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Reflective backward analysis to assess the operational performance and eco-efficiency of two industrial districts

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Abstract

Purpose – The best strategy to apply for the future cannot disregard a careful analysis of the past and is the one capable of seizing opportunities from outside. Manufacturing sectors are characterized by sudden changes, and in this work, we analyze the ceramic tiles sector characterized by a mature technology in which innovation has played a key role.

Design/methodology/approach – This study aims to provide a sectorial analysis based on a historical data set (2004–2019) to highlight how an industry is performing both operationally and in terms of eco-efficiency. For this purpose, from a methodological point of view, the data envelopment analysis (DEA) was used.

Findings – The results of the analysis show that the Spanish ceramics industry shows a growing economic trend by taking advantage of lower industrial costs, while the Italian industry is characterized by a modest decline partially mitigated by exports. The industrial districts are an aggregation of companies that in the ceramic sector has allowed to combine innovation, sustainability and digitalization and is a model toward the maximization of sustainable efficiency because it is a place of aggregation of resources and ideas.

Originality/value – This study experiments with an innovative way of addressing traditional industry analysis, namely, integrating the reflective management approach with DEA-based backward analysis. This provides decision makers with the basis for new interpretations of variable trends.

Keywords Ceramic tiles industry, Data envelopment analysis, Eco-efficiency index, Industrial districts, Operational performance, Innovation

Paper type Research paper

Nomenclature

ASCER	Spanish ceramic tile manufacturers' association	DMU	Decision -making unit
		ETS	Emissions trading system
DEA	Data envelopment analysis	EU	European Union

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GHG	Greenhouse gas	VRS	Variable returns to scale
ROI	Return on investment		

1. Introduction

In recent years, the manufacturing industry has undergone a substantial process of transformation, in order to cope with the needs of the digitalization of production processes imposed by the advent of Industry 4.0 (Ali and Aboelmaged, 2021; Frederico *et al.*, 2021) and the challenge of sustainability (Bag *et al.*, 2021; Kumar *et al.*, 2020). In this context, for manufacturing companies, improving production efficiency becomes a priority objective (Fernández Campos *et al.*, 2019; Gharfalkar *et al.*, 2018). The concepts of efficiency that economic theory has formally defined are numerous (Günter and Gopp, 2021; Yazdani *et al.*, 2021). Among them, technical efficiency, as a performance indicator, refers to the ability to use resources in such a way as to produce the greatest possible amount of output with the available inputs, that is, to use the least amount of input to produce a certain amount of output (Appolloni *et al.*, 2021a, b; de la Fuente-Mella *et al.*, 2020). In this sense, the analysis of technical efficiency can be oriented toward increasing output (output-efficiency) or reducing input (input-efficiency) (Kumbhakar and Tsionas, 2021). The translation of business objectives into performance indicators is a critical operation that can give rise to a plurality of risks, especially in periods of uncertainty (Settembre-Blundo *et al.*, 2021). This is because, in the presence of complex systems, which manufacturing supply chains are (Huaccho Huatuco *et al.*, 2021), it is necessary to identify those variables that best capture and measure the efficiency of a process with respect to a given objective (Fallahpour *et al.*, 2021; Pamucar *et al.*, 2021).

Considering the temporal dimension, a measure allows companies to predict future behaviors or to quantify results already obtained based on the analysis of time series. In the analysis of the performance of processes, time series provide important information since they can describe the trend of an economic or technological variable and also explain the reasons that determine its variations (Zhang and Jia, 2021). Moreover, the predictive capacity of this analysis is based on the assumption that the past and present contain relevant information to forecast the future evolution of the observed variable. Predictive capacity, linked to historical knowledge of what has already occurred, and competitive context adaptation are the basis of any business strategy (Ibrahim and Harrison, 2020). As a result, the formulation of a competitive strategy is aimed at linking a company with its reference context, and the environment that most influences a company's performance is the sectoral one. Industrial economics indicates how the structure of a sector directs its action and determines its performance (Jiao *et al.*, 2021). Therefore, analysis of the main structural characteristics of a sector and their interactions allows the prediction of probable competitive behavior and consequent performance levels (Muhtaseb *et al.*, 2020).

Among the industrial sectors that have shown great resilience, especially in periods of crisis, are industrial districts, which have reacted more quickly than other manufacturing systems (Appolloni *et al.*, 2021a, b; Mohammed *et al.*, 2021). These comprise a group of small-to-medium sized companies, characterized by belonging to the same sector of industrial and economic activity, which constitute a socio-territorial entity (Grandinetti, 2019). Within the European manufacturing framework, Italy and Spain are characterized by a production structure made up primarily of small- and medium-sized enterprises often organized into industrial districts (Cainelli *et al.*, 2018). In this context, the literature pays attention to the ceramic industrial districts by highlighting the crucial role played by resource efficiency, technological innovation and market trends (Dondi *et al.*, 2021). It is worth highlighting that the sector has long paid attention to sustainable practices (Ferrari *et al.*, 2021).

Within this industry, the subsector producing ceramic wall and floor tiles is the most important in terms of turnover (about 30% of the total). Among the producing countries, Italy and Spain are the largest ceramic tile producers in the European Union (EU), together accounting for about 80–90% of its total production (Ros-Dosdá *et al.*, 2018). The industry has been characterized by change over the past decade and has progressed toward sustainability and Industry 4.0 approaches (García-Muiña *et al.*, 2020). However, the increasing competition among manufacturing firms in global markets, made even more insidious by the socio-economic crisis that occurred in the pandemic period (2020–21), is confronting these firms with the need to investigate what strategy to focus on for the future (Medina-Salgado *et al.*, 2021). In addition, the literature places a great deal of emphasis on the comparison between Spain and Italy, as they are considered two reference manufacturing models for industrial ceramics (Dondi *et al.*, 2021).

Based on what has been previously stated, this article aims to achieve the following research objectives:

(1) Develop a novel approach to sectoral analysis by combining traditional time series research with reflective backward analysis.

(2) Validate the reflective backward analysis by applying it to two key European industrial districts, in order to compare their operational performance and eco-efficiency levels.

(3) Provide private and public decision makers with additional information to support their drawing up of strategic agendas and industrial policies.

To this end, the ceramics sector has been selected as an example of a manufacturing sector characterized by mature technology, which has implemented both sustainability and digitalization models. The two industrial districts of Italy and Spain are taken as case studies and a sector analysis based on historical data is carried out. The methodology used is a combined approach of linear regression (Mohammed *et al.*, 2021), data envelopment analysis (DEA) (Lombardi *et al.*, 2019) and the eco-efficiency index (Belucio *et al.*, 2021). For this reason, the analysis will be conducted on the top 20 firms of both districts. To the best of our knowledge, there is no study that evaluates the performance of the ceramic production sector using DEA; therefore, the research is conducted in this study. This paper is unique within the area of performance management in the ceramics industry. The analysis can be repeated on a global scale for the sector in question and indications for all other sectors that may present similar characteristics.

The paper is constructed as follows: Section 2 presents the methodology used and the related input data in order to illustrate the main results, which are presented in Section 3. Section 4 presents a discussion. Section 5 concludes with final remarks.

2. Materials and methods

The use of quantitative methods (modeling, statistics and surveys) is aimed at testing hypotheses or assessing relationships (correlation). The social sciences have extensive use of these methodologies, but a precise definition of the field of analysis is needed (Sovacool *et al.*, 2018).

2.1 Study context and case focus

Ceramic tiles are used in the building and construction field to cover floors and walls in order to give the surfaces functional and aesthetic properties (Montorsi *et al.*, 2016). The ceramics industry is rated as energy- and resource-intensive (Castro Oliveira *et al.*, 2020). The literature looks at different methodologies, depending on the goal to be achieved. Some authors highlight the aspects that link materials and technological assets (Arzani *et al.*, 2018), while others evaluate the economic aspects that characterize different companies in a country by considering historical data (Masum, 2012). A more complex approach is that which considers multiple indicators in evaluating the sector (Ardekani *et al.*, 2013), while other studies focus on industrial clusters (Zuo and Yang, 2010).

The ceramics industry is organized in both Italy and Spain as industrial districts (Sassuolo and Castellón, respectively), that is, it agglomerates a large number of small- and medium-sized firms that have a related production specialization and are geographically located in a defined territory (Hervas-Oliver and Parrilli, 2017). These industrial districts are characterized by a systemic behavior: they exploit specific local resources and external global knowledge developing environments suitable for open innovation, where the creation and dissemination of knowledge is more powerful (Albors-Garrigos and Hervas-Oliver, 2019). The strong innovative thrust of the two districts has been reflected in Italy, especially in the areas of plant engineering and aesthetic development of the product, and in Spain in the areas of glazing and decoration systems (Gabaldón-Estevan, 2016). Moreover, Italy, following the experience acquired in the ceramics district of Sassuolo, has also developed an avant-garde regulatory framework in the fields of environment, and health and safety of workers, which has also become the reference for the Spanish environmental policies for the ceramics industry (Ferrari *et al.*, 2019).

The two districts are therefore particularly appropriate for carrying out a comparative sectoral analysis aimed at highlighting the variations in their productive, economic, social and environmental performance over time. In addition, for both districts, a subcluster was created consisting of the top 20 companies by turnover, with the aim of verifying whether, within the set of companies considered in the study, there was a group that performed better than average.

2.2 Definition of input data

Collecting data to conduct an empirical study is a challenge for researchers and a methodological problem, especially when variables of a very different nature are analyzed (Kampakis, 2020). This is particularly evident in sectoral analysis from the perspective of the historical evolution of outcomes. In order to resolve the heterogeneity of the data, in this study it was decided to construct a customized data set using a plurality of data sources both in aggregate form (for sectors) and specific form (for individual companies), covering the ceramics industries in Italy and Spain. Production data were collected by consulting the annual reports published by the two associations of ceramic producers in Italy and Spain, Confindustria Ceramica and ASCER (Spanish Ceramic Tile Manufacturers' Association), respectively. The economic-financial data have been elaborated by consulting the annual financial statements of both the sector and the individual companies, integrating this information with the data contained in the reports published annually by KPMG in which the performance of the two ceramics districts in Spain and Italy is compared. The historical series of CO_2 emissions at sector level, on the other hand, have been collected from the EU Emissions Trading System (ETS) data viewer. For the individual companies constituting the top 20 subcluster, CO_2 emissions have been determined from the combustion of natural gas, whose CO_2 emission factor is 56.1 tCO_2/TJ [1]. By matching data availability, it was possible to identify nine useful performance evaluation criteria covering a 16-year time frame (2004–2019). This time frame is very interesting to understand the evolutionary dynamics of these industries, because it includes two discontinuity factors: the financial crisis of 2008–2012 (ACIMAC, 2017) and the digitalization of processes that was introduced by companies mainly in the period 2015–2018 (Garcia-Muiña *et al.*, 2018). However, due to the plurality of data sources used, it was not possible to include the year 2020, which would have provided an interesting view of the pandemic period (Butt, 2021). In fact, the organizations that collect and process the sectoral data publish their results at times that are not synchronized with each other; therefore, it follows that the most recent data for all the sources consulted are corresponding to the year 2019.

Since the data set also contains some sensitive data, all the details were subjected to normalization following a procedure already applied in other studies where it was necessary to preserve privacy during data mining (Ahmad *et al.*, 2014). This transformation does not compromise the implementation of the analysis or the observation of the input data – see Figure 1.

2.3 Correlation matrix

A correlation matrix is a table that proposes the relationship between the variables examined through the calculation of correlation coefficients. Each cell shows the correlation between two variables. The correlation matrix is typically used in sustainability analysis as a diagnostic for more advanced analyses (D'Adamo *et al.*, 2020; Hristov *et al.*, 2021). The correlation matrix is square and symmetric. The correlation coefficient measures not only the strength but also the direction of the relationship between two variables, varying from -1 (the strongest negative linear relationship) to 1 (the strongest positive linear relationship). Analyses were reported for all nine variables identified in Section 2.3 for a time period of 16 years.

2.4 DEA model

In order to perform a backward analysis, it will be interesting to evaluate the efficiency of the two clusters of ceramic firms from a temporal point of view. This work classifies years by comparing their levels of greenhouse gas (GHG) emissions and economic indexes, such as return on investment (ROI) and net profit, with production, average selling price, employees and staff costs. The comparison is based on an efficiency indicator obtained from the DEA (Charnes *et al.*, 1978). DEA is a linear programming technique used to evaluate the efficiency of a homogeneous set of units characterized by multiple inputs and outputs. In the output-oriented version of DEA, efficiency calculation can be formulated by maximizing outputs in order to meet predetermined levels of input. Banker *et al.* (1984) formulated the DEA for decision-making units (DMUs) that operate under variable returns to scale (VRS). The advantage of the DEA is that it produces an aggregate measure of efficiency for each DMU using a plurality of input and output, whose measurement units may also be varied (Charnes *et al.*, 1997). The disadvantage is that the efficiency value attributed to each DMU is relative, that is, it depends on the efficiency of the other units that are in the sample.

Usually, GHG emissions are modeled by DEA as an undesirable output, being an undesirable result of a productive process, and must be minimized (Scheel, 2001). There are three main approaches to modeling undesirable outputs in a DEA model. The first uses the reciprocal of the undesirable output as DEA output: let u_j be the undesirable output of j-th DMU, then the applied transformation is $f(u_j) = 1/u_j$. In this way, the undesirable output is modeled as being desirable (Golany and Roll, 1989). The second models the undesirable output as input by using the transformation $f(u_j) = -u_j$ (Gomes and Lins, 2008): thus, in the process of reducing the inputs, the undesirable outputs are also reduced. The third approach uses the transformation $f(u_j) = -u_j + \beta_j$, where β_j is a positive scalar, big enough so that the final values are positive for each DMU (Ali and Seiford, 1990). The DEA model is also used to evaluate the ceramics industry (Yenilmez, 2013).

This analysis uses output-oriented DEA, where the DMUs evaluated are the years analyzed, the outputs are GHG emissions ($kgCO_2/m^2$) or economic indexes such as net profit

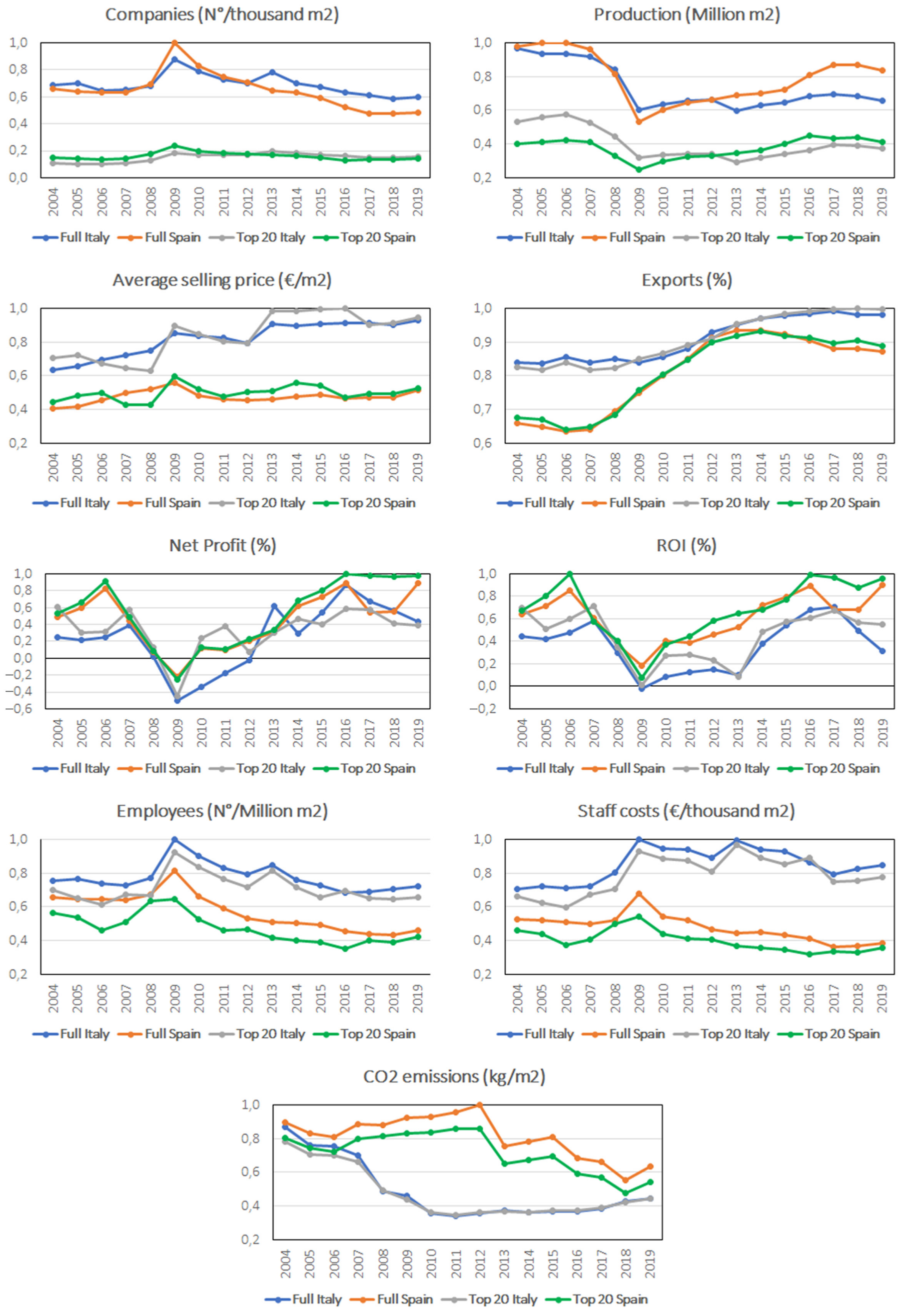

Figure 1.
Normalized input data

(%) and ROI (%)and the inputs are production (m^2), average selling price (€/m^2), employees (n) and staff costs (€). Here, the undesirable output (GHG) is modeled following the first approach. In this way, among years with similar levels of production, price, employees and costs, the most efficient is the one with the lowest level of emissions or the highest level of economic performance.

The literature places considerable emphasis on the advantages of DEA for performing analyses that optimize the input-output relationship (Daultani *et al.*, 2021; Pratap *et al.*, 2021). Its fields of use are multiple. In fact, DEA is able to assess both economic and environmental performances related to corporate governance and technology innovation (Sueyoshi and Goto, 2014). The analysis can concern the performance of a specific industry within a wide geographical area in order to highlight the presence of possible clusters (Tian and Lin, 2018). Other studies combine both environmental and economic measurement, as well as contributions from different territories, by applying them to the waste sector (Lombardi *et al.*, 2021). In addition, the DEA approach is used to optimize the overall performance of a ceramic tile company by considering resilience and labor factors (Salehi and Veitch, 2020). Consequently, this work will consider a time series covering two countries (Italy and Spain) to provide both economic and environmental assessments in the ceramic tiles sector.

2.5 Eco-efficiency index

Eco-efficiency is an index typically used to assess efficiency improvements relative to specific products, sectors or cities. It is calculated as the ratio of an economic output to its environment (Bian *et al.*, 2020). In addition, this indicator, when applied in conjunction with the DEA methodology, provides a complete view of the efficiency of the object of analysis (Torregrossa *et al.*, 2018). In this work, the eco-efficiency index was calculated for two variants. In the first, the economic output was represented by net profit, in the second by ROI. For both, the environmental impact was GHG emissions. As in the previous phases, normalized data were used (Figure 1), and the choices of final parameters were consistent with those proposed by DEA.

3. Results

3.1 Historical data analysis

The peaks of production were recorded in Spain in the years 2005–2006, and the difference with Italy has always tended to be contained. However, starting in 2016, it has become increasingly significant until, in 2019, reaching a value that is larger than a quarter. In contrast, there are no differences between the top 20 companies in the two countries. In addition, the black-out phase of the sector in 2009 and, for Italy, also that of 2013 should be underlined. The year 2019 marks a decrease of 4% compared to the previous year in both countries. Both production and the number of employees of the top 20 companies are about half of the total. In particular, the data in Figure 1 show evidence of the peak in 2009 for the employees per unit of production. This is motivated by the value at the denominator (production) having its minimal value in the year examined. From the absolute data (which, for privacy reasons, cannot be shown), we deduce that the absolute number of workers fell by 40 and 35%, respectively, in Spain and Italy in 2019 compared with 2004. Contrary to the production figure, the number of employees in Italy is a third greater than in Spain. For this reason, the relative figure does not show any significant difference. Similar observations concern the number of companies, but for these data, the reduction in 2019 compared to 2004 is more significant in Italy (−40%), compared to Spain (−37%), thus reaching an equal number. Finally, the analysis of operations and society data concludes with staff costs. In Italy, they have decreased by 18% in 2019 compared to 2004, but the drop is much more significant in Spain (−38%). The figure for the top 20 companies is still about half of the national figure. The absolute cost in Italy of this item is 73% higher than in Spain. The peaks of 2009 and 2013 in Figure 1 are explained by the relative figure compared to production.

Investigating the data of the market dimension shows a significant growth of the average selling price in Italy compared to Spain (+47% vs. +26% in 2019 compared to 2004), and we arrive at an Italian current price that is 80% higher than the Spanish one. There are no differences within the same country. The export data show Italy as excelling, which is characterized by the continuous peak value in recent years. Spain reached a peak in 2013 but then is characterized by a decrease that is, however, very contained. There are no differences within the same country, and Italy has a higher percentage figure than Spain by about ten points.

As far as economic data are concerned, both net profit and ROI highlight the crisis of 2008–2012 (Hoffmann *et al.*, 2017) with the lowest values but also the better performance of Spain compared to Italy. Regarding ROI, if the full value is analyzed, the difference is 5.4%, while it is 3.7% when considering the top 20. For Spain, growth of 2.4% is recorded in 2019 compared to 2004, while for Italy there is a decrease of 1.2%. Italy is in a phase of decline, but the top 20 manage to mitigate this economically difficult period. This is not, however, verified in terms of net profit. In addition, we also have a difference of 1.8 and 3.9% in 2019 compared to 2004 when considering Italy and Spain, respectively. Spain has a higher value of 4.4%, and the difference is even more significant if we look at the comparison in terms of the top 20 (5.7%).

With regard to environmental data, an important result emerges. Despite the lower production, Italy has a lower value of emissions per unit of production than Spain by about a quarter. It should also be highlighted that in 2019, Italy recorded a decrease of 49% compared to 2014, while Spain stopped at 29%. Italy's virtuous behavior has been constant in recent years.

3.2 Parameters analysis

The first phase of the backward analysis measures the relationship, if any, among the parameters chosen in this paper. Building on what was described in Section 2.3, Figure 2 proposes the correlation matrix using a color structure to identify relationships. Where they are significant but verified only in one of the four groups, they are not considered because they are specific to that context (e.g. the two economic criteria for production are verified by a positive correlation only in Spain's top 20).

Full Italy										–1,00
	I	II	III	IV	V	VI	VII	VIII	IX	–0,80
I	1									–0,60
II	0,95	1								–0,40
III	–0,35	–0,30	1							–0,20
IV	0,60	0,60	–0,92	1						0,00
V	–0,02	–0,07	–0,90	0,70	1					0,20
VI	–0,49	–0,49	–0,61	0,33	0,83	1				0,40
VII	–0,82	–0,72	0,06	–0,29	0,31	0,68	1			0,60
VIII	–0,88	–0,80	0,41	–0,63	–0,03	0,36	0,78	1		0,80
IX	–0,16	–0,12	0,93	–0,82	–0,87	–0,65	–0,01	0,27	1	1,00

Full Spain										–1,00
	I	II	III	IV	V	VI	VII	VIII	IX	–0,80
I	1									–0,60
II	0,85	1								–0,40
III	–0,12	–0,61	1							–0,20
IV	0,97	0,93	–0,30	1						0,00
V	0,22	0,32	–0,50	0,22	1					0,20
VI	–0,74	–0,28	–0,57	–0,59	0,12	1				0,40
VII	–0,64	–0,83	0,62	–0,69	–0,36	0,13	1			0,60
VIII	–0,64	–0,83	0,62	–0,69	–0,36	0,13	1,00	1		0,80
IX	0,71	0,79	–0,35	0,76	–0,03	–0,36	–0,66	–0,66	1	1,00

Top 20 Italy										–1,00
	I	II	III	IV	V	VI	VII	VIII	IX	–0,80
I	1									–0,60
II	0,63	1								–0,40
III	–0,57	–0,99	1							–0,20
IV	0,72	0,97	–0,95	1						0,00
V	0,26	0,79	–0,79	0,77	1					0,20
VI	–0,16	0,58	–0,63	0,49	0,86	1				0,40
VII	–0,63	–0,32	0,28	–0,30	0,05	0,32	1			0,60
VIII	–0,82	–0,65	0,59	–0,64	–0,17	0,13	0,81	1		0,80
IX	–0,38	–0,90	0,94	–0,84	–0,73	–0,68	0,18	0,47	1	1,00

Top 20 Spain										–1,00
	I	II	III	IV	V	VI	VII	VIII	IX	–0,80
I	1									–0,60
II	0,62	1								–0,40
III	–0,61	–0,98	1							–0,20
IV	0,98	0,75	–0,73	1						0,00
V	–0,13	0,47	–0,40	0,00	1					0,20
VI	–0,74	–0,05	0,04	–0,61	0,47	1				0,40
VII	–0,74	–0,91	0,94	–0,84	–0,10	0,26	1			0,60
VIII	–0,74	–0,92	0,92	–0,83	–0,19	0,23	0,97	1		0,80
IX	0,71	0,63	–0,69	0,76	–0,13	–0,52	–0,81	–0,75	1	1,00

Figure 2.
Correlation matrix. Key: I (employees), II (companies), III (production), IV (staff costs), V (average selling price), VI (exports), VII (net profit), VIII (ROI) and IX (CO_2 emissions)

The correlation between the variables shows a strong correlation in all four groups of companies with respect to only two variables (net profit and ROI). In Italy, there is a slightly less strong relationship. This result, as both are associated with the economic component, could be taken for granted, but this is not the case. Since the ceramics industry is a resource-intensive (natural raw materials) and energy-intensive (electricity and natural gas) sector, industrial costs are strongly influenced by the volatility of the prices of these inputs in the supply markets. It follows that the magnitude of the selling prices of the ceramic product is affected by these variations. There are also relationships that occur only at the individual country level. With regard to Italy, the number of employees is negatively correlated with the two economic criteria, due to the cost of labor that typically characterizes this country. Staff costs and average selling price are negatively correlated with production. The strong influence of the cost of the staff on productivity can find its explanation in the trade-off between expertise and effectiveness of the employees. The ceramics sector, over the time period being considered, has undergone several technological leaps and bounds, the latest of which was the complete digitalization of processes with the introduction of Industry 4.0 technologies. These disruptions required the upskilling of staff and, often, the need to hire more specialized personnel, which, however, were not always available due to the lack of suitable education from technical schools and universities. So, the lack of alignment between technological innovation and technological education is responsible for the negative impact on productivity. These last two variables also have a negative correlation with emissions. In addition, average selling price is positively correlated with exports, highlighting how Italian products are recognized as valuable (the so-called "Made in Italy" effect). Finally, there is a positive relationship between production and emissions. This trend can be explained by the progressive introduction of more and more restrictive environmental regulations, with Italy being a pioneer in the introduction and Spain following suit. With regard to Spain, staff costs have a positive relationship with employees and the number of companies, showing how competition brings benefits to all parties involved. In addition, there is a negative correlation of both economic criteria with the number of companies. Mergers and acquisitions that have occurred over time in both ceramics' districts have contributed to greater value creation through productive and organizational synergies that have been reflected in economies of scope, scale and knowledge, with positive effects on economic performance (Kumar, 2019).

3.3 DEA results

DEA analysis aims to evaluate the time trend of the efficiency for Italy and Spain from 2004 to 2019 (Figure 3). This analysis uses output-oriented DEA with variable returns of scale in which DMUs are the 16 years under evaluation, outputs are GHG emissions or economic performance indexes (net profit and ROI) and the inputs are production, average selling price, employees and costs. The results are presented both for the entire ceramic tiles sectors (all the firms) and for the sectors' top 20 firms. Note that:

(1) Numerical results are not comparable between countries.

(2) For each country, evaluated over a specific time series, the model identifies the highest efficiency (equal to 1) in the year in which it shows the best performance; such a score does not indicate that the country has achieved absolute efficiency (optimum use of inputs vs. outputs).

Actually, the significant result of this analysis is the efficiency trend, not the individual annual values.

Up until 2009, Spain had an inefficient trend in CO_2 emissions, but starting in 2010 it began a decisive change in gear. In fact, although the trend is slightly downward, Spain still tends to keep its output above 0.9, and therefore very close to the frontier point. On the other hand, the

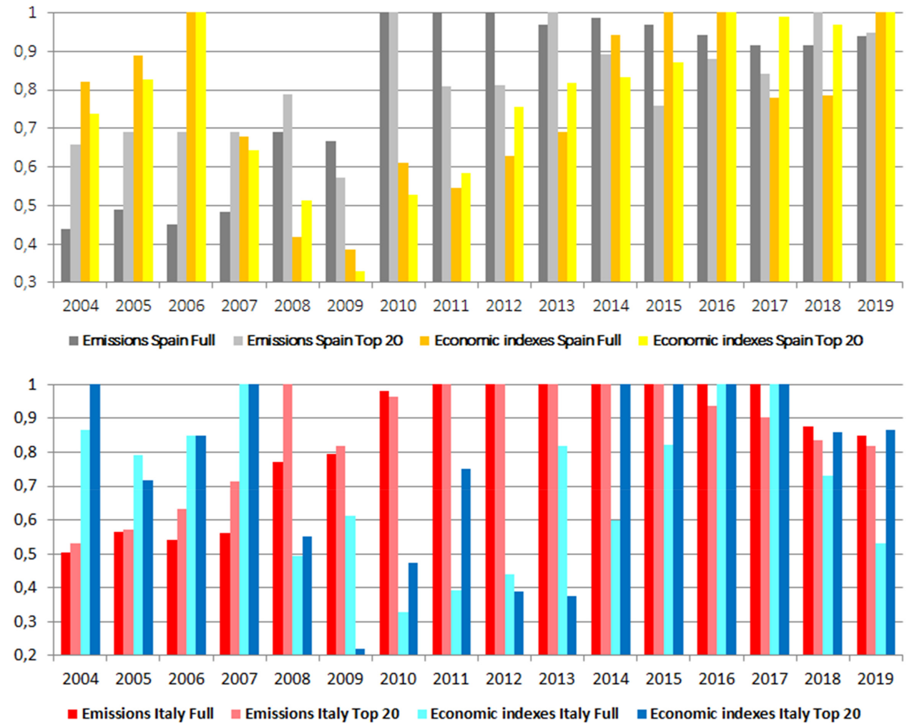

Figure 3.
Measurement of efficiency expressed in terms of emissions and economic criteria

trend of the top 20 is not clearly identifiable as it tends to be very erratic. In terms of economic indicators, Spain shows a decidedly upward trend. However, even though the frontier is reached in the two-year period 2015–2016, in the following years there is a significant decrease, before reaching efficiency again in 2019. In contrast, in the last four years, the top 20 show a decisive positive trend. These results can be explained by the progressive change in production type made by the Spanish ceramics industry, which for a long time stood out in the markets for the production of wall tiles (identified as monoporous), while the Italian industry has specialized since the 1990s in the production of floor tiles (identified as porcelain stoneware). The manufacture of monoporous, unlike porcelain stoneware, in addition to natural raw materials such as clays, feldspars and sands, also requires the use of carbonate minerals (calcite and dolomite). Monoporous tiles during firing release significant quantities of CO_2 due to the decomposition of carbonates. In contrast, porcelain stoneware, although fired at higher temperatures but not containing carbonates, does not release significant quantities of CO_2. In recent years, the Spanish ceramics industry has changed its production mix, moving toward porcelain stoneware at the expense of monoporous, competing with the Italian industry in the most profitable markets, given that the selling price of porcelain stoneware is higher than that of monoporous. This has been reflected in a decrease in CO_2 emissions and an improvement in the economic performance of Spanish companies.

The Italian ceramics industry has shown a steady trend in emissions and is fully efficient in the period 2011–2017, which, however, has been interrupted in the last two years analyzed. The top 20 companies follow a similar trend but precede this reversal since 2016. The economic indicators also show a mirror-image situation that is particularly evident in the period 2014–2017. Similar to the behavior of the Spanish Top 20, there is also a strong accentuation of the anomalous trend for the Italian top 20. The incremental adoption of digital printing technologies for the glazing and surface decoration phases of tiles, which reached its peak in the two-year period 2017–19, has caused a worsening of environmental performance. The inks used for digital printing are chemical compounds of a mainly organic nature that, during the firing phase, release substances that are included in the calculation of atmospheric emissions. Moreover, the Italian ceramics industry was the first to experiment with significant product innovation, introducing large format slabs (e.g. 120 × 220 and 120 × 280 cm) capable of perfectly emulating the finest natural marble and granite. However, the higher industrial costs to manufacture the slabs and a market response that was not always consistent in terms of demand volumes, with sales prices below expectations, caused negative impacts on the economic performance of Italian companies.

In general, the irregular evolution recorded in both countries during the historical period analyzed is attributable to both technological discontinuities and changes in demand, factors that together have characterized the construction sector worldwide in recent years. This, however, demonstrates the dynamism of the Italian and Spanish ceramics industry to adapt to change.

3.4 Eco-efficiency results

As the literature has shown (Section 1), the combined DEA and eco-efficiency index can provide comprehensive answers regarding efficiency. While the first analysis is able to assess the time profile, the second allows for a comparison of different alternatives. In this way, the backward analysis takes on a more complete profile. In accordance with Section 2.5, Figure 4 provides an eco-efficiency index. The two variants are proposed according to the economic output taken as reference.

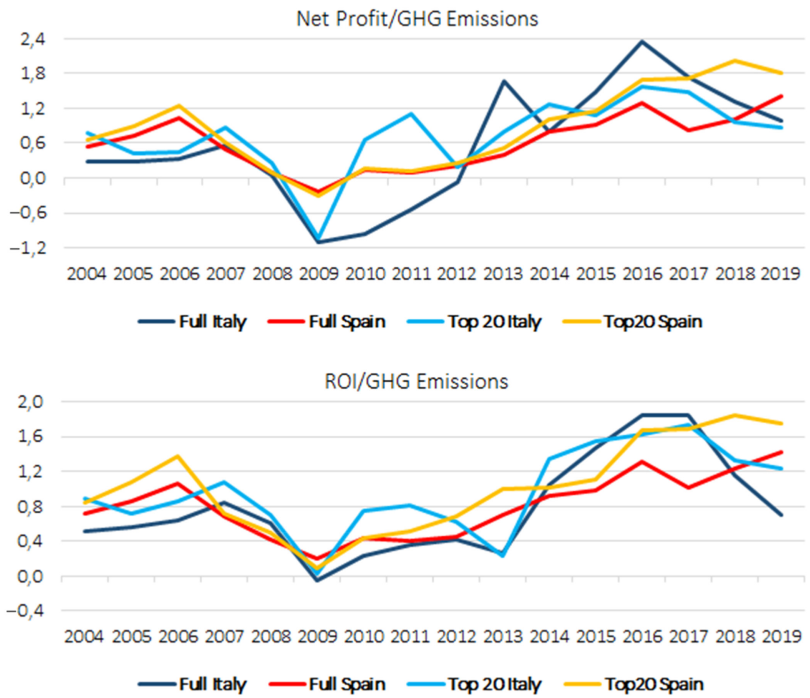

Figure 4.
Eco-efficiency index for two variants

Results vary from year to year, so an analysis is needed that cannot be generalized. Italy peaks in 2016 (2.36 and 1.57 in terms of net profit/GHG emissions for the entire country and top 20, respectively) and 2017 (1.85 and 1.73 in terms of ROI/GHG emissions for the entire country and top 20, respectively). Spain peaks in 2019 for the overall data, and in 2018 for the top 20. It records 1.41 and 2.02 in terms of net profit/GHG emissions and 1.42 and 1.85 in terms of ROI/GHG emissions, respectively. Figure 4 thus captures the efficiency toward which Spain is striving, driven in particular by the top 20, a result that is mainly explained by the economic component. The overall Italian value was the best in the period 2015–2017, but undergoes a decrease in the years to follow. In particular, ROI shows a significant decrease. The differences in the eco-efficiency index highlight how the economic analysis varies according to the indicator considered. In fact, the results of the two variants do not provide mirrored results. The existence of multiple economic indexes serves precisely to capture more information. Net profit measures the performance of the business, while ROI concerns the return on the money that has been invested in the business. Efficiency reached its lowest point in 2009, and this result has already been highlighted above. The year 2009 was an extremely negative year for both the Italian and Spanish ceramics industry, as the ROI trend clearly shows. The effects of the financial crisis that began in 2008 had their full impact on the construction sector, with a drastic drop in ceramic tile sales. In addition to this global conjuncture, for the Italian ceramics industry there was the collapse of the domestic market and, following the real estate crisis, the very sharp slowdown of the American market, which has always been the preferred destination for the premium products of Italian companies. The trend of the efficiency indexes records the nature and the new peculiarities of the slowdown of the world economy that followed the crisis that began in 2008, and continued until 2013, the year in which the Italian ceramics industry showed a divergent trend in ROI and net profit. The significant increase in net profit is the effect of the imposition of duties on imports of Chinese ceramic tiles into Europe. Italian companies were able to capture part of the turnover freed up by sales of Chinese products in Europe, generating new profits. On the other hand, the crisis in the Italian credit system, triggered also by the new European constraints placed on banks, has abruptly slowed down investments, and this drop is well represented by the decrease in ROI. The Industry 4.0 plans launched simultaneously in both Italy and Spain in 2016 have had different effects on the ceramics industries of the two countries. Italian ceramics companies immediately seized the opportunity to take advantage of government incentives to digitize their factories, and in fact there is a rapid growth in investments, as indicated by ROI. The subsequent sudden decrease in ROI indicates the complete refurbishment of Italian factories, which translates into a decline in investment. In contrast, Spanish companies responded to the stimulus of the State plan more slowly, and the transformation continued in 2018 and 2019.

Finally, it is worth noting that sensitivity analysis always plays a key role in assessing the impact of performance (Dwivedi *et al.*, 2021; Ikram *et al.*, 2021). In this work, however, the data are historical and are therefore not subject to randomness. Consequently, in all analyses conducted, alternative scenarios are not evaluated. The only exception is the eco-efficiency index which is proposed in two variants to capture all economic and environmental nuances.

4. Discussion

This sectoral study, comparing two major European manufacturing industries, offers several points of reflection on the role of industrial policies within the actions that make up a country's economic policy. The relationship between industrial and economic policy is still a particularly contentious issue in most industrialized countries, as there is a lack of consensus on the limits of the scope of industrial versus economic policy. Industrial policy must unquestionably aim to promote the competitiveness of industrial firms. The controversy begins, however, when it comes to establishing the roles between companies and public administrations. Within the framework of the actions implemented by a country to promote industrial competitiveness, it is necessary to define what should be considered part of industrial policy and what should be considered a component of other policies.

A possible answer to this controversy comes from the experience matured in the industrial districts relative to the industrial and social relations between public and private agents, and on this point this study finds foundation and justification. These local ecosystems are characterized by a strong propensity for collaboration among the various public and private actors who operate within them. They are also the structures that can most quickly identify emerging societal and consumer needs, thanks in part to the strong interactions within their value chains that make individual firms and the entire district system more agile in capturing change opportunities and more resilient to external threats. In fact, industrial policies, such as the Industry 4.0 plans implemented by the Italian (2016) and Spanish (2016) governments, have been seized by the two ceramics districts as an opportunity to digitize their factories. With these operations, the two local ecosystems, thanks to the synergies between private and public operators, have transformed the effects of an industrial policy into an economic policy that was developed indirectly. Technological progress has triggered the sectoral redistribution of income, labor factors, knowledge and, consequently, social welfare. All these would obviously be goals of economic policies, but in the ceramics districts, the classic top-down policy process is reversed into a bottom-up one, making eco-systems more ready to respond to crises, as happened with the recession of 2007–2013 and more recently with the pandemic crisis that started in 2020.

The results of the analysis have shown that the Spanish ceramics industry is advancing economically, thanks to the advantage of lower industrial costs, while the Italian ceramics industry shows a modest decline that is partly offset by a higher rate of exports. The two industries have already implemented models of sustainable manufacturing with respect to available technology, by managing to effectively combine the digitalization of factories with practices of environmental sustainability also induced by particularly stringent regulations, compared to non-European producers. These best practices, common to all companies in the two sectors and not only to the top 20, have not yet obtained adequate recognition from the market in terms of premium price.

The approach to sector analysis proposed in this study can be framed within the context of reflective management practices. The backward analysis can be seen as a way of learning both through and from the experience gained by investigating the time series of variables. Reflecting on the outcomes obtained in the past allows us to obtain new interpretations of the present and thus improve future practices in a process of lifelong learning.

5. Conclusions

Today, the Italian and Spanish ceramics districts are leading industrial realities in the European manufacturing landscape. Despite the economic crises that have severely tested the two industries in this last decade, the companies have continued to pursue technological innovation, digitalization of processes and improvement of environmental performance, in the awareness that sustainability is a key element to maintaining competitiveness in global markets. Thanks to a continuous comparison between companies and local institutions, with the participation of their supervisory authorities, environmental performance has improved, reaching levels of excellence with respect to European parameters, and economic performance and social cohesion have been safeguarded even in the most difficult periods. This demonstrates the validity of the application of the principles underlying sustainable development and the circular economy as enabling factors for the growth of economies.

Businesses are required to be efficient in order to compete in the marketplace, and therefore the temporal analysis of this parameter as well as the comparison among companies becomes relevant. Italy presents a maximum eco-efficiency index in the 2016–2017 period, and Spain in the 2018–2019 period. However, it should be emphasized that efficiency in these sectors is indispensable because this is a full-cycle processing industry, with high intensity of energy and resource use, and requiring continuous improvements and careful control of industrial costs to remain competitive with producers in emerging countries or where there is greater availability of human and natural resources. Moreover, it is from this perspective that industrial districts are necessary to keep a nation's industrial system competitive. Indeed, the strong interdependence among the enterprises of the districts favors economies of scale, of scope, of knowledge and of learning, and therefore the general competitiveness of the industrial system.

From a theoretical viewpoint, this study provides a significant contribution to traditional sectoral analysis, proposing a new methodological approach based on backward analysis. This new perspective of investigation offers further interpretive options of reality by exploiting the temporal dimension that, crossing past and present, improves the predictive potential of the analysis. Therefore, from this aspect, the study has achieved the first research objective.

Moreover, the results obtained from this research also have relevant managerial implications. The methodological approach of reflective backward analysis can become a useful tool to support the decision-making processes of economic agents. This has a double managerial potential. On the business side, entrepreneurs can use reflective backward analysis, both at the micro level to analyze the performance of their companies over time and at the meso level to build benchmarks with aggregate industry data by defining baselines for comparison. On the side of public economic agents, the new methodological approach can be used at the micro level for a comparison between companies and at the meso level to monitor the status of a sector. In both cases, the information obtained can be used to lay the foundations for new industrial policies. In this regard, we can consider the second and third research objectives as having been achieved.

The work has some limitations such as the limited data available (equal to 16 years) and the exclusively meso-sector perspective. Future directions of the work will aim to investigate the behavior of individual companies at the micro level and to identify future strategies in which to evaluate how sustainability can create a competitive advantage.

Note

1. Commission Delegated Regulation (EU) 2019/331 of December 19, 2018 determining transitional union-wide rules for harmonized free allocation of emission allowances pursuant to Article 10a of Directive 2003/87/EC of the European Parliament and of the Council.

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