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ORIGINAL PAPER

Corporate social responsibility and total factor productivity: the case of European mining industry

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Abstract

The aim of this research is to investigate the effect of corporate social responsibility (CSR) on total factor productivity (TFP) in the European mining industry, considering micro- and macroeconomic indicators of the relationship between CSR and TFP. Employing data from 40 European mining companies from content analysis, CSR Hub, and the World Bank between 2018 and 2021, this paper utilizes a combination of Data Envelopment Analysis (DEA) and panel regression techniques to test the research hypotheses. The findings suggest that the TFP of European mining firms is positively affected by CSR initiatives implemented by the companies. Also, the empirical results depict that the CSR-TFP relationship is mainly established on institutional criteria. The results also indicate that CSR-related factors, namely, transparency and reporting, training, health and safety, and resource management, are the impacting indicators. The study broadens the horizons of this line of research and can be beneficial to CEOs, managers, experts, policymakers, decision-makers, and economists in the field of mining who are willing to promote responsible and sustainable mining.

Keywords Corporate social responsibility · Total factor productivity · Efficiency · Mining industry · Firm performance · Sustainability

Introduction

In recent years, the incorporation of social and environmental initiatives by corporations has resulted in a greater focus on corporate social responsibility (CSR) strategies associated with achieving sustainable development goals and gaining a competitive advantage within their respective markets (Moon 2007; Cantele & Zardini 2018; Porter & Kramer 2006; Cristina Ferreira Caldana et al. 2022; Thakhathi 2021). The latest discussions regarding CSR initiatives and corporate governance have headed towards recent social and environmental issues to demonstrate the governing systems of corporations and processes that can lead to positively improving the social behavior of the companies (Afsar & Umrani 2020; Pons et al. 2021). As a result, CSR and issues related to sustainability have been a topic of interest among researchers, executives, and decision-makers. Numerous academic studies have investigated whether adopting CSR can improve a company's financial performance. There are studies that confirm that CSR affects financial performance (Kim 2022), community engagement (Panwar et al. 2016), reputation (Miras-Rodríguez et al. 2020), and market value (Wang and Qiao 2022). Despite the prominence of the topic, the consistency between stakeholders' and shareholders' interests has remained inconclusive. It can be assumed that companies' motivation in their implemented CSR initiatives may affect their CSR performance (Poursoleyman et al. 2022). Also, the undecided conclusion could stem from the fact that CSR strategies differ from sector to sector (Kim et al. 2014).

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As more scholars have looked at how CSR is used in the mining industry, the accountability of mining companies has also been called into question. The following explains the cause for this enthusiasm: First, the contribution of mining to the economy is well known. Mining is essential to the growth of economies and is also helpful to society (Mancini & Sala 2018). Through the extraction of critical minerals and metals, mining is linked to the creation of a nation's sustainable prosperity (Monem 1999). Second, relative to other economic sectors, the mining industry has been subject to stringent criteria, such as the Social License to Operate (SLO) within the idea of sustainability reporting to multiple stakeholders, such as NGOs, governments, the media, and society (Provasnek et al. 2017). Due to the direct relationship between mining and the environment (Kahhat et al. 2019) and society (Kemp 2010), the requirement for mining businesses to implement CSR initiatives becomes significant from a public perspective (Hamann 2003). Given this rationale, the relationship between corporate social responsibility (CSR) and financial gain for mining firms has remained unclear. On the one hand, firms may be reluctant to embrace CSR strategies because of the costs associated with them. In contrast, it could have a beneficial effect on economic success by enhancing the company's reputation. The contribution of mining companies is often linked to macroeconomic variables (Medina 2021). However, the evaluations have focused on their financial performance. As a result, the research community has not focused on a more comprehensive method for evaluating CSR and its effects on macroeconomic and microeconomic performance.

There have been some efforts to assess the nexus between CSR and the financial performance of mining companies. The aforementioned studies tend to demonstrate the positive correlation between CSR and the financial performance of the mining firms through indicators such as return on assets (ROA), return on equity (ROE), net profit margin (NMP), and Tobin's Q (Pan et al. 2014; Nguyen et al. 2022; Yousefian et al. 2023). As accounting indicators, the use of financial measures, such as ROA or ROE, to quantify the economic performance of the mining industry may fail to reflect the full spectrum of economic outcomes connected with mining activities (Yang et al. 2019), this study suggests instead the use of total factor productivity (TFP) as a more inclusive metric of economic performance in the mining industry. TFP evaluates the efficiency with which inputs are converted to outputs, capturing both technical efficiency and technological advancement (Perelman 1995). It can provide a comprehensive view of the economic performance (Rubashkina et al. 2015) of the mining industry by considering both, the quantity of resources extracted and the efficiency with which they are extracted.

This paper has adopted a combination of two methods: Data Envelopment Analysis (DEA) to calculate and analyze the total factor productivity of mining companies in Europe and panel regression to investigate the relationship between CSR and TFP. The sample consists of 40 European mining companies in 16 countries across Europe. The overall findings indicate that CSR and TFP are positively correlated, with indicators from firm-level and macroeconomics statistically impacting CSR. Furthermore, it is shown that the positive effect of CSR is mainly based on firm indicators, although the positive CSR-TFP relationship is confirmed through macroeconomic indicators.

Our study contributes to the literature in several ways. Firstly, mining industry performance is measured at the microeconomic scale, which is called technical efficiency. Existing literature, even though there are a few, investigates the nexus between CSR and firm performance in the mining industry using analysis of financial performance ratios (Tarjo et al. 2022; Wasara & Ganda 2019; Hilmi et al. 2021; Akisik & Gal 2014; Fourati & Dammak 2021). Nonetheless, the financial ratios could explain the strength of a company from different monetary standpoints and may be limited to a few variables. Total factor productivity, conversely, is able to take a vast number of variables into account to assess the corporation's performance, providing a multidimensional analysis as it enables assessment of the production process during all its stages (Nadiri 1970). This research employs the DEA Malmquist Index to calculate mining companies' productivity scores as well as provide an overall analysis of the industry's economic performance among CSR-implementing companies, and four panel regression models to evaluate the relationship between productivity and CSR performance. As of the date of writing the manuscript, there has not been any research regarding the nexus of TFP and CSR in the mining industry. Secondly, the paper investigates a sample of European mining companies, which allows for a broader sense of the industry among various countries in Europe. The holistic approach of this research enables the readers to identify impacting variables in the CSR-TFP relationship from a macroeconomic and firm-level point of view.

The paper is structured as follows: Sect. 2 provides the theoretical background, existing studies related to our study, and hypotheses in the development process. In Sect. 3, the variables, methodology, and data are discussed in detail. Section 4 demonstrates the analysis and discussion of the results. Finally, the conclusion of the study is presented in Sect. 5.

Literature review

Hypotheses development

In recent decades, the research regarding CSR has been receiving attention to a great extent. There is a polarity discussion so as to identify the reasons why companies should invest in CSR initiatives. Neoclassical economic theory can explain the Shareholder Theory as it indicates that maximizing profit should be considered the main responsibility of a company's leader contemplating the law (Ferrero et al. 2014). On a similar note, there has been recent criticism of CSR activities given that the primary purpose of the firm should be gaining financial success (Orlitzky 2015; Porter & Kramer 2006). Based on this perspective, CSR programs by companies are considered resource-wasting, and therefore, the resource should be utilized to maximize the value of the company (Lazonick & O'sullivan 2000). Conversely, the Stakeholder Theory discusses that ethical business practice according to the interests of all stakeholders (e.g., shareholders, society, and the environment) eventually results in increased performance and profitability (Cots 2011; Chia et al. 2020; Harrison et al. 2019).

Based on the aforementioned theories, a significant number of researchers have made efforts to evaluate the nexus between financial performance and that of CSR in various sectors. Notwithstanding that the majority of the studies confirm the positive correlation between CSR and financial performance (Long et al. 2020; Hou 2019; Chen & Wang 2011; Sayekti 2015), there has not been a conclusive result to it. This might stem from the fact that each industry has specific CSR criteria (Kong et al. 2020). Studies regarding the assessment of CSR in the mining industry have recently gained more attention from scholars. Fauzi and Idris (2009) and Devie et al. (2020) investigated Indonesian mining companies to confirm the positive association between financial performance and CSR activities. The same results were obtained for the mining industries of Vietnam (Nguyen et al. 2021), Australia (Nguyen et al. 2022), China (Pan et al. 2014), India (Bag & Omrane 2022), South Africa (Chetty et al. 2015), and the USA (Giannarakis et al. 2016) as they affirm that the relationship between CSR and traditional financial ratios (i.e., ROA, ROE, NPM) is positive.

Nevertheless, evaluating the performance of mining companies solely based on financial indicators may restrain the analysis of such complex multi-operational firms, which, in some cases, have multiple products as outputs based on multiple inputs. Consequently, the concept of productivity is proposed for this paper, as it indicates the extent of converting inputs to outputs considering the process (Wazed & Ahmed 2008). Hence, this study employs three complementary theories to broaden the horizon of CSR research regarding the impact of CSR performance on the total factor productivity of the mining industry, both given micro- and macroeconomic variables.

The role of CSR on firms' productivity performance

There are numerous indicators that can prove the effectiveness of CSR initiatives on the productivity of mining and other sector firms. In fact, CSR can lead to having a robust reputation (Aqueveque et al. 2018; Rothenhoefer 2019; Javed et al. 2020; Esen 2013) which allows companies to recruit and maintain more efficient employees (Story & Neves 2015; Sun & Yu 2015; Chaudhary 2020) which, as a result, can provide the corporations with higher labor productivity. Furthermore, an increasing number of investors may be willing to invest in companies with more socially responsible practices (Widyawati 2020) which contributes to having higher capital for the firm following the trend of Socially Responsible Investment (SRI). Isnalita and Narsa (2017) studied the relationship between CSR disclosure and firm value through the mediating role of customer loyalty by investigating Indonesian mining companies listed on its stock exchange between 2008 and 2014. The results show that customer loyalty is in fact correlated with CSR, and as a result, it can create more market share for the company. Product pricing is another factor that is positively impacted by CSR, as it enables companies to price their products more competitively while maintaining fairness (Matute-Vallejo et al. 2011). As for mining companies, CSR initiatives can be employed as a tool to enable mining companies to attract investors (Lauwo et al. 2016). The affirmative financial and performance effects depict that CSR has a positive association with the industry's outputs. Hence, to investigate more details regarding the sector's output and inputs and CSR performance, the following hypothesis has been proposed:

H1. CSR performance has an impact on total factor productivity in the European mining industry.

CSR and macroeconomic indicators nexus with TFP

The economic strength of a country contributes to its total factor productivity (Beugelsdijk et al. 2018). Corporations are considered one of the wealth creators of a country (Panigrahi et al. 2022), specifically those of the mining sector (Aryee 2001). In fact, the activities of microeconomic enterprises impact the economic development of a country (macroeconomics) (Baqaee & Farhi, 2019). The menu cost theory implies a relationship between the menu cost of microeconomics and development at the macroeconomic level (Gordon 1990). Regarding CSR, Robertson (2009) investigated CSR within the macroeconomic concept in Singapore, Turkey, and Ethiopia. The study used social contract theory (ISCT) integrated with institutional factors. Similarly, Ćwiklicki and Jabłoński (2015) studied the relationship between economic development and corporate social responsibility at the level of national economics not only through monetary indicators but diverse aspects such as ethics. Another study conducted by Halkos and Skouloudis (2016) analyzed the CSR performances of 86 nations consisting of advanced, emerging, and developing economies, which resulted in confirming the relationship between CSR and national institutional conditions. However, the potential moderating effects of macroeconomic indicators on the CSR-TFP relationship, on the other hand, have received relatively little attention thus far. In light of these findings, the hypothesis that CSR and macroeconomic indicators such as GDP growth and inflation may have an effect on total factor productivity is supported. Specifically, a hypothesis is suggested that implies increased TFP in the European mining industry can be achieved through the implementation of CSR practices and favorable macroeconomic conditions. Therefore, the second hypothesis is proposed as follows:

H2. CSR-TFP relationship of the European mining industry depends mainly on macroeconomic indicators.

The role of firm-level indicators and CSR on TFP

Companies located in different countries vary in terms of their macroeconomic situation. As a result, their institutional circumstances might change their CSR performance and its effect on productivity. Therefore, the assessment of the quality of firm-level indicators related to total factor productivity in the industry is proposed. Most of the studies involving firm-level indicators are related to the financial performance of the companies. However, there are a few studies investigating productivity and firm indicators. ROA and firm size are two important performance indicators of firms, as a higher ROA indicates a higher efficiency (Kartikasari & Merianti 2016), and the larger a company, the better its performance (Kuncová et al. 2016). Bosch-Badia (2010) studied productivity and profitability using the DuPont extended method and found a correlation between ROA, TFP, and labor productivity. On a similar note, Hromova et al. (2006) investigated the effect of ROA on TFP in a railroad operation over a period of seven years. Furthermore, Leung et al. (2008) confirmed the relationship between firm size and total factor productivity in the manufacturing and non-manufacturing sectors between Canada and the USA. The same positive relationship is confirmed in the USA (Dhawan 2001), Spain (Diaz & Sanchez 2008), and India (De & Nagaraj 2014). However, there has not been any study regarding the industry's productivity and CSR relationship considering firm-level indicators. Therefore, the third hypothesis for this paper is as follows:

H3. CSR-TFP relationship of the European mining industry depends mainly on firm-level indicators.

Table 1 Sample distribution by countries

Country	*Number of mining firms*
Austria	1
Belgium	1
Cyprus	1
Finland	2
France	2
Germany	1
Italy	1
Netherlands	1
Norway	1
Poland	3
Romania	1
Russia	8
Spain	4
Sweden	2
Switzerland	1
The United Kingdom	10
Total	40

Methods and materials

Data collection

The sample for this study has been chosen based on the regional and industry categories of the CSRHub database. The sample is selected based on the availability of their necessary financial variables, which are extracted from companies' annual reports. Due to this reason, the sample includes 40 companies from 16 countries in Europe between 2018 and 2021, resulting in a balanced panel of 160 observations. The sample, derived from CSRHub, comprises mining companies located in Europe. Although Russia is a transcontinental country, spanning Eastern Europe and Northern Asia, the categorization of Russia as a European country was determined by the rating provider.[1] It is noteworthy that companies from the United Kingdom and Russia constitute 25% and 20% of the sample, respectively. This is attributable to the fact that corporations listed on CSRHub, which meet the criteria of being situated in Europe, being a mining company of comparable size, and having accessible annual reports, have effectively limited the inclusion of companies from other countries.

[1] The Russian Federation is listed as a country in Europe on CSRHub as can be access through the following webpage: https://www.csrhub.com/geographic_region/Europe. The data retrieved on 20 May 2022.

The sample distribution for the study across the countries is presented in Table 1.

Total factor productivity as dependent variable

To calculate the total factor productivity scores, DEA has been adopted as it allows assessment of technical efficiency given the fact that total factor productivity can change due to changes in either technical efficiency or technology (Abbott & Wu 2002). Farrell output-oriented technical efficiencies are a common measure of productive efficiency, especially when comparing the performance of companies or industries. In conjunction with the Malmquist Index, which assesses productivity change over time, the method is frequently employed. The Farrell method provides a valuable basis for comparing enterprises or industries, whereas the Malmquist index permits the evaluation of productivity change over time. Utilizing the Malmquist productivity index permits the estimation of the proportion of firm productivity change attributable to each of these variables. In addition, it uses the concept of distance function, which enables using multiple inputs and multiple outputs regardless of the specifics of the calculation object, such as cost minimization. The output set can be the base of the output distance function. Equation (1) explains the basic distance function.

$$d_o(x, y)\min\left\{ \delta : \left(\frac{V}{\delta}\right)\varepsilon P(x) \right\} \tag{1}$$

where x and y are points in metric space, $P(x)$ is a set of translations of (x), and $(\frac{y}{\delta})$ represents the scaled version of (y) by factor (δ). The distance function will have a value of one if (y) lies on the outer boundary of the feasible production set and a value larger than one if (y) lies outside the feasible production set (Ray 2004).

The Malmquist index estimates TFP change between two points by evaluating the distance of each point to the common technology ratio. Based on Simar and Wilson (1999), the output-oriented index for TFP change between the base year and the year t can be calculated using Eq. (2):

$$M_o\left(y_s, x_s, y_t, x_t\right) = \left[\frac{d_o^s(y_t, x_t)}{d_o^s(y_s, x_s)} \times \frac{d_o^t(y_t, x_t)}{d_o^t(y_s, x_s)}\right]^{1/2} \tag{2}$$

where d_o^s shows the period (t) observation distance to the period s technology. A value over one for (M_o) indicates the growth in TFP from period (s) to period (t), whereas a value less than one implies inefficiency. Equation (2) is the geometric mean of two productivity indicators, namely: period (s) technology based, and period (t) technology based.

The index can be also written as shown in Eq. (3):

$$M_o\left(y_s, x_s, y_t, x_t\right) = \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)}\left[\frac{d_o^s(y_t, x_t)}{d_o^t(y_t, x_t)} \times \frac{d_o^s(y_s, x_s)}{d_o^t(y_s, x_s)}\right]^{1/2} \tag{3}$$

where the (d_o^t) to (d_o^s) ratio outside the brackets refers to the output-oriented technical efficiency during the (s) and (t) periods. The efficiency change can be defined as the ratio of Farrell's technical efficiency in period (t) to that of period (s). The measurement of technical change can be done through the other parts of Eq. (3). Technological change between the periods is calculated at (x_t) and (x_s). Therefore, efficiency change and technical change are presented in Eqs. (4) and (5), respectively.

$$\text{EfficiencyChange} = \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)} \tag{4}$$

$$\text{TechnicalChange} = \left[\frac{d_o^s(y_t, x_t)}{d_o^t(y_t, x_t)} \times \frac{d_o^s(y_s, x_s)}{d_o^t(y_s, x_s)}\right]^{1/2} \tag{5}$$

The resulting structure is depicted below, which shows a constant return to scale technology with a single output-input ratio. Each period, the company operates below the technology of the period. Thus, there is a lack of technical sufficiency in the given periods. Based on Eqs. (4) and (5), the following are obtained:

$$\text{EfficiencyChange} = \frac{y_t/y_s}{y_s/y_a} \tag{6}$$

$$\text{TechnicalChange} = \left[\frac{y_t/y_b}{y_s/y_a} \times \frac{y_s/y_a}{y_s/y_b}\right]^{1/2} \tag{7}$$

Theoretically, the four distance measures mentioned in Eq. (2) need to be evaluated for each company correspondingly to each pair of adjoining periods through mathematical modeling or econometrics techniques. In TFP analysis, the returns to scale properties play a vital role (Fox 2005) as the ratio of output per input considering one factor for each may not represent the correct TFP changes. If the Variable Returns to Scale (VRS) method is implemented in the technology used to estimate distance functions for the indirect calculation of Malmquist TFP, it is essential to impose Constant Returns to Scale (CRS) assumptions (Zofio 2007). This is necessary to ensure that the resulting measures accurately reflect the increases or losses in TFP that result from changes in scope. Failure to implement CRS assumptions could result in erroneous measurements of productivity change.

Considering the availability of reliable panel data, the required distances can be computed using DEA linear programming. Due to the fact that for each company, four distance functions between two periods need to be calculated, four linear programming (LP) problems need to be solved

(Odeck 2006). Equations (8), (9), (10), and (11) show the required LPs.

$$\left[d_o^t(y_t, x_t)\right]^{-1} = max_{\Phi,\lambda}\Phi, \tag{8}$$

$$St - \Phi y_a + y_t\lambda \geq 0,$$

$$x_a - x_t\lambda \geq 0$$

$$\lambda \geq 0$$

$$\left[d_o^s(y_s, x_s)\right]^{-1} = max_{\Phi,\lambda}\Phi \tag{9}$$

$$St - \Phi y_a + y_s\lambda \geq 0,$$

$$x_a - x_s\lambda \geq 0$$

$$\lambda \geq 0$$

$$\left[d_o^t(y_s, x_s)\right]^{-1} = max_{\Phi,\lambda}\Phi, \tag{10}$$

$$St - \Phi y_a + y_a\lambda \geq 0,$$

$$x_a - x_t\lambda \geq 0$$

$$\lambda \geq 0$$

$$\left[d_o^t(y_t, x_t)\right]^{-1} = max_{\Phi,\lambda}\Phi \tag{11}$$

$$St - \Phi y_a + y_a\lambda \geq 0,$$

$$x_a - x_t\lambda \geq 0$$

$$\lambda \geq 0$$

In Eqs. (10) and (11), where production points are compared to technologies from distinct time periods, the parameters are not required to be greater than or equal to one, as they are when calculating Farrell output-oriented technical efficiencies. It is possible that the data point lies above the feasible production set. Most probably, this will occur in Eq. (11), where a production point from period (t) is contrasted to technology from period (s). If technological advancement has occurred, a value of l is conceivable. Note that if a technical regression has occurred, it could also occur in Eq. (10), though this is less likely.

The data used to calculate the TFP scores are total revenue as the output and total assets and employee numbers as the inputs for the 40 selected European mining companies as decision making units (DMUs) of the analysis between 2018 and 2021. The currency for the study has been considered in US dollars for the time period consisting of 160 observations.

CSR indicators as independent variables

The independent variables used in this study are human rights and supply chain (HRSC), leadership (LSHP), product (PRD), resources management (RCSMNG), training health and safety (THS), and transparency and reporting (TRRP) to measure CSR performance using CSRHub's ratings and rankings. CSRHub has developed a novel method for accumulating CSR metrics from over 175 companies in five stages, in order to rank and rate the companies in their respective categories. First, the data is mapped to a central outline, with the CSR performance of each company positioned within 16 subcategories aligned with 17 United Nations Sustainable Development Goals that fall under one of the four primary categories: Community, Employee, Environment, and Government. Next, the data undergoes the rating procedure on a scale of 0 to 100, with 100 as the full score. In order to avoid prejudice, ratings from multiple CSR sources are compared for each company in the next stage. Regarding step four, the weights for each adopted source are utilized to estimate the ratings for the designated subcategories. Ratings that lack sufficient information are removed from the database as a final step.

Control variables

To minimize the possible bias that may be caused by CSR indicators on TFP, a set of control variables have been employed that are aligned with our hypotheses as mentioned in Sect. 2. The variables can be categorized into two groups:

The first group is related to firms and microeconomics. The natural logarithm of the total assets of each firm depicts the size of the firm (Hirsch et al. 2022), and the ROA of each firm is calculated through the ratio of net income to total assets (Adaningtyas & Koesrindartoto 2021). The second category belongs to macroeconomic variables, namely, GDP growth (Behr et al. 2013) and inflation rates (Freeman & Yerger 1997) of the countries where the companies are located.

Methodology

To assess how CSR can have an effect on TFP of the mining industry through firm-level and macroeconomic indices, after calculation of TFP through the DEA Malmquist index, the following panel regression models are utilized so

Table 2 Research variables definition

Variables	*Acronyms*	*Definition*	*Source*
Total factor productivity score	TFP	Technical efficiency scores are calculated through the DEA Malmquist index with total revenue as the output and total assets and employees as the inputs	Content analysis/authors' calculation
Human rights and supply chain	*HRSC*	Human rights and supply chain rating of each company	CSRHub
Leadership	*LSHP*	Leadership	CSRHub
Product	*PRD*	Product	CSRHub
Resources management	*RCSMNG*	Resources management	CSRHub
Training, health, and safety	*THS*	Training, health, and safety	CSRHub
Transparency and reporting	*TRRP*	Transparency and reporting	CSRHub
Firm size	*SIZE*	Natural logarithm of total assets	Content analysis/authors' calculation
Return on assets	*ROA*	Net income/total assets	Content analysis/authors' calculation
GDP growth	*GDPG*	Annual GDP growth rate	WorldBank
Inflation	*INF*	Annual inflation rate	WorldBank

Table 3 Malmquist index productivity analysis summary of annual means for the European mining industry between 2018 and 2021

Years	*Efficiency change*	*Technological change*	*Pure efficiency*	*Scale efficiency*	*TFP change*
2019	0.923	0.954	1.025	0.901	0.881
2020	0.975	0.893	0.993	0.982	0.871
2021	0.839	1.380	0.947	0.885	1.157
Mean	0.910	1.055	0.988	0.922	0.961

as to examine the hypotheses and extract possible affecting variables on mining industry TFP through the micro- and macroeconomic indicators:

Model 1.

$$TFP_{it} = \alpha + \beta_1 HRSC_{it-1} + \beta_2 LSHP_{it-1} + \beta_3 PRD_{it-1} + \beta_4 RCSMNG_{it-1} + \beta_5 THS_{it-1} + \beta_6 TRRP_{it-1} + \varepsilon_{it}$$

Model 2.

$$TFP_{it} = \alpha + \beta_1 SIZE_{it-1} + \beta_2 ROA_{it-1} + \varepsilon_{it}$$

Model 3.

$$TFP_{it} = \alpha + \beta_1 GDPG_{it-1} + \beta_2 INF_{it-1} + \varepsilon_{it}$$

Model 4.

$$TFP_{it} = \alpha + \beta_1 HRSC_{it-1} + \beta_2 LSHP_{it-1} + \beta_3 PRD_{it-1} + \beta_4 RCSMNG_{it-1} + \beta_5 THS_{it-1} + \beta_6 TRRP_{it-1} + \beta_7 SIZE_{it-1} + \beta_8 ROA_{it-1} + \beta_9 GDPG_{it-1} + \beta_{10} INF_{it-1} + \varepsilon_{it}$$

where *TFP* is the total factor productivity of the firm, *HRSC* is the human rights and supply chain rating; *LSHP* is the leadership rating; *PRD* is the product rating; *RCSMNG* is the resources management rating; *THS* is the training, health, and safety rating; *TRRP* is the transparency and reporting rating; *SIZE* is the natural logarithm of total assets; *ROA* is the return on assets; *GDPG* is the GDP growth; *INF* is the inflation rate; and ε_{it} is the specific error term. The definitions of the variables used in the study are shown in detail in Table 2.

Results

The DEA model used for this study is output-oriented, following Hosseinzadeh et al. (2016) for the firms during the time period. Total factor productivity growth has been decomposed into technological change and technical efficiency change (TEC). The annual average Malmquist index and decomposed values of technical change and efficiency change are presented in Table 3. As mentioned earlier, a value over 1 indicates an improvement in productivity, and a value below 1 implies inefficiency. The findings indicate that the efficiency change, technological change, pure efficiency, and scale efficiency of European mining companies changed over time. In 2019, the efficiency change was 0.923, the technological change was 0.954, the pure efficiency was 1.025, and the scale efficiency was 0.901. The TFP change was 0.881. In 2020, efficiency change increased to 0.975%,

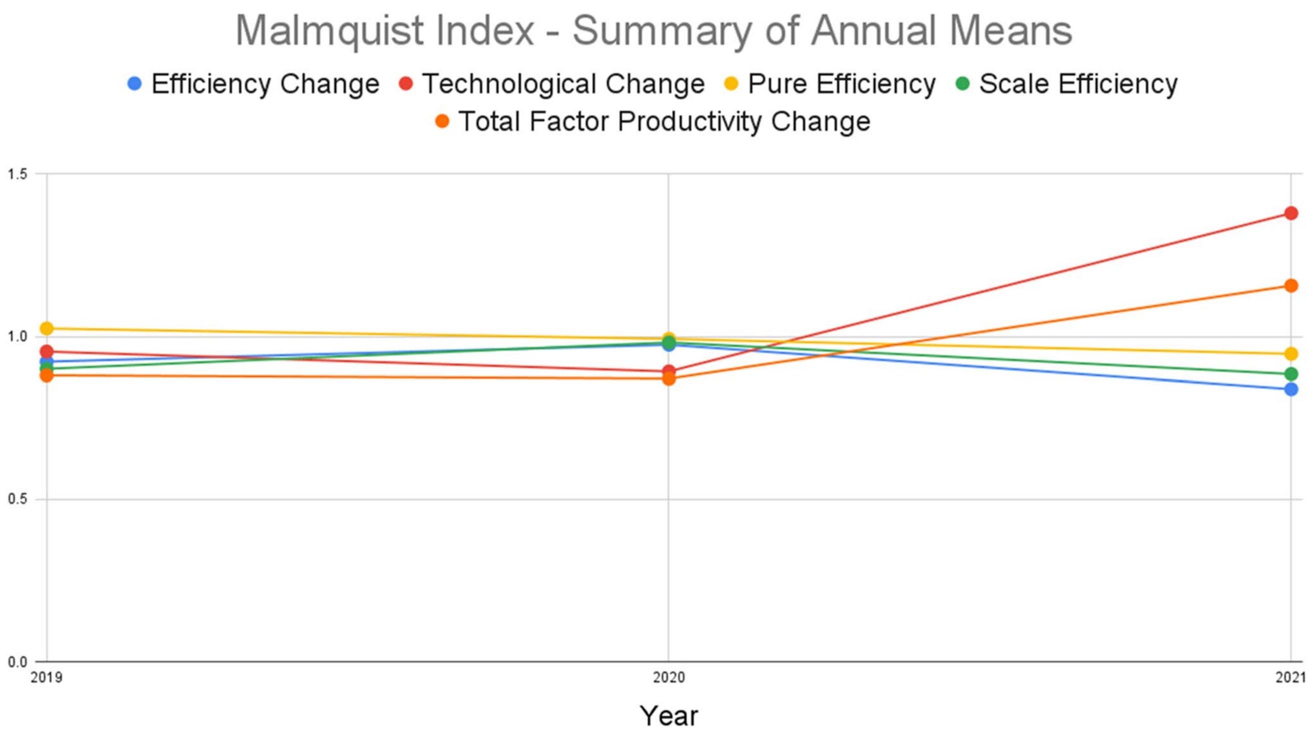

Fig. 1 The Malmquist index summary of annual means

technological change decreased to 0.893%, and pure efficiency decreased to 0.993%. However, scale efficiency increased to 0.982, while TFP change decreased marginally to 0.871. In 2021, efficiency change decreased to 0.839, while technological change increased to 1.380, resulting in a decrease in pure efficiency to 0.947 and scale efficiency to 0.885. Nonetheless, TFP change grew substantially to 1.157. The average efficiency change over the past three years was 0.910; technological change was 1.055; pure efficiency was 0.988; scale efficiency was 0.922; and TFP change was 0.961. Furthermore, in order to proceed with the research, the Variable Returns to Scale (VRS) technical efficiency scores of companies have been adopted as TFP indicators for each company given the related year. VRS may be preferable for the mining industry due to the nature of mining operations, which frequently involve complex and unpredictable factors such as varying ore quality, geological conditions, environmental regulations, and in this case, CSR initiatives that can influence production output and input quantities. VRS enables mining companies to more flexibly alter their production scale in response to changing conditions, thereby enabling them to potentially optimize their efficiency and adapt more effectively to shifting market conditions. Table 3 and Fig. 1 show the results for the productivity analysis summary of annual means.

Table 4 presents the descriptive statistics of the study, showing the differences in the values of the means among the variables considered for models. The mean value for TFP is 0.6947 with a standard deviation of 0.2642, a minimum value of 0.195, and a maximum of 1. HRSC has a mean value of 52.9296, a standard deviation of 10.1869, and a minimum and maximum of 21.98 and 86.25, respectively. For LSHP, the mean value is 52.0540 and the standard deviation value is 7.9213, ranging from 24.26 to 75.81. The average value for RCSMNG is 50.8091 with a standard deviation of 10.6929, and it varies between 7.93 and 80.09. THS and TRRP are comparable as their respective mean values are 54.0638 and 53.3004, with minimum

Table 4 Descriptive statistics of variables

Variable	*Obs*	*Mean*	*Std. dev*	*Min*	*Max*
TFP	160	0.6947	0.2642	0.195	1
HRSC	160	52.9296	10.1869	21.98	86.25
LSHP	160	52.0540	7.9213	24.26	75.81
PRD	160	46.5678	9.7931	20.88	67.44
RCSMNG	160	50.8091	10.6929	7.93	80.09
THS	160	54.0638	12.6354	26.77	78.17
TRRP	160	53.3004	9.9202	26.68	82.02
SIZE	160	21.7192	1.6156	17.71	24.10
ROA	160	6.9476	9.1550	− 16.85	41.79
GDPG	160	0.9550	5.0199	− 11.30	7.50
INF	160	3.3956	3.9875	− 3.60	16.90

Table 5 Pearson correlation matrix

	TFP	*GDPG*	*INF*	*SIZE*	*ROA*	*HRSC*	*LSHP*	*PRD*	*RCSMNG*	*THS*	*TRRP*
TFP	1										
GDPG	−0.046	1									
INF	−0.013	0.074	1								
SIZE	0.167	0.058	0.073	1							
ROA	0.052	0.163	0.261	0.355	1						
HRSC	0.12	−0.06	−0.151	0.387	0.174	1					
LSHP	0.067	0.072	−0.189	0.269	0.064	0.658	1				
PRD	0.351	−0.051	−0.106	0.272	0.094	0.534	0.377	1			
RCSMNG	0.116	0.041	−0.081	0.409	0.004	0.646	0.615	0.338	1		
THS	0.135	−0.08	−0.147	0.364	0.030	0.561	0.677	0.279	0.549	1	
TRRP	0.128	0.118	−0.124	0.413	−0.013	0.535	0.687	0.369	0.531	0.577	1

Table 6 Panel regression analysis

	CSRIN-TFP (Model 1)	*CSRFI-TFP (Model 2)*	*CSRME-TFP (Model 3)*	*CSR-TFP (Model 4)*
TFP				−2.33386
GDPG			−1.800386	−0.300216
INF			0.300233	−0.80523
SIZE		−2.92791		2.537916
ROA		4.150657		0.350115
HRSC	0.340877	0.513804	0.065038	0.544243
LSHP	−0.702717	−1.444707	1.047081	−0.512103
PRD	−1.258521	−1.231767	0.020237	1.068712
RCSMNG	1.769325	2.092566	1.250743	1.692753
THS	2.770824	2.764779	1.426017	−1.74467
TRRP	−1.894817	−2.404927	−2.186926	1.231672
Method	Panel EGLS (cross-section weights)	Panel EGLS (cross-section weights)	Panel least squares	Panel least squares
Homoskedasticity probability	0.0112	0.0032	0.0210	0.0237
F-statistic	126.1448	134.0886	29.11004	29.1789
Durbin-Watson	2.126257	2.085691	2.425401	2.444654
Model VIF	0.290546	0.414352	0.471602	0.573993

and maximum values of 26.77 and 26.68 and 78.17 and 82.02, correspondingly. The mean values of SIZE, ROA, GDPG, and INF are 21.7192, 6.9476, 0.9550, and 3.3956, respectively.

Pearson correlations for all variables are shown in Table 5. According to Pallant (2011), the correlation between variables should not exceed 0.7; otherwise, it might create a multicollinearity problem. As can be seen from the results, no correlation greater than 0.687 is found between variables. Therefore, the correlation between explanatory variables depicts the lack of multicollinearity in the test.

Discussion

Table 6 demonstrates the four models proposed for the study. Regarding Model 1, CSR indicators without the moderating role of micro- or macroeconomic variables have a statistically positive effect on TFP. Training, health, and safety are the only indicators having statistical significance on the model (p-value = 0.006). In addition, the results demonstrate that the model is statistically significant with a p-value of 0.000, an adjusted R^2 of 97.2%, and an F-statistic of 126.144. Because none of the other variables are associated with the model, they have no impact on TFP directly. In addition, the Durbin-Watson statistic

Table 7 Summary of the results

Hypothesis	Test performed	Results
H1	CSR performance positively impacts total factor productivity of mining firms	Partially accepted
H2	CSR-TFP relationship depends more on macroeconomic indicators	Partially accepted
H3	CSR-TFP relationship depends more on firm-level indicators	Accepted

value was found to be 2.1262, which is less than 2.5000, indicating that there is no autocorrelation in the model. The model VIF was also found to be 0.2905, indicating that the model lacked multicollinearity. Model 2 tests the relationship between CSR and TFP given the firm-level indicators as control variables, which demonstrates a significant relationship with a *p*-value of 0.000. The model's reliability is represented by an adjusted R^2 of 97.5% and an *F*-statistic of 134.088. ROA (0.000) and resource management (0.038) are statistically positively correlated variables, while firm size (0.004) is negatively correlated. With a Durbin-Watson statistic value of 2.0856 and a model VIF value of 0.4143, the model lacks autocorrelation and multicollinearity. Considering macroeconomic variables, Model 3 evaluates the relationship between the European mining companies' TFP and the CSR indicators. Due to the statistically significant relationship between the dependent variable and the independent variables, the model results partially accept hypothesis 2. The only influencing indicator is transparency and reporting, with a *p*-value of 0.0308 indicating a negative effect. There is no statistical correlation between the remaining variables and the independent variable. The regression model's explanatory coefficients have an *F*-statistic of 29.1100, an adjusted R^2 of 89.2%, and a *p*-value of 0.000. The absence of autocorrelation in the model is indicated by the Durbin-Watson statistic with a value of 2.4254. In addition, the VIF for the model is 0.471602, which mitigates the multicollinearity concern. Finally, Model 4 examines the impact of CSR activities on TFP, considering both micro- and macroeconomic indicators. The model cannot confirm a statistical significance between CSR and TFP, with a *p*-value of 0.000, an adjusted R^2 of 89.6%, and an *F*-statistic of 29.1789. By analyzing the *p*-values of the indicators, it is determined that two variables influence TFP: GDP growth (0.0214) and ROA (0.0126), which have a negative and positive correlation with the dependent variable, respectively. Given that the model VIF value is 0.573993, there is no multicollinearity. The null hypothesis of autocorrection is rejected considering that the Durbin-Watson statistic value is 2.444654.

Overall, the results suggest that CSR can have a partial positive effect on total factor productivity in the mining industry. Additionally, it can be discussed that the CSR-TFP relationship is aligned with a weak sustainability approach rather than a strong sustainability theory, which explains that the social and environmental performance of a company is not associated with macroeconomic performance (Pelenc & Dubois 2020). Consistent with Stakeholder Theory, it can be argued that benefiting all stakeholders can provide companies with a higher competitive advantage (Harrison et al. 2010). This competitive advantage can stem from increased reputation (Harrison et al. 2010), employee productivity (Istvan 1992), and competitive product pricing (Hinterhuber & Liozu 2014). For mining firms, this can be interpreted as the potential of CSR as a tool for positively impacting productivity by improving the inputs, such as labor, a more appropriate usage of input, for instance, assets, and possibly increasing the output through increasing the chance of obtaining SLOs to produce more, thereby increasing revenue. However, it seems that transparency and reporting, along with resources management and training, health, and safety, are the most impactful criteria that mining companies can use as a proxy to increase their TFP or reduce inefficiency. Table 7 shows a summary of the research hypotheses and their associated results.

Conclusion

The topic of corporate social responsibility and its financial impact on firms has been growing over the past few decades. In the current study, the impact of CSR on total factor productivity in the European mining industry was studied using a combination of DEA and panel regression. The paper employed a sample consisting of 40 European mining companies across 16 countries over a four-year period between 2018 and 2021. The results indicate that CSR can partially impact the total factor productivity of companies based on various macroeconomic and institutional factors. To begin with, it seems that CSR positively benefits the mining industry through a few CSR criteria such as transparency, resource management, training, health, and safety. Moreover, it is confirmed that CSR-TFP follows a weak sustainability approach, which indicates that the CSR-TFP relationship is mainly established through institutional indicators. All in all, the findings of this paper can contribute to the CSR and firm performance of the mining industry by explaining the effects and affecting indicators of CSR implementation on total factor productivity as a proxy for the optimized usage of a company's resources.

This research can have practical implications for managers and CEOs in the mining industry, as they might find it useful to implement CSR initiatives based on the positively impacting criteria, avoid non-related indicators, and align their decision-making processes according to the findings of this paper. As a matter of fact, the conclusions tend to imply that CSR activities by mining companies can be to the benefit of the companies should they be implemented correctly. Mining industry policymakers can also benefit from this study given that both micro- and macroeconomic indicators have been discussed through the process of this research, and it is suggested that a firm-level framework of CSR can be beneficial to the company and the industry alike. Lastly, this study may be of interest to investors as the positive role of CSR on a firm's performance is confirmed.

Undeniably, further research is needed to overcome the limitations of the study, as this can be the first step in broadening the horizons of this line of research. Due to data availability, the study period is relatively short. Upcoming studies may cover an extended period to assess the CSR-TFP relationship of mining companies, preferably before 2019, as COVID-19 might be an influencing factor on the linkage between CSR initiatives and efficiency at mining firms. Also, this study utilized DEA as the methodology for calculating TFP to reduce the effect of unknown factors. However, future studies may employ other efficiency methods to obtain even more accurate productivity scores.

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Declarations

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