDOs analyzed. The objective of this section is not to restate the descriptive patterns observed in the DuPont analysis, but to formally assess whether PDO membership exerts an independent effect on profitability once firm-specific characteristics are controlled for, and to determine whether this effect varies across PDOs and firm sizes. By incorporating controls related to legal structure, size, age and growth, the regression analysis allows us to isolate the net impact of PDO certification on Return on Assets (ROA) and to test the robustness of the previously identified heterogeneity. In addition, the inclusion of an interaction term between PDO membership and firm size enables an explicit evaluation of whether the economic value of PDO certification depends on the scale of the olive oil mill.

In all models, the Chi^2 value is statistically significant (at different levels of confidence), indicating that the set of model variables has explanatory power. The adjusted R^2 values for subsample models range from 15 to 26.5%, suggesting that although some key explanatory factors are captured, other unobserved variables also influence profitability. However, the consistency of results across subsamples, the statistical significance of key

Table 7 Results of the random effects regression models (REM)

| ROA | Coefficient | Z | Coefficient | Z | Coefficient | Z | Coefficient | Z | Coefficient | Z |
|---------------------------|---------------|----------|-------------------|---------|-------------------|---------|------------------------|----------|------------------|----------|
| | All companies | | Priego de Córdoba | | Les Garrigues | | Aceite del Bajo Aragón | | Aceite de Lucena | |
| PDO | 0,0126 | 0,17 | -0,3612 | 0,93 | -0,5809 | -1,30 | -0,0369 | -0,56 | 0,2830 | 1,51 |
| Cooperative | -0,0233 | -2,14** | -0,0671 | -2,15** | -0,1191 | -0,84 | -0,0154 | -0,83 | -0,0217 | -1,59 |
| Firm size | 0,0015 | 0,37 | 0,0017 | 0,06 | -0,0359 | -1,22 | -0,0071 | -2,14** | 0,0077 | 1,59 |
| Age | 0,0027 | 0,27 | -0,0181 | -0,81 | 0,0960 | 1,37 | 0,0206 | 1,20 | -0,0206 | -1,69* |
| Growth | -5,38e-7 | -4,85*** | 0,0283 | 1,13 | -9,79e-07 | -2,38** | 0,0294 | 1,52 | -0,0026 | -2,66*** |
| PDOxFirm size | -0,0004 | -0,10 | 0,0239 | 0,92 | 0,0424 | 1,21 | 0,0036 | 0,81 | -0,0169 | -1,58 |
| Constant | -0,0039 | -0,07 | 0,0908 | 0,23 | 0,2211 | 0,63 | 0,0454 | 0,69 | -0,0200 | -0,26 |
| Nº Obs | 1,067 | | 109 | | 95 | | 108 | | 163 | |
| R ² adjustment | 0,0885 | | 0,1509 | | 0,1914 | | 0,1837 | | 0,1524 | |
| Wald Chi ² | 1240,29** | | 14,29** | | 27,18*** | | 11,37* | | 29,17*** | |
| | Baena | | Estepa | | Sierra de Cazorla | | Sierra Mágina | | Siurana | |
| PDO | -0,4384 | -1,66 | 0,4421 | 1,35 | 0,5065 | 2,03** | 0,5224 | 3,19*** | 0,1255 | 2,54** |
| Cooperative | -0,0559 | -1,70* | -0,0701 | -1,21 | 0,0473 | 1,05 | -0,0267 | -2,20** | -0,0187 | -1,88* |
| Firm size | -0,0183 | -1,23 | 0,0307 | 1,59 | 0,0117 | 0,76 | 0,0338 | 3,45*** | 0,0055 | 1,02 |
| Age | 0,0008 | 0,04 | -0,0089 | -0,40 | -0,0211 | -1,12 | 0,0027 | 0,30 | -0,0013 | -0,16 |
| Growth | 0,0195 | 8,72*** | 0,0061 | 0,30 | 0,0005 | 1,86* | 0,0024 | 0,36 | -0,0002 | -0,68 |
| PDOxFirm size | 0,0287 | 1,79 | -0,0274 | -1,42 | -0,0314 | -1,67* | -0,0341 | -3,15*** | -0,0079 | -2,43** |
| Constant | 0,3126 | 1,34 | -0,3867 | -1,56 | -0,1298 | -0,76 | -0,4989 | -3,15*** | -0,0543 | -0,96 |
| Nº Obs | 148 | | 94 | | 81 | | 127 | | 142 | |
| R ² adjustment | 0,1797 | | 0,1851 | | 0,1789 | | 0,2246 | | 0,2647 | |
| Wald Chi ² | 95,07*** | | 11,43* | | 70,28*** | | 63,44*** | | 25,93*** | |

Significance levels: 1% (***); 5% (**); 10% (*)

variables, and the representativeness of the sample support the validity of the conclusions drawn.

The results for the entire sample do not show a significant effect of PDO membership on ROA. However, when the analysis is disaggregated by individual PDOs, the results show that in three of the nine PDOs analyzed, the effect is positive and statistically significant. Specifically, the Sierra Mágina PDO shows a highly significant relationship (at the 1% level), while in the PDOs Siurana and Sierra de Cazorla, the effect is also positive and significant (at the 5% level). In contrast, for the PDOs Baena, Estepa, Priego de Córdoba, Les Garrigues, Aceite del Bajo Aragón and Aceite de Lucena there is no significant evidence that PDO membership improves profitability.

It is noteworthy that in the three PDOs where a positive effect has been observed, it has previously been noted that companies registered in these PDOs operate with higher margins than non-registered companies, yet with lower asset turnover (except for Sierra Mágina, which also shows higher asset turnover). On the other hand, for those PDOs where significantly higher asset turnover has been observed for companies registered in contrast to those not registered (Estepa, Les Garrigues and Aceite del Bajo Aragón), the results of the model do not find any significant effect due to PDO membership.

This finding suggests that the effectiveness of the quality label largely depends on the strategy adopted by the mills: those that use the PDO as a tool to justify higher prices achieve greater margins and they are more likely to improve their profitability, whereas in cases where the label is mainly associated with increased volume but not improved margins, no significant impact on profitability is observed.

These results are consistent with previous evidence on the economic effects of collective quality labels reported in other agri-food industries, particularly in the wine sector (Sellers-Rubio & Más-Ruiz 2013; Moreno-Gené et al. 2026). While empirical analyses on the profitability impact of PDO certification in the olive oil sector remain scarce, our findings provide new sector-specific evidence showing that PDO affiliation can be associated with improved economic performance. At the same time, the results indicate that the effect of PDO certification is not uniform across designations, highlighting significant heterogeneity among PDOs. This differentiated impact has also been documented in studies focusing on the wine industry (Sellers-Rubio & Más-Ruiz 2013; Moreno-Gené et al. 2026), suggesting that the economic value of PDOs depends on how effectively each designation is managed and positioned in the market.

Regarding the moderating effect of firm size, the results show that when PDO membership has a significant positive influence on profitability, the interaction between PDO affiliation and total assets indicates that this positive effect is stronger among smaller olive oil mills. This suggests that although PDO certification generally benefits affiliated firms, its impact is significantly greater for smaller enterprises, which typically have fewer financial and marketing resources to develop and promote individual brands and therefore rely more heavily on the collective visibility provided by the PDO.

While this size-contingent effect of collective brands has been documented in other agri-food sectors (Benavente 2013; Deluze & Lanotte 2010; Sellers-Rubio et al. 2021), the present study provides novel evidence that this mechanism also holds in the olive oil sector, for which firm-level empirical analyses on the moderating role of size remains scarce.

As for the control variables, the legal structure of the mills (cooperative) shows a negative and significant effect on profitability, both for the overall sample and for specific subsamples (Priego de Córdoba, Baena, Sierra Mágina, and Siurana). This result aligns with Property Rights Theory, which suggests that cooperatives tend to adopt decisions that are less profit-oriented, and with Marcos et al. (2013), who argue that such organizations often prioritize market presence over financial performance.

Firm size, measured as the logarithm of total assets of the previous year, exhibits a heterogeneous and highly context-dependent effect on profitability across PDOs. For the full sample and for most individual PDO subsamples, firm size does not display a statistically significant impact on ROA. However, two notable exceptions emerge. In Aceite del Bajo Aragón, firm size is associated with a significant negative effect on profitability, suggesting that increases in scale may be linked to organizational rigidities or diminishing efficiency gains in this region. By contrast, in Sierra Mágina, firm size shows a positive and significant effect on ROA, indicating that larger mills may benefit from scale-related advantages such as improved market access or operational efficiency. These contrasting results underscore that the relationship between size and profitability in the olive oil sector is not uniform and depends on regional and organizational characteristics rather than following a generalizable pattern.

Regarding firm age, no significant effect is observed for the full sample or most subsamples, suggesting that maturity alone does not determine profitability in this sector.

Finally, sales growth, measured as the annual change in sales, displays a predominantly negative effect on profitability for the full sample and two subgroups (Les Garrigues and Aceite de Lucena), whereas positive effects are observed in two other subgroups (Baena and Sierra de Cazorla). This pattern is consistent with the theoretical discussion of the variable, which highlighted that rapid growth can generate operational inefficiencies, increased coordination costs, and financial pressures, particularly for younger firms or those with limited resources, while moderate growth may support profitability in certain contexts.

Conclusions

This study has examined the impact of Protected Designation of Origin (PDO) membership on the profitability of Spanish olive oil mills. While the benefits of collective brands have been widely studied, the declining number of registered companies, low uptake by new producers, and the disappearance of certain PDOs, such as “*Aceite de la Comunidad Valenciana*”, have cast doubt on the practical effectiveness of this label as a tool to enhance the economic performance of the sector.

The analysis focused on nine PDOs with significant commercial relevance in the Spanish olive oil market. The sample includes 202 mills located in protected areas, of which approximately half are PDO members, and the other half are not.

The profiles of PDO and non-PDO mills differ: those registered under a PDO tend to be cooperatives and have greater longevity, while non-registered mills are more often recently established capital companies. This pattern suggests a certain disconnect between newer firms and traditional quality labels.

The DuPont analysis reveals that although overall differences in profitability between the two groups are in most cases not statistically significant, there are notable differences

in the components of profitability. In some PDOs, registered mills achieve higher profit margins, indicating that they leverage the label to position their product as premium and obtain higher prices. However, in other PDOs the opposite strategy is observed: Lower margins are offset by higher turnover. This duality highlights that the usefulness of PDO membership is not uniform and depends on how it is integrated into the commercial strategy of each region.

The findings of the regression model, incorporating additional control variables, demonstrate that PDO membership does not universally enhance financial performance, and that not all PDOs contribute equally to the profitability of their members. Indeed, only a small number of these have been shown to have statistically significant positive effects, although no significant negative effects have been reported in any case.

When a significant effect of PDO on profitability was observed, it was also found that firm size had a moderating effect: The positive impact of PDO membership on profitability is stronger for smaller mills and diminishes as firm size increases. This pattern aligns with previous evidence from other agri-food sectors, which suggests that larger firms typically have the resources to develop and promote their own brands, whereas smaller firms rely more heavily on the collective visibility and differentiation offered by a PDO (Benavente 2013; Deluze & Lanotte 2010; Sellers-Rubio et al. 2021). Importantly, this study provides novel evidence that the same mechanism operates in the Spanish olive oil sector, where firm-level analyses of the moderating role of size were previously lacking.

Another key finding is that the positive significant effect of PDO membership on profitability is most pronounced in those PDOs where registered companies achieve higher profit margins than non-registered mills, indicating that the true value of the PDO lies in its ability to support premium pricing through perceived quality. Conversely, when the label is used primarily as a volume-driven tool without price differentiation, its contribution to profitability appears more limited, highlighting the importance of strategic marketing and positioning in realizing the economic benefits of PDO affiliation.

These findings carry important implications for both PDO Regulatory Councils and producers in the sector. On the one hand, the evidence confirms that PDO membership can enhance profitability, especially for smaller firms. This should encourage newer producers, who often remain outside these schemes, to reconsider their strategic approach. On the other hand, Regulatory Councils should promote a clearer and more coherent quality differentiation strategy aimed at strengthening the prestige of the PDO label and supporting mills in marketing their products at higher margins.

In this context, it is essential to incorporate modern marketing tools, such as social media and digital channels, to reinforce the identity of the PDO and communicate its unique attributes. Only through a solid communication and positioning strategy can the PDO remain an effective instrument for adding economic value to the product and enhancing the competitiveness of olive oil mills in an increasingly demanding global market.

Recommendation on PDO membership

Based on the evidence from this study, the decision to apply for PDO registration should be understood as context-dependent rather than universally beneficial. For smaller olive

oil mills, PDO membership can act as a strategic signaling tool in terms of collective visibility, market recognition, and product differentiation, which in several PDOs are associated with higher operating margins and improved profitability. However, this effect is not systematic across all regions, and in some PDOs certified firms do not outperform their non-certified counterparts.

For larger firms, the evidence suggests that PDO membership does not consistently translate into higher profitability. Firms with sufficient scale and resources may rely more effectively on individual branding and alternative commercialization strategies, reducing their dependence on collective quality labels. Moreover, the aggregate results indicate that the overall effect of PDO membership may be driven by specific PDOs, highlighting the importance of regional characteristics and governance structures in shaping economic outcomes.

Overall, PDO certification should be viewed as a strategic option rather than a guaranteed profitability-enhancing mechanism, whose effectiveness depends on firm size, the commercial strategy adopted, and the specific PDO context in which the firm operates.

Therefore, we recommend that firms consider PDO membership as a strategic tool primarily when it can be leveraged to strengthen product differentiation and justify premium pricing. Simply obtaining the label without integrating it into a coherent marketing and quality strategy may yield limited economic benefits. Regulatory Councils and producers should focus on ensuring that the PDO conveys a clear, distinctive quality signal, supported by modern marketing channels, to maximize its contribution to profitability and competitiveness in the Spanish olive oil sector.

Beyond the individual firm, our results have broader implications for rural development and regional policies. The findings suggest that public support for PDOs should not be treated as a one-size-fits-all solution; instead, policy interventions, such as those framed within the Common Agricultural Policy (CAP), should be tailored to help smaller mills transform the PDO label into a genuine strategic signaling tool. Without this differentiation, there is a risk that collective labels become a bureaucratic burden rather than a competitive engine for the most vulnerable actors in the supply chain.

Limitations and future research

This study has some natural limitations that should be considered when interpreting the results. First, the analysis focuses on nine Spanish PDOs with significant commercial relevance, which may limit the direct extrapolation of the findings to other olive oil producing regions or international contexts. Nevertheless, the focus on Spain, a leading producer in the global olive oil market, provides valuable and policy-relevant insights.

Second, firm performance is measured through Return on Assets (ROA), a widely used indicator in agri-food economics, but one that does not capture other dimensions of firm performance such as brand value, innovation capacity, or long-term strategic positioning. Future research could complement this approach by incorporating alternative performance measures.

In addition, the available information is expressed in monetary terms, which prevents a detailed analysis of unit prices and production costs. Access to physical production and sales volumes would allow future studies to better distinguish between profitability gains driven by premium pricing and those resulting from efficiency improvements.

Finally, while this study provides firm-level evidence on the heterogeneous effects of PDO membership in the olive oil sector, further research combining quantitative and qualitative approaches could deepen the understanding of the organizational, marketing, and governance mechanisms through which PDOs create economic value.

Abbreviations

| | |
|------|--|
| CNAE | National Classification of Economic Activities |
| CPI | Consumer Price Index |
| EBIT | Earnings before interest and taxes |
| EVOO | Extra Virgin Olive Oil EVOO |
| FGLS | Feasible Generalized Least Squares |
| MAPA | Ministry of Agriculture, Fisheries, and Food |
| OLS | Ordinary least squares |
| PGI | Protected Geographical Indication |
| PDO | Protected Designation of Origin |
| REM | Random effects model |
| ROA | Return on Assets |
| SABI | Iberian Balance Sheet Analysis System |
| TSG | Traditional Specialties Guaranteed |

Acknowledgements

Not applicable

Author contributions

JG and JM designed the work, **SS** searched and prepared the data, **JM** decided the methodology, **SS** run the models using a statistical software, **JG, JM and SS** interpreted the results, **SS** have drafted the work, **JG and JM** have substantively revised it.

Funding

This research has received the financial support from the Patronat de Promoció Econòmica of the Diputació de Lleida.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate/for publication

Not applicable.

Competing Interests

The authors declare no competing interests.

Received: 23 October 2025 Revised: 3 March 2026 Accepted: 18 March 2026

Published online: 26 March 2026

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