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The Moderating Role of CEO Gender in the Relationship between Psychological Biases and Corporate Social Responsibility

Mariam BOUZGUENDA ¹

Résumé

La responsabilité sociétale des entreprises (RSE) est devenue un domaine de plus en plus important pour les entreprises et leurs parties prenantes. Comprendre les facteurs qui influencent la RSE, notamment les traits des directeurs généraux (PDG), est crucial pour promouvoir des pratiques commerciales durables. Cette étude examine l'impact des biais comportementaux des PDG, en particulier le narcissisme et la surconfiance, sur la RSE. Elle explore également le rôle modérateur du sexe du PDG dans la relation entre ces biais et les résultats de la RSE. À partir de données de 362 entreprises européennes cotées sur l'indice STOXX 600 entre 2019 et 2023, l'étude utilise une analyse quantitative pour évaluer la relation entre les biais comportementaux des PDG et la performance en matière de RSE. Les résultats montrent que le narcissisme et la surconfiance des PDG contribuent de manière significative à un engagement accru dans la RSE. De plus, l'étude révèle que les PDG féminines modèrent positivement la relation entre ces biais et la RSE, mettant en lumière le rôle potentiel du genre dans la définition des pratiques de responsabilité sociétale. Ces résultats suggèrent que les entreprises pourraient bénéficier de la prise en compte des profils psychologiques de leurs PDG lors de l'élaboration de stratégies de RSE et que le leadership féminin pourrait offrir des avantages distincts dans la promotion des initiatives de RSE.

Abstract

Corporate social responsibility (CSR) has increasingly become a critical focus for businesses and their stakeholders. Understanding the factors influencing CSR, especially the traits of Chief Executive Officers (CEOs), is essential for promoting sustainable business practices. This study investigates the impact of CEO behavioral biases, specifically narcissism and overconfidence, on CSR. Additionally, it explores the moderating role of CEO gender in the relationship between these biases and CSR outcomes. Using data from 362 European companies listed on the STOXX 600 index between 2019 and 2023, the study employs quantitative analysis to assess the relationship between CEO behavioral biases and CSR performance. The results demonstrate that both CEO narcissism and overconfidence significantly contribute to enhanced CSR engagement. Furthermore, the study finds that female CEOs positively moderate the relationship between these biases and CSR, highlighting the potential role of gender in shaping corporate responsibility practices. These findings suggest that companies may benefit from considering the psychological profiles of their CEOs when developing CSR strategies, and that female leadership could offer distinct advantages in promoting CSR initiatives.

Key words: CEO Narcissism, CEO Overconfidence, CEO Gender, CSR, CSR Dimension

JEL Classification: G3. G4. M14

¹ Faculty of Economics and Management of Sfax, Sfax University, Tunisia; mariembouzguenda@hotmail.fr

1. Introduction

Given the rapid changes in the market landscape, including the emergence of new markets and increased competition, adapting management practices has become crucial. As a result, companies must adopt a responsible approach to continue delivering value efficiently and respond to an ever-evolving environment (Chwiłkowska-Kubala et al., 2023). This approach is reflected in their Corporate Social Responsibility (CSR) efforts, which involve initiatives that go beyond the company's self-interest to improve societal well-being (McWilliams and Siegel, 2001). According to Kidaye and Saoussany (2021), Corporate Social Responsibility is a practice that emphasizes a company's ethical intentions and values. It has evolved from a voluntary initiative to a mandatory component of corporate strategy, contributing to the creation of shared value (Phan et al., 2024). CSR goes beyond meeting the needs of investors and customers; it fundamentally represents a company's commitment to being responsible toward all its stakeholders. At the heart of CSR, it is about balancing the interests of stakeholders and shareholders, while responding to societal, environmental, and economic responsibilities (Rahman et al., 2024). Previous studies have mainly focused on external factors, such as market pressures and stakeholder expectations, overlooking how CEO personal traits, such as narcissism and overconfidence, affect CSR strategies. Understanding how CEO biases impact CSR decisions is crucial, given the emphasis on individual leadership. Additionally, the moderating role of CEO gender in these dynamics remains underexplored. This study aims to fill these gaps by examining the relationship between CEO behavioral biases, CSR, and the influence of CEO gender.

However, despite the growing importance of CSR, the underlying research problem addressed in this study lies in the lack of understanding of the impact of the psychological traits of leaders, particularly the behavioral biases of CEOs, on companies' engagement in CSR initiatives. While studies have explored CSR from various angles, very few have focused on the psychological influences of leaders on CSR practices. CEO narcissism and overconfidence, for example, are underexplored traits that may play a crucial role in strategic decision-making related to CSR. This study aims to fill this gap by examining how these behavioral biases influence CEOs' decisions and, consequently, how companies engage in responsible actions.

In this study, the Upper Echelons Theory proposed by Hambrick and Mason (1984) is followed as a conceptual framework. This theory is valuable for understanding how the personal values of CEOs contribute to the variability in CSR practices. It posits that the CEO plays a central role in the CSR process, with their managerial background, personal values, and attributes deeply influencing their decisions and actions (Long et al., 2022; Bhaskar et al., 2023; Erdiaw-Kwasie et al., 2023).

Recent studies have focused on understanding the conditions and factors that drive companies to adopt socially responsible behaviors (Bhaskar et al., 2023). Research by Petrenko et al. (2016) and Tang et al. (2018) suggests that certain CSR initiatives may stem from the personal needs of the CEO. In this regard, the study explores how behavioral and psychological factors, specifically narcissism and overconfidence, are linked to CSR practices. Additionally, the

originality of this research lies in its analysis of the moderating role of CEO gender, a factor rarely explored in the CSR context. In the current business environment, corporate social practices have gained importance, as they provide a crucial means to strengthen relationships with key stakeholders (Choi et al., 2023; Chwiłkowska-Kubala et al., 2023). Several studies observe that CSR is increasingly seen by practitioners as a tool to attract investors, qualified employees, suppliers, and target customers, while meeting social expectations alongside economic goals (Atif et al., 2023; Puchakayala et al., 2023). The concept of stakeholder diversification, inspired by Freeman's Stakeholder Theory (2001), provides a comprehensive explanation of the diverse nature of stakeholders and their impact on CSR activities. This theory remains central in CSR analysis due to its ability to account for stakeholder diversity. Consequently, companies seek to foster a positive image of their CSR commitment to effectively manage stakeholder perceptions (Wright and Ferris, 1997; Bingham et al., 2011; Liang et al., 2024).

The main research question addressed in this study is to understand the relationship between behavioral biases (narcissism and overconfidence) and Corporate Social Responsibility (CSR) as a whole, as well as within each CSR category. The second question explores the moderating effect of CEO gender on the relationship between CEO behavioral biases and CSR. This research contributes to the theoretical understanding of Corporate Social Responsibility by investigating the impact of CEO behavioral biases, specifically narcissism and overconfidence, on CSR practices. It advances Upper Echelons Theory by linking these psychological traits to both overall CSR and its various categories.

The significance of this study lies in its ability to shed light on an underexplored area of Corporate Social Responsibility (CSR): the impact of CEO behavioral biases on strategic decision-making related to CSR. The findings will contribute to academic literature by offering new insights into how CEOs' psychological biases can influence CSR practices. The applicability of this study is significant for companies, which will be better able to understand how the personal characteristics of their CEOs shape CSR strategies. Moreover, the introduction of CEO gender as a moderating factor will provide practical insights for companies seeking to increase diversity in their leadership teams to optimize the impact of CSR initiatives.

This theoretical framework enhances the understanding of the interactions between CEOs' individual characteristics and corporate social behavior, providing valuable insights for both academic research and practical applications.

The remainder of this paper is organized as follows: Section 2 provides the literature review and hypothesis development; Section 3 outlines the research methodology; Section 4 presents the modeling techniques selected for the research; Section 5 evaluates and discusses the empirical results; and, finally, Section 6 concludes the study.

2. Literature review

Recent trends indicate that companies worldwide are increasingly incorporating corporate social responsibility (CSR) into their business strategies (Qiu et al., 2021; Lal et al., 2022;

Bhaskar et al., 2023; Phan and Ha, 2024; Rehman et al., 2024). Numerous studies highlight the positive impact of CSR on environmental sustainability, economic growth, profitability, and stock performance (Awawdeh et al., 2021; Ho et al., 2022).

Firstly, CSR has emerged as a crucial tool for creating value among stakeholders within business organizations (Le et al., 2021; Chen and Xie, 2022; Bhaskar et al., 2023; Shahzadi et al., 2024). Secondly, CSR is increasingly recognized as a fundamental aspect of standard business operations (Yang and Jiang, 2023; Elbardan et al., 2023). Finally, existing literature also shows that CSR has quickly become a significant priority for CEOs and their firms (Abbey, 2022). The extensive body of research on CSR has focused on understanding the factors that drive CEOs to adopt CSR as a strategic initiative. This research indicates that CEOs' psychological traits are crucial in determining their inclination toward CSR activities (Petrenko et al., 2016; Zhang et al., 2017; Tang et al., 2018; Bhaskar et al., 2023; Liang et al., 2024). Thus, based on the existing literature, the theoretical connections between various CEO characteristics and CSR engagement are explored.

2.1. The impact of the CEO overconfidence on the CSR and on its categories

Research indicates that the psychological biases of corporate CEOs significantly influence their decision-making processes (Wang, 2023). One such bias, CEO overconfidence, has become increasingly relevant in the context of corporate social responsibility (CSR), a critical area closely tied to the characteristics of the CEO (Bhaskar et al., 2023; Grove et al., 2024). An overconfident CEO, who tends to overestimate their capabilities and prospects, is likely to view CSR initiatives as opportunities to enhance the company's image and drive long-term success (Chang, 2015; Campbell and Helleloid, 2016; Erdiaw-Kwasie et al., 2023). This heightened confidence can lead to bold and ambitious decisions in sustainability and social engagement, underpinned by a strong belief in the potential of these initiatives to generate a competitive edge. Moreover, CEO overconfidence can significantly impact CSR by making the CEO more inclined to invest in CSR initiatives, driven by the conviction that these efforts will improve the company's reputation and create long-term value (Kim et al., 2018; Puchakayala et al., 2023). Such confidence can result in ambitious strategies for sustainability and community engagement, even in the absence of immediate tangible evidence of success. In this regard, the following hypothesis is formulated:

Hypothesis 1: CEO overconfidence is positively associated with CSR and its dimensions.

2.2. The impact of the CEO narcissism on the CSR and on its dimensions

Narcissism is defined as a personality trait characterized by an excessive preoccupation with oneself, a need for admiration, and a lack of empathy for others (Morf and Rhodewalt, 2001). CEO narcissism, a prominent manifestation of this trait, significantly influences decision-making, making it a key area of interest for both scholars and practitioners (Byun and Al-Shammari, 2021; Chatterjee and Pollock, 2017; Zhang et al., 2017; Shan et al., 2023). While narcissistic CEOs are often perceived as self-centered and egotistical, their desire for admiration and recognition can drive them to adopt Corporate Social Responsibility (CSR) initiatives as a

means to enhance both their own public image and that of their organization (Al-Shammari et al., 2019). Narcissistic leaders are inclined to make bold decisions and pursue ambitious projects, including those related to CSR, in order to distinguish themselves from their peers (Petrenko et al., 2016). This pursuit of distinction not only serves to consolidate their power but also to legitimize their leadership in the eyes of stakeholders. Under certain conditions, these traits may positively influence CSR practices, as narcissistic CEOs aim to be perceived as visionary and morally responsible (Morf and Rhodewalt, 2001; Campbell et al., 2004; Resick et al., 2009; O'Reilly et al., 2014; Maccoby, 2017; Chi et al., 2019). Therefore, the following hypothesis is proposed:

Hypothesis 2: There is a positive relationship between the CEO narcissism, and the CSR and its dimensions.

Table 1: Chronological Summary of Literature Review

Authors	Year	Key Findings
Campbell et al.	2004	Narcissistic leaders adopt ambitious projects for self-promotion.
Petrenko et al.	2016	Narcissistic CEOs pursue CSR initiatives to enhance their public image.
Chang	2015	Overconfident CEOs view CSR as an opportunity to achieve competitive advantage.
Zhang et al.	2017	CEO personality traits significantly shape CSR practices.
Kim et al.	2018	Overconfident CEOs invest in CSR for long-term value creation and reputation.
Al-Shammari et al.	2019	Narcissistic CEOs use CSR to enhance both their own and their organization's image.
Byun and Al-Shammari	2021	Narcissistic leaders make bold decisions, including CSR, to differentiate themselves.
Bhaskar et al.	2023	CEO traits such as overconfidence and narcissism influence CSR engagement.
Wang	2023	CEO biases (e.g., overconfidence) influence corporate strategies.
Grove et al.	2024	Overconfident CEOs tend to invest more in CSR initiatives despite uncertain outcomes.
Liang et al.	2024	Narcissistic CEOs prioritize CSR to bolster their image and distinguish themselves.
Phan and Ha	2024	CSR is increasingly a priority for CEOs and integrated into strategic decisions.
Rehman et al.	2024	Psychological traits of CEOs play a central role in advancing sustainability goals.

2.3. The moderating effect of the CEO gender on the relationship between the CEO overconfidence and overall CSR

Based on studies conducted over the last few decades, it has been demonstrated that female CEOs exhibit stronger ethical views and more positive attitudes toward CSR compared to their male counterparts (Harjoto and Rossi, 2019). Chu et al. (2023) highlight the greater importance that women place on sustainable development and corporate environmental and social responsibilities, suggesting that these priorities align well with their skills and psychological traits, such as conflict resolution, adaptability to change, and the ability to motivate and inspire others, while also alleviating stress for subordinates and reducing turnover probability. Thus, women are generally better equipped and more rational than men when it comes to investing in CSR-related decisions and activities (Furlotti et al., 2019; Wernicke et al., 2022; Choi et al., 2023; Liang et al., 2024).

Women leaders are often described as having greater empathy and a stronger ability to understand and respond to the needs of others. This trait could amplify the impact of overconfidence on CSR decisions, as a female CEO might not only believe in her capability but also feel a moral responsibility to make a positive difference. Therefore, if overconfident CEOs are inclined to prioritize CSR, a female CEO could further enhance these CSR activities. This leads to the following hypothesis:

Hypothesis 3: A female CEO positively moderates the relationship between CEO overconfidence and overall CSR.

2.4. The moderating effect of the CEO gender on the relationship between the CEO narcissism and overall CSR

The gender of the CEO may significantly moderate the relationship between narcissism and CSR, particularly when the CEO is female.

First, female CEOs are often perceived as more ethical and more concerned with sustainability and social responsibility. A narcissistic female CEO may be especially motivated to leverage CSR to enhance her image, while ensuring these initiatives align with strong ethical values. Second, female leaders are frequently associated with greater empathy and sensitivity to stakeholder needs. This empathy could strengthen the link between narcissism and CSR, as a female CEO may feel that she not only has the power but also the moral responsibility to make a positive impact. Third, a narcissistic female CEO might adopt a long-term perspective on her own image and the company's reputation, investing more in CSR to ensure a lasting and positive legacy.

To explore how CEO gender reinforces this relationship, we propose the following hypothesis:

Hypothesis 4: A female CEO positively moderates the relationship between CEO narcissism and overall CSR.

3. Research methodology

3.1. The sample and data collection

This study examines a sample of European firms listed on the STOXX 600 index, covering the period from 2019 to 2023. The dataset includes 362 companies, yielding 1810 firm-year observations. The empirical analysis draws on multiple sources: CSR data were obtained from Thomson Reuters ASSET4, while financial information was sourced from the Datastream database. CEO behavioral biases were manually collected through a review of Bloomberg, annual reports, company websites, and financial statements. Statistical analysis was performed using STATA software.

Table 2: Sample descriptive

Panel A: the selection steps of the final sample		
Description	Number of companies	
Initial sample listed on the STOXX 600	600	
Financial firms	138	
Firms with insufficient annual reports	63	
Firms with insufficient data	37	
Final sample	362	
Study period	5	
Total observations	1810	
Panel B: Distribution of the sample by sector		
Sectors	N	%
Oil and gas	16	4.4%
Basic materials	25	6.8%
Industries	74	20.2%
Consumer goods	58	15.8%
Health Care	29	7.9%
Consumer Services	56	15.3%
Telecommunications	24	6.5%
Utilities	33	8.9%
Technologies	47	14.2%
Total	362	100%
Panel C: Countries of the European region in the STOXX Europe 600 Index		

Switzerland	Norway	Finland
Britain	Poland	France
Austria	Portugal	Germany
Belgium	Spain	Ireland
Denmark	Sweden	Italy
Netherlands		Luxembourg

3.2. Measurements of variables

3.2.1. Measurements of the dependent variables

Based on findings from Mattingly and Berman (2006), McCarthy et al. (2017), Wang et al. (2018), Escrig-Olmedo et al. (2019), Adeneye et al. (2023), and Ma et al. (2023), we use ESG scores as a measure of corporate social responsibility (CSR). The CSR score is sourced from the ASSET4 database within Thomson Reuters DataStream, and it ranges from 0 to 100. In this study, we adopt the CSR score calculated by ASSET4 to ensure comparability across companies.

Table 3. Measurements of dependent variables

Dependent variables	Measurements	Authors
Overall CSR	The social responsibility score of each firm were calculated based of index scores in five categories was considered the overall CSR score of.	Jo and Harjoto (2012); Ghoul et al. (2017); Ahn and Lee (2019); Choi et al. (2023); Chen et al. (2023).
Environment	The environmental score assesses a company's influence on the entire ecosystem, encompassing both living and non-living components like air, soil, water, and energy use. It evaluates how effectively the company implements sustainable practices to mitigate environmental risks and preserve natural resources.	Jo and Harjoto (2012); Ghoul et al. (2017); Ahn and Lee (2019); Choi et al. (2023); Chen et al. (2023).
Social	The social score evaluates how well a company fosters trust and loyalty among its stakeholders, including society and customers, by implementing effective management practices. It assesses the company's performance in areas such as employee engagement, workplace safety, diversity, and equality within the workforce.	Jo and Harjoto (2012); Ghoul et al. (2017); Ahn and Lee (2019); Choi et al. (2023); Chen et al. (2023).

Governance	The governance score evaluates a company's adherence to and effectiveness in upholding corporate governance principles. It includes metrics such as the frequency of board meetings and the presence of independent directors.	Jo and Harjoto (2012); Ghoul et al. (2017); Ahn and Lee (2019); Choi et al. (2023); Chen et al. (2023).
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3.2.2. Measurements of the independent variables

CEO narcissism

We measure the extent of the CEO narcissism via a four-point index, as developed by Chatterjee and Hambrick (2007). It includes:

- (1) The importance of the CEO image size in the company's annual report.
- (2) The importance of mentioning the CEO name in corporate press releases.
- (3) The importance of the CEO monetary remuneration.
- (4) The importance of the non-monetary CEO remuneration.

These elements reflect one or more general aspects of a narcissistic personality. To obtain a single index of narcissism for every CEO, it is necessary to compute the mean of these four indicators, following the approach of Chatterjee and Hambrick (2007); Oesterle et al. (2016) and Al-Shammari et al. (2019).

CEO overconfidence

For the study of Schrand and Zechman (2012), the overconfidence is a score involving five measures. They are as follows:

- (1) Investment excess adjusted by industry.
- (2) The net amount of acquisitions achieved by the company in industry.
- (3) The company's industry-adjusted debt-to-equity ratio.
- (4) Risky debt.
- (5) The dividend yield.

After calculating the five dimensions, we determine the overconfidence score. In this context, "Over" is a dummy variable coded 1 if no less than three out of the five dimensions indicate that the company is more likely to have an overconfident CEO, and 0 otherwise (Schrand and Zechman 2012; Kouaib and Jarboui 2016).

3.2.3 Measurements of the Moderate variable

The CEO gender (GENDER): We use a binary variable equal to 1 if the CEO is male, and 0 otherwise (Manner 2010; Marquis and Lee 2013; McCarthy et al. 2017; Zou et al. 2018 and Chu et al. 2023).

Table 4. Measurements of independent and moderate variables

Independent variables	Measurements	Authors
OVER	The indicator variable is coded 1 if at least three out of five components of the score indicate that the firm is more likely to have overconfident CEOs, and 0 otherwise: ▪ XSINVEST_INDADJ is greater than 0, ▪ ACQUIRE_INDADJ is greater than 0, ▪ DERATIO_INDADJ is greater than 0, ▪ RISKYDT is equal to 1, and ▪ DIVYLD is equal to 1.	Schrand and Zechman (2012); kouaib and Jarboui (2016).
NARCI	The narcissism variable is the weighted average equal to four dimensions: ▪ The importance of the size of the CEO photography in the annual report of the company. ▪ The importance of mentioning the name of the CEO in the press releases of the companies. ▪ The importance of the CEO monetary remuneration. ▪ The importance of the CEO's non-monetary remuneration.	Chatterjee and Hambrick (2007); Ahn and Kwon (2020).
Moderate variables	Measurements	Authors
CEO GENDER	A dichotomous variable equals 1 when the CEO is male and 0 otherwise.	McCarthy et al. (2017); Zou et al., (2018); Lim et al., (2021).

3.2.4. Measurements of the control variables

McCarthy et al. (2017) and Pan et al. (2021) suggest that various proxies used to control for firm characteristics can potentially affect the CEO's decisions regarding corporate social responsibility.

Firm Performance (ROA): Firm performance is assessed using the ratio of net income to total assets in year t.

Firm Size (SIZE): Firm size is determined by the logarithm of total assets.

Firm Age (AGE): Firm age is measured by the natural log of number of years of existence of the company since its creation.

Debt (DEBT): Firm debt is calculated as the ratio of total debt to total assets.

This study incorporates several firm-level control variables, drawn from the existing literature, which may influence CSR activities. Numerous studies (Chatterjee and Hambrick 2007; McCarthy et al. 2017; Dremptetic et al. 2020; Biju et al. 2023; Erdiaw-Kwasie et al. 2023; Puchakayala et al. 2023; Yan et al. 2023; Bagh et al. 2024) indicate that factors such as firm performance, size, age, and debt are likely to affect a company's CSR initiatives.

Table 5. Measurements of control variables

Control variables	Measurements	Authors
ROA	It is the company performance as measured by the ratio of operating income to total assets.	Tang et al. (2018)
SIZE	The natural log of total assets.	Orij et al. (2021)
AGE	The natural log of number of years of existence of the company since its creation.	Činčalová and Hedija (2020)
DEBT	Total debt divided by total assets.	Benlemlih,(2017); Pan et al. (2021)

4. Research models

Econometrically, we employ regression models to test and validate our previously formulated hypotheses.

Model 1

$$CSR_{it} = \beta_0 + \beta_1(OVER) + \beta_2(NARCI) + \beta_3(ROA) + \beta_4(SIZE) + \beta_5(AGE) + \beta_6(DEBT) + \varepsilon_{it}$$

The moderating effect occurs when the moderating variable Z alters the strength of the relationship between the independent variable X and the dependent variable Y (Baron and Kenny, 1986). In our study, CEO gender serves as a moderating factor in the relationship between behavioral biases (overconfidence and narcissism) and overall CSR.

Model 2

$$\text{Overall CSR}_{it} = \beta_0 + \beta_1(OVER) + \beta_2(GENDER) + \beta_3(GENDER * OVER) + \beta_4(ROA) + \beta_5(SIZE) + \beta_6(AGE) + \beta_7(DEBT) + \varepsilon_{it}$$

Model 3

$$\text{OverallCSR}_{it} = \beta_0 + \beta_1(\text{NARCI}) + \beta_2(\text{GENDER}) + \beta_3(\text{GENDER} * \text{NARCI}) + \beta_4(\text{ROA}) + \beta_5(\text{SIZE}) + \beta_6(\text{AGE}) + \beta_7(\text{DEBT}) + \varepsilon_{it}$$

With:

Overall CSR: it denotes the overall CSR score; OVER: it designates the CEO confidence level; NARCI: it stands for the narcissism degree; GENDER: it designates the gender of CE; ROA: it denotes the firm performance; SIZE: it refers to the firm size; AGE: it denotes the firm age; DEBT: it stands for the debt ratio; and ε : it is a constant.

5. Empirical results and discussion

5.1 Descriptive statistics

The descriptive statistics presented in Table 6 reveal that the average overall CSR score for the period from 2019 to 2023 is 62.63%. The averages for each CSR category are 63.07% (model 1.1), 60.17% (model 1.2), and 66.31% (model 1.3), respectively. This indicates that companies in our sample are actively engaged in nearly all categories of social responsibility throughout the sampling period.

Table 6. Descriptive statistics of variables

Panel A: Summary on statistics of dependent variables						
Variables	N	Mean	SD	Minmum	Maximum	Median
Overall CSR	1810	62,63	14,90	10,43	95,3	66,41
Environment	1810	63,07	28,45	0	99,79	68,59
Social	1810	60,17	25,76	0	99,79	63,59
Governance	1810	66,31	27,00	0	99,15	73,53
Panel B: Summary on statistics of independent variables						
OVER	1810	0,76	0,42	0	1	1
NARCI	1810	0,62	0,62	-1	1	1
Panel C: Summary on statistics of control variables						
SIZE		16,23	1,54	10,32	19,87	84,36
AGE		3,83	0,93	0,45	6,21	3,79
ROA		7,61	7,99	-24,54	69,32	6
DEBT		23,46	16,58	0	92,74	22,74
Panel D: Summary on statistics of Moderate variables						
CEO GENDER	Modaliti es	Frequenci es	Percenta ge			
	0	322	17.8%			
	1	1488	82.2%			

The overall CSR score in the sample ranges from a minimum of 10.43% to a maximum of 95.3%, with a standard deviation of 14.9%. Across the various CSR dimensions, scores range from 0% to 99%. Regarding the independent variable, CEO overconfidence (OVER), the average level of overconfidence is 0.76, indicating that 76% of the CEOs in the sample exhibit high overconfidence. For the narcissism variable (NARCI), the average score is 0.62, suggesting that the CEOs generally display narcissistic traits. Panel C of Table 6 summarizes the control variables. The average firm size, measured as the logarithm of total assets, is 16.23, equivalent to approximately \$2.79 million. The average firm age, calculated as the logarithm of the number of years since incorporation, is 3.83, which corresponds to approximately 46.43 years. The average return on assets (ROA) is 7.61%, with a minimum of -24.54% and a maximum of 69.32%. The company leverage ratio, defined as total debt to total assets, has an average of 23.46%, with a minimum of 0% and a maximum of 92.74%. Panel D of Table 6 shows the descriptive statistics for the moderating variables. It reveals that 82.2% of the CEOs in our sample are men, while 17.8% are women.

Table 7. Results of the multicollinearity test

	OVER	NARCI	ROA	SIZE	AGE	DEBT	GENDE R	VIF
OVER	1,0000							1,02
NARCI	0,0400 (0,0891)	1,0000						1,01
GENDER	0,0905 (0,0001)	0,0577 (0,0036)						1.01
ROA	0,0160 (0,4971)	0,0486 (0,0389)	1,0000					1,20
SIZE	-0,0991 (0,0000)	0,0564 (0,0164)	0,0819 (0,0004)	1,0000				1,08
AGE	0,0966 (0,0000)	-0,0063 (0,7900)	-0,2966 (0,0000)	0,0106 (0,0000)	1,0000			1,29
DEBT	-0,0214 (0,3640)	-0,0600 (0,0108)	0,0651 (0,0056)	0,1141 (0,0000)	0,3365 (0,0021)	1,0000		1,07

5.2 Correlation

At this stage, conducting a pairwise correlation test is essential to detect any potential multicollinearity among the variables. The Spearman correlation matrix (Table 7) shows that most of the correlations are below 0.8, indicating that multicollinearity is not a major concern among the independent variables. The next step is to calculate the Variance Inflation Factor (VIF). As shown in Table 7, all VIF values for the variables in the main model are below 10. These results confirm that multicollinearity is not an issue, allowing us to proceed with the multivariate regressions in our analysis.

5.3 Results of the regression analysis

Multivariate tests: Individual-effects tests/ Hausman test/ heteroscedasticity test

Our regression modeling frameworks indicate that the individual effects test results support the use of panel data econometrics. The Hausman test reveals a chi-squared statistic with a p-value below 1%, leading us to select a fixed effects model over a random effects model. Furthermore, we identified persistent issues with heteroscedasticity. In response, we addressed both serial autocorrelation and heteroscedasticity. As a result, we excluded the fixed effects robust and OLS-based techniques. After careful consideration, we determined that the Feasible Generalized Least Squares (FGLS) method is the most appropriate for estimating our models.

Table 8. The results of the individual-effects tests

Tests	Homogeneity test	Specification test	Heteroscedasticity
Models	Fisher test	Hausman test	Breush Pagan test
M1	1969.72 (0,0000)***	106.78 (0,0000)***	333.65 (0,0000)***
M(1.1)	1793.32 (0,0000)***	69.49 (0,0000)***	618.99 (0,0000)***
M(1.2)	1719.00 (0,0000)***	21.16 (0,0035)**	600.09 (0,0000)***
M(1.3)	1434.31 (0,0000)***	28.88 (0,0002)***	694.14 (0,0000)***

Overall estimation

The impact of the CEO overconfidence on the CSR and on its categories

Our research examines the correlation between CEO overconfidence and corporate social responsibility (CSR), including its various dimensions (Karavitis et al., 2024). As presented in Table 9, CEO overconfidence is positively correlated with CSR activities across the proposed model specifications: overall CSR and its environmental, social, and governance dimensions, thus fully supporting Hypothesis 1. For example, in the environmental dimension, Hirshleifer et al. (2012) argue that a CEO with strong confidence in their vision is more likely to direct R&D efforts toward solutions that not only satisfy market needs but also address societal and environmental challenges. This may include the development of recyclable materials, renewable energy sources, or waste-reducing products. This perspective helps explain the positive relationship between CEO overconfidence and the environmental dimension of CSR (McCarthy et al., 2017; Grove et al., 2024). Consistent with these findings, our results indicate that overconfident CEOs tend to prioritize innovative sustainability projects, which not only enhance the firm's competitive advantage but also improve its environmental impact. In the context of the social pillar (model 1.2), a highly confident CEO is often more inclined to undertake large-scale social initiatives, driven by a strong belief in their success. These initiatives may include community support programs, diversity and inclusion efforts, or investments in employee well-being. Such projects can reinforce the company's social

commitment and elevate its reputation. The positive effect of CEO overconfidence on the social dimension of CSR is consistent with prior research highlighting the role of confident leaders in promoting ambitious, socially responsible projects (Campbell et al., 2004; Zhang et al., 2017; Bhaskar et al., 2023; Grove et al., 2024).

The impact of the CEO narcissism on the CSR and on its categories

As shown in Table 9, a positive and significant relationship exists between CEO narcissism and the environmental, social, and governance dimensions of CSR, consistent with the findings of Petrenko et al. (2016) and Kim et al. (2018). Additionally, the results from models (1.1) (environmental dimension) and (1.2) (social dimension) reveal a positive and significant correlation. These findings support the conclusions of Petrenko et al. (2016) and Kim et al. (2018), suggesting that CEO narcissism generally has a favorable impact on CSR activities. Narcissistic CEOs are often driven by a desire to be seen as visionary and socially responsible leaders, motivating them to initiate and promote ambitious social projects such as diversity and inclusion programs, community support initiatives, or philanthropic endeavors (Jaafar Kadhim Alataby and Alkhafaji, 2024).

However, the governance dimension shows a negative and significant relationship at the 1% level, consistent with the findings of Ahn and Lee (2019). This result is not entirely surprising, as Tang et al. (2018) argue that hubristic CEOs, who share traits with narcissistic CEOs, can have a detrimental impact on CSR initiatives. Narcissistic CEOs often prioritize financial performance over other activities (Ahn and Lee, 2019). Indeed, CEOs with pronounced narcissistic tendencies tend to be more focused on financial outcomes than on other aspects of the business (Anderson and Tirrell, 2004; Resick et al., 2009; Amernic and Craig, 2010; Hales et al., 2012; Rijsenbilt and Commandeur, 2013; Patel and Cooper, 2014; Olsen and Stekelberg, 2016; Ahn and Lee, 2019; Erdiaw-Kwasie et al., 2023).

In this context, the differing priorities of narcissistic CEOs become evident depending on the specific CSR dimension under consideration (Ahn and Kwon, 2020; Shan et al., 2023; Jaafar Kadhim Alataby and Alkhafaji, 2024).

Table 9. Regression results of model (1)

Variables	Model (1)		Model (1.1)		Model (1.2)		Model (1.3)	
	Z	p-value	Z	p-value	Z	p-value	Z	p-value
OVER	3,00	0,003***	1,86	0,006***	15,17	0,000***	0,98	0,000***
NARCI	0,75	0,076**	4,94	0,000***	3,14	0,002***	-0,32	0,000***
ROA	2,65	0,008***	1,35	0,178	3,55	0,000***	7,15	0,000***
SIZE	14,98	0,000***	19, 17	0,000***	9,03	0,000***	19,47	0,000***
AGE	7,81	0,000***	4,82	0,000***	2,68	0,007***	10,60	0,000***
DEBT	2,14	0,032**	-0,75	0,455	5,56	0,000***	2,34	0,019**
R-square	0.9920		0.9805		0.9965		0.9854	

Prob>F	0,0000	0,0000	0,0000	0,0000
Wald Chi2	2165.03	2387.01	1050.24	1151.32
Prob> chi2	0,0000	0,0000	0,0000	0,0000

The moderating effect of Gender CEO on the relationship between the CEO overconfidence and overall CSR

Table 10 shows that the results from Column Model 2 indicate a positive relationship between OVER*GENDER and CSR at the 1% significance level ($p < 0.001$). This evidence supports Hypothesis 3, highlighting the effectiveness of female CEOs in driving CSR. In summary, CEO overconfidence can indeed motivate a company to invest more in CSR, with this effect being even more pronounced when the CEO is female. This dynamic underscores the complex interaction between personality traits, gender, and societal expectations of leadership. Companies led by overconfident female CEOs may, therefore, not only strive for high financial performance but also engage more deeply in innovative and impactful CSR practices.

The moderating effect of Gender CEO on the relationship between the CEO narcissic and overall CSR

The results from Column Model 3 of Table 10 show that NARCI*GENDER is positively related to CSR at the 1% significance level ($p < 0.001$). This evidence supports Hypothesis 3, indicating that a female CEO positively moderates the relationship between CEO narcissism and overall CSR. A narcissistic CEO is naturally inclined to engage in CSR activities, driven by a desire for recognition and prestige. This tendency is particularly reinforced when the CEO is female, as leadership qualities often associated with women—such as ethics, empathy, and a long-term sense of responsibility—enhance the impact of narcissism on CSR decision-making.

Table 10. Regression results of models (2) and (3)

Variables	Model (2)		Model (3)	
	Z	p-value	Z	p-value
OVER	3,39	0,001***		
OVER*GENDER	1,12	0,000***		
NARCI			0,90	0,000***
NARCI*GENDER			1,65	0,000***
ROA	4,56	0,000***	5,34	0,000***
SIZE	4,62	0,000***	4, 17	0,000***
AGE	6,50	0,000***	6,98	0,000***
DEBT	-1,46	0,032**	-1,21	0,225
R-square	0.9890		0.9894	
Prob>F	0,0000		0,0000	
Wald Chi2	11120.11		11627.18	
Prob> chi2	0,0000		0,0000	

The effects of control variables

CEO overconfidence and narcissism are not the only factors influencing CSR. In fact, there is a positive and significant relationship between Return on Assets (ROA) and CSR (Campbell et al., 2004; Tang et al., 2018). Higher profitability provides companies with additional resources, increasing their likelihood of engaging in various CSR activities. Additionally, firm size and age are positively correlated with CSR, as shown by research from Drempetic et al. (2020) and Biju et al. (2023), which demonstrates a significant positive correlation between firm size and CSR scores. Furthermore, the level of debt also shows a positive relationship with certain dimensions of CSR, supporting the findings of Pan et al. (2021) and Karavitis et al. (2024).

6. Conclusion

This research aims to explore the impact of CEO psychological and behavioral characteristics on Corporate Social Responsibility (CSR) and its various dimensions. It also investigates whether the presence of a female CEO positively moderates the relationship between CEO behavioral biases and overall CSR. Using a sample of 362 firms listed on the STOXX Europe 600 index from 2019 to 2023, we employed FGLS regression models to draw our conclusions. Our analysis reveals that overconfident CEOs tend to invest across all CSR dimensions (Bhaskar et al., 2023; Grove et al., 2024). In contrast, narcissistic CEOs are more inclined to focus their investments on the environmental and social dimensions specifically (Ahn and Kwon, 2020; Shan et al., 2023; Jaafar Kadhim Alataby and Alkhafaji, 2024). Moreover, our findings suggest that the presence of a female CEO strengthens the overall relationship between CEO overconfidence and CSR (Hypothesis 3). Similarly, a female CEO enhances the link between CEO narcissism and CSR.

The findings of our study offer several practical implications for academic researchers, stakeholders, and policymakers.

For academic researchers, the insights gained from examining the relationship between CEO characteristics, such as overconfidence and narcissism, and CSR practices provide a new direction for future research. Specifically, exploring the psychological traits of CEOs in relation to CSR can offer deeper insights into how leadership influences corporate behavior. Our study also opens opportunities for further investigation into the moderating role of CEO gender, providing a more nuanced understanding of leadership dynamics in CSR decision-making.

For stakeholders, particularly investors, understanding CEO traits can be a valuable tool in evaluating how these characteristics shape CSR strategies within companies. Overconfident or narcissistic leaders may be more inclined to pursue ambitious and authentic CSR initiatives, which, while potentially risky, could present attractive investment opportunities. Investors can use this knowledge to assess how CEO personality traits align with long-term sustainability goals, helping identify companies with strong CSR commitments.

For policymakers, our study lays the groundwork for developing regulations and policies that promote leadership behaviors conducive to effective CSR practices. Recognizing the influence of CEO traits on CSR outcomes can guide the creation of policies that encourage responsible leadership. For instance, policies aimed at increasing diversity in leadership roles, such as enhancing the representation of women in executive positions, could have a significant positive impact on CSR practices. Additionally, policymakers could introduce regulatory frameworks that incentivize companies to invest in CSR initiatives through tax breaks, subsidies, or public recognition programs. These strategies would align leadership behaviors with societal and environmental objectives, fostering more sustainable and impactful CSR practices across industries.

Building on the above implications, our study also offers valuable insights for portfolio managers and practitioners involved in investment decision-making. By recognizing the impact of CEO psychological traits on CSR practices, portfolio managers can refine their investment strategies. Overconfident or narcissistic leaders may drive companies to undertake bold and innovative CSR initiatives, potentially leading to higher long-term returns despite the associated risks. By incorporating CEO traits into ESG evaluations, portfolio managers can better assess the sustainability of their investments and identify companies with a robust commitment to CSR.

Furthermore, from a practitioner's standpoint, understanding how CEO traits influence CSR decisions provides actionable insights for corporate decision-makers. Companies can leverage this knowledge to select leaders whose traits align with their CSR objectives, ensuring that leadership behaviors foster long-term sustainability goals. This approach can help mitigate the risks of overly ambitious CSR initiatives while maximizing their positive social and environmental impact.

However, like any research, our study has certain limitations. It is based on a relatively small sample of companies, which may limit the generalizability of our findings. Additionally, the narrow focus on specific psychological traits of CEOs is due to the unavailability of comprehensive data, which constrains the scope of our conclusions. Future research could build on this study by exploring additional psychological biases that may impact CSR performance. For instance, biases such as CEO over-optimism, risk aversion, or narcissistic supply could be examined to assess their influence on decisions related to CSR initiatives. While the absence of specific data on these biases in our sample limits this exploration, it opens an intriguing avenue for future research that could further deepen our understanding of the psychological factors influencing CSR engagement. These biases can be effectively identified using a combination of qualitative and quantitative methods, such as the Narcissistic Personality Inventory (NPI), interviews, or surveys. Moreover, future studies could address these limitations by incorporating additional CEO factors that may affect CSR commitment and activity selection, such as compensation, ownership structure, entrenchment, and role duality. Exploring other corporate factors, such as board characteristics (size, diversity, and independence), could also provide a more comprehensive understanding of the determinants of CSR.

Ethical Statement

This manuscript is an original work of the authors. It has not been published previously and is not under consideration for publication elsewhere. There are no conflicts of interest to declare that are relevant to the content of this article. This research does not involve any human participants, human data, or human tissue. The authors declare that there was no external funding for this research.

Contributions

Bouzguenda Mariem worked on conceptualization, methodology and writing original draft. Jarboui Anis has played a crucial role in visualization, reviewing and supervision.

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La finance durable au Maroc : quelle dynamique ?

Lobna BOUMAHDI¹ et Abdelouhab HAMLIRI²

Résumé

Le concept de finance durable étant relativement récent, témoignant ainsi d'un changement significatif dans la conscience et les pratiques du monde financier. Concilier performance économique et impacts sociaux, sociétaux et environnementaux positifs, en finançant des entreprises qui contribuent activement au développement durable, la finance durable se décline en différents modèles tel que : l'Investissement Socialement Responsable (ISR), l'investissement vert, la finance solidaire, le micro-crédit, ...

L'objectif de cette communication est de mettre l'accent sur l'état des lieux de développement de la finance durable au Maroc, l'un des pionniers africains en termes de durabilité et qui a pris des mesures proactives et innovantes en matière de politiques RSE et développement durable. Pour ce faire, on va analyser les engagements et les initiatives des divers acteurs, afin de comprendre la dynamique et les particularités de ce type de financement dans le pays à travers une étude qualitative réalisées auprès de 10 entreprises labélisées CGEM pour la RSE au Maroc et sur la base d'une étude documentaire.

Mots clés : développement durable, RSE, finance durable, économie verte, Maroc

Abstract

The concept of sustainable finance being relatively recent, reflecting a significant change in the consciousness and practices of the financial world. Reconciling economic performance and positive social and environmental impacts, by financing companies that actively contribute to sustainable development, sustainable finance comes in different models such as: Socially Responsible Investment (SRI), green investment, solidarity finance, micro-credit, ...

The objective of this communication is to focus on the state of play of the development of sustainable finance in Morocco, one of the African pioneers in terms of sustainability and which has taken proactive and innovative measures in terms of CSR and sustainable development policies. For this, we will analyze the commitments and initiatives of the various actors, in order to understand the dynamics and particularities of this type of financing in the country through a qualitative study carried out with 10 companies labeled CGEM for CSR in Morocco and based on a documentary study.

Key words: sustainable development, CSR, sustainable finance, green economy, Morocco

¹ Faculté des Sciences Juridiques Economiques et Sociales – Mohammedia, Université Hassan II Casablanca – Maroc ; boumahdi.jobna@gmail.com

² Faculté des Sciences Juridiques Economiques et Sociales - Ain Chock, Université Hassan II Casablanca – Maroc ; abdelouhab.hamliiri@gmail.com

1. Introduction

Pendant longtemps jugée comme court-termiste, la finance représente aujourd'hui une opportunité et joue un rôle clé pour soutenir l'économie réelle et les projets d'optimisation des ressources et du bien-être. Si la finance est l'ensemble des mécanismes qui apportent à l'économie les capitaux dont elle a besoin pour fonctionner. La finance durable renvoie aux pratiques et réglementations de la finance qui prennent en compte, en plus des critères financiers, des critères extra financiers tels que des critères liés à la dimension environnementale, sociale, sociétale ou éthique, dans l'analyse, la sélection et la gestion des projets d'investissements.

Ce terme générique de la finance durable, qui se situe entre la finance et la prise en compte des dimensions du développement durable, ne cesse d'occuper de plus en plus de place au sein de notre société et dans les pratiques managériales des entreprises. Le but étant de favoriser l'intérêt de la collectivité sur le moyen et le long terme. La finance durable est, alors, l'un des leviers pour la transformation des sociétés et des économies vers une économie plus soutenable et durable. Cela passe par le privilège qui est accordé aux opérations financières qui prennent en compte des critères extra-financiers souvent appelés critères ESG – environnementaux, sociaux et sociétaux et de gouvernance (Bennis L., 2023).

Le concept de finance durable étant relativement récent, témoignant ainsi d'un changement significatif dans la conscience et les pratiques du monde financier. S'intéresser à la croisée entre les aspects de la responsabilité sociétales des entreprise et le développement durable (RSE/DD) et la finance sous l'ongle de la « finance durable » revient à rechercher les mécanismes et modèles permettant de concilier performance économique et impacts sociaux et environnementaux positifs tout en finançant des entreprises qui contribuent activement au développement durable. La finance durable se décline ainsi en différents modèles tel que : l'Investissement Socialement Responsable (ISR), l'investissement vert, la finance solidaire, le micro-crédit, ...

L'objectif de cette communication est de mettre l'accent sur l'état des lieux de développement de la finance durable au Maroc, l'un des pionniers africains en termes de durabilité et ayant pris des mesures proactives et innovantes en matière de politiques RSE et développement durable. Pour ce faire, on va analyser les engagements et les initiatives des divers acteurs, afin de comprendre la dynamique et les particularités de ce type de financement dans le pays en se basant sur une étude qualitative réalisées auprès de 10 entreprises labélisées CGEM³ pour la RSE au Maroc⁴ et sur la base d'une étude documentaire.

³ Confédération Générale des Entreprises du Maroc.

⁴ Le Label CGEM pour la Responsabilité Sociale de l'Entreprise (RSE) constitue pour le contexte marocain une reconnaissance du respect, par les entreprises marocaines, de leur engagement à observer, défendre et promouvoir les principes universels de responsabilité sociale et de développement durable dans leurs activités économiques et leurs relations sociales.

2. La finance durable : un nouveau paradigme en finance

La finance durable est incontestablement un secteur en pleine mutation, elle se révèle comme un des leviers majeurs en matière de développement des marchés et de financement de la transition économique. C'est ainsi nous observons que des nouveaux dogmes émergent en matière de finance où les acteurs financiers optent progressivement pour des investissements en faveur des projets durables et se dirigent vers une économie plus durable et responsable. Certes, la finance durable suscite de plus en plus d'intérêt, mais ce concept demeure encore vague. Une définition précise et unifiée « de ce type de finance n'est pas disponible et n'est peut-être pas possible en raison des différentes traditions dont sont issus les acteurs de la finance éthique » (Fayolle A., 2023). De manière générale, la finance durable regroupe l'ensemble des activités financières permettant d'avoir un impact positif sur l'économie effective, la société et l'environnement. Les acteurs financiers peuvent orienter les capitaux vers des investissements durables et responsables.

On parle de finance durable pour désigner les pratiques financières qui intègrent les critères extra-financiers. La finance durable consiste à investir dans un fonds qui associe performance économique et impacts environnementaux et sociaux positifs. Elle serait d'une certaine manière le développement durable (DD) appliqué à l'économie et à la finance. Tout l'enjeu est donc de financer des entreprises respectueuses des trois piliers du DD.

La logique de la « finance durable » ou « finance verte » est simple : dans la finance classique, les investisseurs placent leur argent dans des projets en fonction de leur rentabilité, alors que dans la finance durable, ils investissent dans des projets supposés contribuer à la transition écologique et sociale. Pour identifier ces projets, on a mis en place des indicateurs dits ESG (environnementaux, sociaux et de gouvernance) qui doivent permettre de mesurer la performance dite « extra-financière ». La finance durable est supposée être à la fois rentable et utile pour favoriser le développement de projets plus durables.

2.1. Une petite histoire de la finance durable

La finance durable n'est pas un concept nouveau, Les initiatives pour verdir la finance et l'économie s'accroissent d'année en année.

Les premières évocations d'une finance plus durable remontent aux années 1960, lorsque les investisseurs ont commencé à s'intéresser aux questions de responsabilité sociale / sociétale des entreprises « RSE » ;

Dans les années 1990, les normes de développement durable commencent à se mettre en place : en 1992, le Sommet de la Terre de Rio consacre le principe du développement durable. Le protocole de Kyoto (1997) prépare le terrain pour une économie durable en définissant les mécanismes de la finance en matière de réduction des émissions de gaz à effet de serre. Et en 1998, l'ISO publie la norme ISO 14001, relative au management environnemental, ainsi que plusieurs autres normes relatives à la responsabilité des entreprises, visant à encourager le basculement vers un système économique (et donc une finance) plus responsable.

Dans les années 2000, de plus en plus d'initiatives apparaissent pour tenter de mettre en adéquation le monde de la finance avec les objectifs collectifs de transition écologique et sociale. Les Principes pour l'Investissement Responsable (PRI) sont ainsi lancés en 2006 sur une initiative de l'ONU, pour promouvoir l'investissement responsable dans le monde entier. Les PRI ont pour objectif de sensibiliser les investisseurs institutionnels aux problématiques environnementales, sociales et de gouvernance (ESG) et de les encourager à intégrer ces critères dans leurs processus de décision d'investissement. Les premiers labels, mis en place par des agences de notation, sont mis en place pour distinguer la finance dite durable de la finance classique. En France, par exemple, le premier label ISR est mis en place par Novethic en 2009. Durant cette période, de nombreuses initiatives ont vu le jour pour promouvoir la finance durable, telles que les Green Bonds, les Social Bonds et les Sustainability Bonds. La crise de 2008 qui a mis en lumière des prises de risques excessives dans la finance traditionnelle, la complexité et l'opacité de certains montages financiers. En réaction, est apparue une volonté de donner du sens à la finance et de la rendre plus transparente.

L'année 2014 marque un certain tournant dans l'histoire de la finance durable :

Le *Montreal Carbon Pledge* a été signé par 120 institutions qui investissent. Ces derniers s'engagent à réaliser puis publier leur empreinte carbone,

Les *Green Bond Principles* (GBP) rassemblent une liste de bonnes pratiques faites par et pour les [banques](#).

En 2015, les Nations Unies adoptent les 17 Objectifs de développement durable (ODD). Ils détaillent la marche à suivre pour parvenir à un avenir meilleur et plus durable pour tous. Ils répondent aux défis mondiaux, notamment ceux liés à la pauvreté, aux inégalités, au climat, à la dégradation de l'environnement, à la prospérité, à la paix et à la justice. La même année, la COP21 à Paris aboutit à l'Accord de Paris, qui engage les pays à limiter le réchauffement climatique à 2°C et contient des propositions pour encourager le secteur financier à s'engager pour le climat. De plus en plus d'acteurs internationaux mettent donc en place des référentiels supposés encadrer la finance durable. En 2018, la Commission européenne présente par exemple son plan d'action pour la finance durable.

En 2020, la Commission européenne publie la Taxonomie européenne, qui établit une classification des activités économiques durables. La même année, la SFDR entre en vigueur, obligeant les gestionnaires d'actifs à publier des informations sur la prise en compte des critères ESG dans leur processus d'investissement. En 2021, la Commission européenne propose la directive CSRD pour renforcer les obligations de reporting en matière de durabilité des entreprises, afin notamment de servir de référentiel à l'évaluation des investissements durables. Dès lors, de nombreuses initiatives sont nées pour favoriser un monde plus durable.

2.2. Les modèles de la finance durable

La finance durable désigne l'ensemble des pratiques financières visant à favoriser l'intérêt de la collectivité sur le long terme. Elle repose sur une vision éthique à long terme de l'investissement financier. L'adjectif « durable » provient de la traduction du mot anglais « sustainable » soutenable. La finance durable cherche, alors, à concilier performance économique et impacts sociaux et environnementaux positifs, en finançant des entreprises qui contribuent activement au développement durable. Elle se décline en différents modèles, dont certains se recoupent.

La finance durable permet alors d'orienter et d'allouer les financements émis par différents financeurs vers des actions et des activités ayant un impact positif sur la société tels que : les logements sociaux, les énergies renouvelables, ...

L'investissement Responsable (IR) : Il permet d'intégrer des critères ESG dans les processus d'investissement et de gestion. L'investissement responsable incite les entreprises et sociétés de gestion à prendre en compte des critères extra-financiers. Il repose, donc, sur une épargne investie sur des projets conciliant conjointement, d'un côté, la performance financière, et d'un autre côté, le respect de l'environnement €, la considération et le bien-être des salariés (S : formation des salariés, dialogue social, emploi de personnes en situation de handicap, prévention des risques, conformité réglementaire, etc.), enfin les bonnes pratiques de gouvernance (G : lutte contre la corruption, transparence de la rémunération des dirigeants, féminisation des conseils d'administration, etc.).

La Finance verte : Elle réunit l'ensemble des opérations financières qui vise à soutenir des projets respectueux de la transition énergétique et écologique et de la lutte contre le changement climatique. En d'autres termes, la finance verte consiste à financer les initiatives et réglementations qui visent à faciliter les investissements avec impact positif sur l'environnement (milieux, écosystèmes) en favorisant la transition énergétique et la lutte contre le réchauffement climatique. Il s'agit de pratiques financières ayant une thématique plus ciblée et qui sont concentrées exclusivement sur le pilier environnemental favorisant la transition vers une économie plus durable et résiliente.

Les pratiques durables englobées par la finance verte peuvent inclure la production d'énergie renouvelable, l'efficacité énergétique, la gestion durable des ressources naturelles, la gestion des déchets, le transport durable, la construction écologique, la protection de la biodiversité et de l'environnement, et la lutte contre le changement climatique. Ses outils principaux sont les obligations vertes « green bonds ». Ces emprunts servent à financer des projets contribuant à la transition écologique : gestion de l'eau, des déchets, de l'énergie, etc.

La finance verte offre de nombreux avantages pour les entreprises marocaines qui s'engagent dans des pratiques durables. Tout d'abord, elle permet de réduire les coûts d'exploitation en améliorant l'efficacité énergétique, en optimisant l'utilisation des ressources naturelles et en minimisant les déchets. Ensuite, elle peut contribuer à améliorer l'image de marque de l'entreprise, en démontrant son engagement en faveur de l'environnement et de la responsabilité sociale. Enfin, elle permet de réduire les émissions de gaz à effet de serre, contribuant ainsi à l'effort global de lutte contre le changement climatique.

La Finance solidaire : Elle regroupe les placements dont l'engagement est orienté sur des critères sociaux : activités d'insertion liées à l'emploi, au social et au logement, à la solidarité internationale et à l'environnement. La finance solidaire recouvre l'ensemble des initiatives et réglementations visant à faciliter le financement de projets destinés à lutter contre l'exclusion et à améliorer la cohésion sociale. La rentabilité financière n'est pas la priorité de l'épargnant. L'objectif recherché est par exemple de favoriser la réinsertion, la solidarité internationale, de lutter contre le chômage, contre le mal logement

La finance solidaire repose sur une épargne placée par les épargnants sur des produits financiers solidaires. Cette épargne collectée est ensuite orientée vers des porteurs de projets développant des activités à forte utilité sociale. Un investisseur (entreprise ou particulier) peut également décider d'investir directement sous forme d'actions dans le capital d'entreprises solidaires. Enfin, des prêts peuvent également être attribués aux particuliers sous forme de microcrédits ou de prêts solidaires. On parle alors de financements solidaires.

Le Social business : Mis en avant par le prix Nobel de la paix Muhammad Yunus (créateur du microcrédit), le social business (entreprise sociale) est un concept d'entreprise, utilisant les profits de cette dernière pour produire une valeur ajoutée « sociale » auprès de la communauté dans laquelle elle se situe. Il concentre les entreprises dont la finalité est principalement sociale. Les bénéfices sont réinvestis dans la lutte contre l'exclusion, la protection de l'environnement, le développement et la solidarité. L'entreprise ne reverse aucun dividende, elle réinvestit ses profits dans son Social Business.

En 2009, lors du Forum économique de Davos, Muhammad Yunus a dressé une liste des 7 principes du Social Business :

1. L'entreprise a pour objectif la suppression de la pauvreté ou de s'attaquer à des problèmes sociaux dans le domaine de la santé, de l'éducation, de l'accès à la technologie ou de l'environnement. Son objectif n'est donc pas la maximisation du profit.
2. L'entreprise doit assurer sa viabilité financière et économique
3. Aucun dividende n'est distribué, les investisseurs ne récupèrent que leur investissement.
4. Lorsque les montants investis sont remboursés, les profits sont réinvestis dans l'entreprise afin qu'elle puisse s'améliorer et s'agrandir.
5. L'entreprise se doit de respecter l'environnement
6. La main d'œuvre doit obtenir le salaire du marché et de meilleures conditions de travail.
7. ... Le faire dans la joie.

Les entrepreneurs du social business cherchent à apporter une solution aux problématiques de la société. La finalité sociale de l'entreprise prime sur sa finalité lucrative. Ces entreprises sociales réinvestissent leurs excédents dans la lutte contre l'exclusion, la protection de l'environnement, le développement et la solidarité.

3. La dynamique de la finance durable au Maroc : état de lieux et perspectives

Le Maroc a été parmi les pays précurseurs au monde dans la mise en place de politiques publiques visant à une meilleure protection de l'environnement. Ce choix s'est imposé au Maroc suite aux années de sécheresse récurrentes vécues durant le siècle dernier et s'est traduit

par la mise en place de politiques audacieuses et avant-gardistes visant à préserver les ressources naturelles. Il était donc naturel que le Maroc soit le premier pays méditerranéen et le premier pays africain à accueillir à Marrakech la Conférence des Parties (COP) dans sa 7^{ème} édition en 2001 puis dans sa 22^{ème} édition en 2016.

Depuis, le Maroc s'est engagé à tout mettre en œuvre pour devenir une plateforme au service de l'Afrique. Cela se fait à travers le partage d'expériences notamment dans l'aménagement du territoire, par la création de l'Institut International du Développement Durable et aussi par l'accueil régulier de forums et conférences en liaison directe avec le Développement Durable. Ainsi il est important de signaler que le Maroc est classé parmi les champions du Monde dans les politiques publiques de Développement Durable et qu'il a été désigné en Mars 2021, par l'ONU, comme Champion de Haut Niveau du Dialogue.

Cette consécration traduit le choix stratégique du Maroc de poursuivre ses 7 efforts par la mise en place, depuis le début de ce siècle, de politiques sectorielles en phase avec les engagements pris dans le cadre des recommandations des Nations Unies et des COPs tout en veillant à intégrer, du fait de sa géographie très riche et variée, les dimensions humaines, sociale et territoriale. Ainsi, le Maroc a mis en place une batterie de dispositifs réglementaires dont les principales sont celles relatives au Secteur de l'Energie, de l'Agriculture et des activités dites AFATs, de l'Eau, du Recyclage des déchets, ...

3.1.Cadre institutionnel de la transition verte et du développement durable

Sur la base d'une qualitative réalisées auprès de 10 entreprises labélisées CGEM pour la RSE au Maroc, l'engagement du Maroc dans le développement durable se caractérise à la fois par sa pleine participation à de nombreuses négociations internationales, par une intervention de l'Etat au plan législatif et en tant qu'initiateur d'une dynamique de pluri-acteurs pour renforcer les dispositifs institutionnels, ainsi que par le foisonnement des initiatives prises par les acteurs économiques et sociaux.

Dans ce cadre, pour réaffirmer son engagement, le Maroc a pris l'initiative d'adopter la (loi-cadre 99-12, 2014). Selon cette loi, « le développement durable est une valeur fondamentale » à partager par tous les membres de la société. Indépendamment de l'engagement étatique, les entités privées sont requises d'incorporer les dimensions environnementales et de développement durable dans les dispositifs de production, en impliquant les parties prenantes dans des approches respectueuses de l'environnement, d'estimer les conséquences écologiques de leurs activités, et d'établir la nécessité d'une communication claire et accessible concernant leurs actions vis-à-vis de l'environnement.

De même, et pour honorer ses engagements et s'aligner aux objectifs de développement durable (ODD), le Maroc a mis en œuvre les fondements d'une économie verte à travers un dispositif légal et réglementaire de l'économie verte et circulaire au Maroc (Alami Nouredine N. & Al., 2024). Dans ce sens, on peut citer :

2006 : La loi sur le Recyclage des déchets⁵ ;

⁵ Dahir n° 1-06-153 du 22 novembre 2006 portant promulgation de la loi n° 28-00 relative à la gestion des déchets et à leur élimination.

2010 : La loi sur les énergies renouvelables⁶ ; La loi sur l'utilisation des sacs jetables en plastique⁷ ; La loi sur les aires protégées⁸ ;

2011 : La constitution marocaine a consacré la politique ancestrale de protection de l'environnement en inscrivant dans son article 31 le droit à un environnement sain et au développement durable ;

2012-2014 : Charte Nationale de l'Environnement et du Développement Durable⁹. (La loi cadre n°99-12, 2014) qui devrait s'étaler jusqu'en 2030, et qui du fait du caractère transversal du développement durable, va prendre en compte toutes les stratégies sectorielles initiées notamment la Stratégie nationale de l'eau, la stratégie d'énergie, le plan Maroc vert, l'Initiative Nationale pour le développement humain ou le pacte national sur l'émergence industrielle.

2021 : Le Nouveau Modèle de Développement a été validé en 2021 et il introduit l'ambition du Maroc à horizon 2035.

Pour réussir ses ambitions en matière de durabilité, le Maroc a aussi mis en œuvre une série de réformes politiques, institutionnels, juridiques et socio-économiques pour mettre à niveau les services publics et améliorer les conditions d'accueil de l'investissement. On peut citer sans être exhaustif la réforme du code du travail, les progrès reconnus en matière de respect des droits de l'homme avec la création d'un conseil consultatif des droits de l'Homme, puis de l'instance Equité et Réconciliation, la stratégie de lutte contre la corruption, l'Initiative Nationale pour le Développement Humain....

3.2.La transition vers la finance durable au Maroc

La transition verte, durable et inclusive est d'ores et déjà une réalité pour le Maroc. Ce chantier majeur remonte à environ deux décennies, sous la vision éclairée de Sa Majesté le Roi Mohammed VI, et s'appuie aujourd'hui sur un cadre de mise en œuvre éprouvé et en forte dynamique de consolidation. Ainsi, environ 400 millions d'obligations durables ont été émises en 2020 (Amzil et Lazaar, 2021).

La vulnérabilité du Maroc face aux changements climatiques, la dégradation continue de son environnement au détriment de la croissance (déforestation, pression sur les écosystèmes naturels, désertification, stress hydrique, etc.), et la dépendance énergétique du pays par manque de ressources fossiles sont autant de facteurs qui ont propulsé le pays vers l'adoption du modèle de l'économie verte et inclusive.

Par ailleurs, le Royaume a fait le choix d'opérer une intégration de la dimension de durabilité dans sa politique globale dans un souci de maintenir l'équilibre entre les impératifs de son développement socioéconomique et l'utilisation rationnelle de ses ressources naturelles. Pour le Maroc, l'économie V&I est une démarche débouchant sur une amélioration du bien-être

⁶ Dahir n°1-10-16 du 11 février 2010 portant promulgation de la loi n°13-09 relative aux énergies renouvelables. Ce cadre a permis au Maroc de mettre en place sa politique ambitieuse de production d'énergie solaire et éolienne.

⁷ Dahir n°1-10-145 du 16 juillet 2010 portant promulgation de la loi n° 22-10 relative à l'utilisation des sacs et sachets en plastique dégradable ou biodégradable.

⁸ Dahir n° 1-10-123 du 16 juillet 2010 portant promulgation de la loi n°22-07 relative aux aires protégées.

⁹ Le premier texte a été élaboré en 2012 et a été promulgué pour contenir à ce jour 7 principes : (a) Intégration, (b) Territorialité, (c) Solidarité, (d) Précaution, (e) Prévention, (f) Responsabilité et (g) Participation. Il est la consécration de la Charte Nationale.

humain et une réduction des inégalités à long terme sans exposer les générations futures à des risques environnementaux et des pénuries écologiques majeurs.

En effet, les différentes réalisations consolidées sur les volets socio-économique, environnemental, et de gouvernance, ainsi que le retour d'expérience accumulé sur l'ensemble des secteurs stratégiques dénotent d'ambitions concrétisées, avec d'autres qui émergent ou s'agrandissent avec l'adoption du Nouveau Modèle de Développement du Royaume.

La stratégie du pays en termes de financement durable s'accroît autour de deux volets :

- Disponibilité et maturité des principaux instruments pour le financement de la transition.
- Nécessité de renforcement des instruments existants et de développement de nouveaux mécanismes financiers innovants, tout en assurant un accompagnement rapproché des porteurs de projets durables.

A cet effet, on présentera dans ce qui suit le mapping des instruments économiques et financiers nécessaires à l'économie verte et inclusive au Maroc en détaillant les prérequis pour chaque instrument. Ceci inclurait les recommandations en matière de mise en place d'une fiscalité verte, incitative et positive, l'orientation de la commande publique, le développement d'instruments financiers flexibles tels que le tiers investissement, le capital-risque, la finance mezzanine ou encore les outils obligataires innovants tels que les Sukuk bonds, les diasporas bonds ou les SDG bonds en renforcement des obligations existantes comme le gender bonds et les green bonds.

Tiers-investissement (on-bill financing) : instrument permettant d'inciter les ménages ou les petites entreprises à investir dans des équipements durables (énergie propre, transport durable, EE, etc.). Ce dernier est adapté aux projets qui génèrent : i) des économies potentielles importantes pour les particuliers et/ou TPE – suscitant ainsi l'intérêt de mettre à niveau leurs équipements (i.e. énergie, transport durable etc.) ; ii) des cash flows récurrents de remboursement, répondant au souci de garantie pour le financeur. Un organisme tiers avance les frais, l'expertise, le diagnostic et réalise les travaux. Les économies d'énergie permettent au "client" bénéficiaire des travaux de rembourser l'ensemble de l'investissement au tiers.

Capital-risque (venture-capital) : Financement de la création ou du développement d'une entreprise à risque mais à fort potentiel, sous la forme d'une prise de participation.

Finance mezzanine : financement hybride entre dette et fonds propres qui donne au prêteur le droit de convertir sa dette en une participation dans l'entreprise en cas de défaillance une fois les prêteurs plus seniors payés. Le financement mezzanine est prioritaire par rapport aux capitaux propres purs, mais subordonné à la dette pure. Par conséquent, les prêts mezzanine offrent des rendements plus importants que les dettes plus séniores, tout en comportant plus de risques.

Sukuk bonds : instrument de finance islamique semblable à une obligation dans la finance conventionnelle, qui est conforme à la loi religieuse islamique. Les sukuk impliquent une participation directe dans la propriété des actifs et fournissent aux investisseurs des flux de paiement non spéculatifs.

Diasporas bonds : correspondent à des obligations émises par un pays à destination de ses expatriés. Ces obligations permettent aux pays en développement ayant besoin de financement de se tourner vers les expatriés en situation aisée. Elles peuvent être émises régulièrement, sur une base annuelle ou ponctuellement (besoin spécifique de financement).

Obligations ODD (SDG bonds) : obligations souveraines destinées au financement des ODD avec une attribution ex ante. Au sens large, les SDG bonds regroupent l'ensemble des obligations dont le produit, strictement défini ex-ante, est utilisé pour financer un objectif durable, favorable à l'avancement de l'Agenda 2030. En cela ces obligations regroupent principalement the Climate/green bonds pour le financement de projets verts au sens large (ODD6, ODD7, ODD13, ODD14, ODD15) ; the Social bonds pour le financement de projets sociaux (ODD1, ODD5, ODD10) ; the Gender bonds pour le financement de projets visant l'égalité des sexes (ODD5).

4. Conclusion

En conclusion, la finance verte représente une opportunité importante pour les entreprises marocaines de concilier développement économique et respect de l'environnement. Les avantages qu'elle offre, tels que la réduction des coûts d'exploitation, l'amélioration de l'image de marque et la réduction des émissions de gaz à effet de serre, sont indéniables. Cependant, pour tirer pleinement parti de la finance verte, les entreprises marocaines doivent surmonter des défis tels que les coûts initiaux élevés et le manque de connaissances et de compétences nécessaires.

Des exemples d'entreprises marocaines qui ont adopté la finance verte montrent qu'il est possible d'adopter des pratiques durables tout en étant économiquement viables. Ces entreprises ont investi dans des projets d'efficacité énergétique, de gestion des déchets, de production d'énergie renouvelable, de construction écologique et de protection de l'environnement, tout en améliorant leur image de marque et leur performance financière.

Il est donc temps pour les entreprises marocaines de prendre conscience des avantages de la finance verte et de s'engager activement dans des pratiques durables. Il est également important que les autorités et les régulateurs encouragent et facilitent cette transition vers une économie verte, en mettant en place des politiques, des incitations et des cadres réglementaires adaptés. En fin de compte, la finance verte est une opportunité pour le Maroc de promouvoir une économie plus durable, résiliente et prospère, tout en contribuant à la lutte contre le changement climatique et à la protection de l'environnement.

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A Comparative study of Automatic Prediction Methods for Phosphate Fertilizer Production Forecast in Tunisia

Mansouri Mounira¹, Nabila Mansouri² et Soulef Smaoui³

Résumé

En Tunisie, l'industrie du phosphate s'est considérablement développée et devenue un pilier de l'économie nationale. Cependant, des défis environnementaux et sociaux sont apparus, nécessitant un engagement en faveur de la durabilité. Les prévisions de production facilitent la planification économique en donnant un aperçu de l'approvisionnement futurs et influencent les décisions d'investissement et les stratégies commerciales. Cette étude illustre l'importance de la prédiction automatique de la production d'engrais phosphatés basée sur des méthodes automatiques. Multiples méthodes de prévision automatique ont été utilisées, y compris des méthodes statistiques traditionnelles (ARIMA, ARIMAX), les modèles d'apprentissage automatique (ANN, SVR). Une étude comparative est menée sur des données historiques de la production d'engrais phosphatés en Tunisie. Ces données couvrent la période de 2010 à 2020. La métrique d'erreur absolue moyenne (MAE) est utilisée pour évaluer les performances de ces méthodes en prouvant une supériorité des méthodes d'apprentissage automatique.

Abstract

In Tunisia, the phosphate industry has developed significantly and has become a pillar of the national economy. However, environmental and social challenges have emerged, requiring a commitment to sustainability. Production forecasts can aid economic planning by providing insight into future supply levels, which influences investment decisions, resource allocation and trade strategies. Indeed, this study aims to illustrate the importance of automatic prediction of phosphate fertilizer production based on automatic methods. Multiple automatic forecasting methods have been employed, including traditional statistical methods such as time series analysis (e.g., ARIMA, ARIMAX), machine learning models (e.g., ANN, SVR). A comparative study on phosphate fertilizer production prediction methods in Tunisia is conducted based on historical data on phosphate fertilizer production in Tunisia. This data covers the period from 2010 to 2020. Mean Absolute Error (MAE) metric is used to evaluate selected prediction method. Experimental studies have shown suitable performance, especially for machine learning models.

Key words: Forecasting, Fertilizer, Time Series, Machine Learning, ANN

¹ Faculty of Economics and Management of Sfax, Sfax University, Tunisia; mansourimounira177@gmail.com

² Digital Research Center of Sfax SM@RTS : Laboratory of Signals, systems, artificial Intelligence and networks
Sfax, Tunisia; nabila.elmansouri@crns.rnrt.tn

³ Faculty of Economics and Management of Sfax, Sfax University, Tunisia; soulef.smaoui@fsegs.usf.tn

1. Introduction

The prediction of fertilizer production is a critical input in the food and organics production chain. Therefore, the increase in its production could be planned adequately without compromising the environment.

Demand forecasting is one of the most fundamental parts of supply chain management. In fact, demand forecasting has significant implications for planning, capacity, and inventory management decisions. Furthermore, phosphate fertilizer prediction is an important duty in Tunisia. This study theme, which is centered on time series modeling and forecasting, receives significant interest.

The autoregressive integrated moving average (ARIMA) model is a popular and effective time series model. The ARIMA model's appeal stems from its statistical features. Although ARIMA models are highly flexible in that they can represent a variety of time series, including pure Autoregressive (AR), pure Moving Average (MA), and combined AR and MA (ARMA) series, their main constraint is the model's presumed linear form. In that example, a linear correlation structure is assumed among the time series values, which means that the ARIMA model is unable to capture nonlinear patterns [Stellwagen and Tashman (2013)]. However, the dynamic behavior of most time series in our daily lives, with their autoregressive and inherited moving average terms, makes it difficult to forecast nonlinear time series containing inherited moving average terms using computational intelligence methodologies such as neural networks [Tealab et al. (2017)].

Analyzing fertilizer production over time poses a significant challenge due to limited and often unsatisfactory data availability [Carla (2022)]. As a result, developing effective machine learning models becomes difficult. Although some initiatives applying machine learning and statistical methods are commonly used to predict fertilizer production, a thorough evaluation of data analytics approaches to improve predictions under different step-ahead horizons is needed. We explored in this paper, a comparative study between traditional time series forecasting methods such as ARIMA, linear regression and machine learning methods such as SVR and ANN.

This article is structured in five sections. The first section introduces the topic. The second provides a literature review to situate the study. The third section outlines the methodology used. The fourth presents the experimental results and analysis. The final section offers a conclusion and directions for future research.

2. Literature review

The scientific community is conducting a lot of research because fertilizers are important from a social and economic standpoint. We are especially interested in reviewing studies that deal with fertilizer production prediction in this research. A systematic mapping at Jstor, ScienceDirect, Econlit, Francis-Taylor, Wiley, Econpapers is done using the query string: (“predict” OR “forecast”) AND “fertilizer” AND (“production”) AND (“Phosphat”). journals or conference articles were considered. Also, Only English articles were returned. The query

returned 46 articles. The query was executed on August, 2024. All abstracts were analyzed, and 17 articles were selected for further reading based on their relevance.

Based on the earlier work of Yule (1926) and Wold (1936), Box and Jenkins (2016) developed a practical approach to building ARIMA models, which has the fundamental impact on the time series analysis and forecasting applications. Recently, Artificial Neural Networks (ANNs) have been extensively studied and used in time series forecasting. Zhang et al. (2023) presented a recent review in this area. The major advantage of neural networks is their flexible nonlinear modeling capability. ANNs, can work without any specification of a particular model form. In fact, the model can be adaptively structured based on the features presented from the data. So, where no theoretical guidance is available, this data-driven approach is good for many empirical data sets to generate an appropriate data process. Hence ANN, it has been applied in modeling and forecasting data from different knowledge areas [Burges et Refenes (1999), Iacus (2001), Gooijer, D., Hyndman, R.J. (2006), Philip et Wilbert (2012), Michele et Cira (2015)]. however, in the literature there is a large part of the proposed ANN models that are exclusively based on a nonlinear autoregressive structure, and only a few of them considered the generating process of the nonlinear time series that has in addition to the autoregressive, a moving averages component. To tackle this issue, some authors propose using high-order neural models such as the Nonlinear Autoregressive Moving Average (NARMA) network and the Autoregressive Neural Network (ARNN). Specific examples of these approaches are presented by Connor and Martin (1994) and Guo et al. (2021).

In the context of fertilizer analysis, the work in [Carla (2022)] explores the combination of preprocessing techniques and machine learning. The authors compare the results with the baseline ARIMA model. To address this, we propose a process that incorporates series cross-validation during training and performs data analytics to predict fertilizer usage across different prediction horizons.

3. Methodology

Time series forecasting refers to the process of predicting future values of a variable based on its past observations, where the data points are indexed in chronological order. In this study we perform a comparative study between traditional methods and machine learning methods. Among existing methods, we select the following ones:

Linear Regression: Linear regression is a statistical approach that depicts the correlation between many variables by fitting a linear equation to the observed data. In the context of time series forecasting, this strategy uses time as one variable and the target variable as another. In this case, the variables used are time, which is represented by months ranging from January 2010 to December 2020 and the monthly production of the phosphate during this period.

The underlying premise of linear regression is the assumption of a linear relationship between the independent variable (time) and the dependent variable (the variable under prediction). This relationship can be quantitatively described by a straight-line equation, commonly represented as:

$$y = m x + c \quad (1)$$

In this equation, y is the dependent variable, x is the independent variable (time), m is the line's slope, and c is the intercept

ARIMA: (Autoregressive Integrated Moving Average) models in their seminal text-book, Time Series Analysis: Forecasting and Control. ARIMA models attempt to identify patterns in the historical data. Their goal is to identify the process that is generating and influencing the historical pattern, which is called the data generating process. An ARIMA model consist of three components, each component is used to model a certain type of pattern. The autoregressive component “AR” accounts for the patterns between any one time period and previous periods. The Moving Average component “MA” (usually called the error feedback term) tracks the adaptation of new forecasts to prior forecast errors. The integrated component “I” connotes a trend or other “integrative” process in the data [Stellwagen et Tashman (2013)].

SVR: One popular method for time series forecasting is Support Vector Regression (SVR), which leverages the power of Support Vector Machines (SVMs) for regression analysis. SVR aims to find a function that approximates the mapping from input features to the target variable. SVR uses support vectors, which are a subset of the training data points, to define a hyperplane that maximizes the margin around the predicted values [Guo et al. (2021)].

ANN: An Artificial Neural Network (ANN) for time series forecasting is a computational model composed of interconnected nodes (neurons) organized into layers. These networks are trained on historical time series data to learn the underlying patterns and relationships between input variables (e.g., past values of a time series) and output variables (e.g., future values of the time series). Once trained, the ANN can make predictions on unseen data points [Tealab et al. (2017)].

4. Experimental Study

4.1. Dataset

Selected methos are tested on the Tunisia phosphate monthly production. The database covers monthly phosphate production in Tunisia from 2010 through 2020. Production is measured in tones at the end of each month (see Table 1).

Table 1: Tunisia phosphate monthly production during 2010 to 2020

somme	PRODUCTION MENSUELLE DU PHOSPHATE (TONNE)	day	month	year
0	259604.00	31	1	2010
1	143796.00	28	2	2010
2	228200.00	31	3	2010
3	116807.00	30	4	2010
4	228727.00	31	5	2010
...	...	...	...	...
122	57497.46	31	5	2020
123	39398.30	30	6	2020

124	92031.12	31	6	2020
125	141335.40	30	6	2020
126	39440.70	31	7	2020

(127 rows x 5 columns)

4.2. Test protocol

To implement and test Machine Learning (ML) methods, the data is divided as follow: 70% for training, 15% for validation and 15% for testing. Hence, production before covid'19 period (2010-2018) are used for learning phase whereas phosphate production's data during covid'19 period (2019-2020) are used to test ML models.

4.3.Results

Forecasting performances are computed based on the Means Squared Error (MSE). MSE is a quantitative metric to evaluate the accuracy of an automatic estimator by computing the average squared difference between the estimated values and the actual value. The forecasting results in term of MSE are as follow (Table1):

Table 1: Forecasting results in terms of MSE

Method	MSE
SVR	26973268278.75
Linear Regression	10902089570.7336
ARIMA	0.026
ANN	0.021

Table 1 shows that the highest performance is achieved with the ANN model, exhibiting an MSE of 0.021. This analysis emphasizes the advantages of ANNs over other techniques. ANNs, along with ARIMA models, usually outperform linear regression and SVR due to their ability to model complex relationships and nonlinear data. ANNs are adaptable and can detect patterns in complicated datasets, whereas ARIMA models specialize on time series analysis, which captures trends and seasonal variations. These approaches excel in situations when the connections between variables are not strictly linear, producing better results in complex cases

5. Conclusion and Future Directions of Research

This paper is focused on modeling and automatic forecasting in time series using both traditional and machine learning methods. Experimental results show that Artificial Neural Networks (ANNs) are powerful computational models inspired by the structure and function of the human brain. They are widely used for time series forecasting due to their ability to capture complex patterns and nonlinear relationships within datasets. Here's a breakdown of using ANNs for time series forecasting.

Although, these methods reach a good performance, recent research in these areas is moving toward the use of deep learning models. Indeed, the advent of deep learning has created a plethora of opportunities for modeling and predicting time series data.

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