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Paper presented at the IXth Congress of the Romanian financial auditor profession

From Tax Avoidance to Tax Compliance – Realities and Trends in Financial Reporting in Romania

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Abstract

Most of the financial and accounting empirical studies on Romanian companies analyse populations or samples of companies listed on the Bucharest Stock Exchange, either on the regulated market or on the alternative AeRo market. This study aims to analyse accounting data provided by unlisted companies and available on a portal of the Ministry of Public Finance (https://data.gov.ro/). These companies apply Romanian accounting standards (RAS). The authors calculated the effective tax rate (ETR) as the ratio of current income tax expense to profit before tax and used this indicator (following models already found in the literature) as a proxy for measuring the level of the corporate income tax avoidance. The main results show that, if the average ETR is used, there are almost no differences between the statutory rate and the effective one. However, intuitively, this result does not seem to characterize the Romanian economic environment very well, so in the present study was used the ETR-STR differential. The latter indicator shows a completely different situation, with significant differences between ETR and STR. This result confirms, to a certain extent that, at an individual level, the accounting income is very often far from the tax income, 2/3 of the observations being in situations characteristic for the application of tax avoidance techniques, with effective rates significantly lower than the statutory ones.

Key words: *corporate income tax; tax avoidance; private companies; effective tax rate; statutory tax rate;*

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1. Introduction

Most recent research in accounting is based on the financial indicators resulting from the financial reports of the listed companies. For Romania, this population of companies and – often – samples extracted from it are quite limited in size and do not allow the generalization at country level of the results produced by various studies. At the time of the documentation of this study, on the Romanian financial market – Bucharest Stock Exchange (BSE) – are listed, on the regulated market, 82 companies registered in Romania; to these are added another 260 companies listed on the alternative AeRo market. We reach less than 350 companies which, no matter how big they are and no matter how many Romanian subsidiaries they control, represent only a very small part of the total number of active Romanian companies. According to the data published by ANAF, in the fiscal statistical bulletin for the 1st quarter, 2025 (https://static.anaf.ro/static/10/Anaf/Informatii_R/Buletin%20statistic%20fiscal%20nr%201%202025.pdf, accessed at July 5th, 2025), at the end of December 2024, there were 764,766 corporate tax payers (622,058 on the same date as in 2023) and 332,704 micro-enterprise tax on revenues payers (459,417 on the same date as in 2023). Thus, on December 31, 2024, we had a total of 1,097,470 taxpayers reviewed by the Romanian tax authority. If we establish a simple ratio, the listed companies represent very little over 0.03% of the total and no matter how many subsidiaries they have, they still do not come close to at least 1%. In these circumstances, it would be extremely interesting to analyse the population of unlisted companies or at least samples of them, in order to be able to propose conclusions that better characterize the Romanian economic environment at national level.

In principle, the Ministry of Public Finance (MFP) has access to data reported by firms that meet their annual (and semi-annual) submission obligations of financial statements. From this data, MFP publishes some information, available individually on the ministry website (https://mfinante.gov.ro/info-pj-selectie-nume-si-judet). This site is very useful for identifying and analysing individual companies. On the contrary, for analysis on large populations of firms, manual data collection by individual access to the site would be extremely time consuming. MFP somehow meets the curiosity of some users and groups some of this data on the data.gov.ro portal. Even if the number of companies available for the last years on this portal is relatively small compared to the total of companies operating in Romania, we still find several tens of thousands of observations to be analysed annually, which can represent a quite useful sample in characterizing the global population of Romanian companies.

The orientation of companies towards fiscal optimization/tax avoidance (TA) shows that companies perceive the benefits of this kind of behaviour (Abdul Wahab, 2016) and can manifest itself through various techniques. In the particular context of Romania, a trend towards doing business through micro-enterprises could be very clearly observed, for which the corporate tax is replaced by the revenues tax. The latter is much easier to manage and much less burdensome for firms that meet the criteria for classification as micro-enterprises. As regards corporate tax payers, the trend towards tax planning/tax avoidance (TA) can be identified by analysing the effective tax rate (ETR): an ETR lower than the statutory or legal rate (STR) signals the possible application of some TA techniques.

In the context of public and private research and discussions on the tax avoidance/reduction of corporate tax payments, we can mobilize the information on data.gov.ro, in the sense of using it for the purpose of ETR calculation, as a proxy that allows us to measure the difference between the theoretical and the actual tax reported. Considering the fact that such a relationship is investigated mainly by comparing the accounting regime of revenues and expenses with their tax regime, our analysis can make sense only in the case of companies that pay corporate income tax. This limitation involves the removal of firms which, in the period under review, had to pay tax on revenues as micro-enterprises, which further diminishes the number of observations.

As mentioned earlier, the indicator we intend to use is *the effective tax rate* (ETR), calculated as the ratio between the corporate tax expense and the income before tax. The second step is to establish the differential ETR-STR. The latter legal (statutory) corporate tax rate has been 16%, since 2005. Through the differential ETR-STR we can avoid the effect of some compensations between the individual observations. If this differential is significant, then the difference between accounting and tax treatment of revenues and expenses is also significant, with the possible intervention of some tax optimization/tax avoidance techniques. On the other hand, the significant differences between accounting income and taxable income suggest a certain *de facto* disconnection between accounting and taxation, after the *de jure* disconnection is a reality demonstrated in literature (Istrate, 2024). We are aware that the negative difference between ETR and STR, even if it is a credible proxy for TA, does not allow any

distinction between legal and illegal actions from which the reported tax decreased (Jimenez-Angueira, 2018). ETR is, in fact, the most widely used variable to approximate TA in the literature on the tax behaviour of firms (Sarhan et al., 2024) and has the major advantage that it can be calculated based on data from financial statements.

Our main results show that, if we take into account individual observations (eliminating the compensation introduced by the calculation of averages), the differences between ETR and STR become statistically significant; with the identification of some behaviours that can fit the tax avoidance, for a majority (almost two-thirds) of the analysed observations.

Continuing the analysis of the ETR-STR differential by categories of companies, depending on some criteria frequently used in literature, it can be seen that, for example, the negative differential is significantly different for small companies compared to large ones, in the sense that large companies seem to have more resources and more opportunities from which to reduce the declared tax, that is to reach lower ETR. Significant differences also arise in the case of firms more leveraged to those less leveraged. Significant are also the results of the analysis according to the profitability of the companies (over and below the median), or according to the presence of provisions in the balance sheet. Less clear results occur when we consider the weights of some asset categories on the balance sheet.

The continuation of this study proposes a brief review of the literature, followed by the presentation of the data and the methodology, a results section, to finish with the conclusions and references.

2. Literature review

In a review of the literature on proxies used by researchers to measure tax avoidance/optimization/tax planning/tax aggressiveness – TA - (Istrate, 2023), a long list of such indicators was identified, proposed by various authors and previously centralized mainly by Hanlon & Heinzman (2010), the most commonly used being ETR. It is calculated as the ratio between income tax expense and the profit before tax reported by companies. The literature proposes three variants of ETR, depending on the amount taken into account in the numerator: current tax expense, total tax expense (current and deferred), income tax paid. Calculations can also be made on an annual or multi-annual basis (3, 5, or even 10 years). However, ETR is not always a meaningful indicator, especially in the context of changing tax rates. In these circumstances, the difference between ETR and STR can provide a clearer picture of the company's tax situation; similarly, the ratio between the two rates (ETR/STR) can also be calculated. The hundreds of studies in which ETR or its derivatives are used as dependent or independent variables demonstrate the usefulness of this indicator in research and in the analysis that could be carried out by decision-makers at the level of companies, groups of companies, or tax authorities.

Most studies using ETR refer almost exclusively to listed companies, mainly due to the availability of data on these companies (Athira & Jijo Lukose, 2024). Badertscher et al. (2019) consider that listed companies, being more exposed, give rise to higher levels of non-conforming tax avoidance (higher accounting income and lower taxable income), unlike unlisted companies, which achieve higher levels of conforming tax avoidance (reduction of taxable income, along with accounting income). On the other hand, it is considered that listed companies are more exposed, in the sense that there are more parties monitoring their activity, and that they would therefore have an interest in limiting the extent of tax avoidance for reasons related to reputation and public image. Based on this argument (to which are added the closer links between ownership and management), Jacob & Rohlfing-Bastian (2020) consider that unlisted companies are more inclined to engage in TA. In the case of large populations of companies analysed, the public/private nature of the company can be introduced as a discriminating factor: for example, Athira & Jijo Lukose (2024) analyse ETR developments by separating listed companies from unlisted ones. The listed-unlisted distinction is also considered by Pierk (2016), who finds that listed companies are more aggressive in their tax avoidance than unlisted ones.

With regard to the present study, the companies analysed are not listed, which does not really allow for comparison with the results of many studies published in this field. Fortunately, there are other authors who have analyzed unlisted companies. Sanchez-Ballesta & Yagüe (2021) find that SMEs are less aggressive in terms of TA, even if they engage in upward earnings management (which can be assimilated to conforming tax avoidance), meaning that incentives related to reporting higher net incomes prevail over the interest in engaging in tax optimization (in line with the results of Pierk, 2016). Floropoulos et al. (2024) identify 12 studies (published between 2005 and 2021)

that analyse the tax behaviour of private companies and find significant differences between it and the behaviour of listed companies.

Thomsen & Watrin (2018) calculate the differences between statutory and effective tax rates and find, for European companies over a 12-year period (2005-2016), a decrease in these differences, which can be interpreted as a reduction in tax avoidance attempts. A complementary explanation for these results could be that, over time, statutory tax rates have fallen and mechanisms to combat tax avoidance have been developed by the authorities.

Analyses of the effective tax rates of Romanian companies have also been published in studies that took into account listed Romanian companies. Lazăr & Istrate (2018) use a much more comprehensive ETR, in the sense that they take into account all taxes and fiscal/social contributions expensed by companies (income tax being only one of these taxes and not the most important one). As expected, Lazăr & Istrate (2018) report a negative effect of the increase in the tax burden on the profitability of companies. Using ETR (calculated using the same formula as in our study: current tax expense relative to gross profit), Istrate (2024) finds, for Romanian companies listed on both the regulated market and the AeRo alternative market, average effective tax rates significantly higher than the statutory rate, with a fairly clear downward trend over the period (2012-2021 for companies applying IFRS and 2000-2021 for companies applying Romanian standards).

The TA measurement is also done by Mocanu et al. (2021) for unlisted companies, based on their involvement in tax litigations with the authorities, disputes that resulted in convictions. The population analyzed by Mocanu et al. (2021) is identified on the Romanian court portal and includes a limited number of observations (236 companies), with observations over a five-year period and compared with the same number of companies with no tax issues. TA is approximated by Mocanu et al. (2021) by the differences between the accounting net income and the reconstituted taxable income as a ratio between the tax expense and the statutory tax rate, without taking into account the meaning of these differences.

3. Data and research methodology

The data processed in this study comes from a public portal (https://data.gov.ro/organization/mfp), where the Romanian Ministry of Public Finance has posted the main indicators from the financial statements submitted by Romanian companies. In column 1 of **Table no. 1** can be seen that the data made public by the Ministry of Finance is quite uneven in terms of numbers from year to year.

Table no. 1. Observations analysed

Year	Number of observations			Threshold METR (euro)
	Total	From which CIT		
		N	%	
0	1	2	3	4
2024	77,669	43,977	56.62	500,000
2023	79,949	44,167	55.24	500,000
2022	76,639	32,470	42.37	1,000,000
2021	71,808	28,215	39.29	1,000,000
2020	78,670	26,902	34.20	1,000,000
2019	76,664	27,353	35.68	1,000,000
2018	79,340	25,950	32.71	1,000,000
2017	93,138	36,207	38.87	500,000
Total 2017-2024	**633,877**	**265,241**	**41.84**	

Source: the portal data.gov.ro, accessed at 29 March 2024, 17 January 2025 and 6 July 2025

The tax classification of companies paying corporate income tax or tax on revenues (as microenterprises) is not available: we could not find the information on data.gov.ro, so it was necessary to use approximations. Therefore, in order to identify approximately the companies paying corporate income tax (CIT), only the observations with

sales higher than the threshold for classification under the micro-enterprise tax on revenues (METR) were retained (in column 3 of **Table no. 1**). We multiplied by the leu/euro exchange rate at the ending of the financial year immediately preceding each financial year. We did not take into account the total revenue indicator, as it may also include some revenues that are not included in the calculation of the threshold or in determining the basis for calculating the METR: pseudo-revenues from, income from subsidies, income from the cancellation/reduction of impairment adjustments and provisions, exchange rate differences, discounts received/granted).

In this study, we only consider observations from 2017 to 2024, as during this period the threshold for recognition as an METR payer increased significantly from €100,000 in 2016 to €500,000 (starting in February 2017) and €1,000,000 (starting in 2018, to drop again to €500,000 in 2023 and 2024). These important thresholds have created the conditions for many companies to turn more seriously to METR, given that it is an easy tax to manage and its consequences on the company's treasury have been considered much more bearable than those of other taxes (especially CIT). These arguments (to which others undoubtedly add) have made METR a preferred tax, to the detriment of corporate income tax, a fact somewhat acknowledged by the vehement opposition from the business community when the government initiated procedures to change the law, in the sense of significantly tightening the conditions for classification as micro-enterprises, by bringing the threshold back to EUR 500,000 (starting in 2023 and continuing in 2024), then to EUR 250,000 (starting in 2025) and EUR 100,000 (2026), but also introducing new restrictions, particularly legal restrictions on the number of METR-paying companies in which a person can hold more than a 25% stake, the type of activity carried out, or the existence/non-existence of at least one employee. For the last two years (2023 and 2024) we also retained only companies with sales higher than the specific METR threshold, which certainly led to the exclusion of other companies with lower revenues but which do not meet other criteria introduced for these last two fiscal years.

Table no. 2. Comparison between the number and the percentage of the firms analysed and the total number of companies paying CIT

Year	Number of observations from companies supposed to pay corporate income tax		Percentage of companies analysed in total population*** %)
	Total*	Number of companies published by ANAF as being a corporate income tax payers**	
2024	43,977	726,473	6.05
2023	44,167	578,688	7.63
2022	32,470	128,114	25.34
2021	28,215	121,269	23.27
2020	26,902	118,477	22.71
2019	27,353	115,987	23.58
2018	25,950	103,993	24.95
2017	36,207	137,253	26.38
Total	**265,241**	**2,030,254**	**13.06**

* We reached this number by processing the information from data.gov.ro, that is after retaining only the companies whose sales exceeds the ceiling for tax on revenues of microenterprises. The total on the last column and the last row (for the eight years of the period) is not statistically significant – is only used to establish the 13.06% percentage for the whole period.

** Number published by ANAF in the fiscal statistical bulletins related to the 1st quarter of the year following each of the 8 years analysed, available at https://www.anaf.ro/anaf/internet/ANAF/despre_anaf/strategii _anaf/rapoarte_studii, last consulted on 6 July 2025

*** The significant restriction of the access to category of micro-enterprise paying tax on revenues, starting with 2023, is materializing in a massive increase in the number of companies paying corporate income tax and, therefore, in a decrease of the share of those retained in our sample, even if their absolute number in 2024 is the highest.

Source: own processing

On the other hand, for the years analysed in this study, the number of observations from data.gov.ro is limited in relation to the number of companies that the Romanian tax authority (ANAF) reports as paying corporate income tax. **Table no. 2** shows that we have, on average, about 13% of income tax-paying companies in our analysis. The difference is justified by companies that apply IFRS, banks and other financial and similar institutions, but especially by the fact that the data.gov.ro portal does not collect all the data available from what has been reported as financial statements to the authorities. In the period prior to the one covered by this study, on the same portal of the Ministry of Public Finance, we can find a much larger number of observations: over 600,000 per year in 2009-2014 and just over 100,000 per year in 2015 and 2016. We did not take into account this pre-2017 period, given that the threshold for micro-enterprises was low (€100,000) and did not represent a major attraction in terms of tax optimization through inclusion in this special category of companies.

We calculated the income tax expense by subtracting net profit from profit before tax, as these two indicators appear on data.gov.ro. In a first phase, the available data provides 265,241 observations (**Tables no. 1 and no. 2**), for which our approximations suggest that they would be subject to CIT. A summary of the observations is presented in **Table no. 3**, which also shows that the vast majority of companies for which the ministry provides public information report profits (89.75%), which tends to reinforce the results of the analyses.

Table no. 3. A brief description of the observations related to corporate income tax payers in the period 2017-2024

Year	Number of observations from companies supposed to pay corporate income tax				
	Total	From which			
		Reporting net profit		Reporting net income less than or equal to zero	
		N	%	N	%
2024	43,977	38,940	88.55	5,037	11.45
2023	44,167	39,566	89.58	4,601	10.42
2022	32,470	30,019	92.45	2,451	7.55
2021	28,215	26,015	92.20	2,200	7.80
2020	26,902	24,038	89.35	2,864	10.65
2019	27,353	24,599	89.93	2,754	10.07
2018	25,950	23,165	89.27	2,785	10.73
2017	36,207	31,700	87.55	4,507	12.45
Total	**265,241**	**238,042**	**89.75**	**27,199**	**10.25**

Source: own processing

The effective tax rate (ETR) is calculated as the ratio between income tax expense on the one hand and the profit before tax, on the other. There are no deferred taxes in RAS, so we have only one way to calculate ETR, using current income tax expense as the numerator. In order to eliminate/mitigate the effects of outliers, we opted to limit ETR values between 0 and 1, as in many articles in the literature: Gaertner (2014), Balakrishnan et al. (2019), Chyz et al. 2019, Habib et al. (2024). There were 6,086 observations with negative ETR, of which 5,988 are due to positive income tax expense reported on a negative income before tax. For these 5,988 observations, we winsorized the ETR to 1. In the other 98 observations with an initial negative ETR, the tax expense is negative, which leads us to consider an ETR = 0. Conversely, we found 724 observations with ETR > 1, which we brought to 1, equivalent to an income tax equal to the income before tax.

After calculating the ETR, we determined the difference between it and the STR, as Abdul Wahab et al. (2017) or Braga (2017) did; in the literature, STR-ETR often appears in reverse, as in Thomsen & Watrin (2018), Araujo et al. (2021), Amiram et al. (2018), Sanchez-Ballesta & Yagüe (2021), or Majeed & Yan (2019). Because the meaning of

the difference is important in identifying TA, we counted the observations with negative differences (ETR < STR) separately from those with positive differences (ETR > STR), but also calculated averages after converting them into absolute values, which gave us a clearer picture of the overall differences between the two indicators.

We performed analyses based on classic financial indicators frequently used in the literature: company size, profitability (ROA), the share of fixed assets in total assets, the share of cash in the total assets, and the presence of provisions in the balance sheet.

4. Results

After eliminating the outliers by bringing them to 0 or 1, we calculated an average ETR of 17.09% for the eight-year (**Table no. 4**). Compared to the statutory income tax rate and despite the significant differences that may arise between the accounting income and taxable income, this average ETR could suggest that the Romanian companies analysed behave, on average, in a manner consistent with tax compliance in terms of income tax, without engaging in TA. Indeed, the difference between the ETR of 17.09% and the statutory/legal rate (STR) of 16% is small and does not seem to lead to the identification of excessive tax avoidance behavior. For the years analysed, the differences between the STR and the average ETR are insignificant, with a fairly clear downward trend in the ETR. We can attribute this trend to better tax management on the part of companies paying income tax, given that relatively large companies with resources and, probably, interested in applying tax optimization techniques have remained in this category.

The decline in ETR from 2017 to 2022, averaging 0.3 percentage points per year, is close to the 0.4 percentage point ETR found by Dyreng et al. (2017) for a period of 25 years, leading the authors to conclude that TA increased significantly during that period. In our case, the data for only 6 years does not allow us to make such a statement, especially since the average ETR remains very close to the statutory rate and it would be interesting to add more years to the analysis in order to identify a possible long-term trend. The significant increase in ETR in 2023 is probably explained by the large number of observations in that year, but also by the fact that many profitable companies that, in 2022, paid only METR, entered the category of CIT payers and did not have time to adapt their tax policies in order to reduce their tax expenses or, perhaps, did not have the means to do so.

Table no. 4. Average ETR for the 2017-2024 period

Year	Average ETR by years, total observations (%)	Statutory income tax rate (%)
2024	17.72	16.00
2023	17.22	16.00
2022	15.88	16.00
2021	15.55	16.00
2020	16.26	16.00
2019	17.58	16.00
2018	17.94	16.00
2017	18.08	16.00
Total	**17.09**	**16.00**

Source: own processing

This result is somewhat unexpected, given the major *de jure* differences between the accounting and taxation of the revenues and expenses in Romania.

In order to see the extent to which this approximation between the effective rate and the statutory rate is confirmed, it is therefore necessary to analyse the difference between the two. The first step we took in this regard was to consider individual observations. Applying the t-test for ETR and STR to all observations analysed (265,241), we arrive at a two-tailed P(T<=t) much lower than 0.05, which shows us that the differences between ETR and STR are, however, significant if we analyse them individually. To identify the meaning of these significant differences, we calculated the differential ETR-STR and obtained a number of 168,933 observations (63.85%) in which ETR < STR, compared to 96,308 observations with ETR ≥ STR (**Table no. 5**).The simplest interpretation of these results suggests that most companies (about two-thirds of them) pay less tax than the statutory rate applied to the income before tax, with an average difference of 5.97 percentage points (p.p.), and that we can suspect a certain orientation towards TA in the case of these companies. In the opposite situation, the effective rate is higher than the statutory rate with 13.47 p.p. This helps us better understand why the t-test gives significant differences between ETR and STR. To get an even clearer picture of these differences, we put them in absolute values and got an average difference between ETR and STR of 8.69 p.p, which we can also consider quite significant. Therefore, the analysis of the difference between ETR and STR clearly refutes the general trend suggested by the ETR averages in Table 4.

Table no. 5. Differential ETR-STR for the 2017-2024 period

Year	Observations with ETR≥STR		Average differential, for companies with ETR≥STR (percentage points)	Observations with ETR<STR		Average differential, for companies with ETR<STR (percentage points)	Differential ETR-STR, in absolute value (percentage points)
	N	%		N	%		
2024	16,321	37.11	13.48	27,656	62.89	-5.22	8.28
2023	13,954	31.59	16.89	30,213	68.41	-6.02	9.45
2022	9,594	29.55	13.24	22,876	70.45	-5.72	7.95
2021	7,999	28.35	12.89	20,216	71.65	-5.73	7.76
2020	8,526	31.69	13.53	18,376	68.31	-5.90	8.32
2019	11,944	43.67	11.83	15,409	56.33	-6.37	8.75
2018	11,360	43.78	12.69	14,590	56.22	-6.43	9.17
2017	16,610	45.88	12.68	19,597	54.12	-6.89	9.55
Total	**96,308**	**36.15**	**13.47**	**168,933**	**63.85**	**-5.97**	**8.69**

Source: own processing

The figures reported in **Table no. 5** describe a situation that is completely different from what results from the simple average of the ETR over the entire period and confirm the results of the t-test mentioned above. In the case of negative differences (ETR < STR), we can estimate that a significant number of companies (almost 2/3 of the total) apply tax optimization techniques that lead to a reduction in reported income tax. We say tax optimization and not tax evasion or tax fraud because we assume that these companies have not broken tax laws—we have no evidence to suggest otherwise. It is very possible, for example, that ETR < STR results from tax exemptions or reductions (investments, positive equity, other facilities), tax credits or similar items, or tax deductions and non-taxable revenues greater than non-deductible expenses. In turn, very large positive differences (ETR > STR) could be generated by non-deductible expenses that are (much) higher than tax deductions or tax credits.

Of course, the averages, both for total ETR and for the difference between ETR and STR, can hide numerous extremes, and it becomes interesting to continue the analysis by taking into account discriminating factors, such as the those mentioned above in the methodology section. It would also be useful to mobilize other types of data—to which we do not have public access – regarding, for example, the structure of shareholding, the degree of exposure to foreign operations, presence in tax havens, membership in groups of companies, and involvement in intra-group transactions, etc.

4.1. The difference ETR-STR according to firm size

According to Romanian accounting standards, the size of companies is determined by taking into account three indicators: total assets, turnover, and number of employees. In fact, financial and accounting literature enshrines these measures of company size: Hashmi et al. (2020) remind us that assets, sales, number of employees, and market capitalization are the most commonly used indicators for measuring company size. It is even possible to calculate an aggregate size indicator that takes all three variables into account. As far as we are concerned, we consider that the most appropriate indicator in our analysis is sales, on the grounds that sales flows are more representative of unlisted Romanian companies than the balances recorded in the balance sheet or the number of employees.

To ensure better comparability of the figures used over time, we divided the amounts in lei by the average euro exchange rate, then calculated the median sales for each year. The result would have been the same for the figures reported in lei (except for the total period row), but expressing them in euros makes the comparison over time between the medians of the sales more relevant. We consider companies with sales above the median to be large, and the others to be small.

Table no. 6 reports the differences between ETR and STR, depending on the size of the company.

Table no. 6. Differential ETR-STR for the 2017-2024 period, by firm size, according to the median of the sales (in percentage points)

Year	Median of sales (euro)	ETR-STR≥0 (percentage points)		ETR-STR<0 (percentage points)		Abs (ETR-STR) (percentage points)	
		Large firms	Small firms	Large firms	Small firms	Large firms	Small firms
2024	2,004,966	13.94	13.13	-4.88	-5.61	7.78	8.79
2023	1,957,984	12.72	20.13	-5.46	-6.65	7.46	11.45
2022	2,771,424	12.46	13.91	-5.29	-6.19	7.22	8.67
2021	2,636,524	12.27	13.39	-5.38	-6.11	7.14	8.37
2020	2,564,534	13.60	13.47	-5.64	-6.18	7.98	8.66
2019	2,509,163	10.94	12.62	-5.98	-6.81	8.00	9.51
2018	2,469,303	11.39	13.83	-6.19	-6.69	8.31	10.02
2017	1,575,563	11.60	13.60	-6.32	-7.55	8.56	10.53
Total period	**2,256,751**	**12.31**	**14.42**	**-5.55**	**-6.44**	**7.76**	**9.63**

Source: own processing

In **Table no. 6** we observe, first of all, that the median sales increased systematically from 2018 to 2022 – years in which the threshold for METR payers exceeded €1,000,000. For 2017 and 2023/2024 (€500,000), the median is naturally lower due to the large number of companies with revenues between the two thresholds.

Regarding the ETR-STR differential, we applied the t-test, and the differences between small companies (sales below the median) and large companies (sales above the median) are significant. In fact, we rerun the calculations for the other size indicators (total assets and average number of employees), and the results (not reported here) are similar and significant.

Overall, the figures reported by small firms lead to more significant ETR-STR differences than those reported by large firms, both for positive and negative differences and in absolute values. This result may suggest greater fiscal aggressiveness on the part of small companies in the case of negative differences, i.e., a greater inclination toward TA. Conversely, in the case of positive differences, small companies appear to be more exposed, in the sense that the data they provide show significantly higher effective tax rates than those calculated for large companies. In all cases, the differences between ETR and STR are significant and, in the case of positive differences for small firms, almost double the statutory tax rate of 16%.

Although the ETR-STR differences are significant for all companies, they are slightly lower for large companies, which can be interpreted as an indication that large companies, knowing that they are more exposed – precisely because of their size – pay more attention to the application of tax optimization techniques.

4.2. ETR-STR and the leverage

In the literature we find conclusions from studies according to which more leveraged companies may have lower ETRs for at least two reasons. First, more liabilities may have generated interest and similar expenses, which reduce taxable income and, therefore, income tax. Also, debt, to the extent that it stems from the company's desire to make investments, can lead to a reduction in taxable profit as a result of the tax exemption facility for invested profit. At the same time, investments do not immediately translate into spectacular increases in profits, as they are specific to the launch phases of certain products/activities. High debt can also be interpreted as a financial constraint, in the sense that the company has more limited access to loans, in which case internal resources obtained through tax optimization may be cheaper (Wilson, 2009; Law & Mills 2015) and the ETR would be lower. A decrease in ETR – as a measure of the company's tax planning – is also found by Edwards et al. (2016) for companies subject to various financial constraints, not necessarily related to debt.

Leverage was calculated as the ratio between liabilities (total assets – equity) on the one hand, and total assets on the other, after which the observations were divided into two groups: low leverage (below the median) and high

leverage (above the median), both for each year analysed and for the entire period. Table no. 7 shows a very clear differentiation between companies with low debt and those with high debt. For all categories of ETR-STR (negative, positive, absolute value), companies with high leverage have significantly different – higher – figures in terms of the differences between the effective rate and the statutory rate (the t-test confirms this statement).

Table no. 7. Differential ETR-STR for the 2017-2024 period, by leverage (in percentage points)

Year	Median of leverage (L)	ETR-STR≥0 (percentage points)		ETR-STR<0 (percentage points)		Abs (ETR-STR) (percentage points)	
		High leverage	Low leverage	High leverage	Low leverage	High leverage	Low leverage
2024	0.5802	15.00	11.49	-6.46	-4.16	10.06	6.51
2023	0.5647	18.65	14.19	-6.85	-5.34	11.37	7.54
2022	0.6122	15.28	10.08	-6.39	-5.17	9.59	6.31
2021	0.5659	15.10	9.39	-6.76	-4.93	9.61	5.91
2020	0.5776	15.53	10.65	-7.37	-4.66	10.42	6.22
2019	0.5907	14.63	8.39	-8.04	-4.94	11.22	6.29
2018	0.6071	15.76	8.98	-8.10	-4.98	11.77	6.57
2017	0.6255	15.99	8.94	-8.82	-5.15	12.31	6.78
Total period	**0.5899**	**15.76**	**10.37**	**-7.38**	**-5.06**	**10.94**	**6.61**

Source: own processing

It is possible that these results are also influenced by a specific of Romanian companies, especially the unlisted ones. Many of these companies, especially when they have few associates/shareholders (or even unique associate) are indebted by contracting loans from these associates/shareholders. Such indebtedness is often not cost-bearing or, if there are such costs (interests), then they are subject to a special tax regime, being deductible with some difficulties.

4.3. ETR-STR and the profitability

It is expected that more profitable companies will pay higher taxes, but it should also be borne in mind that they have greater resources for tax avoidance (McGuire et al., 2012). Thus, we could expect that the profitability of the company will influence the effective tax rate. To measure profitability, we chose the ratio return on sales (ROS); here too, we considered that sales is a more representative measure of companies' activity and that it can better characterize their operational performance. Table no. 8 shows that for the profitability indicator we chose (ROS), there are significant differences in the ETR-STR differential, both overall and for each year, with significantly lower figures for more profitable companies. It is also interesting to note that, on average, better profitability brings ETR below STR for all three ETR indicators. Thus, companies with above-median profitability have (much) smaller differences between ETR and STR than companies with below-median profitability. The differences are significant (according to the t-test) and probably reflect a specific feature of the Romanian economy – it would be worth doing the calculations for other economies, especially in Central and Eastern Europe, to get a broader picture of the financial profiles of companies in this region.

These results can be explained by the fact that, in the case of investments in equipment and other fixed assets eligible for tax exemptions on invested profits, more profitable companies benefit from higher amounts exempt from income tax, which can significantly reduce the tax due, even if the taxable result is high. Apart from the tax exemption on invested profits, it is possible that for profitable companies, the amounts granted as sponsorships may go up to 0.75% of sales, until they reach 20% of the calculated CIT. This confirms the statement we quoted above from the literature, according to which the trend is for companies with high profits to try to reduce their tax liability through tax optimization techniques.

Table no. 8. Differential ETR-STR for the 2017-2024 period, according to the median of the ROS (in percentage points)

Year	Median of ROS	ETR-STR≥0 (percentage points)		ETR-STR<0 (percentage points)		abs(ETR-STR) (percentage points)	
		Large ROS	Small ROS	Large ROS	Small ROS	Large ROS	Small ROS
2024	0.0528	2.27	18.46	-3.20	-7.88	2.97	13.04
2023	0.0582	2.21	21.72	-4.92	-7.78	4.50	14.40
2022	0.0605	1.90	17.20	-5.00	-6.82	4.52	11.37
2021	0.0589	2.03	16.59	-4.82	-7.07	4.42	11.10
2020	0.0499	2.19	18.56	-4.24	-8.29	3.84	12.80
2019	0.0436	2.00	17.58	-4.64	-8.98	3.79	13.72
2018	0.0418	2.05	18.94	-4.62	-9.15	3.79	14.55
2017	0.0417	2.11	19.64	-4.57	-10.19	3.67	15.42
Total period	0.0508	**2.08**	**18.71**	**-4.46**	**-8.29**	**3.91**	**13.47**

Source: own processing

4.4. ETR-STR according to the weight of some asset/liabilities items

The presence of certain structures in the balance sheet may be related to ETR. The items most frequently found in the literature are fixed assets, inventories, and treasury. We calculated the ratio between the values of these indicators and total assets, determined the median, and calculated the average ETR-STR differential, by year and in total.

The differences between the two categories of companies – with fixed asset weights (IMO = fixed assets/total assets) above the median and below the median, respectively – are significant (according to the t-test) for all three situations we are analysing in terms of the ETR-STR differential. We see that a higher share of fixed assets can be associated with higher ETR-STR differentials than in the case of fixed asset shares below the median. In the case of ETR-STR<0, where we can say that tax optimization is significant, the higher differential for companies with higher proportions of fixed assets could be explained by the tax deductions associated with this type of asset: first, the tax exemption on profits invested in certain fixed assets can be significant and may prove that the respective tax facility is frequently activated by companies paying income tax. Second, tax depreciation deductions may be higher than accounting deductions; these could be, for example, accelerated or declining tax depreciation, or depreciation over tax periods shorter than accounting periods. At the same time, companies with more fixed assets may be more leveraged, which generates interest-deductible expenses and reduces both the taxable and accounting incomes (**Table no. 9**).

Table no. 9. ETR-STR, depending on the share of total fixed assets (IMO), for the period 2017-2024

Year	Median of the capital intensity (IMO)	ETR-STR≥0 (percentage points)		ETR-STR<0 (percentage points)		abs(ETR-STR) (percentage points)	
		Big IMO	Small IMO	Big IMO	Small IMO	Big IMO	Small IMO
2024	0.2975	14.20	12.67	-5.89	-4.59	9.14	7.43
2023	0.2928	18.33	15.39	-6.89	-5.16	10.58	8.32
2022	0.2743	13.98	12.54	-6.48	-4.95	08.65	7.24
2021	0.2859	14.29	11.53	-6.55	-4.90	08.71	6.81
2020	0.2869	15.76	11.25	-6.66	-5.15	09.57	7.07
2019	0.3066	12.98	10.78	-7.21	-5.47	09.63	7.88
2018	0.3103	14.28	11.24	-7.29	-5.49	10.20	8.13
2017	0.3261	14.32	11.15	-7.72	-6.01	10.64	8.46
Total period	**0.2970**	**14.81**	**12.03**	**-6.79**	**-5.15**	**9.70**	**7.69**

Source: own processing

Given the balance sheet equality between assets and equity + liabilities, we can expect the situation to be reversed in the case of inventories and cash. Indeed, our calculations – not reported in the text – show significant differences between the ETR-STR differential for companies with above-median inventories/cash flow and those below the median. Thus, the average positive differential (ETR-STR > 0) over the entire period is 12.38 p.p. for companies with above-median inventory shares in assets, compared to 14.57 p.p. for companies with below-median inventories. The same is true for the negative differential (-5.49 p.p. versus -6.45 p.p.) and for the absolute value (7.99 p.p. versus 9.39 p.p.). In the case of cash, the differences are even more significant (according to the t-test, as in the case of the share of inventories) and have the same meaning as for inventories: 11.56 p.p. compared to 15.15 p.p. (for companies with ETR-STR>0), -5.13 p.p. compared to -6.87 p.p. (for companies with ETR-STR<0) and 7.32 p.p. compared to 10.07 p.p. for the differential taken in absolute values.

Table no. 10. Differential ETR-STR for the 2017-2024 period, according to the presence of the provisions in the balance sheet (in percentage points)

Year	ETR-STR≥0 (percentage points)		ETR-STR<0 (percentage points)		abs(ETR-STR) (percentage points)	
	with provisions	without provisions	with provisions	without provisions	with provisions	without provisions
2024	19.67	12.52	-6.19	-5.06	11.07	7.84
2023	17.99	16.72	-6.89	-5.88	10.38	9.31
2022	17.18	12.41	-6.79	-5.52	10.07	7.53
2021	15.40	12.31	-6.98	-5.49	09.62	7.38
2020	17.99	12.47	-7.51	-5.57	11.10	7.72
2019	14.11	11.40	-8.04	-6.04	10.65	8.39
2018	15.08	12.25	-8.18	-6.09	11.16	8.79
2017	14.94	12.36	-8.68	-6.63	11.47	9.27
Total period	**16.60**	**12.91**	**-7.27**	**-5.74**	**10.67**	**8.34**

Source: own processing

Romanian accounting standards also include the principle of prudence, which justifies a significant part of the detailed rules, especially regarding the treatment of favourable vs. unfavourable differences in value found during inventory or at other occasions, in relation to the company's assets and liabilities. Of course, the application of these rules requires a high-performance information system, and the costs of designing and operating such a system are significant, which many companies are not fully prepared to bear. This leads us to assume that many companies do not make any provisions or adjustments for depreciation, precisely in order to avoid the costs of additional actions and records. Continuing with our assumptions, we believe that compliance with these consequences of prudential rules is particularly important when accounting and financial reporting are verified, especially by financial audits. As few companies are subject to auditing requirements, we expect fewer companies to report adjustments/provisions. From the data published by the MFP, we have no indication of the existence of impairment adjustments, but we can identify the companies that report provisions in their balance sheets. This latter information is also incomplete, as some companies may use their provision accounts during the financial year without having a closing balance: this information could be seen in the profit and loss account – if we had access to its entire structure, which is not the case – but we cannot detect it on the balance sheet. In the data retained in the analysis, out of the 265,241 observations, 225,146 (84.88%) do not show provisions in the balance sheet, leaving relatively few observations (40,095) in which companies report such probable liabilities: 15.12%. For companies paying CIT, the presence of provisions is sometimes also correlated with their tax deductibility: we know that the Tax Code significantly restricts this deductibility, which may have an effect on the presence of the aforementioned structures in the balance sheet. The link between taxation and

accounting in the case of provisions can also manifest itself in another way – although we believe this is unlikely to happen, especially in Romania – there are provisions that are recognized for tax purposes and are not necessarily accounted for as such: so the tax presence of some provisions is not necessarily conditional on their reporting in the balance sheet (this is confirmed by a specific line in the tax deductions section of the income tax return).

In the case of the ETR-STR differential, the differences between the two categories of firms (with and without provisions, respectively – **Table no. 10**) are statistically significant (according to the t-test), in the sense that firms with provisions report higher ETR than STR in all three situations. The explanation probably lies, as shown above, precisely in the non-deductible nature of the respective provisions. For companies with provisions in their balance sheets, we tested whether the ETR-STR differential shows differences, depending on whether the observations are above or below the median of the share of provisions in total assets: the results (not reported) show that there are no significant differences, with almost all observations being on the same coordinates, depending on the direction of the ETR-STR difference.

5. Conclusions

The disconnect between accounting and taxation is a global trend observed in many studies (Floropoulos et al., 2024), as a result of developments in accounting and financial reporting standards, as well as tax regulations.

Following the publication by the MFP of accounting indicators reported by Romanian companies in their annual financial statements, we collected several observations for the period 2017-2024, given that the portal consulted only presents a portion of eligible Romanian companies. In order for the analyses proposed in this study to be meaningful, we removed from the observations those that we assumed to come from companies paying micro-enterprise revenues tax, taking into account the thresholds for classification in this category. Our analysis period begins in 2017, because in that year the threshold increased significantly from €100,000 (in 2016) to €500,000 (starting in February 2027), reaching €1,000,000 in 2018 and remaining at this level until 2022, after which it fell again to €500,000 in 2023 and 2024.

Under these circumstances, we have 265,241 observations regarding companies that we assume to be corporate income tax payers – the risk of error is low, given that we have only taken into account sales, as we do not have the information necessary to identify other revenues that is included in setting the aforementioned thresholds. It is also likely that the excluded observations include companies that pay income tax, even if they have revenues/sales lower than the aforementioned annual thresholds, for reasons related (especially in 2023-2024) to the failure to meet other criteria for classification in the category of micro-enterprises paying revenues tax.

In the case of corporate income tax payers, the literature proposes a relevant indicator used as a proxy to characterize the tax behaviour of firms. This is the effective tax rate (ETR) in its simplest form (the only one available for the observations we had access to): the ratio between current income tax expense and profit before tax. This ETR is often an indicator that measures the level of tax avoidance. We calculated the ETR for all available observations and, after bringing the extremes to 0 and 1 (i.e., 0% and 100%), we calculated the average (17.09%), which differs very little from the statutory rate (STR) of 16%, valid throughout the analysed period. However, the conclusion of almost perfect tax compliance would be too simplistic, especially given that the Romanian tax authorities seem to have major difficulties in collecting public revenues. Thus, we compared the ETR individually with the STR and, applying the t-test, we found that the differences between the ETR and the STR are, nevertheless, significant. To operationalize this situation, we continued by calculating the ETR-STR differential and interpreting it. We thus find that most of the companies in the sample (63.85%) have ETRs lower than STRs and that the average difference between the two rates is significant, standing at -5.97 p.p.; it follows that, on average, almost two-thirds of the companies in the sample pay an effective tax rate of just over 10% of gross profit. For the remaining 36.15% of observations, where ETR > STR, the average difference is much greater, rising to almost 13.5 p.p. and bringing the effective rate to almost 30%. In any case, putting together the positive and negative differences – by calculating their absolute values – we arrive at a differential of 8.69 p.p., more than half of the statutory tax rate.

Continuing the analysis, we established the average ETR and the ETR-STR differential, based on relevant indicators present in the literature, such as company size, leverage, profitability, and the presence and weight in the balance sheet of certain assets or liabilities.

If we measure the size of the company by total sales, we find that smaller companies (with below-median sales) report higher ETRs and that the differences between the two categories of companies (large vs. small) are statistically significant. The results are roughly the same if firm size is measured by total assets, but for the number of employees, the differences are significantly blurred.

On average, lower debt leads to lower ETRs, which does not necessarily correspond to the results reported in the relevant literature: it is true that the companies analysed in this study are not listed and that the results of most other studies refer to listed companies. It is very likely that the behaviours of the two categories of companies (listed vs. unlisted) differ in terms of their reaction to debt. The results we obtained by considering the average ETR are confirmed by the ETR – STR differential: for all three categories (negative, positive, and absolute differences), we find relevant differences between companies with low debt vs. companies with high debt, in the sense that the former show smaller ETR-STR differentials than the latter.

In terms of profitability, for the ROS indicator, there are significant differences in ETR, both overall and for each year, with significantly lower figures for more profitable companies. It is also interesting to note that, on average, better profitability brings ETR below STR for all three ETR indicators.

Analyzing the ETR-STR differential, we observe opposite effects of the weights of the two asset structures: while for fixed assets, levels above the median lead to significantly larger negative differentials than levels below the median, in the case of inventories, the situation is reversed. For cash, observations with levels above the median lead to larger differentials than those with levels below the median. The presence of provisions in the balance sheet leads to larger ETR-STR differentials than the absence of provisions.

The limitations of the study relate primarily to the sample analysed: even though the number of observations is very large, it corresponds to only a fraction, slightly over 10%, of the total population. Thus, the possibilities for generalising the results are limited, especially since we have no control over how the MFP selected the companies whose financial data is made public on the platform from which it was downloaded. Another limitation is the lack of data that would allow us, according to the models established in the literature, to perform analyses based on non-financial indicators related to governance (ownership structure, family or non-family nature, intervention of an auditor, structure and size of the board, where applicable, professional experience of key persons in the company's management, etc.). We can also point out as a limitation the lack of an econometric model through which ETR or the ETR-STR differential can be correlated with relevant financial or non-financial variables.

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Sustainability, Digitalization and Artificial Intelligence – Impact on the Transformation of the Role of Audit Committee in the Context of Modern Corporate Governance

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Abstract

In an increasingly complex and regulated economic context, audit committees (AC) are becoming a strategic pillar of modern corporate governance. The accelerated advance of artificial intelligence (AI) and the new sustainability reporting requirements (CSRDS, ESRS) are transforming the role of these predominantly financial structures into multidimensional actors responsible for transparency, non-financial risk assessment and oversight of the use of emerging technologies. The study explores how in which audit committees must adapt their functions by integrating multidisciplinary skills (financial, ESG, digital and ethical) and by overseeing integrated reporting according to European standards. The documentary analysis compares the implementation of European and national regulations at the level of listed companies in Romania (OMV Petrom, Banca Transilvania, Romgaz, Electrica). The study applies a qualitative exploratory research, based on documentary analysis, to highlight the challenges and adaptation needs of corporate governance, in particular of the audit committee, generated by the use of artificial intelligence and the requirements of ESG reporting. The results of the research highlight the fact that in the period 2025-2035, the audit committee must evolve towards a proactive and strategic role, capable of ensuring the balance between profitability, social responsibility and the ethical use of artificial intelligence, thus becoming a guarantor of sustainability and integrity of organizations.

Key words: *corporate governance; audit committee; artificial intelligence; Environmental, Social, Governance Reporting; modern organizations;*

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Introduction

The rapid transformations generated by digitization, globalization and compliance requirements will profoundly reshape the way organizations operate. In this context, three key concepts: audit committee (AC), artificial intelligence (AI) and sustainability indicators (ESG) define the new corporate governance framework.

The main objective of the study is to analyze and predict the transformation of the role of the audit committee by correlating European and national regulations with the practices of listed companies in Romania.

The evolution of the role of the audit committee involves the transition from a traditional vision, centered on the supervision of financial statements and the relationship with the external auditor, to a multidimensional strategic role, integrating the monitoring of non-financial risks, ESG criteria and technological challenges. According to the EU Corporate Sustainability Reporting directive 2022/2464 (CSRD) and the European Sustainability Reporting Standards adopted by EU Delegated Regulation 2023/2772 (ESRS), the quality and credibility of non-financial information must be ensured with the same rigour as financial reporting.

At the same time, digitisation and the use of AI are transforming the reporting and auditing processes, which requires members to have new powers to analyse data, evaluate algorithms and ensure compliance with the principles of ethics and transparency. AI brings opportunities through continuous audit, anomaly identification and predictive analysis, as well as significant risks related to algorithmic transparency and decision-making responsibility. In this respect, EU regulation 2024/1689 (AI Act), together with national legislation (OMF no. 85/2024, OMF 1421/2024 and law 162/2017 on Audit), reinforce the role of the audit committee as a guarantor of modern ethics and governance.

Given that financial reporting reflects only one aspect of the company's activity, namely economic and financial operations, it must be significantly supplemented with environmental, social and governance reporting, i.e. reporting according to ESG (Environmental, Social and Corporate Governance) criteria.

However, harnessing these benefits requires radical changes in the professional skills of accountants and auditors, in particular in relation to the valuation of information assets, the use of massive data in decision-making and their integration into the risk management system.

1. Review of specialized literature

The role of the auditor in sustainability reporting derives directly from CSRD and ESRS standards. These regulations introduce a "limited assurance" requirement for ESG information, placing the auditor in a position to validate non-financial data collection processes and assess the risks of "greenwashing" and lack of transparency. Recent literature (Sihombing & Nurhaliza, 2025) shows that the independence and size of the audit committee significantly influence ESG performance, confirming that this body can no longer be regarded only as a guarantor of financial reporting, but also as a supervisor of corporate sustainability.

Corporate governance is the set of mechanisms and processes by which organizations are led and controlled (Gul et al., 2003). This includes internal structures such as the board of Directors, audit Committee, external auditor and external factors such as regulations or shareholder structure (Hillman & Keim, 2001). After financial crises and corporate scandals (Enron & WorldCom), governance was strengthened through reforms geared towards transparency and accountability (Khan et al., 2022). However, the current challenges go beyond the financial sphere, including sustainability, ethics and digitalisation, which calls for an expanded strategic role for the audit committee.

The concept of artificial intelligence, introduced by John McCarthy in 1956, evolved from expert systems to advanced algorithms of “machine learning” and “deep learning”, with direct applications in auditing. Research shows that AI enables automated transaction analysis, anomaly detection, Continuous Audit and Real-Time Strategic insight generation (Wassie & Lakatos, 2024). However, the literature draws attention to the challenges of algorithmic transparency, bias and decision-making responsibility (Roberts & Babuta, 2023). In this context, the AI Act sets strict rules for the use of AI systems, especially high-risk ones, which implies new powers for auditors and supervisors.

Regarding the intersection of ESG, AI and AC, recent literature highlights the convergence between sustainability, digitization and corporate governance. The *Harvard Law School Forum on Corporate Governance* (2025) study highlights that "audit committees must

understand how the company uses artificial intelligence, ensure that internal control and risk management systems are properly updated, and ensure that human judgment remains central to ESG-related decision-making". This perspective confirms that the future of the audit committee will go beyond traditional financial tasks, becoming a multidimensional strategic actor, responsible for overseeing integrated reporting, monitoring technological risks and guaranteeing organizational ethics.

2. Research methodology

Starting from the objective of the research aimed at analyzing and forecasting the transformation of the role of the audit committee in modern corporate governance, by integrating sustainability, digitization and artificial intelligence correlated with the impact assessment of European and national regulations, the present study uses a qualitative research methodology of exploratory type, based on documentary analysis as the main investigative tool. The purpose of this research is to identify challenges and needs to adapt trends in corporate governance in particular as a result of developments in the use of AI and ESG reporting requirements.

The objective of this method is not to validate statistical assumptions, but to understand the context, trends and implications. To carry out this research we proceeded to collect, select and interpret the information extracted from the official websites: directives, regulations, ordinances, sectoral norms, but also Sustainability Reports, professional guides, academic studies. This method allows to correlate the normative framework with the practice of organizations, identifying discrepancies, challenges and opportunities and provides an overview of the field.

The paper has an observational character, focusing on description and interpretation of the data included in the sample subjected to research with emphasis on the impact on AC, Digital Evolution and ESG reporting.

Given the importance of International Financial Reporting Standards (IFRS) to ensure comparability and transparency of information in the post-crisis era, new directions are also emerging, such as integrated reporting, real-time reporting, continuous audit, use of Big Data, Integration of ESG criteria and technologies such as XBRL (eXtensible Business Reporting Language).

This standard is now widely recognized and recommended by accounting and reporting standards developers such as the IASB board and the U.S. Financial Accounting Standards Board, the world's largest stock exchanges, capital markets regulators, trade registers, financial and Statistical Services, analysts and auditors. This underlines the unique role of the XBRL language as the basis for the programmatic convergence of various accounting standards systems and reporting approaches, based on a common set of indicators, and demonstrates the observability of this innovation. The operation of the XBRL language is based on taxonomies, which are universal labeling formats of accounting terms, reporting indicators and data. A possible difficulty in disseminating this innovation lies in the need to constantly update these taxonomies, taking into account frequent changes in the methodology of accounting standards themselves and approaches to recording operations in accounting.

Thus, modern innovations in corporate reporting – Big Data and integrated reporting in the context of digital transformation – provide the necessary foundation for the development of integrated reporting, by combining financial and non-financial data in a coherent framework, designed to accurately reflect the performance and sustainability of the company.

2.1 Analysis of the European and national legislative framework

At European level, the research covered three fundamental regulations: CSRD, which is the basis for sustainability reporting and its assurance; ESRS, which sets mandatory reporting standards; and AI Act, the general framework for the responsible use of artificial intelligence systems, with direct relevance to governance and risk management. The CSRD introduces the obligation to develop integrated reporting, combining financial and non-financial information (ESG), assigning the audit Committee the responsibility to ensure the accuracy, comparability and credibility of such data.

At national level, CSRD transposition was achieved through OMF no. 85/2024, updated with OMF no. 1421/2025, supplemented by law no. 162/2017, transposing directive 2014/56/EU and accounting regulations according to OMFP 1802/2014, updated by OMFP 2844/2016. Also, sectoral adjustments were introduced through geo no. 137/2024, as well as the FSA

norms no. 4/2024 and no. 14/2024, NBR order 1/2024 to ensure consistency with European requirements.

In parallel, AI Act classifies artificial intelligence systems according to the level of risk and imposes strict controls on critical data, forcing organizations to integrate robust governance and transparency mechanisms.

This regulatory development requires audit committee members to acquire new skills, from digital expertise and knowledge of AI and Sustainability regulations, to complex data analysis and emerging risk assessment skills. The transformation marks the transition from a predominantly financial role to a multidimensional one, where technological and ethical oversight becomes essential to the credibility and competitiveness of the organization.

In this framework, the statutory obligations of the audit committee derive mainly from the CSRD: large and listed companies must report their sustainability performance, and the committee has the responsibility to oversee these reports, alongside financial ones. The relationship with the statutory auditor requires that sustainability reports be subject to an independent assurance mission, initially of the " *limited assurance"* type, followed later by " *reasonable assurance"* . AC must ensure that non-financial data collection and reporting processes are robust and reliable and that sustainability risks, including those related to “greenwashing” and lack of transparency, are correctly identified, reflected and communicated to stakeholders.

2.2 Analysis of corporate documents

In order to try to shed light on the requirements of these regulations and how they begin to be applied by the market, we conducted a comparative analysis of the governance and sustainability reports for 2024 for four companies listed on the Bucharest Stock Exchange (OMV Petrom, Banca Transilvania, Romgaz, Electrica), starting from a comparison matrix regarding the requirements of the European Union, their transposition in Romania and their reflection in corporate practices. The sample of the four large companies listed on the Bucharest Stock Exchange was selected on the basis of sectoral relevance and availability of public reporting. The sources used were the annual corporate governance reports, as well as the sustainability reports (ESG) published for 2024, when they had the legal obligation to report.

3. Results obtained

3.1. Comparative Matrix: EU regulations applied in Romania by companies

In this research, a matrix was developed that includes tracking the application of EU requirements, transposition into national law and how companies applied the legal provisions. The analysis consisted in making a map of the European requirements (AI Act, CSRD) and the relevant national ones, correlated with the corporate governance practices in Romania. As a methodological tool was used the comparative Matrix, structured on three levels: EU regulations, national transposition and reflection in corporate documents. The main objective was to identify the gaps between the European standards and their concrete application in the context of Romanian corporate governance. The results are presented in **Table no. 1**.

Analyzing the results in **Table no. 1**, it is observed that all companies involve AC in the supervision of sustainability reporting, thus:

- **OMV Petrom**: The Board of Directors monitors internal control systems and risk management and through general governance also oversees sustainability reporting, according to ESRS (GOV-5) requirements;
- **Banca Transilvania**: the 2024 sustainability report explicitly states that the Board of Directors verifies the compliance of ESG reporting and is the only company that directly details the role of the committee in the ESG area;
- **Romgaz**: in the AC Charter, it expressly provides for the attribution of "monitoring sustainability reporting", confirming the integration of CSRD into its mandate;
- **Electrica**: in the 2024 public documents they refer to the general oversight of reporting by the Council and the Board of Directors, but do not explicitly detail the role of the Board of Directors on CSRD reporting, the responsibility is reflected indirectly through external assurance and general governance.

In practice it seems that all companies involve AC in the supervision of sustainability reporting, but it is reflected differently, from indirect role (Electrica), to clear mention (BT) and formal mandate in the AC Charter (Romgaz). Overall, there is a convergence towards integrating sustainability into AC responsibilities, but the degree of detail differs between companies.

Table no. 1. Comparative Matrix: EU regulations, Romania and company transposition

Domain / Criterion	EU requirements (AI Act/CSRD)	Transposition Romania (correct)	Reflection in companies (OMV Petrom, Banca Transilvania, Romgaz, Electrica)
The role of the audit committee in the ESG	The CSRD has amended the audit directive so that it monitors the ESG reporting process and the dialogue with the auditor/insurer, and a guide for "limited assurance" is issued.	Law 162/2017 (amended by Geo 137/2024) and the BSE Corporate Governance Code require that it supervises reporting (including non-financial) and internal controls / risks; The BSE code explicitly recommends that AC supervise the preparation of sustainability reports.	**OMV Petrom** in the 2024 report describes the role of the Board of Directors that monitors internal control systems and risk management; Internal audit reports are communicated to the Board, and the role on sustainability appears through the ESRS 2 GOV-5 requirement on controls for sustainability reporting and governance. **BT** in its 2024 report states that the Board of Directors verifies compliance with ESG regulations, and there is also an ESG committee at the executive level. The governance document in sustainability reporting shows that the internal audit reports to AC on the sustainability reporting process; the board oversees ESG information. **Romgaz** in the 2024 report describes sustainability governance and includes independent assurance report; Board-level oversight is integrated into the governance structures presented. The AC charter (2025) explicitly states that it "monitors sustainability reporting", confirms the AC mandate on CSRD/ESRS. **Electric** in the 2024 report it describes sustainability governance, the audit and risk committee also having a sustainability oversight role, and in the 2023 report it includes a 2030 Strategy on shaping a sustainable future. In the 2024 public documents, a mandate of the AC strictly on CSRD reporting is not expressly detailed; oversight occurs through general governance and external assurance.
Sustainability reporting (ESG)	CSRD: -reporting in the" Sustainability Statement "according to the ESRS, part of the administrators' report; -publication in 2025 for the year 2024; -compulsory insurance (originally "limited assurance"); -include indicators EU taxonomy.	OMF 85/2024 operationalizes CSRD in Romanian accounting regulations (ESRS, structure, publication, responsibilities); Geo 137/2024 introduces sustainability reporting in law 162/2017 and geo 75/1999;	**OMV Petrom:** 2024 Sustainability Report included in the Annual Report and prepared according to ESRS (with taxonomy indicators), audited by KPMG, limited assurance ISAE 3000 (KPMG) on the sustainability statement. **Banca Transilvania:** 2024 ESRS Sustainability Report, limited assurance audit conducted by Deloitte, there is a separate limited assurance report published. **Romgaz:** 2024 Sustainability Report with "limited assurance", according to ESRS; limited assurance issued by PwC.

		OMF 1421/2025 postpones by 2 years the deadlines for some categories (not for PIE >500 employees, who have already reported on 2024).	**Electrica:** 2024 Sustainability Reporting included in the Annual Report, prepared according to ESRS; Limited assurance report issued by Deloitte Audit. Sustainability statement 2024 included in the administrators ' report.
Artificial intelligence and digitization	You Act (Reg. (EU) 2024/1689): -risk classification, prohibitions applicable in 6 months, phased obligations; -member states should designate competent national authorities (AI governance) and prepare implementation.	Romania: at the level of September 2025 is in discussions on the designation of the National Authority and the establishment of the specific framework for sectoral application it's still in the works.	In the 2024 reports, companies cover digitization / cybersecurity in governance and risks. AI Act specific reporting is not yet a distinct component (emphasis remains on ESRS/taxonomy and internal control processes). **OMV** -2024 Report explicitly mentions AI-related risks and the integration of related measures into security controls; emphasis on digitalization. **BT** -The sustainability report notes a significant share of Chatbot/AI-generated applications in 2024 used in product distribution. In January–February 2025 BT launched ChatBT (AI) in the BT Pay app. **Romgaz** -Compliant **In** the submitted reports, details about digitalization and references to AI are not very prominent in public documents 2024. **Electrica** - Many mentions of digitalization/"smart metering" and modernization initiatives are presented in the 2025-2030 Sustainability Strategy, but the reports do not make many explicit references to AI.
Ethics and transparency	ESRs G1 calls for Business Conduct policies, anti-corruption, integrity warning mechanisms; AI Act introduces transparency obligations for certain systems (e.g. generated content).	The BSE code and FSA rules complete the framework: ethics policies, whistleblowing channels, governance reporting; FSA sectoral rules updated in 2024.	All 4 companies publish ethics policies and whistleblowing channels in their 2024 reporting/IR pages. **BT** details mechanisms and compliance (AML, anti-corruption, data protection).

Source: own research, based on legislation and the reports of the 4 companies on their websites

In terms of sustainability reporting, all analyzed companies have published for the financial year 2024 a sustainability statement according to ESRS, in line with the requirements of OMFP 85/2024. These statements have been subject to independent *limited* assurance, providing credibility to the information presented.

According to the reports submitted by the companies in the sample, it resulted that: Banca Transilvania obtained an insurance report from the auditor Deloitte, Romgaz from the auditor PwC, and Electrica published a limited insurance report related to the consolidated reporting from the auditor Deloitte. OMV Petrom has chosen to integrate sustainability reporting directly into its 2024 annual report, according to ESRS, with an assurance report issued by auditor KPMG. This uniformity in corporate practice shows that large companies listed on BSE in Romania have quickly aligned themselves to the requirements of CSRD.

Regarding the presence of artificial intelligence and digitization we must specify that AI Act does not require transposition, but member states must designate national authorities for application. In Romania, this process is still ongoing. The 2024 corporate sustainability reports are mainly focused on ESRS and the EU taxonomy, with general references to digitisation and cybersecurity. Banca Transilvania mentions the use of digital solutions and the launch of a "chatbot-AI" for banking services, and OMV Petrom refers to the integration of AI in internal process optimization and risk management. Romgaz and Electrica mention digitalization and smart grids, but do not yet highlight dedicated AI projects. There is a trend, so, ESG reporting is already standardized, but the explicit integration of AI Act requirements into corporate documents is to emerge with the strengthening of the national regulatory framework.

In terms of ethics and transparency, in the case of the analyzed companies, they comply with the requirements of the ESRS (G1), the BSE code and the ASF norms through ethics policies and whistleblowing mechanisms, with a more detailed level of compliance in the case of Banca Transilvania, which shows a solid alignment between European standards, national framework and corporate practice.

3.2 Trends regarding the impact of the Audit Committee at the level of organizations in Romania in the period 2025-2035

In order to highlight the dynamics of legislative and organizational transformations at European level and their impact on Romanian practices, **Table no. 2** captures the main development directions in ESG reporting, digitization and corporate governance.

The comparative structure allows to identify trends imposed by the EU regulatory framework, challenges encountered at national level and direct implications for the role of AC, which becomes a central player in ensuring transparency, integrity and consistency of Integrated Reporting.

Table no. 2. Trends on EU audit committee implications and challenges for Romania

Development direction	EU-wide trends (2025-2035)	Challenges for Romania	Implications for the Audit Committee
ESG reporting and sustainability	Phased application CSRD-EU directive 2022/2464 according to which the first companies report for the year 2024 with publication in 2025 ESRs adopted by Reg. EU delegate 2023/2772 Limited insurance at the beginning, with a perspective towards "reasonable" in the medium term	Transposition / implementation by OMF 85/2024, ASF norm 4/2024, NBR order 1/2024; Practical compliance and coordinated controls remain; SMEs have limited costs/know-how.	AC oversees the reporting integrated into the administrators ' report (financial+ESG), ensure the robustness of internal controls on ESG data and the insurance plan, including coordination with the statutory auditor
Artificial intelligence & digitization	AI Act-Reg. EU 2024/1689 entered into force on 1 august 2024 with full application 2 august 2026; Prohibitions and AI literacy of February 2, 2025; GPAI rules of august 2, 2025; High-risk" systems have extended transition until 2027	Missing detailed national guidelines for AI in some sectors Uneven technological maturity	AC needs to understand AI risk classification, "high-risk" controls, data governance, "third-party" it dependencies, and operational resilience testing; To connect AI risks with ESG and reporting

Ethical governance & transparency	Strengthening the Ethics Framework/whistleblowing: Dir. EU 2019/1937 (whistleblower protection); Digital governance & security through NIS2 ESG standards of conduct in ESRs G1	Romania: Law 361/2022 transposes whistleblowing, effective implementation still variable in companies	AC becomes a guarantor of integrity and Ethics in the use of AI and ESG reporting, with the role of supervising internal warning channels and responding to cyber incidents that may affect reporting
Competences of AC members	Trend towards interdisciplinary profile (financial, ESG, legal, IT / AI) with alignment with EU Best Practices on diversity and specific expertise (ESRS requires disclosure on governance / skills)	ESG/AI training offer still limited The need for national programs to train members as well as management	AC includes members with expertise in sustainability, data/AI, cybersecurity with ongoing training plan and skills assessment reported in ESRS Section 2 / G1
Reporting integration	Migration to Integrated Report (unified report management) The CSRD requires the inclusion of the sustainability chapter in the administrators ' report and digital format (XBRL)	Romania aligns, but implementation may delay at process/system level (data collection, controls, XBRL, ESG audit trail)	AC becomes supervisory "hub" for consistency, traceability and data quality between financial & ESG; AC coordinates the interface with the auditor

Source: own research, based on legislation

Thus, AC becomes the central pivot in aligning Romanian companies with European standards, and the success of its implementation depends on its ability to integrate financial expertise with ESG, it and ethical competences.

The role of AC, of the auditor, both internal and external, in the coming period 2025-2035, will undergo a profound transformation driven by technological advance, especially of AI through increasing pressures for transparency and sustainability. Thus, the auditor transforms from a mere verifier into a strategic management partner, able to anticipate emerging risks (such as AI ethics and ESG vulnerabilities), evaluate data-driven decisions and validate algorithmic models or automated processes. This change is supported by the use of AI (Continuous audit, automated analysis, "text mining", "machine learning") and by the need to acquire hybrid skills that combine financial expertise with digital and analytical skills. If we are to mirror the auditor's skills in the next period, starting from the known, traditional ones, they will have to be updated with digital and strategic skills.

In a context marked by ESG reporting, digitization and new governance standards under revision following recent global events such as, previous financial crises, Covid 19 Pandemic, the war in Ukraine, the war in Israel, climate change with the presence of drought in Europe etc., everything is in updating, reviewing and changing.

The analysis is exploratory in nature, being limited by the small number of companies and the dependence on publicly available information, so the conclusions drawn are indicative, but constitute a solid basis for future research on larger samples.

Conclusions

This study aimed to analyze and forecast the transformation of the role of AC in the period 2025-2035, by correlating European and national regulations with the practices of some listed companies in Romania. The research method used was qualitative, exploratory, based on documentary analysis of legislation (CSRD, ESRS, AI Act), national ordinances and norms, as well as governance and sustainability reports published by companies such as OMV Petrom, Banca Transilvania, Romgaz and Electrica. The results show significant differences in maturity: for example, OMV Petrom and Banca Transilvania already integrate ESG reporting and process digitization, while Romgaz and Electrica are still in early stages of adaptation, which confirms the gap between European regulations and national implementation.

In this context, AC extends its responsibilities beyond financial verification, becoming a multidimensional

strategic actor with a role in overseeing integrated reporting, managing AI-related risks and ensuring Ethics in corporate governance.

In this context, the management of modern organizations, auditors, as well as AC members will have to constantly update their competencies, management and auditors by integrating digital and strategic expertise, and AC through a deeper specialization, be able to respond to the challenges generated by AI, sustainability and modern governance.

In conclusion, the development of interdisciplinary competences of AC members and the consolidation of continuous training are essential conditions for Romanian organizations to respond to the pressures of transparency, sustainability and digitization, thus ensuring their competitiveness on the European market.

The study can be a starting point for future research by extending the analysis to a wider sample of companies at national, european and even global levels.

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Sustainability in the Public Health System, between Regulation, Reporting and Change Management

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Abstract

This study analyzes how sustainability principles are integrated in public hospitals in Romania. In a context marked by increasing European regulatory pressures (CSRD/ESRS) and increased social expectations, public hospitals should adapt, even in the absence of an explicit legal obligation. The qualitative-comparative research analyzes 32 hospitals subordinated to the Ministry of Health and other government structures, using thematic analysis of official data. The results highlight significant differences in the implementation of sustainability, identify emerging voluntary practices and institutional gaps in compliance preparation. In this context, external public audit becomes an important tool for assessing how public healthcare units integrate sustainability into governance, reporting and resource management processes. By verifying compliance and performance, audit can support not only institutional transparency and accountability, but also accelerate the transition towards a sustainable healthcare system. The study provides an analytical framework, as well as recommendations for public policies, contributing to the foundation of sustainable governance in the public health system.

Key words: *sustainability; public hospitals; external public audit; public policies; non-financial reporting;*

JEL Classification: *H83, M42, I18, Q56*

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Introduction

In recent decades, sustainability has become a strategic imperative for all types of organizations, regardless of sector or legal status. In the European Union in particular, the transition to a sustainable economy is supported by a complex legislative framework, including the recently adopted Corporate Sustainability Reporting Directive (CSRD) and the associated standards (*European Sustainability Reporting Standards*, ESRS). Although these regulations primarily target large private sector entities, their impact extends beyond them, significantly influencing public expectations, strategic directions of authorities and good practices in the public sector, including in the health sector.

Hospitals, as essential institutions for social cohesion and the well-being of the population, are exposed to an increasingly complex context, in which operational efficiency should be coupled with social responsibility, transparency and concern for environmental impact. However, in Romania, public hospitals are currently not legally required to apply CSRD or report according to ESRS.

In particular, public hospitals in Romania include units either subordinated to the Ministry of Health or under the coordination of other ministries or public structures (Ministry of National Defense, Ministry of Internal Affairs, Ministry of Justice, Ministry of Transport, Romanian Academy, etc.). This administrative diversity generates not only differences in the approach to governance, but also significant variations in the capacity and motivation to adopt sustainability measures, be they strategic, operational or reporting.

The literature on sustainability in the healthcare sector is growing, but often remains focused on cases from developed countries, where ESG regulations are directly or indirectly applicable. In Romania, applied research in the public healthcare sector in relation to sustainability is limited, especially regarding departmental hospitals, which operate under distinct administrative and management rules.

In this context, it is becoming increasingly relevant to analyze how external public audit can support the verification of compliance and performance in relation to sustainability objectives, thus contributing to institutional accountability and strengthening public trust. Thus, the audit not only validates the efforts of institutions, but can also act as a strategic guidance tool, especially in the absence of explicit legal reporting requirements.

This research aims to provide an empirical perspective on how public hospital institutions in Romania respond to sustainability requirements, in the absence of an explicit legal obligation. Through a comparative and exploratory approach, the article analyzes a sample of 32 public hospitals, 22 of which are subordinated to the Ministry of Health and 10 departmental, in order to assess the degree of integration of ESG principles, forms of voluntary reporting and mechanisms of institutional adaptation.

The research is based on documentary analysis of official public sources, structured on thematic dimensions relevant to sustainability. By identifying gaps, good practices and development potential, the study provides a useful analytical framework for decision-makers, practitioners and researchers, as well as an original contribution to the sustainability literature in the public health sector.

The approach is preceded by an examination of the specialized literature, intended to contextualize sustainability in the health system and to substantiate the methodological approach adopted.

Literature review

In the context of increasing global concerns for sustainability and transparency, the European Union adopted Directive 2022/2464, known as the Corporate Sustainability Reporting Directive (CSRD), in 2022. It extends non-financial reporting obligations for large and listed companies, imposing detailed standards on the disclosure of information related to social, environmental and governance (ESG) impacts (European Commission, 2022).

The objective of the CSRD is to ensure comparable, transparent and relevant reporting of sustainable aspects, in order to support the decisions of investors, authorities and the general public. In this framework, multinational companies, which have significant economic importance, are mainly targeted (EFRAG, 2023).

Public institutions, including hospitals in Romania, are not directly forced to apply the provisions of the CSRD, as they do not fall under the category of "companies" covered by the directive (European Commission, 2023). However, the involvement of public institutions in European funding processes and public-private partnerships makes them

sensitive to certain sustainability requirements. European funds (e.g., the National Recovery and Resilience Plan, PNRR) require certain standards of resource management, efficient energy management, as well as other non-financial reporting indicators for funded projects (Ministry of Investments and European Projects, 2023). Therefore, hospitals may be motivated to voluntarily implement sustainability policies and practices, especially in the areas of green infrastructure, efficient digitalization, and health crisis management, in order to meet the requirements of partners and funders.

In this context, external public audit has a strategic relevance in strengthening transparency and institutional accountability in the public health sector. Although the literature on sustainability auditing is more developed in the private sector, researches are beginning to explore the role of Supreme Audit Institutions (SAIs) in assessing ESG performance in the public sector (INTOSAI, 2023; OAG Canada, 2022). In Romania, the Court of Accounts has the competence to verify how public resources are used, and extending its mandate to sustainability auditing can support the transition of the health system towards greener, more equitable and more transparent practices. Therefore, external public audit is not only a financial control mechanism, but can become an instrument of sustainable governance, contributing to increasing public trust.

Thus, even if there is no explicit legal obligation to report CSRD, adapting its principles can represent an important step towards more transparent governance and responsible management of public resources (Osapiens, 2024).

Established models such as Kotter's 8-Step Model, ADKAR (Awareness, Desire, Knowledge, Ability, Reinforcement) and *Lewin's Unfreeze–Change–Refreeze Theory* are widely applied for the sustainable implementation of ESG policies (Hiatt, 2006). Advanced analytical methods such as Strong Sustainability Paradigm based Analytical Hierarchy Process, SSP AHP (Wątróbski et al., 2023) offer robust ways to assess sustainability through criteria such as equity, quality and adaptability. Studies using AI (Artificial Intelligence) and IoT (Internet of Things) in hospitals contribute to the efficiency of energy consumption and the implementation of ESG in real time.

The concept of sustainability in healthcare has evolved significantly, especially by integrating governance, social responsibility and environmental protection dimensions in the organization of healthcare institutions. Theoretical studies such as those by Braithwaite (2018) and Leung et al. (2023) highlight the transition from purely clinical medical models to patient-centered systems with environmental and social concerns.

In recent decades, the healthcare sector has undergone a significant transformation, influenced by factors such as demographic changes, technological evolution and economic pressures. Sustainability in healthcare has become a central objective, reflected in the implementation of ESG (Environmental, Social, Governance) principles. Hospitals are institutions that not only consume resources, but also have an impact on the environment by generating medical waste (Wójtowicz & Wójtowicz, 2024). This section reviews the relevant specialized literature in the healthcare sector.

The ESG (Environmental, Social, Governance) model, established within multinational companies, has been gradually adopted in the healthcare sector, especially in the Nordic countries, the UK and Canada.

The World Health Organization, through its *Health in the Green Economy* programme (WHO, 2012), highlights the need to reduce the environmental footprint of healthcare systems. Initiatives such as *Global Green and Healthy Hospitals (GGHH)* and Healthcare Without Harm provide a practical, structured framework, including key objectives such as efficient waste management, green procurement and energy efficiency.

The European CSRD (Corporate Sustainability Reporting Directive) and the related ESRS standards impose, starting with 2024, concrete non-financial and ESG reporting obligations for large organisations, including in the healthcare sector (European Commission, 2022; EFRAG, 2024). Reporting models such as GRI and SASB have been adapted for hospitals, highlighting positive correlations between rigorous ESG reporting and operational and staff retention improvements (McKinsey & Company, 2022).

Theoretical and conceptual studies (Braithwaite, 2018; Leung et al., 2023) highlight the need for an adaptive management model that embeds sustainability in infrastructure, human resources, and clinical governance. Triple Bottom Line (TBL) models (Elzinga & Johnson, 2017) or evidence-based design (Ulrich & Zimring, 2004) also provide a solid basis for assessing the impact of sustainability on the quality of hospital services.

A 2024 Delphi study proposes the SOLAR (Sustaining of Lean Adoption in Hospitals Roadmap) model, which

combines implementation science and theory of change, providing a roadmap for adopting sustainable practices in hospitals (BMC Health Services Research, 2024).

In 2025, the analysis of governance factors relevant to the implementation of sustainability in European hospitals highlights mechanisms based on managerial knowledge, leadership involvement, staff commitment and the use of technology, factors that predominate compared to barriers, but could become facilitators through appropriate strategic approaches (van Schie, 2024).

Emerging literature brings to the fore the concepts of digital leadership, integrated IoT circuits, indicating how sustainable change is no longer only managerial, but also technological and behavioral (Ismail et al, 2025; Sepetis, A., Parlavantzas, 2025, Sepetis et al, 2024).

Wójtowicz & Wójtowicz (2024) conducted an analysis of ESG reporting in public hospitals in the EU, finding better performance in northern Europe compared to the south.

Patrici etal. (2025) and Piechocka-Kałużna etal. (2021) highlight that the ESG paradigm is still emerging in hospitals, especially in the public sector, where reporting costs and lack of standardization limit their implementation.

Candio (2024) and Borges et al. (2022) demonstrate the positive correlation between ESG scores and financial performance in European healthcare organizations.

Zariņš & Siders (2025) analyze the transposition of CSRD in public hospitals in Latvia, France and Germany, discussing regional legislative differences.

In Spain, the study on sustainability reporting in public hospitals by Andrades et al. (2024) highlights the progressive institutionalization of ESG reporting, but highlights the need for clear protocols and reducing confusion related to content and standardization.

Advanced methods for assessing sustainability in healthcare systems have been proposed by Wątróbski et al. (2023), which provide a framework focused on equity, quality and adaptability. They propose the SSP-AHP (Strong Sustainability Paradigm Analytic Hierarchy Process) framework, a multi-criteria model for assessing social sustainability, with five key domains, equity, quality, adaptability, innovation, participation. Fatehi et al (2023) present a systematic review on the use of AI for predicting energy consumption in hospital organizations, highlighting the potential of modeling and implementation challenges.

Recent bibliometric analyses (Luque Alcaraz et al., 2024) confirm the increase in the number of publications on sustainability in healthcare, with a focus on the role of healthcare personnel as a key factor in sustainability.

The link between ESG score and financial performance was investigated by Candio (2024), who found a positive correlation between governance components and financial results in European healthcare companies. In the same vein, Borges et al. (2022) extend the perspective on integrated effects on financial performance.

Empirical analyses such as that carried out by Schwab et al. (2025), which examines the introduction of sustainable strategies in German hospitals, highlight barriers such as lack of resources, insufficient leadership and technical complexity. The identification of specific environmental indicators for hospitals is addressed by Menezes Galvão et al. (2023), who highlight the need for EKPI (Environmental KPIs), focusing on energy, waste, water and mobility.

The comparative study carried out by Zariņš & Siders (2025) analyses the transposition of the CSRD Directive in public hospitals in the EU (Latvia, France, Germany) and highlights the legislative differences and related sanctions. Other articles (Osapiens, 2024) highlight the importance of CSRD for transparency and accountability in hospitals.

Agboola (2025) proposes the integration of ESG into management reporting as a strategic decision-making factor, and Liu (2025) investigates the long-term benefits of ESG adoption.

Torres Bosch et al. (2025) develop a conceptual model for integrating IoT into sustainable processes, also demonstrated in a healthcare case, an approach that can be adapted for smart hospitals.

Galvão et al. (2023) identify two main categories of sustainability indicators in hospitals, optimizing water and energy consumption, and monitoring and reducing the impact of hospital activities on the environment (waste, effluents, emissions). The results suggest that the potential for reducing social and environmental impacts in hospitals is considerable, and the involvement of medical staff is essential for the implementation of these practices.

The study by Dolcini et al. (2025) analyzes the integration of environmental sustainability into hospital performance management systems, highlighting the importance of adopting environmental strategies in improving the efficiency of health institutions. The authors propose the implementation of performance indicators that include

environmental aspects, in order to contribute to reducing environmental impact and increasing the long-term sustainability of hospitals.

The Romanian context brings interesting perspectives. The study by Mesteru (2025) highlights the urgent need to improve sustainability in the private healthcare sector in Romania, especially in terms of energy efficiency, social equity and financing models. By comparing with countries such as Germany, the USA and Japan, the author proposes the adaptation of international good practices to create a more sustainable and accessible healthcare system in Romania. Coman & Grigore (2017) discuss the role of innovation in the sustainability of the healthcare system, addressing in particular prevention programs and the social effects of smoking. Rotaru et al. (2024) provide an analysis of Romanian regulations and active projects, especially in promoting the concept of "age-friendly healthcare", integrating environmental and societal objectives in a European context. Dobre et al. (2025) investigate the correlation between corporate governance and financial performance in the Romanian environment, highlighting the importance of governance in achieving sustainable performance. In the healthcare sector, Ivanković et al. (2024) provide an empirical study on quality indicators in Romanian public hospitals, highlighting the importance of institutional commitment. Other works have addressed patient perception (Radu et al., 2021) and satisfaction in public hospitals.

International studies on sustainability in public hospitals remain relatively rare compared to the private sector.

Research methodology

This current study comparatively analyzes how public hospitals in Romania, subordinated to the Ministry of Health, respectively to other public institutions (departmental hospitals), integrate sustainability principles (ESG) into their institutional activity, given that there is no formal reporting obligation under EU Directive 2022/2464 on CSRD/ESRS. The study investigates voluntary organizational behaviors related to ESG practices with a focus on the potential for future compliance and institutional readiness.

The central objective is to identify emerging models of voluntary compliance, good practices and institutional obstacles, relevant in the context of alignment with European regulations.

The research questions are:

- *To what extent does the integration of sustainability differ between hospitals subordinated to the Ministry of Health and departmental ones?*
- *What type of voluntary reporting initiatives or ESG practices are visible in the two institutional categories?*

The research hypotheses are:

I1: *Departmental hospitals (especially military ones, MAI, SRI, Justice) are more conservative in transparency and communication of ESG initiatives, compared to hospitals in the Ministry of Health network.*

I2: *Hospitals in the Ministry of Health network have greater exposure to European requirements regarding funded projects, which stimulates the implementation of ESG practices (even informally).*

I3: *No category of hospitals is currently legally required to apply CSRD/ESRS, but significant differences in institutional readiness and openness towards these standards are observed.*

According to Directive (EU) 2022/2464 on corporate sustainability reporting (CSRD), the obligation falls on large entities (with over 250 employees, turnover > 40 million EUR) and public entities, or listed on the stock exchange.

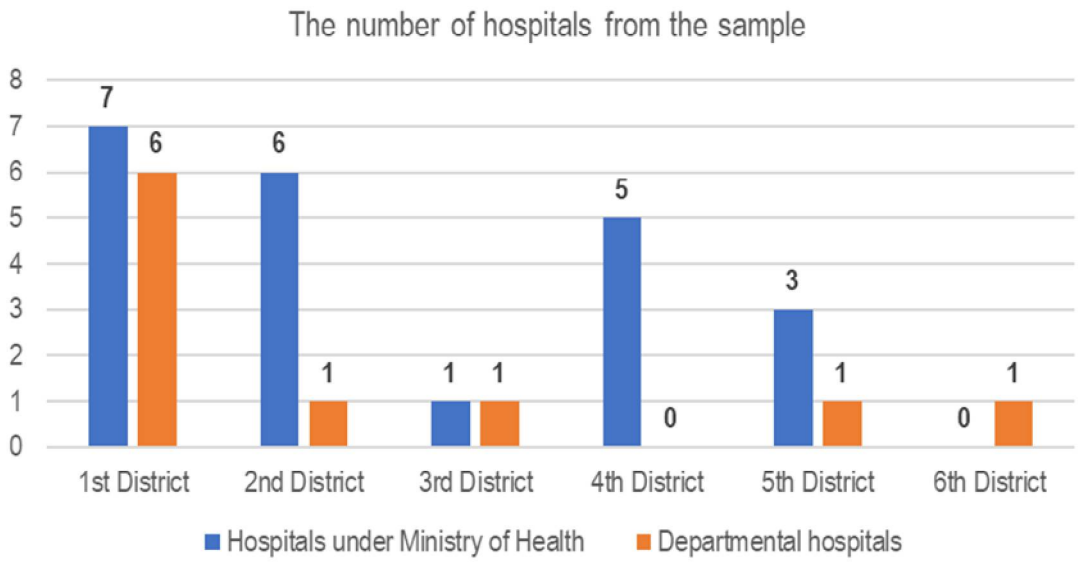
Public hospitals in Romania are organized as budgetary public institutions, without commercial legal personality; they are not included in the category of entities of public economic interest defined by the directive; they do not fall, in their current form, under the direct obligation of CSRD/ESRS, but are indirectly influenced by projects financed through PNRR or EU funds, institutional expectations or possible future national regulations.

This current exclusion from regulation provides an ideal framework for the comparative analysis of voluntary institutional reactions and preparation for future compliance.

The research carried out is a qualitative comparative one, through an extensive case study, with thematic analysis on two types of institutions (**Figure no. 1**).

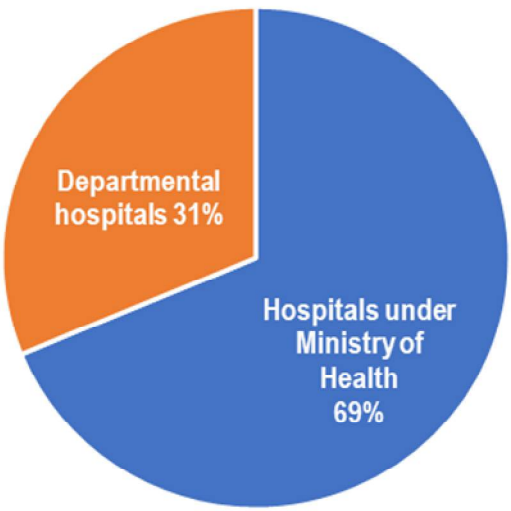
The analyzed sample includes 32 public hospitals, respectively 22 public hospitals subordinated to the Ministry of Health, including in this category university hospitals and representative county hospitals, according to the official list published by the Ministry of Health, and 10 departmental public hospitals, subordinated to various ministries, such as the Ministry of National Defense, the Ministry of Internal Affairs, the Ministry of Justice, the Ministry of Transport, the Romanian Intelligence Service or the Romanian Academy (**Figure no. 2**).

Figure no. 1. The sample



Source: own projection

Figure no. 2. Composition of the analyzed sample



Source: own projection

A purposive sampling technique was used, based on criteria such as the status of a public institution with hospital medical activity, different administrative subordination, to ensure comparability, accessibility to public data, strategic relevance (large, university, military or national hospitals).

The data collection and analysis were carried out by accessing the official websites of the hospitals, strategies, funded projects, official press releases, legislation and European documents on ESG/CSRD, activity reports, management plans, information on digitalization and energy efficiency.

The analysis carried out is an inter-institutional comparative, qualitative thematic (Braun & Clarke, 2006), organized by ESG dimensions: energy efficiency, waste management, green infrastructure; digital innovation, modernization of services; transparency, accountability, governance; staff training initiatives, social inclusion; reporting, sustainability projects (even without ESRS formalization).

The research does not use primary data (from interviews or questionnaires), but exclusively public and official secondary sources, which limits depth but maximizes transparency. Some hospitals (especially departmental ones) may publish less information, which affects comparative symmetry. However, the fact that the analysis focuses on voluntary compliance in the absence of mandatory compliance brings major methodological and practical added value.

The qualitative thematic analysis was conducted in accordance with the methodology proposed by Braun & Clarke (2006), organized by ESG dimensions:

- **E (environment)**: energy efficiency, green infrastructure, waste management;
- **S (social)**: digitalization, modern services, social inclusion, staff training;
- **G (governance)**: institutional transparency, managerial accountability, voluntary reporting initiatives.

This paper offers a unique contribution to the ESG literature applied to the public healthcare sector in Central and Eastern Europe, namely the case of Romania, supporting public policies by highlighting gaps and good practices between institutions in different administrative networks.

Results of the research and discussions

The research results highlight a number of significant differences between the institutional networks analyzed. Hospitals in the Ministry of Health network demonstrate a greater openness to good ESG practices, due to external pressures related to European funding and participation in digital transformation and energy efficiency projects. Departmental hospitals tend to exhibit a more conservative and less transparent organizational culture, with an emphasis on institutional security and rigid hierarchies, which limits the communication of ESG initiatives. In both categories, there are isolated ESG initiatives, but these are not formalized according to the CSRD/ESRS, reflecting the lack of a national framework adapted to the public sector.

The analysis of the 32 public hospitals in Bucharest reveals an almost non-existent visibility of sustainable initiatives. There are no sustainability reports, ESG indicators, or public strategies for social inclusion or open governance. This reveals a strong need for ESG awareness, auditing and reporting in the public healthcare system.

Environmental Dimension (E)

Regarding the environmental dimension, a concrete example of a green initiative could be the implementation of an energy efficiency model, the use of sustainable technologies and the implementation of modern ecological infrastructure standards. However, most of the hospitals analyzed did not publish strategies, reports or initiatives related to the reduction of energy consumption, the management of medical waste or the development of green spaces, fundamental aspects of environmental responsibility.

Social Dimension (S)

Within the social dimension, the public data analyzed do not indicate relevant social inclusion programs, continuous staff training, or corporate social responsibility initiatives. Although these aspects are essential for the quality of medical services and social cohesion, they seem to be generally not addressed or not communicated transparently by the institutions in the sample, with few exceptions (**Table no. 1** and **Table no. 2**).

Governance Dimension (G)

In terms of governance, institutional transparency and accountability are still low, especially in the case of departmental hospitals, where access to public information is limited (**Table no. 1**). Hospitals in the Ministry of Health network display some openness by publishing activity reports and management plans, but these do not usually include specific ESG indicators or policies.

Currently, the lack of explicit public data on ESG implementation in hospitals suggests low transparency, especially in the public healthcare sector.

Table no. 1. Comparative Analysis of ESG Reporting in Public Hospitals from Bucharest

Hospitals	ESG (using available data)	Observations	ESG dimensions
Hospitals in the Ministry of Health network (22 hospitals)	Limited information; rare public ESG initiative	Most have no ESG reports or green projects disclosed	E (not disclosed), S (partially), G (not disclosed)
Departmental Hospitals (10 hospitals)	No public visibility on ESG	Reduced accesibility to information	E (not disclosed), S (partially), G (partially)

Source: own projection

Table no. 2. Comparative-exploratory Presentation of Integrating ESG in Public Hospitals from Bucharest

Item	Hospitals in the Ministry of Health network	Departmental Hospitals
Buget of Revenue and Expense	86%	80%
Wealth and Interest Statements	95%	70%
Code of conduct	86%	60%
Code of ethics	82%	60%
Integrity Plan	86%	50%
Environment	10%	20%
Social	40%	70%
Governance	0	10%

Source: own projection

The results of this exploratory analysis indicate that the public healthcare system in Bucharest is at an early stage of integrating ESG principles. The visibility of environmental, social and governance initiatives is low, suggesting the level of importance given to institutional sustainability, as well as a need to promote transparency and accountability in this area. Regarding the environmental dimension, hospitals should monitor air quality, have urban gardens, implement solar panels, energy-efficient design and green infrastructure, given the high consumption of resources. The social dimension should provide access to modern medical services, health education programs, community spaces, and rehabilitation facilities. Governance should consider public-private partnerships or with various NGOs, ESG reporting, as well as dialogue with authorities and other stakeholders.

Conclusions and recommendations for future research

The comparative study conducted on the 32 public hospitals in Bucharest highlights a low level of explicit integration of ESG principles in the institutional activity, both in hospitals subordinated to the Ministry of Health and in departmental ones. The lack of policies and reports dedicated to sustainability indicates that these institutions operate mainly outside the formal framework of European regulations on ESG reporting, which limits transparency and the potential for social and ecological responsibility.

The environmental dimension is almost absent from strategies and public communications, with the exception of isolated initiatives such as projects of some hospitals to reduce the impact on the environment by collecting unused medicines or other waste, which also provide a positive example through sustainable infrastructure and energy efficiency.

The social dimension is insufficiently explored and communicated, and aspects related to inclusion, training and social responsibility are missing in most cases from the institutional discourse.

Governance is marked by limited transparency, especially in hospitals subordinated to the Ministry of Health, which highlights the need for clearer communication and accountability mechanisms. In this regard, external public

audit can become an important tool for objectively assessing institutional transparency and compliance with good governance principles, filling the lack of formal ESG reporting.

All these findings reflect both a lack of external pressure and direct legal obligations regarding ESG in the public healthcare sector, as well as a clear need for awareness and development of institutional capacities for the integration of sustainability.

The main public policy recommendations may concern the development of a national methodology for ESG reporting in the public sector, adapted to the specifics of budgetary institutions and in accordance with the ESRS principles, but without imposing excessive administrative requirements, the integration of ESG requirements within projects financed from EU funds (PNRR, ERDF, etc.), in order to stimulate voluntary compliance, the creation of an inter-ministerial ESG coordination mechanism in the healthcare sector, which would include representatives of the MH, MApN, MAI, MJ and other departmental structures, in order to harmonize good practices, professional training and development of institutional capacity on sustainability, for managerial and technical staff in hospitals, the publication of a transparent platform of ESG good practices in the healthcare system, which would serve as a guide for public hospitals.

The implementation of these recommendations can contribute to the modernization of the public healthcare sector both in Bucharest and in the country, with positive effects on operational efficiency, quality of medical services, employee satisfaction and responsibility towards the environment and society. At the same time, the adoption of solid ESG practices in hospitals can become a factor of competitiveness and a positive image, in line with global sustainability trends.

For a thorough understanding and effective adoption of ESG principles in Bucharest public hospitals, we recommend collecting primary data through questionnaires and interviews with managers and medical staff, to identify perceptions, obstacles and unpublished good practices; ESG audits that assess infrastructure, resource consumption and internal policies, to identify critical points and opportunities for improvement; developing an ESG reporting platform adapted to the public healthcare sector, to increase transparency and stimulate voluntary initiatives or initiating pilot projects in collaboration with local and European authorities to implement sustainable practices in infrastructure and social responsibility.

In conclusion, the transition to sustainable governance in the health system is a strategic necessity, which must be supported by clear public policies, adequate resources and an organizational culture open to change. External public audit, as an independent and objective verification mechanism, can play an important role in monitoring progress and contribute to increasing public trust.

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Changes in Accounting Estimates. Exploring Impact and Trends

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Abstract

*This study explores the frequency and distribution of changes in accounting estimates across different industries and company sizes, and develops a typology of firms: **one time-changers**, **occasional changers** and **chronical changers**. The findings indicate that industries characterized by complex operations and high uncertainty, such as manufacturing and services, report the largest number of estimate adjustments, whereas sectors such as agriculture and public administration predominantly record single adjustments. The results confirm a significant association between industry type and the frequency of changes ($p< 0.001$). Moreover, the study makes an original contribution by identifying and analyzing patterns in firms' accounting estimate changes. It also investigates the impact of firm size on the number of changes in accounting estimates – an aspect that has received limited attention in the existing literature, which has primarily focused on the underlying motivations for adjustments or on earnings management strategies.*

The findings of this study are relevant for managers, investors, auditors, and standard-setters, as they support decision-making processes and the development of control and reporting policies tailored to the specific characteristics of each industry. Nevertheless, the study is exploratory in nature but can serve as a foundation for future research adopting predictive or longitudinal approaches, incorporating a larger sample of companies and additional variables captured at the individual level.

Key words: *accounting estimates; changes in accounting estimates; IAS 8; ASC 250; industry; company size; one-timers; occasional changers; chronic changers;*

JEL Classification: *M41, M42, R32, G32, L25*

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1. Introduction

In the business environment, particularly within the current financial and economic dynamics, the quality of financial reporting plays a crucial role. Both primary and secondary stakeholders have a direct interest in the accuracy of financial-accounting information. The importance of maintaining the quality of financial-accounting information has been extensively discussed both at the normative level by regulatory bodies (IASB – *International Accounting Standards Board*, FASB – *Financial Accounting Standards Board*, SEC – *Securities and Exchange Commission*, EFRAG – *European Financial Reporting Advisory Group*) and within the academic field (Barth et al., 2001; Dechow et al., 2010).

One of the greatest challenges arises when, within the complex picture presented by financial statements, there are elements that rely on the application of expertise and professional judgment. We refer here to accounting estimates, which are based on the available data, yet uncertainty and subjectivity cannot be avoided. Given the highly dynamic nature of the financial and economic environment, new information may become available. In this context, accounting estimates require revision, leading to changes in accounting estimates, which are then reflected in the current or future reporting periods.

According to FASB (2005), changes in accounting estimates are a necessary consequence of the emergence of new information, but at the same time they may also represent "an appealing mechanism through which managers achieve their reporting objectives" (DeFond et al., 2019). The challenge for stakeholders, and especially for auditors, stems from this very paradox: while changes in accounting estimates are necessary, they also carry the "potential" to become a tool for manipulation.

With regard to potential risks, concerns have been raised both by practitioners (KPMG, 2016; Ernst & Young, 2017) and by academic researchers (Ghosh & Siriviriyakul, 2019; Beaulieu et al., 2022; Chung et al., 2022; Albrecht et al., 2024; Li & Luo, 2024).

When it comes to changes in accounting estimates, standard-setting authorities (IASB, FASB) consider them merely a means of updating or disclosing additional information required for financial reporting. Their expectations align with the findings of existing research (Ghosh & Siriviriyakul, 2019). The authors of this research argue that the likelihood of using changes in accounting estimates as a means of intentional misrepresentation is low, precisely because of the inherent risks that are evident to investors as well as the disclosure requirements in financial reporting (Ghosh & Siriviriyakul, 2019).

On the other hand, it is precisely this heightened exposure to the risk of intentional misrepresentation that enables managers to manipulate results through changes in accounting estimates - whether such changes are necessary or not.

The aim of this study is to analyze and classify companies based on the frequency of changes in accounting estimates, in order to identify behavioral patterns that can provide relevant insights regarding the quality of financial reporting, the stability of accounting policies, and the associated potential risks. Accordingly, this paper seeks to provide a starting point for observing recurring patterns in how companies adjust their estimates, facilitating comparisons within and across industries.

We proceed from the premise that a clearer understanding of the frequency of changes in accounting estimates, along with grouping companies into categories (clusters) or developing patterns, offers a useful analytical framework for companies and investors (in assessing financial quality and stability), for auditors, and as a foundation for future predictive research.

2. Literature review

To identify the current state of research on this topic, we began with a quantitative analysis of works already published in the literature. We accessed three leading databases: Web of Science (WOS), Springer Link, and Science Direct–Elsevier. This part of our research was facilitated through the ANELIS Plus platform, which provides electronic access to scientific and research literature.

Following the search protocols of each database, in the Web of Science Core Collection (WOS), searches were conducted using the "Topic" field, which covers titles, abstracts, and author keywords. Using the query "changes in accounting estimates," nine articles were initially identified, of which two were excluded due to irrelevance. The remaining seven articles, published between 2017 and 2025, indicate a growing interest in this subject in recent years. This increase is also explained by the availability of the accounting estimate changes module provided exclusively by Audit Analytics since 2013. An alternative search using the phrase "accounting estimate

changes" returned only one article, already included among the seven selected.

In Springer Link, using the same search structure adapted to the database, we obtained three results, two of which were book chapters addressing accounting estimates only tangentially, and one article already found in WOS.

On Science Direct platform, following the same approach, we retrieved 69 articles using the search structure "accounting estimate changes" OR "changes in accounting estimates". However, only nine were openly accessible, and upon review, the topic of accounting estimate changes was addressed tangentially, appearing no more than five times in these nine studies.

These observations indicate that the topic of accounting estimate changes still leaves ample room for exploration (DeFond et al., 2024). Over the years, the literature has paid particular attention to the inherent uncertainty of accounting estimates and the risk of intentional misstatement, with significant implications for auditors (Bell & Griffin, 2012; Christensen et al., 2012; Bratten et al., 2013; Griffin, 2014; Joe et al., 2017).

Given the increasing number of accounting estimates in a dynamic business environment, management must periodically evaluate the input data used for these estimates. Adjustments to accounting estimates are therefore inevitable; as economic conditions change, new information and assumptions emerge, making it imperative for managers to accurately reflect the financial reality. Nevertheless, in this context characterized by uncertainty, there remains the potential for biased adjustments.

In response, IASB and FASB have contributed to creating a more coherent and rigorous framework for managing and reporting changes in accounting estimates through recent standard revisions (IASB, 2021; FASB, 2009; FASB, 2015a; FASB, 2015b). Both IAS 8 – *Accounting Policies, Changes in Accounting Estimates and Errors*, issued by IASB, and ASC 250 – *Accounting Changes and Error Corrections*, issued by FASB, have clarified the distinction between changes in accounting policies and changes in estimates. Moreover, both authorities treat changes in estimates prospectively (IASB, 2003; IASB, 2014; FASB, 2015a).

In addition to the limited volume of literature, the findings on the motivation behind changes in accounting estimates are inconsistent. Some authors argue that these changes are strategically motivated (Beaulieu et al., 2018; Seidel et al., 2020; Chung et al., 2022; Albrecht et al., 2024) to achieve profit targets or other reporting objectives. Conversely, other studies provide empirical evidence suggesting that accounting estimate changes primarily serve to reflect new information (Cassell et al., 2015; Ghosh & Siriviriyakul, 2019). While management may have incentives to manipulate earnings through estimates and related changes, this is considered unlikely due to the ease with which markets can detect distortions, driven by rigorous financial reporting and disclosure requirements (Ghosh & Siriviriyakul, 2019). Li & Luo (2024) examined the impact of estimate changes during periods of crisis or uncertainty (e.g., COVID-19), highlighting the challenges for investors in assessing true performance and for auditors in identifying intentional opportunism.

Most studies associate changes in accounting estimates with earnings management and managerial opportunism, and some also explore the potential for these firms to issue financial restatements (Albrecht et al., 2024; Beaulieu et al., 2023).

Following a logical perspective, we start from the idea that accounting estimates are increasingly necessary in a dynamic market environment but require careful attention from investors and auditors due to their susceptibility to manipulation for various reasons already analyzed in the literature (Christensen et al., 2012; Bratten et al., 2013; Griffin, 2014; Abernathy et al., 2015; Brink et al., 2016).

At the same time, adjustments to accounting estimates are essential to accurately reflect business conditions and new information. Based on the necessity of estimates and subsequent changes, we can conclude that while such adjustments are inevitable and indispensable, they paradoxically represent a source of vulnerability and an avenue for potential manipulation, often manifesting in financial restatements (Beaulieu et al., 2023). This raises the question of how financial statement quality and audit quality can be maintained despite regulatory efforts.

Therefore, there is a continued need to explore accounting estimates and their changes due to the ongoing controversies and sometimes contradictory findings in existing research. Our exploratory study aims to contribute to the literature by developing a perspective focused on characterizing aggregated company behavior, rather than solely analyzing the individual motives behind changes. The main objective is to identify reporting patterns and classifications that enable understanding of behavioral differences across firms regarding estimate changes. This analysis can serve as a foundation for future quantitative and qualitative studies on accounting estimate changes.

In the following section, we develop our study framework, explaining how we created this behavioral classification of companies reporting changes in accounting estimates.

3. Research methodology

For this study, we used data provided by Audit Analytics, a comprehensive database that includes information on accounting estimate changes within one of its modules. The available data in Audit Analytics pertain only to U.S.-listed companies. Using the most recent data available on this topic, the database provided information on estimate changes up to June 30, 2025.

We initially started with 14,704 observations, representing 5,383 companies, covering the period 1999-2005. From this initial dataset, we removed observations corresponding to the 1999-2003 period, which accounted for 1,656 observations and 759 companies (**Table no. 1**). These observations were excluded for two main reasons. First, the Audit Analytics database does not code accounting estimate changes for periods prior to 2002. Second, the reporting requirements related to internal control over financial reporting, introduced by the Sarbanes-Oxley Act of 2002 (Section 404), began to be gradually implemented in 2003, leading to a significant improvement in the quality and comparability of reported information. After these exclusions, the final dataset comprised 13,048 observations for 4,624 companies.

Financial sector companies were included in the analysis to maintain the representativeness of all industries and to avoid introducing bias, given that these firms provide relevant information regarding the frequency and impact of accounting estimate changes.

Table no. 1. Sample selection

Step	Description	Number of observations	Number of companies
1	Initial observations from Audit Analytics (1999–2025)	14,704	5,383
2	Minus: observations from the period 1999–2003 (Audit Analytics does not code changes prior to 2002; SOX internal control reporting requirements came into effect in 2003)	1,656	759
	Total observations remaining for analysis	**13,048**	**4,624**

Source: own projection, based on processed data

For each company, Audit Analytics reported all accounting estimate changes disclosed in annual or quarterly filings. The data were primarily extracted from the following forms: 10-Q, 10-K, 20-F, 40-F, and 6-K, supplemented with information from SEC comment letters. Audit Analytics also provides the period during which estimate changes occurred, the reason for these changes (classified according to a well-defined taxonomy), their impact on earnings, as well as additional information about the companies in question.

Based on all the information provided by Audit Analytics, we created our own dataset, extracting only the information necessary to achieve the objectives of this study. It should be noted that our research is exploratory and descriptive in nature.

To identify potential reporting patterns of accounting estimate changes, the sample companies were grouped into three distinct categories, defined according to the number of reported changes over the analyzed period.

The first category consists of **one time changers** – companies that made only one change to accounting estimates throughout the entire observation period. This group may reflect firms with stable accounting policies, making adjustments only in the context of specific, well-justified events. The second category includes **occasional-changers** – companies that recorded between two and five estimate changes during the sample period. This pattern may suggest a moderate level of adjustments, typically correlated with changes in economic conditions, regulatory updates, or periodic revisions of accounting policies. The third category comprises **chronical changers** – companies reporting more than five accounting estimate changes. The high frequency of adjustments in this group may be associated with a more volatile operating environment, significant

uncertainties, or, in some cases, managerial practices involving a high degree of subjectivity in financial reporting.

The thresholds were established to capture distinct behaviors, ranging from firms that rarely change estimates to those that do so frequently, thereby facilitating a clearer understanding of estimate-change patterns. As there is no universal convention in the literature for these thresholds, this classification is descriptive and aims to organize the data for further analysis.

Table no. 2. Variable description

Variable Name	Description	Details
COMPANY_NAME	Company name	According to Audit Analytics
YEAR_CAE	Year in which accounting estimate changes occurred	2004–2025
CAE_TYPE	Cause of the accounting estimate changes or the item triggering the change	14 types of changes according to Audit Analytics taxonomy (see ***Appendix 1***)
CODE_CAE	Code assigned by the author for each cause	1–14
EFFECT_CAE	Net effect generated by the estimate change	Positive, Negative, Unidentified
CODE_EFFECT	Code assigned by the author	1 – Positive2 – Negative3 – Unidentified
SIC_CODE	Industry code	According to Audit Analytics
TOTAL_CHANGES	Number of estimate changes (based on the number of years and the number of occurrences of the company in the database)	Processed in Stata
CHANGER_TYPE	Classification of companies based on the number of accounting estimates	• One time changers – 1 change • Occasional-changers– 2-5 changes • Chronical changers – more than 5 changes
INDUSTRY_NAME	Industry name based on SIC codes	Agriculture, Mining, Construction, Manufacturing, Transportation, Wholesale, Retail, Financial Services / Finance, Services, Public Administration
INDUSTRY_CAT	Numeric code for each industry	Processed in Stata, coded from 1 to 10 (according to SIC code and existing industry types)
COMPANY_SIZE	Company size	Natural logarithm of total assets, processed in Stata

Source: own projection, based on processed data

In Table no. 2 we present the working variables extracted from Audit Analytics or created subsequently in the statistical and econometric software Stata. These variables allowed us to perform the statistical tests necessary to present the impacts and trends related to changes in accounting estimates.

4. Results and discussions

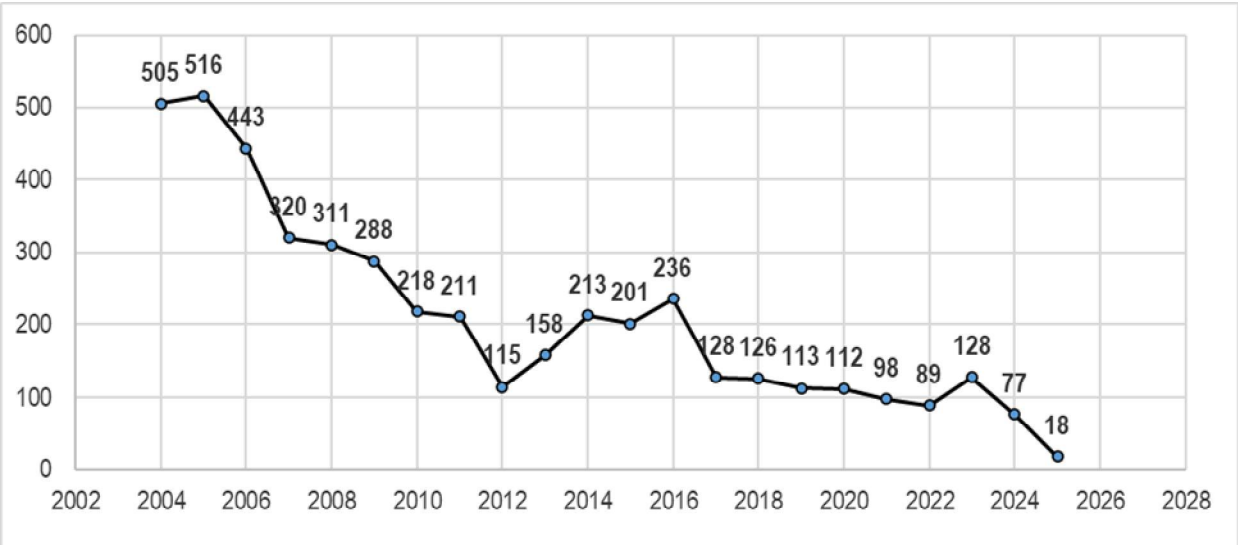
The statistical analyses we conducted are reported based on the number of companies included in the sample. To understand the distribution of accounting estimate changes across companies and industries, we performed several descriptive statistical tests.

As shown in **Figure no. 1**, the number of distinct companies reporting at least one accounting estimate change during the period 2004 - June 2025 is presented. The data clearly indicate a pronounced decline in the number of companies reporting estimate changes, from 505 companies in 2004 to only 77 companies in 2024, and 18 companies reporting changes in the first two quarters of 2025.

The results for the 2004–2008 period, characterized by a higher number of companies reporting estimate changes, can be explained by the introduction or intensification of reporting obligations (Cohen et al., 2008). Similarly, the 2008–2010 period shows a gradual decline, likely due to economic changes, including the financial crisis of 2008–2009. This aligns with prior research suggesting that firms reduce or avoid accounting estimate changes during unstable periods, as such changes may be more easily interpreted as earnings management or negative signals by market participants (Chan & Laux, 2010; Daske et al., 2013).

Additionally, the downward trend in the number of estimate changes may reflect the continuous efforts of IASB and FASB to provide clarifications and additional guidance for accounting estimate treatment.

Figure no. 1. Evolution of accounting estimate changes by year



Source: own projection, based on processed data

The distribution of companies across categories, as described above, based on the number of reported changes, is presented in **Table no. 3**. **Table no. 4** shows the distribution by category and year. Notably, 54.24% of the sample consists of **one-time changers**, indicating that more than half of the companies made only one change in estimates, possibly in response to a specific event. **Occasional-changers**, representing 36.76% of the sample (with 2-5 estimate changes), were likely influenced by cyclical or industry-specific factors. The final category, **chronical changers**, accounts for 9% of all companies reporting estimate changes during the 2004-2025 period. This category warrants particular attention due to the potential for managerial opportunism.

Table no. 3. Distribution of companies by change type

Changers_type	Frequency	Percentage	Cumulative
One-time changer	2508	54.24	54.24
Occasional changer	1700	36.76	91.00
Chronic changer	416	9.00	100.00
Total	**4624**	**100.00**	

Source: own projection, based on processed data

Table no. 4. Distribution of companies by year and change category

YEAR	One-time	Occasional	Chronic	%One-time	%Occasional	%Chronic
2004	239	189	77	47.33	37.43	15.25
2005	241	227	48	46.71	43.99	9.30
2006	232	167	44	52.37	37.70	9.93
2007	140	149	31	43.75	46.56	9.69
2008	159	129	23	51.13	41.48	7.40
2009	151	110	27	52.43	38.19	9.38
2010	126	73	19	57.80	33.49	8.72
2011	127	64	20	60.19	30.33	9.48
2012	61	41	13	53.04	35.65	11.30
2013	89	53	16	56.33	33.54	10.13
2014	123	80	10	57.75	37.56	4.69
2015	121	70	10	60.20	34.83	4.98
2016	154	74	8	65.25	31.36	3.39
2017	84	39	5	65.63	30.47	3.91
2018	74	41	11	58.73	32.54	8.73
2019	64	30	19	56.64	26.55	16.81
2020	63	39	10	56.25	34.82	8.93
2021	44	43	11	44.90	43.88	11.22
2022	48	34	7	53.93	38.20	7.87
2023	89	33	6	69.53	25.78	4.69
2024	61	15	1	79.22	19.48	1.30
2025	18	0	0	100.00	0.00	0.00
Total	2508	1700	416	-	-	-

Source: own projection, based on processed data

From **Table no. 4** it is evident that the financial crisis period of 2008-2009 was associated with a decrease in the frequency of accounting estimate changes and an increase in the proportion of single changes, reflecting managerial caution (Bratten et al., 2013).

Descriptive statistics also show a clear concentration of estimate changes in certain sectors, with manufacturing (38.13%) and services (19.49%) together accounting for nearly 58% of all companies reporting estimate changes. Industries such as wholesale, retail, construction, agriculture, and mining exhibit much lower frequencies.

Regarding the effect of accounting estimates on earnings, as reported in Audit Analytics, **Figure no. 2** shows that out of the 4,624 companies, 50% (2,325) reported estimate changes with a positive effect on earnings, while approximately 40% (1,880) reported changes with a negative effect.

Furthermore, to better understand the tendencies of companies in reporting changes to accounting estimates and to examine the extent to which these changes depend on company type or industry, we conducted several statistical tests, including ANOVA, post-hoc tests, and Chi-square tests, the results of which are presented below.

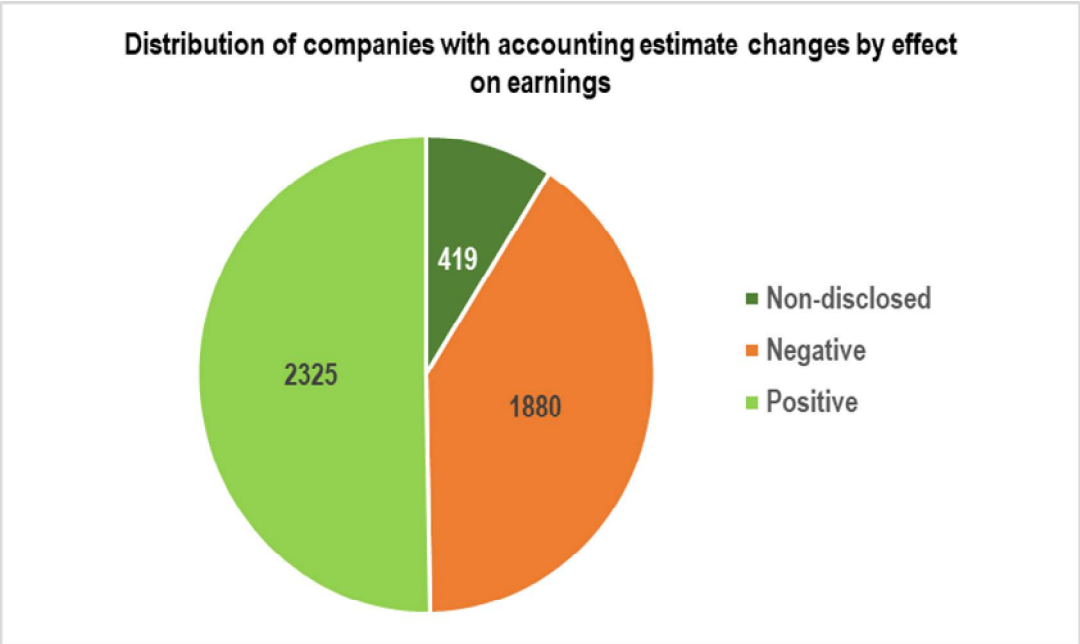
To investigate the relationship between company size and the frequency of changes in accounting estimates, we analyzed differences in company size (logarithm of total assets) according to the category of frequency of changes (changer_type). One-way analysis of variance (ANOVA, **Table no. 5**) revealed statistically significant differences among the three groups: companies with a single change, occasional changes, and recurrent changes in accounting estimates. The results suggest that company size varies significantly depending on the frequency of estimate changes, with firms making recurrent changes having, on average, larger total assets than those with occasional or single changes ($F(2, 4450) = 134.99$, $p < 0.001$).

Subsequent Tukey post-hoc tests indicated that all three categories of companies differ significantly from one another: firms with recurrent changes in accounting

estimates are indeed the largest, followed by those with occasional changes, while firms with a single change are the smallest. Also, the firms with occasional accounting changes are significantly larger than those registering only one change in estimates for the analyzed period.

These findings suggest the existence of a distinct company profile based on the frequency of changes in accounting estimates, with larger firms tending to adjust estimates more frequently. This pattern may reflect the complexity of operations or a higher degree of uncertainty associated with these entities' activities.

Figure no. 2. Effect of accounting estimates on earnings



Source: own projection, based on processed data

Table no. 5. Analysis of variance (ANOVA) for company size by type of change in accounting estimates

Source	Df*	Sum of Squares	Mean Square	F	p-value
Between groups	2	2147.38	1073.69	134.99	<0.001
Within groups	4450	35395.31	4450		
Total	4452	37542.69			

* *Df represents degrees of freedom; "Between groups" reflects the variation explained by the group factor, while "Within groups" indicates unexplained (residual) variation.*

Source: own projection, based on processed data

The results obtained confirm the hypothesis that company size is correlated with the frequency of changes in accounting estimates. This finding supports observations in the literature, where larger firms are associated with a higher degree of operational and financial complexity, necessitating more frequent adjustments of accounting estimates (Dechow & Schrand, 2004). Additionally, according to Ball & Shivakumar (2005), the frequency of estimate changes reflects a higher level of uncertainty in the business environment, a phenomenon that appears more pronounced in firms with large total assets.

To explore whether the frequency of changes in accounting estimates varies across industries, we conducted a Chi-square test of independence between the categorical variable changer_type (frequency of changes: single, occasional, recurrent) and the industry in which companies operate. This test allows us to assess whether

a significant association exists between the two categorical variables. The results (Table no. 6) indicate a significant difference in the distribution of accounting estimate changes across industries (Pearson chi2 (18) = 91.26, p < 0.001).

Thus, the data reveal the existence of distinct industry profiles regarding the frequency of changes in accounting estimates. Industries characterized by complex operations and high uncertainty, such as Manufacturing, Finance, and Services, show a significantly higher proportion of firms with recurrent changes in accounting estimates. In contrast, sectors such as Agriculture and Public Administration are dominated primarily by companies making single changes, suggesting a lower frequency of estimate adjustments in these areas. These findings indicate that the industry in which a company operates significantly influences both the extent and frequency of accounting estimate adjustments, likely due to differences in the complexity of operational processes, industry-specific regulations, and the level of uncertainty associated with the activity.

Table no. 6. Association between the frequency category of accounting estimate changes and company industry (Chi-square Test)

Industry	One-time changers	Occasional changers	Chronical changers	Total
Agriculture	12	5	0	17
Construction	19	20	19	58
Finance	394	217	48	659
Manufacturing	930	653	180	1763
Mining	197	104	12	313
Public Administration	1	0	0	1
Retail	109	80	10	199
Services	494	319	88	901
Transportation	292	265	54	611
Wholesale	60	37	5	102
Total	***2508***	***1700***	***416***	***4624***

Pearson chi2(18) = 91.2552, Pr = 0.000

Source: own projection, based on processed data

Penman and Zhang (2002) emphasize that industries characterized by high uncertainty and strict regulations, such as finance and manufacturing, exhibit a higher frequency of changes in accounting estimates in response to dynamic economic conditions. This relationship between operational complexity, company size, and the frequency of estimate adjustments is also supported by Francis et al. (2004), who argue that these characteristics influence the quality and nature of financial reporting.

We conducted a factorial ANOVA to investigate the combined impact of industry and the frequency of changes in accounting estimates on company size. The interaction between the two variables was not significant (F(15, 4426) = 0.95, p = 0.50), indicating that the effect of the frequency of estimate changes on company size is similar across all industries.

To analyze whether the effect of accounting estimate changes on outcomes differs depending on the frequency of these changes, we performed a Chi-square test on the distribution of effects (positive, negative, undisclosed) across the three categories of firms. The results (Table no. 7) indicate statistically significant differences between groups in the distribution of the effect of changes (Pearson chi2(4) = 26.47, p < 0.001).

Thus, the analysis highlights that firms with single changes exhibit a higher proportion of positive effects from accounting estimate adjustments compared to firms with occasional or recurrent changes. The latter, although

representing a smaller number of observations, show a relatively higher proportion of negative effects, suggesting a different dynamic depending on the frequency of the changes.

Table no. 7. Relationship between the frequency of accounting estimate changes and their effect (Chi-square Test)

Changer_type/ Change effect	N/A	Negative	Positive	Total
One time (1)	265	984	1259	2508
Occasional (2-5)	133	736	831	1700
Chronical (>5)	19	163	234	416
Total	417	1883	2324	4624

Pearson chi2(4) = 26.47, Pr = 0.000

N/A – effect not disclosed on the outcome/ Negative – negative effect on the outcome/ Positive – positive effect on the outcome

Source: own projection, based on processed data

5. Conclusions

The primary objective of this exploratory study was to identify and characterize companies that frequently adjust accounting estimates over multiple years, with the aim of highlighting their distinctive features in terms of size, industry, and the nature of the effects generated, as well as capturing potential trends associated with this behavior.

While previous research has focused on the impact of external shocks, such as the pandemic, or on the timing of estimate changes for earnings management purposes, the present analysis shows that larger firms tend to record a higher number of recurrent adjustments. This finding suggests that structural characteristics of firms, such as size, may influence the complexity and frequency of accounting estimates, thereby complementing the existing literature and providing additional insights for managers, investors, and auditors interested in informational risks and financial reporting strategies.

The exploratory analysis indicates a downward trend in the frequency of accounting estimate changes over the period 2004 - June 2025. Periods of higher frequency (2004-2008) may coincide with the introduction of new reporting requirements, while the subsequent decrease (2008-2010) could be associated with the financial crisis and managerial prudence. The results also show that the financial crisis period was associated with an increase in the proportion of firms with single changes, again suggesting a tendency toward cautious management. The overall declining trend implies that IASB and FASB guidance and clarifications have contributed to reducing the frequency of accounting estimate adjustments.

Furthermore, the results highlight that the group of firms classified as making recurrent changes – i.e., those that performed more than five revisions of accounting estimates during the analyzed period – exhibit distinct characteristics compared to firms with single or occasional changes. These companies are concentrated in industries with a high degree of operational complexity and uncertainty, such as manufacturing, finance, and services, where frequent estimate adjustments are often necessary due to market volatility, technological changes, or legislative updates.

The analysis of company size by type of estimate change and the effect of those changes (modification type × effect of estimate changes) shows that firms making frequent adjustments are, on average, significantly larger than those making occasional or single changes. Thus, size not only increases transaction volume but also the diversity of situations requiring professional judgment and estimate adjustments, explaining why companies with recurrent changes modify estimates more frequently. Chi-square test results indicate that firms with recurrent estimate changes have a relatively higher proportion of negative effects, suggesting that repeated adjustments often reflect the prudent recognition of adverse developments. These findings support the notion that the frequency of accounting estimate changes is not random but is influenced by structural and contextual factors specific to a company's operational environment (Dechow & Schrand, 2004; Francis et al., 2016).

In conclusion, this exploratory study demonstrates that accounting estimate changes are concentrated in industries with complex operations and high uncertainty. These results are useful for managers, investors, auditors, and regulatory authorities, providing a clearer picture of sectors where estimates are more frequently adjusted and, consequently, where financial reporting risks are higher. Understanding these trends can support strategic decision-making processes and the development of control and reporting policies better tailored to the realities of each industry, helping companies manage both

operational and estimate-specific uncertainty more effectively.

Thus, the findings regarding the link between company size and the frequency of accounting estimate changes represent an original contribution, complementing the existing literature, which primarily focuses on the motives and context of estimate changes rather than on firms' structural characteristics.

It should be noted, however, that this study is exploratory and cannot be used to predict future changes in accounting estimates. The results may serve as a starting point for future research with predictive approaches and longitudinal models, which could provide more precise and company-specific estimations.

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Appendix 1

Code	Taxonomy of CAE (Audit Analytics, 2025)
1	Accounts/loans receivable, investments & cash issues
2	Acquisitions, mergers, disposals, re-organizations
3	Asset retirement obligations
4	Deferred, stock-based and/or executive comp
5	Depreciation, depletion or amortization
6	Expenses (payroll, SGA, other)
7	Financial derivatives/hedging
8	Inventory
9	Liabilities, accruals or reserves
10	Other accounting estimates
11	Pension and other post-retirement benefit
12	PPE & Intangible assets
13	Revenue recognition
14	Tax expense/benefit/deferral/other

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Auditing in the Twin Transition Era

Between Professional Judgment, Sustainability Assurance, and Agentic AI – Challenges and Future Directions

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Abstract

This study investigates how the convergence between digital transformation and the sustainability transition – commonly referred to as the Twin Transition – is reshaping financial auditing in the context of emerging autonomous technologies such as Agentic AI. An exploratory qualitative approach is adopted, combining reflexive thematic analysis of the academic literature, evaluation of the regulatory framework (CSRD, ESRS, ISA), and synthesis of the relationships between the digital dimension, the sustainability dimension, and the auditor's professional judgment. Findings highlight that integrating Agentic AI, Blockchain (BT), Big Data Analytics (BDA), and Robotic Process Automation (RPA) into audit engagements can deliver substantial benefits, including continuous auditing, ESG data traceability, and operational efficiency. However, these developments also raise challenges such as algorithmic opacity, data bias, and the lack of adapted standards. The paper proposes a conceptual framework for integrated financial auditing, where professional judgment remains the central decision-making node, complemented by the predictive and adaptive capacities of emerging technologies. Finally, the study outlines avenues for future research on algorithmic auditing, standardization of sustainability assurance, and the development of hybrid auditor competencies, contributing to both the theoretical and practical foundations of auditing in the Twin Transition era.

Key words: *digital transformation; sustainability transition; Twin Transition; auditor; audit profession; professional judgment; Artificial Intelligence (AI); Agentic AI;*

JEL Classification: *M42, O14, O33, Q01, Q55, Q56*

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1. Introduction

The audit profession is undergoing one of the most profound transformations in its recent history, driven by the phenomenon known in the academic literature and European policy as the *Twin Transition* – the convergence of accelerated digital transformation and the sustainability transition (KPMG, 2024; EC, 2025).

More than a technological or regulatory shift, the Twin Transition represents *a systemic reconfiguration of economic and social paradigms*, with far-reaching implications of how organizations create value, report performance, and manage risks (Tiron-Tudor *et al.*, 2025a). These dynamics are further amplified in the context of Industry 6.0, where digital interconnectivity, sustainability imperatives, and intelligent automation converge into a data-driven model of production and governance (Bornet *et al.*, 2024; Deliu & Olariu, 2024; Tiron-Tudor & Deliu, 2024; Stoica & Ionescu-Feleagă, 2024; Deliu, 2025).

Within this new landscape, auditing can no longer be examined in isolation, but must be understood as part of an extended governance ecosystem oriented toward transparency, resilience, and responsibility to both environment and the society (Deliu, 2020, 2024, 2025; Tiron-Tudor *et al.*, 2025b).

The adoption of the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS), together with the rapid development of emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Blockchain (BT), Robotic Process Automation (RPA), and Big Data Analytics (BDA), has prompted a fundamental redefinition of the audit function (Farcane & Deliu, 2020; Bornet *et al.*, 2024; PwC, 2024; EFRAG, 2025).

In this evolving context, the auditor is no longer merely a "validator" of financial information, but rather a *"guarantor" of the credibility of integrated reporting*, being responsible for assessing ESG (Environmental, Social, Governance) impacts and also for interpreting the decisions and implications of digital transformation (Deliu, 2024a).

This reconfiguration introduces a series of epistemological and ethical tensions. On the one hand, professional judgment (anchored in skepticism, discernment, and accumulated experience) remains the cornerstone of assurance engagements (Bogdan *et al.*, 2020; IFAC, 2022; Deliu, 2024b, 2025), particularly in safeguarding the public interest. On the other hand, autonomous algorithms and AI models, especially Agentic AI systems, introduce a new decision-making logic defined by speed, opacity, and adaptive, real-time predictive capabilities (McAfee & Brynjolfsson, 2017; Binns, 2018; Bornet *et al.*, 2024; Schreyer *et al.*, 2024; Abror *et al.*, 2025).

While conventional AI executes predefined instructions, Agentic AI adds operational autonomy: it can define its own objectives, adjust processes, and act proactively within data-driven contexts. This technological leap raises fundamental questions:

- *(RQ1): How can professional responsibility be maintained when decision-making is delegated to an algorithm?*
- *(RQ2): What expertise must auditors develop to effectively understand and evaluate autonomous models effectively?*
- *(RQ3): Is the ethics of auditing compatible with the decision-making autonomy of AI?*

In parallel, pressures related to climate change and social equity are expanding the notion of materiality from the financial sphere to *double materiality*, that is, reporting that considers both the impact on the entity and the entity's impact on the environment and society (EFRAG, 2024). This shift requires a holistic perspective and expanded competencies from financial auditors, who must be able to understand and validate qualitative, narrative, and complex information that cannot easily be quantified using traditional accounting indicators (Adams, 2020; Tiron-Tudor *et al.*, 2025b).

Against this backdrop, the present study investigates the interactions between professional judgment, sustainability, and Agentic AI in the reconfiguration of contemporary auditing. Its purpose is to outline a research agenda that can support the development of theoretical and methodological frameworks for financial auditing in the *Twin Transition* era. The main contributions of this article are:

- understanding the risks associated with delegating decisions to autonomous systems;
- redefining the professional competencies required of auditors in the Twin Transition era.

Rather than framing technology and professional judgment as opposing forces, the article advances the logic of constructive coexistence. The challenge is not whether auditors will be replaced by algorithms, but how

they can remain credible and relevant in an ecosystem where trust is grounded in digital transparency, sustainable accountability, and professional discernment.

The structure of the paper is as follows: The first section outlines the general context of the research, emphasizing the relevance of the Twin Transition phenomenon and the study's objectives. The second section examines the conceptual and normative foundations of the dual transition, highlighting the implications of digital and sustainability transformations for the auditing profession. The third section details the exploratory qualitative approach, the stages of the analytical process, and the methodological rationale. The fourth section presents the conceptual framework developed, which integrates the digital, sustainability, and professional dimensions into a new model of integrated financial auditing. The fifth section discusses emerging trends, theoretical and practical implications, as well as the ethical and epistemological challenges associated with this transformation. Finally, the last section synthesizes the conclusions and outlines directions for future research.

2. Background: Twin Transition – a new interpretive framework for the audit profession

The concept of *Twin Transition* refers to the intersection between digital transformation and the sustainability transition, two simultaneous and interdependent processes that are reshaping business models, value chains, and, consequently, auditing practices. According to the European Commission, this dual transition is essential for achieving the objectives of the European Green Deal and the EU's Digital Strategy (EC, 2025; ECEU, 2025).

From both an economic and professional perspective, the Twin Transition is not limited to the adoption of new technologies; it also requires the integration of environmental and social objectives into decision-making and reporting processes (Tiron-Tudor *et al.*, 2025a). For the auditing profession, this context redefines the auditor's role: moving from a compliance-focused verifier of financial statements to an arbiter of the credibility of integrated reporting, which encompasses both financial and non-financial indicators (KPMG, 2024; PwC, 2024).

2.1 Digital transformation: professional judgment vs. autonomous algorithms

Digital transformation in auditing involves the large-scale adoption of emerging technologies such as AI, BT, and BDA (Appelbaum *et al.*, 2017; Yoon *et al.*, 2021). These tools are fundamentally transforming audit methodology by:

– shifting from sample-based testing to full-population analysis of transactions;

– transitioning from retrospective audits to continuous auditing (Vasarhelyi *et al.*, 2018).

A significant technological breakthrough is represented by the rise of Agentic AI: autonomous systems capable not only of executing instructions, but also of defining objectives, planning actions, and dynamically adapting to changing contexts (Schreyer *et al.*, 2024). Unlike conventional AI, which responds to predefined inputs, Agentic AI has proactive capacities and can make decisions in complex and unstructured environments. Potential applications in auditing include:

– continuous monitoring of accounting transactions and the automatic initiation of investigations when anomalies are detected;

– dynamic adjustment of audit programs based on contextual changes (e.g., regulatory updates, macroeconomic fluctuations);

– aggregation and correlation of ESG data from diverse sources (internal reports, public databases, IoT sensors).

However, the integration of autonomous algorithms raises ethical, legal, and social challenges (Tiron-Tudor *et al.*, 2025a). Concerns include algorithmic opacity (the "black box" problem), systemic biases embedded in training data, and the lack of specific regulatory frameworks (Binns, 2018; Barredo-Arrieta *et al.*, 2020). These risks may undermine both reputational trust and legal accountability. In this context, professional judgment remains indispensable, particularly for:

- interpreting AI-generated outputs within the specific context of the audited entity (Deliu, 2024b);
- verifying the coherence and relevance of the underlying data (Deliu, 2025);
- ensuring compliance with ethical principles and auditing standards (ISA 200; IFAC, 2022).

Scholars stress that, despite technological progress, automation does not eliminate the need for professional judgment; instead, it transforms its very essence (Kokina & Davenport, 2017; Appelbaum & Nehmer, 2020; Deliu, 2024b). The auditor of the future must not only understand algorithmic logic but also acquire the ability to audit AI models themselves, beyond the financial data processed by such systems.

2.2 Sustainability transition: redefining professional competencies

The sustainability transition in auditing is driven by regulatory reforms and growing pressure from investors, regulators, and society for transparent disclosure of ESG performance. The adoption of the CSRD (EU 2022/2464) and the ESRS represents a decisive shift from voluntary reporting to a binding legal obligation to publish detailed information on environmental, social, and governance impacts (EFRAG, 2025).

These regulations institutionalize the principle of double materiality, requiring entities to disclose both how ESG factors influence financial performance (outside-in) and how organizational activities affect the environment and society (inside-out) (Adams, 2020). For auditors this entails:

- validating data that are often qualitative, narrative, and unstructured;
- ensuring the traceability and integrity of data sources;
- assessing the consistency between financial and ESG information.

Accordingly, auditors' professional competencies must be expanded (Deliu, 2024a,b; Tiron-Tudor *et al.*, 2025b) to encompass:

- technical expertise inf ESG standards and the EU taxonomy;
- advanced skills in analysing complex datasets, including the use of AI and BT for validation;
- understanding of climate-related risks and their financial implications;
- communication skills tailored to diverse stakeholder groups.

Thus, the Twin Transition not only reshapes the *scope* of the auditor's work but also redefines the *professional identity* itself, requiring a *hybrid profile* in which technological expertise, ESG competencies, and professional judgment coexist within an integrated framework.

3. Research methodology

This study adopts an *exploratory qualitative approach*, grounded in *a reflexive thematic analysis* of the academic literature and the recent regulatory framework, with the aim of identifying the interactions, synergies, and challenges arising from the convergence of digital transformation, sustainability, and the integration of emerging technologies – particularly Agentic AI – into financial auditing. Such a methodological choice is appropriate for fields in an early stage of theoretical and practical development, where empirical evidence remains scarce and knowledge depends primarily on conceptual analysis and expert interpretation (Saunders *et al.*, 2009; Creswell & Creswell, 2017).

The research process was structured into three main stages:

i. *Literature review* – a targeted analysis of academic studies published between 2015 and 2024, using the Web of Science, Scopus, and Google Scholar databases, alongside professional sources (ACCA, IFAC, EFRAG). Keywords included: "twin transition", "financial audit", "agentic AI", "ESG assurance", "sustainability reporting audit", and "AI in auditing".

ii. *Regulatory and professional framework analysis* – examination of European directives (CSRD, ESRS), international auditing standards (ISA), IFAC guidelines, and recommendations issued by professional bodies (CAFR, PCAOB, IAASB), in order to assess the implications of the Twin Transition for the auditor's role, tasks, and competencies.

iii. *Conceptual analysis and synthesis* – development of an integrative framework mapping cause-effect relationships and interdependencies between digital transformation, sustainability transition, and professional judgment, while simultaneously highlighting risks and opportunities.

The analysis was carried out using the method of thematic synthesis (Thomas & Harden, 2008), by coding the extracted information and grouping it into four main themes (**Table no. 1**).

Given the emergent nature of the field, this research combined a document-based review with the author's reflexive analysis (Schwandt, 1994; Denzin & Lincoln,

2008). Within this interpretive paradigm, the researcher's role extends beyond data collection and synthesis to the critical interpretation of meanings and connections, informed by professional expertise and contextual understanding of financial auditing.

Table no. 1. Themes and subthemes identified in the literature

Themes	Subthemes
Technology and Agentic AI in auditing	automation; algorithmic decision-making; continuous auditing; sustainability auditing – ESG indicator validation; double materiality
Role of professional judgment	professional skepticism; ethics; governance
Risks and challenges	algorithmic bias; AI opacity (black box problem); lack of adapted standards
Strategic opportunities	ESG traceability; operational efficiency; innovation in audit procedures

Source: author's projection

This methodological choice is justified by:

- *Complexity of the subject* – the interplay between auditing, technology, sustainability, and governance requires a flexible approach capable of capturing subtle nuances and multiple interdependencies;
- *Lack of a stable theoretical framework* – in the absence of consolidated theories, it is necessary to construct a conceptual model grounded in heterogeneous sources;
- *Need for depth* – the aim is not the statistical validation of hypotheses but rather the in-depth exploration of relationships and tensions among dimensions.

Through this reflexive approach, the study captures more than the explicit elements of literature and regulation, respectively it highlights the implicit meanings and emerging directions for research, thereby providing a solid foundation for drawing conclusions and developing a future research agenda.

4. Results: Conceptual framework – a new model of integrated financial auditing in the Twin Transition era

Recent literature emphasizes that digitalization and sustainability are not parallel trajectories but convergent processes, whose points of intersection are increasingly evident in ESG auditing (Asante-Appiah & Lambert, 2023; KPMG, 2024; PwC, 2024; Cheng & Li, 2025). Technologies such as BT can ensure the traceability of green certificates and supply chains, while Agentic AI systems enable the analysis of massive datasets on emissions, resource consumption, or organizational diversity, identifying patterns and correlations difficult to detect through traditional human analysis (Deliu, 2024a).

This integration transforms the Twin Transition from a macro-political concept into an *operational catalyst* for the emergence of an *integrated financial auditing model*, where technology becomes a strategic partner of professional judgment and sustainability consolidates its role as a central pillar of assurance.

The model in **Figure no. 1** illustrates the interdependence of the two dimensions of the Twin Transition and how they converge toward a professional core grounded in skepticism, discernment, and ethics.

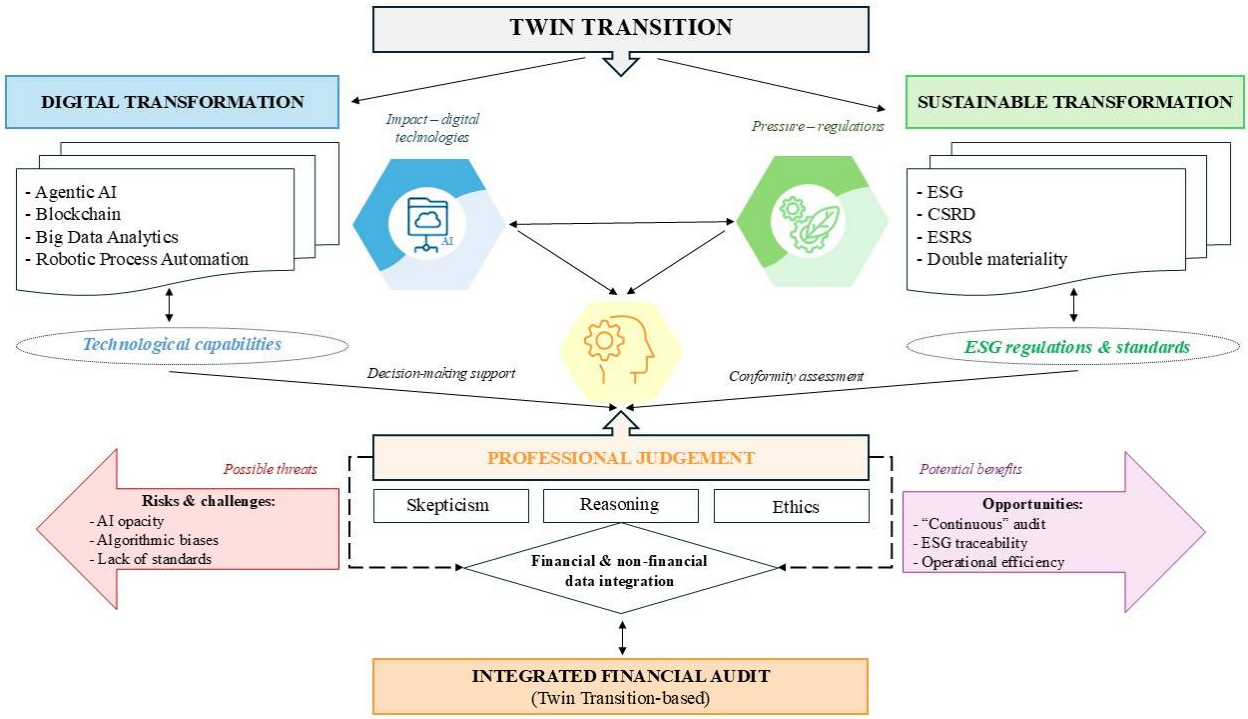
I. Digitalization dimension – technological capabilities and decision support

a. Technologies such as Agentic AI, BT, BDA, and RPA provide *advanced decision support*, enhancing auditors' ability to perform predictive analyses, detect anomalies in real time, and implement *continuous auditing*.

b. *Agentic AI* introduces an *additional layer of operational autonomy*, dynamically adjusting audit processes in response to contextual changes, thereby reducing reaction times and optimizing the prioritization of procedures.

c. This dimension directly improves *operational efficiency* through rapid *integration of multi-source data* (e.g., unstructured data, IoT), but also raises challenges of interpretability and control.

Figure no. 1. Conceptual framework - Model of integrated financial auditing in the Twin Transition era



Source: author's projection

II. Sustainability – normative pressure and compliance evaluation

a. Regulations such as CSRD, ESRS, and the EU taxonomy mandate detailed ESG reporting, in line with the principle of double materiality.

b. Auditors must verify not only the accuracy of financial data but also the coherence, traceability, and integrity of non-financial information, including qualitative and narrative data.

c. The dynamic nature of this regulatory framework demands continuous professional development, interdisciplinary competencies, and adaptation of audit methodologies.

III. Professional judgment – the integration node

a. Serves as the central pivot of the model, anchored in three pillars: skepticism, discernment, and ethics.

b. Mediates between algorithms and final audit decisions, filtering, interpreting, and validating information generated by both traditional sources and autonomous algorithms to ensure relevance and credibility.

c. Enables coherent integration of financial and non-financial data; yet, without robust professional judgment, the risk of accepting algorithmic biases or errors increases significantly.

d. Protects the public interest through critical evaluation of outcomes produced by digital technologies.

IV. Risks and challenges – potential threats

a. AI opacity (black box problem) – difficulty in explaining the logic behind algorithmic decisions.

b. Algorithmic bias and indirect discrimination – systemic errors embedded in training data or model design.

c. Absence of specific standards for auditing AI models and ESG disclosures, highlighting the need for AI auditing protocols and the extension of ISA standards into emerging domains.

V. Strategic opportunities – potential benefits

a. Continuous auditing and proactive monitoring.

b. ESG traceability through BT.

c. Operational efficiency and reduced reporting times.

The proposed framework demonstrates that an integrated financial audit model based on the Twin Transition is not simply an incremental adaptation, but a paradigm shift.

In the *short term*, adoption of this model requires: (i) investment in digital and ESG training for auditors; (ii) adaptation of auditing standards to new technological and reporting realities; (iii) development of methodologies for evaluating Agentic AI systems and BT infrastructures used in auditing.

In the *long term*, this framework can serve as a foundation for applied research on AI governance, the integration of double materiality into auditing, and the procedural design of continuous auditing.

5. Discussion: emerging trends, implications, and ethical-epistemological challenges in financial auditing

The findings confirm that the Twin Transition – the convergence of digital transformation and the sustainability transition – is not a marginal development for the auditing profession, but a *structural process* that profoundly reshapes audit methodologies, professional responsibilities, and the technological infrastructure of assurance. The rise of Agentic AI serves as a *catalyst* for this transition, introducing a level of decision-making autonomy unprecedented in the history of auditing, while at the same time increasing pressure on regulatory frameworks and professional ethics.

Within this context, the proposed conceptual framework demonstrates that transformation does not occur through isolated adjustments, but through a *network of interdependencies* between technological capabilities, normative requirements, and professional judgment, where risks and opportunities coexist in a dynamic balance.

5.1. Emerging trends in financial auditing and future research directions

The analysis of the proposed framework highlights five major trends that are shaping the evolution of financial auditing in the Twin Transition era (**Table no. 2**).

This analysis also identifies several future research directions (**Table no. 3**).

The evolution of financial auditing cannot be dissociated from the broader dynamics of digitalization and global sustainability objectives. In this context, the proposed directions are not only theoretical themes but also represent the practical agenda of the auditing profession for the coming decade.

Table no. 2. Emerging trends in financial auditing under the Twin Transition

Trend	Causes	Effects & implications
1. Integration of Agentic AI in audit processes	Agentic AI transforms auditing from a retrospective, periodic activity into a proactive and continuous process, capable of initiating procedures based on automatic detection of anomalies or contextual changes (e.g., legislative or market shifts).	– increase in operational efficiency; – reduction of response times, but also the emergence of dilemmas regarding decision-making opacity; – algorithmic bias; – attribution of responsibility in case of errors.
2. Expansion of sustainability auditing	Implementation of CSRD and ESRS expands the auditors' mandate beyond verifying financial statements to include ESG indicator validation and the application of double materiality (outside-in and inside-out).	– the need to acquire new competencies (climate impact analysis, social risk assessment, validation of qualitative data); – interdisciplinary collaboration with experts in environment, governance, and social sciences;

3. Recalibration of professional judgment	In an ecosystem dominated by autonomous technologies and sustainability reporting pressures, professional judgment becomes the primary safeguard for quality assurance and the critical filter for algorithmic output.	– auditors must combine professional skepticism with technical understanding of AI models, including notions of AI auditing and algorithmic interpretability.
4. Emergence of integrated audit ecosystems	The merging of financial, sustainability, and technological audits generates integrated platforms for data collection, analysis, and reporting.	– enhanced operational efficiency, but also increased complexity of governance, data security, and system interoperability.
5. Focus on traceability and digital transparency	BT and Distributed Ledger technologies are becoming foundational infrastructures for ensuring the integrity and traceability of both financial and non-financial data.	– strengthening public trust in integrated reporting, but also the necessity to audit these very digital infrastructures themselves.

Source: author's projection

Table no. 3. Future research directions

Research direction	Context
1. Algorithmic auditing and ethical responsibility	– investigation of responsibility-sharing models between the auditor and autonomous systems in cases of erroneous decisions.
2. Standardization of sustainability auditing	– development of unified methodological frameworks for ESG indicator validation, applicable across multiple industries and jurisdictions.
3. Competence mapping for the auditor of the future	– identification of the hybrid skill set (financial, technological, sustainability-related) required in an integrated audit environment.
4. AI interpretability methods applicable in auditing	– development of explainable AI (XAI) models to increase transparency in automated decision-making processes.
5. The impact of the Twin Transition on audit quality	– empirical studies measuring the effects of digital and sustainable transformation on audit effectiveness and trust.
6. Frameworks for continuous auditing	– research into operational models that combine real-time monitoring with reporting in line with international standards.

Source: author's projection

5.2. Theoretical and Practical Implications

5.2.1. Theoretical Implications: A Paradigm Shift in Auditing

From a theoretical perspective, the findings point to an ongoing paradigm shift. Whereas traditional financial auditing was anchored in a post-factum logic (i.e., the retrospective verification of accounting information for a closed period), the combined pressures of digitalization and sustainability are pushing the profession toward proactive and continuous auditing (continuous assurance) (Chan *et al.*, 2018). Therefore:

- Digital transformation alters the epistemological foundations of auditing: moving from sample-based testing to full-population, real-time data analysis (Vasarhelyi *et al.*, 2015).
- Agentic AI introduces a new dimension: the algorithm's ability to prioritize, sequence, and dynamically adjust audit procedures based on contextual data (Omoteso, 2012).
- Sustainability embeds the principle of double materiality, requiring the simultaneous evaluation of financial impacts on the entity and the entity's impacts on the environment and society (EFRAG, 2023).

From an epistemological standpoint, this context challenges traditional assurance models (Power, 2004). Thus, audit theory, historically grounded in objectivity, skepticism, and documentary verification, must now

integrate: concepts from data science and AI, principles from algorithmic ethics, and ESG governance frameworks and impact assessment methodologies.

This interdisciplinary integration lays the foundation for a unified conceptual framework in which financial and non-financial data are treated as inseparable components of the same validation process.

5.2.2. Practical Implications: Recalibrating the Auditor's Role

The results also reveal major practical shifts in auditing:

- *Expanding the competency set*

The modern auditor must combine accounting expertise with data analytics, ESG literacy, and AI knowledge (Tiron-Tudor *et al.*, 2025b). Traditional training must therefore be complemented with modules on BDA, ML, algorithm interpretability (Explainable AI – XAI), and ESG indicator validation. According to ACCA (2025), hybrid skills will be the key differentiator between relevant and marginalized auditors.

- *Adoption of integrated auditing*

The Twin Transition drives the convergence of financial, sustainability, and technological auditing, leading to the creation of integrated audit ecosystems. Within these ecosystems, digital platforms simultaneously manage financial, non-financial, and technical data flows, ensuring traceability and coherence.

- *Changing the auditor-client interaction model*

Auditing will no longer be an annual event but a continuous process of monitoring, dialogue, and feedback. Agentic AI can directly interact with client systems, issuing real-time alerts and recommending corrective actions before issues materialize.

5.3. Ethical and epistemological challenges. Gaps between technological and normative dynamics

This transformation raises pressing ethical challenges on three levels:

i. *Delegation of decision-making to algorithms* – Who bears responsibility for an audit conclusion or opinion generated (wholly or partly) by an autonomous algorithm? In the absence of clear regulation, accountability risks becoming fragmented (Martin, 2019).

ii. *Opacity of AI models* – Complex models such as Deep Neural Networks may deliver high performance but operate as "black boxes", limiting auditors' ability to validate algorithmic reasoning (Doshi-Velez & Kim, 2017).

iii. *Algorithmic bias* – Historical datasets often contain systemic biases which, once learned by AI, are perpetuated or amplified. In auditing, this could lead to discriminatory or erroneous conclusions with severe ethical and legal implications (Pizzi *et al.*, 2020).

A further key finding is the gap between the exponential pace of technological innovation (AI, BT, RPA) and the relatively slow adaptation of auditing standards and ESG regulations. *This asymmetry produces a regulatory vacuum*, in which practitioners adopt technological solutions before appropriate standards exist, potentially undermining consistency, comparability, and public trust in audit reports.

In conclusion, the future of financial auditing is not defined by a binary choice between professional judgment and autonomous algorithms, but by their *critical integration into a unified framework*. Professional judgment remains the ultimate interpretive filter, safeguarding public interest and ethical principles. Agentic AI serves as the engine of efficiency, processing vast datasets and uncovering patterns beyond human capability. The sustainability dimension introduces the moral and societal obligation to assess long-term impacts of economic activity, beyond short-term financial performance. Thus, the Twin Transition is not only reshaping auditing methods and tools but redefining its very mission: shifting from the verification of compliance to the assurance of trust in global corporate governance.

6. Conclusions

This study has shown that the Twin Transition constitutes a structural process that is fundamentally transforming the foundations of financial auditing. The introduction of Agentic AI amplifies this transformation, offering unprecedented opportunities in terms of efficiency and accuracy, while also raising complex challenges related to ethics, governance, and professional accountability.

On the one hand, digital transformation is shifting the logic of auditing from retrospective verification to continuous monitoring, based on exhaustive data analysis and adaptive algorithmic decision-making. On the other hand,

the sustainability transition, reinforced by the implementation of the CSRD and ESRS, extends the scope of auditing to the evaluation of ESG impacts and the application of the principle of double materiality, demanding new skill sets from auditors. Within this context, professional judgment remains an essential anchor of the audit process, but it must be recalibrated to include both the interpretation of algorithmic models and the evaluation of non-financial information. Agentic AI emerges as a strategic enabler, yet one that requires clear standards of transparency, auditability, and accountability.

This paper proposes an integrated conceptual framework that maps the interdependencies among three fundamental dimensions – professional judgment, sustainability, and autonomous algorithms – within the Twin Transition. The model clarifies the epistemological and ethical tensions between algorithmic autonomy and human responsibility, while also highlighting synergies and the potential for constructive coexistence between technology and professional judgment. It further suggests a research agenda centered on standardization, hybrid competencies, and AI interpretability.

The analysis also reveals important implications for both practice and public policy. Auditing professionals must rapidly adapt to an interdisciplinary skill profile, while their continuous education should include domains such as BDA, AI ethics, and ESG governance. For regulatory bodies, it is imperative that legislative developments keep pace with technological evolution by establishing standards that regulate both sustainability auditing and the auditing of algorithms.

Future research may explore longitudinal case studies, evaluate the real impact of autonomous technologies on audit quality, and test the applicability of the proposed framework across different contexts (jurisdictions, industries).

The central finding of this study is that financial auditing in the Twin Transition era cannot be understood as a simple adaptation of existing practices, but rather as a profound redefinition of the profession's mission – shifting from validating financial compliance to guaranteeing the credibility of integrated information within a complex, global, digital, and sustainability-oriented ecosystem.

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The Role of ERP Systems and of Artificial Intelligence in Auditing Organizational Sustainability and Progress

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Abstract

The intersection of digital technologies and sustainability has become very important for researchers and practitioners as a result of the expansion of the phenomenon of artificial intelligence (AI) and digitalization. Integrated ERP systems and technologies based on artificial intelligence (AI) offer both operational efficiency and specific activities that support the achievement of sustainability objectives by organizations, ensuring transparency in data reporting and effectiveness in the implementation of audit processes.

The authors aimed to analyze the impact of ERP systems and artificial intelligence (AI) in sustainability auditing and how they contribute to organizational progress using a quantitative analysis method based on a bibliometric analysis focused on keywords such as: "ERP systems", "sustainability audit", "artificial intelligence" and "corporate reporting".

The results obtained by the authors emphasize the importance of digital ecosystems by using ERP system platforms that have embedded AI functionalities to considerably improve audit quality, regulatory compliance, and stimulate sustainable and responsible behavior of organizations, finding that technology can have a significant impact on the field of sustainability.

Key words: *ERP systems; sustainability audit; artificial intelligence; corporate reporting;*

JEL Classification*: M40, M42, Q20, Q28*

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Introduction

The increased focus on adopting sustainable practices by organizations has fundamentally changed the way corporate performance can be measured, audited and reported, driven by the growing interest of stakeholders (e.g. investors, regulators, consumers and society) in transparency, accountability and measurable progress against environmental, social and governance (ESG) criteria.

Data processing using ERP systems and artificial intelligence helps organizations capture, analyze and validate data to facilitate the most accurate reporting of sustainability issues while ensuring compliance with international standards and providing a complete view of the impact on the social environment. The accuracy and traceability of data processed by these systems are essential to the audit process, reducing the risk of errors as much as possible.

Tools based on artificial intelligence can identify inconsistencies and make various forecasts of the organization's future performance trends.

The aim of the article is to analyze the intersection of ERP systems, artificial intelligence and sustainability auditing using bibliometric analysis, allowing for the systematic mapping of research trends and the exploration of conceptual clusters that underlie the definition of the three concepts. The information presented in this article is useful for:

1. organizations that want to align their technology investments with sustainability strategies, mitigating risks and strengthening stakeholder trust
2. decision-makers and regulators

The article is structured as follows: a section dedicated to the specialized literature with the aim of highlighting the main bibliographic resources that deal with the same topics as the present article, a section dedicated to presenting the research method chosen by the authors, a section dedicated to analyzing the results obtained based on the analysis performed and a section dedicated to presenting the conclusions of the article.

Literature review

Research by other authors has indicated that the intersection between ERP systems and sustainability is in continuous evolution, with particular emphasis on how ERP systems support or hinder the achievement of sustainability goals set by organizations (Chofreh, Goni, and Klemes, 2018; Chofreh et al., 2019).

Although artificial intelligence components integrated into ERP systems bring numerous benefits, costs and workforce training remain substantial obstacles (Dumitru et al., 2023).

However, the implementation of ERP systems significantly enhances the improvement of the quality and integrity of reports, but the dispersed storage of information across departments, data manipulation by the IT department could undermine audit clarity and control (Kanellou and Spathis, 2009). It should also be taken into account that artificial intelligence can allow for the identification of anomalies, the creation of summaries of voluminous documents, allowing for the cross-checking of statements with reports (Appelbaum et al., 2017; Boiral et al., 2021).

Even though artificial intelligence (AI) can significantly contribute to the well-being of employees, especially the organization in general, the environmental and societal costs that may arise must be taken into account (Kumar et al., 2024).

Authors such as Cohen (2020) and Ren (2024) confirmed in their articles that artificial intelligence (AI) allows text extraction from documents processed using ERP systems. ERP systems thus support managerial decisions and non-financial reporting with an emphasis on sustainability (Hawking and Sellitto, 2019; Kumar and Van Hillegersberg, 2021).

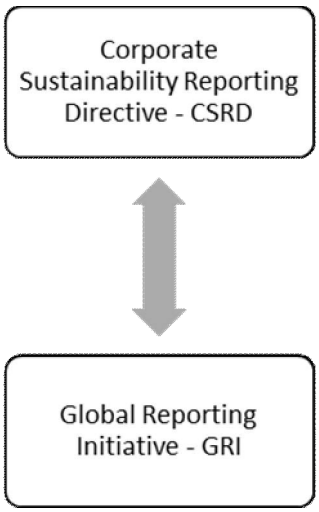
Nguyer et al. (2022) believe that the integration of artificial intelligence into ERP systems "makes predictive analysis, automation of repetitive processes and monitoring of ESG indicators in real time possible".

ERP systems constantly contribute to the collection and reporting of data related to energy consumption, carbon emissions or logistics efficiency (Molla and Abareschi, 2020). The data in these reports is essential and must be presented according to European and international regulations shown in **Figure no. 1**.

Kraus et al. (2022) consider the integration of digitalization into sustainability reporting as a condition for *"competitiveness and access to international markets"*.

According to Appelbaum et al. (2020), separating the collaboration between accounting professionals and IT experts would make it difficult to implement an effective sustainability audit.

Figure no. 1. European and international regulations



Source: La Torre et al., 2020

However, the authors of this article recommend that organizations form multidisciplinary teams that understand both accounting logic and the mechanisms of AI and ERP technologies, which indicates the transformation of academic curricula in the field of accounting and auditing to allow the development of new digital skills.

Research methodology

This article aims to use a quantitative research method focused on bibliometric analysis, with the aim of investigating the role of ERP systems and artificial intelligence in accounting and auditing, tracking organizational progress. The role of bibliometric analysis is to map the intellectual structure of a field or area of research, identifying emerging trends and quantifying scientific productivity.

Figure no. 2. Web of Science categories in which the selected articles are published

Source: Web of Science, 2025

The selection of Web of Science articles was carried out on August 26, 2025 based on the keywords *"ERP systems", "sustainability audit", "artificial intelligence"* and *"corporate reporting"*, returning 17,390 articles. The results obtained were refined using the logical operators AND and OR over a time interval between 2015 and 2025. The reason for choosing this interval was the massive and rapid expansion with which ERP systems and artificial intelligence have developed in relation to sustainability. The Web of Science categories in which the selected

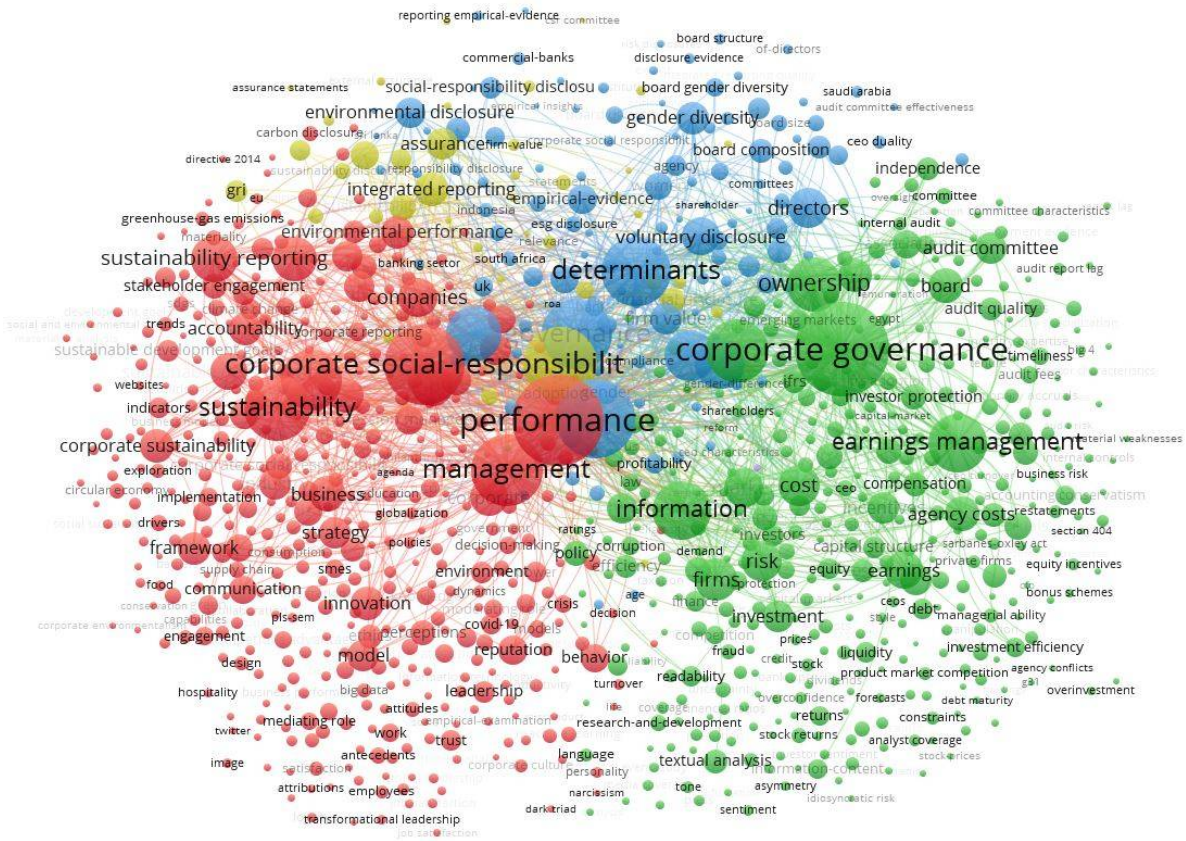
articles were published are those shown in Figure no. 2, most of which are found in the *Business Finance*, *Management* and *Business* categories.

The tool used for the analysis was VOS viewer, performing a co-keyword analysis, identifying the frequency and thematic association of keywords such as *"ERP systems", "artificial intelligence"* and *"sustainability"*.

Results analysis

The results obtained using the VOS viewer application are presented in Figure no. 3, also identifying 6 keyword groups (clusters) presented in detail in Table no. 1.

Figure no. 3. Analysis of selective Web of Science articles (relationship Co Occurrence – All keywords)



Source: Authors' contribution, 2025

Table no. 1. The 6 clusters identified by the authors in Figure 3

Cluster 1 Color: Red *433 elements*	Cluster 2 Color: Green *383 elements*	Cluster 3 Color: Blue *124 elements*
• corporate social responsibility • performance • sustainability • management	• corporate governance • ownership • earnings management • information	• determinants • governance • directors • board composition

Cluster 4 Color: Yellow *42 elements*	Cluster 5 Color: Purple *2 elements*	Cluster 6 Color: Turquoise *1 element*
• integrated reporting • assurance • GRI • environmental disclosures	• heterogenity • quantile regression	• Thailand

Source: Authors' contribution, 2025

Cluster 1 (red) focuses on the topic of *"Corporate Responsibility and Sustainability"*, indicating that the implementation of ERP systems and artificial intelligence are supporting tools to provide transparent and valid data.

Cluster 2 (green) presents concise information on *"Corporate Governance and Financial Management"*, more precisely focusing on how processed data is managed and reported. Thus, the integration of ERP systems and artificial intelligence in an organization automates financial flows, reducing as much as possible the risk of manipulation of accounting information.

Cluster 3 (blue) focuses on *"Determinants and Governance Structures"*, where ERP systems and artificial intelligence are considered essential determinants that ensure organizational progress and compliance with accounting legislation and auditing.

Cluster 4 (yellow) considers the development of the concepts of *"Integrated Reporting and International Standards"*, verifying how these technologies (ERP systems and artificial intelligence) automate reporting so that it is carried out in accordance with international standards, allowing for the reduction of costs and errors.

Cluster 5 (purple) addresses *"Statistical and methodological models"* indicating the main models of advanced quantitative analysis in studying sustainability, such as heterogeneity and quantile regression.

Cluster 6 (turquoise) focuses on regional differences in the adoption of ERP systems and artificial intelligence in sustainability reporting.

However, if we were to consider the keywords in **Figure no. 4**, the authors consider the red cluster to be focused on the relationship between social responsibility and organizational performance. The green cluster indicates the relationship between corporate governance and information asymmetry in accounting and reporting studies, and the merger with the blue cluster suggests increased attention to be paid to the structure of boards of directors.

The authors state that corporate governance and auditing reduce opportunistic behaviors as much as possible, limiting the manipulation of financial results.

According to **Figure no. 5**, the green cluster indicates the maturity of the research addressed on corporate governance with the aim of protecting investors, limiting opportunistic behaviors as much as possible.

Conclusions

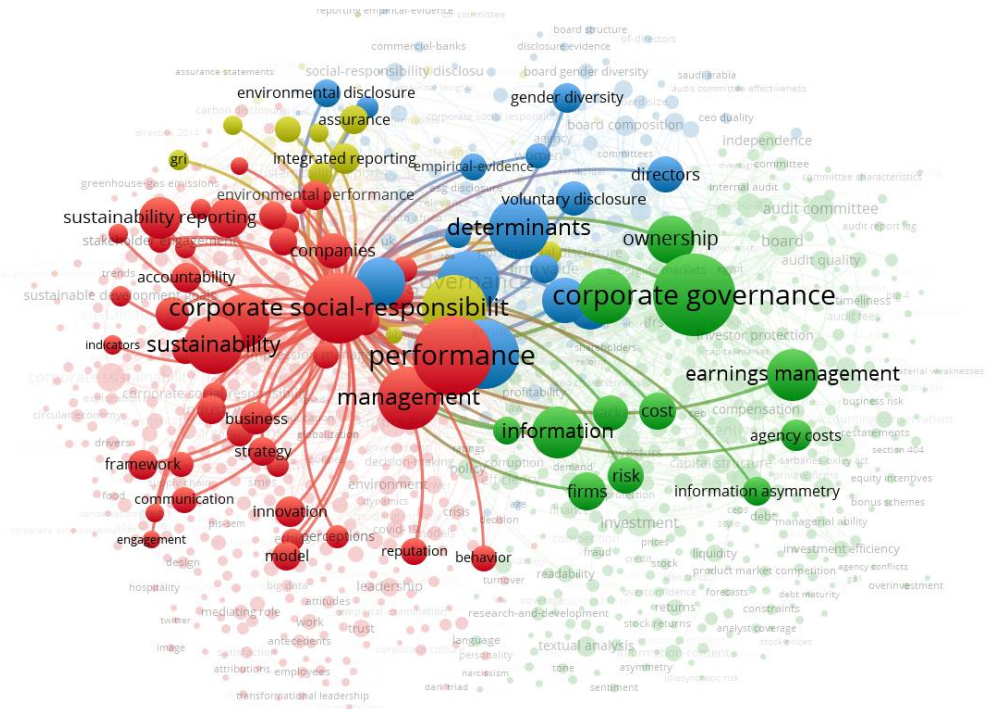
This article aims to analyze how ERP systems and artificial intelligence contribute to improving the sustainability audit process, so as to enable organizational progress. The results obtained from the research highlighted two essential relationships: *sustainability – corporate social responsibility* and *corporate governance – financial performance management*, which responds to regulatory pressures, stakeholder requirements, as well as accelerated technological development.

As mentioned in this article, ERP systems and artificial intelligence are decision-making support tools due to the accuracy, completeness and transparency of data. Thus, the risks of erroneous reporting are diminished, while increasing the trust of stakeholders in the information published by organizations.

The authors identified in the literature that artificial intelligence is considered a catalyst for transformation (e.g., automation of repetitive processes, generation of predictive insights) in order to identify risks and support decision-making within organizations, but also to develop responsible behavior by integrating ESG principles into the organization's strategy.

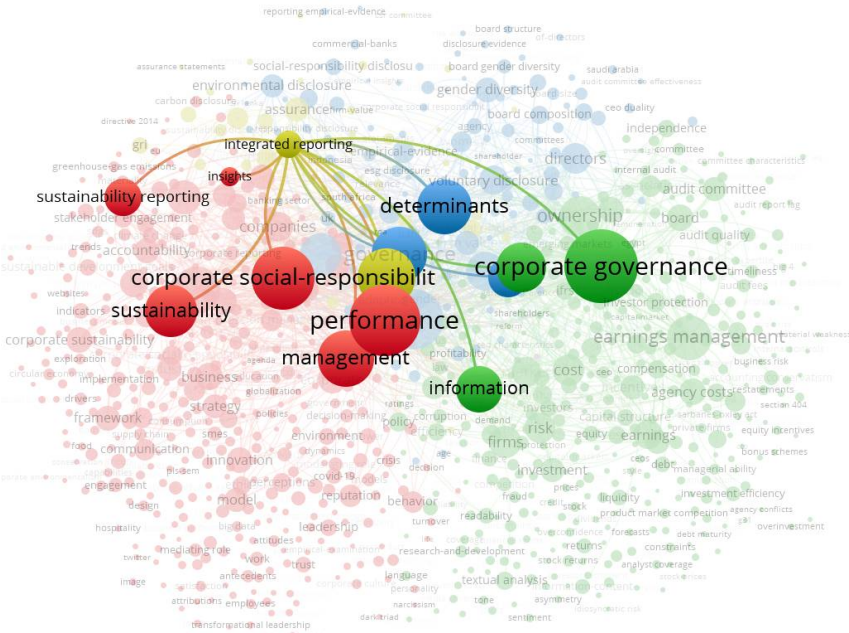
The main limitations of this article are that it focuses on existing literature, highlighting the current state of research. Therefore, further studies should be conducted to reveal the effectiveness of ERP systems and artificial intelligence in sustainability auditing for organizations.

Figure no. 4. The relationship between word groups in the red, green, and blue categories



Source: Authors' contribution, 2025

Figure no. 5. Analysis of the connection between the concepts of "Corporate social responsibility", "Corporate governance" and "Performance"



Source: Authors' contribution, 2025

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Fraud Detection through Emerging Applications – AI Agents

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Abstract

Audit procedures are constantly evolving from the initial stage of sampling and fully human reasoning to that of automation and digitized processing of financial and accounting information. These transformations, however, are of a dual nature: on the one hand, advanced technologies for collection, processing and reporting are emerging, and on the other hand, the volume of information created by digitalization is unprecedented, requiring constant and real-time monitoring of audited transactions. This is the reason why fraud detection is becoming a complex task, in a vicious circle in which new computerized work tools are becoming indispensable in the analysis of targeted processes where technologies of the same nature have sophisticated them to a level that is difficult to audit by traditional or obsolete methods. The exponential increase in the volume of data within contemporary organizations facilitates complex fraud schemes of financial systems, which makes the auditor look for adapted solutions to detect them. This study analyzes how artificial intelligence agents redefine the processes of detecting anomalies in transactions or financial statements, thus transforming themselves into reliable tools in carrying out audit missions.

Key words: *AI agents; digital audit; financial fraud; deep learning; machine learning;*

JEL Classification: *M1, M2, M4, O3*

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1. Introduction

Organizations are facing a major risk, associated with fraudulent activities that can undermine their market reputation, financial health, and the legitimacy of their business (Kranacher, Riley, & Wells, 2011). Favoured by a globalised economic environment, complex taxation, unprecedented cross-border mobility and the acceleration of digitalization, detecting and combating fraud is becoming a persistent and costly challenge that seriously limits traditional methods of detection and combating. The classic audit, based on physical inspections, manual or documentary verifications, becomes inefficient and is even annihilated by the complexity and ingenuity of the new methods of embezzlement and law avoidance.

ISA Standard 240 on the auditor's responsibility to consider fraud and error in an audit of the financial statements clarifies the identification of material misstatements in the financial statements. According to this rule, a distinction must be made between ***mistake*** as "unintentional misrepresentation" and ***fraud*** as "intentional action (...) involving the use of deception for the purpose of obtaining an unfair or unlawful advantage'. At the same time, frauds are classified into "misstatements arising from financial reporting" and "misstatements from embezzlement of assets", the role of the auditor being to identify and assess the related risks through a complete documentation and analysis regarding the objectives of the mission. Within this standard, reference is made to how emerging technologies can pave the way for an audit adapted to a digitalised environment. Thus, ISA 240 recognizes the key role of information technologies during the processes of identifying and assessing fraud risks and emphasizes the importance of adopting an "appropriate level of responsibility and preparation" on the part of auditors, in the context of rapid technological evolution and the increased complexity of the business environment (IASB, 2025).

This article explores the transformative potential of artificial intelligence (AI) agents in the field of financial auditing, with a focus on fraud detection capabilities. The paper starts with an analysis of the evolution of audit processes and the limitations of traditional methods in the face of complex fraud schemes and large volumes of data. Subsequently, the key AI techniques and technologies used in fraud detection are investigated, as well as the benefits and challenges associated with their implementation. Working models related to the audit requirements of ISA Standard 240 are suggested and a relevant case study on the successful application of AI technologies in fraud prevention and detection in the banking sector is described. The article concludes with discussions regarding the ethical implications and the need for regulation of this innovative sector, but also with an insight into possible future trends in the field.

2. Research Methodology

The general purpose of the research is to analyze and evaluate the applicability of AI agents in improving the fraud detection process in financial auditing. The following specific objectives were considered:

- Identifying the main AI technologies used in fraud detection.
- Analysis of the benefits and limitations of implementing AI agents in auditing.
- Assessing the impact of AI agents on the efficiency and quality of the audit process.
- Explore the ethical and regulatory implications associated with the use of AI agents in auditing.

This paper uses a qualitative approach, based on an extensive documentary analysis and a synthesis of the literature. Case studies, academic articles, industry reports, and audit regulations were examined to gain relevant insight into the topic.

The selected data sources are summarized in: International Standards on Auditing (ISA), academic articles from databases such as JSTOR, IEEE Xplore, ScienceDirect, Google Scholar, websites or reports of consulting companies and research organizations.

The data analysis was based on:

- **Content processing:** the selected documents were analyzed to identify recurring themes, key arguments, perspectives and examples relevant to the research objectives.
- **Synthesis of the literature:** the results of different studies and sources have been integrated with the aim of building a coherent and comprehensive picture of the role of AI agents in financial auditing.
- **Comparative analysis: the** approaches, benefits, and limitations of different AI technologies and implementations in fraud detection were compared.

- **Critical analysis:** the arguments and evidence presented in the selected sources were evaluated, identifying strengths, weaknesses and possible gaps or contradictions.

3. Literature Review – Definitions and Ambiguities

Sophisticated fraud schemes as well as the increasing complexity of financial transactions put significant pressure on auditors (Corbett et al., 2019) requiring new detection and combating solutions. The digitalization of audit processes started in force in the 2000s with the introduction of information technologies that integrated data analysis and reporting applications, reducing time and specific human errors.

Although the development in recent years of information solutions dedicated to the analysis of financial-accounting data (*Enterprise Resource Planning* – ERP, for example) is obvious, the increasing complexity of fraud schemes required a different approach. Traditional methods based on standard sampling and checks, with predefined rules and static control rules (Kranacher et al., 2019) have proven to be costly and time-consuming. Due to the exhaustive examination of each transaction or document in the context of large volumes of data, the effectiveness of such models is annihilated in the face of innovative or adaptable fraud systems. Thus, the need for intelligent solutions has increased, capable of analyzing considerable amounts of information, detecting patterns and monitoring financial indicators and transactions in real time.

From the analysis of the research on the topic addressed, it emerges that the adoption of artificial intelligence technologies in audit procedures is based on 4 pillars (Kokina & Blanchette, 2020):

- **Automation:** The ability to analyze large volumes of data in real-time reduces reliance on manual activity.
- **Adaptive learning:** Machine learning models can identify complex and evolving patterns that fixed rules can't capture.
- **Proactive detection:** Intelligent systems can alert the auditor in real-time to suspicious activity, providing a preventive rather than reactive approach.
- **Scalability:** New technologies handle large volumes of data and can be applied in various sectors and fields, making them easy to expand.

In the analysis of financial data, artificial intelligence agents redefine decision-making and operational roles, interpret the context in which transactions take place and seek/apply adapted solutions in real time. The integration of artificial intelligence agents where such an operation is feasible, is based on the rationale of reinvigorating the work tools necessary for fraud detection through greater accuracy and speed (Fanning & Cogger, 2020). Thus, the definitions attributed to these intelligent systems are conceptually close and identify common roles or techniques:

- According to Russell and Norvig (2016), AI agents are autonomous systems that understand context, can make decisions, and act independently to achieve specific goals. The authors define an AI agent as "an entity that perceives the environment, uses processed information to reason and plan its actions to achieve its goals" (Russell & Norvig, 2016, p. 20).
- At the same time, Luger (2020) expresses his opinion, considering AI agents as "logical or software entities, capable of observing the environment, analyzing data and behavioral adaptation to perform tasks, autonomously" (Luger, 2020, p. 45).
- Poole and Mackworth (2010) also state that "an artificial intelligence agent is an intelligent entity that perceives the environment, learns from previous experience, and responds adaptively to achieve its goals" (Poole & Mackworth, 2010, p. 33).
- The Gartner study, published in June 2025, conducted on the advisability of using AI agents, defines these systems as autonomous or semi-autonomous software entities that use artificial intelligence techniques to carry out or make decisions, to act and to achieve precise objectives in a specific physical or digital environment (Gartner, 2025)

However, Gartner's analysis draws attention to the risk of confusion in the terminology used, in particular, by providers of AI-based solutions, in particular between the notions of 'AI agents', 'agent AI' and 'AI assistants'. The phrase "agent AI" covers the range of AI-based solutions that are composed of one or more "software entities that are classified, in whole or in part, as AI agents". AI assistants are "specialized applications or modules in a larger system that incorporate artificial intelligence technologies and perform tasks" at the request of a human factor, through a conversational interface. If the literature considers AI agents to be clearly defined notions

with a precise role within organizations, practice shows that, for reasons related to marketing and sales objectives, a conceptual abuse is made in terms of related terms. Beyond possible ambiguities in the definition, an abusive and unfounded promotion of terminology can give rise to confusion or uncertainty for those interested in acquiring and implementing such systems. This is why Gartner suggests a glossary of terms and outlines a framework for the practical application of AI tools (Gartner, 2025).

This article addresses the notion of "AI agents" in terms of the listed distinctive characteristics – autonomy, perception, adaptive learning and action – in order to demonstrate the applicability in the field of financial audit on the following main directions:

Automating repetitive processes and big data

In the context of high volumes of digital transactions, documents, and communications, AI agents automate accounting checks, data reconciliation, and the detection of potential inconsistencies, thereby reducing the time required and the risk of human error (Russell & Norvig, 2016).

Fraud and Anomaly Detection and Prevention

According to Luger (2020) and Poole and Mackworth (2010), AI agents learn from the perceived environment and can recognize complex, emergent or invisible schemes for traditional algorithms, which, in an audit, favors the automatic identification of suspicious activity and fraud. Machine learning algorithms detect fraud patterns, even in unstructured data such as emails, contracts, or financial reports, thus helping to detect risks in early stages (Lindsay & Vinay, 2021).

Improving the quality and speed of the audit process

AI agents are continuously and autonomously active, by monitoring transactions in real time and flagging suspicious activity, prompting prompt intervention and reducing the risk of financial losses or major fraud (Kranacher et al., 2019). Additionally, these systems can help to conduct a more accurate and faster audit, facilitating informed and timely decisions.

Decision support and personalization

AI agents provide decision-making support to auditors, generating complex analyses and relevant reports in real time. Depending on the specific environment and identifiable risks, they can be programmed to focus on high-risk areas with the aim of tailor-made intervention measures (Poole & Mackworth, 2010).

Capacity for continuous learning and adaptation

AI agents learn from previous experiences, new data collected, and how transactions are conducted, allowing them to adapt to a dynamic environment. In the field of auditing, this feature ensures that systems can respond effectively to evolutionary fraud schemes and legislative or regulatory changes (Durichen et al., 2019).

4. Integrating AI Agents into Fraud Detection – Experiences, Benefits, and Limitations

4.1 Evolutionary stage

In the context of accelerated digitization and, implicitly, increasingly sophisticated fraudulent activities, artificial intelligence and machine learning (ML) have become front-line technologies in detecting and preventing them. Analyzing huge amounts of data quickly and accurately leads to the identification of suspicious patterns and anomalous behaviors that may indicate fraud (Nguyen et al., 2020). The ability of intelligent systems to detect unusual transactions in real-time derives from the ability to simultaneously monitor multiple data sources, including financial transactions, online platform activities, and user behaviors, to identify signs of fraud with high accuracy (Zhao & Kumar, 2022). Traditional methods based on fixed rules, slower and more vulnerable to obsolescence, cannot learn from new fraud patterns and do not deliver alarm signals that warn decision-makers or a possible audit. At the same time, the detection of suspicious activities must take into account, first of all, similar manifestations from the past, already known fraud patterns, the way in which transactions with a negative impact were carried out. For example, in the field of credit and bank cards, machine learning algorithms analyze transaction history to detect fraud attempts such as card cloning, phishing, or unauthorized use of accounts (Li & Wang, 2021). At the same time, retail and e-commerce

companies are implementing AI systems to monitor user behavior, detecting suspicious activity such as multiple logins from different locations or changes in payment details, warning customers or blocking suspicious transactions before damage occurs.

The positive results generated by the integration of AI agents in fraud detection are due to a gradual process and correlated with the digitalization of organizations' operational processes on different levels. Thus, 3 phases can be identified, as presented in **Table no. 1**.

Table no. 1. Evolution of fraud identification and prevention systems

Evolutionary stages	Features
Phase 1: Rule-based systems and manual reviews	- *Traditional fraud prevention is based on static rules and human analysis* - *Detection of potentially fraudulent transactions based on predefined criteria (e.g. transaction size or geographical area)* - *Inefficiency in sophisticated attacks and high degree of "false positive" situations*
Phase 2: Machine learning, behavioral analysis	- *Pattern identification in large data sets* - *Systems based on behavior analysis, adaptation to new fraud tactics* - *Increases the accuracy of fraudulent transaction detections while reducing "false positive" situations*
Phase 3: Advanced AI systems	- *Deep learning algorithms and neural networks are used for real-time fraud detection* - *Considerable volumes of data are analyzed, complex patterns are identified and previously unknown anomalies/patterns that indicate fraudulent behavior are identified* - *The focus is more on the intention than on identifying the perpetrators.*

Source: own processing according to the DataDome website. (n.d.). AI fraud detection. https://datadome.co/learning-center/ai-fraud-detection/

Advanced techniques, such as anomaly detection and unsupervised learning, are used to uncover previously unknown patterns in transaction-related data, but sometimes lead to legitimate operations being identified as fraudulent (Chen et al., 2019). Such situations labelled as 'false positives' require algorithms to be transparent and explainable in order to be controlled and to avoid discriminatory decisions, especially in the case of the application of these technologies in banking, insurance or other sensitive sectors. In the case of the use of AI, the audit must send clear signals about ethics and responsibility in order to build the trust of customers, authorities and public bodies concerned.

4.2 Techniques specific to AI agents – components, mode of operation

Recent studies, and practical implementations such as those from Deloitte, PwC and KPMG have shown that smart systems perform better than traditional methods by more than 20% in predicting fraud risk and uncovering hidden illegalities (Zhang et al., 2022). The overall conclusion converges on the need to transition to smart audit models, which are not based on fixed rules, but on the ability to continuously adapt to new financial threats.

The key AI technologies used in fraud detection are presented in **Table no. 2**.

Table no. 2. Key AI technologies in fraud detection

Techniques	Applicability	Source
Supervised machine learning	Detecting known fraud patterns	Kim & Lee (2021)
Unsupervised learning	Anomaly detection	Mendes et al. (2020)
Natural Language Processing	Analysis of contracts, communication	Lindsay & Vinay (2021)
Neural networks	Detection of complex patterns	Zhang et al. (2022)

Source: own processing from the mentioned sources

Detecting known patterns of fraud involves using supervised learning techniques to identify already recognized patterns or signatures of fraud in the analyzed data. Such an approach involves training an AI system on a set of labeled data, where each example is classified as either legitimate or fraudulent (Nguyen et al., 2020), with specific steps being taken:

i. ***Data collection and labeling*** – the collection of a large volume of transactions or activities is followed by manual or automatic labeling to differentiate between fraudulent and legitimate transactions, thus serving as a training base for supervised learning algorithms (Li & Wang, 2021).

ii. ***Training AI systems –*** the use of algorithms such as logistic regression, decision trees or neural networks facilitates learning from labeled data, distinguishing the characteristics associated with fraud from those of legitimate transactions and thus building a model that represents the "known patterns of fraud" (Chen et al., 2019).

iii. ***Identification of known patterns –*** the trained AI system has the ability to recognise and classify new transactions. Specifically, if a transaction exhibits characteristics similar to those in the learned models (e.g., combinations of characteristics such as a large amount of money in transactions, different locations, or atypical time slots for certain operations), the system will assess it as potentially fraudulent (Nguyen et al., 2020).

iv. ***Application in suspicious activity detection*** – analyzing new and real-time data automatically identifies and flags transactions that resemble known fraud patterns, helping to prevent and reduce financial losses (Zhao & Kumar, 2022).

Detecting anomalies through unsupervised learning involves identifying behaviors or transactions that are out of the ordinary, not previously pre-labeled or classified. These methods are essential if there is no specific data on fraud, or when it occurs in unknown and variable forms (Chandola et al., 2009). Essentially, the technique involves:

i. ***Identification of atypical data/patterns –*** scoring cases that differ significantly from normal patterns of behavior may indicate suspicious activity, fraud, or other unusual incidents (Hodge & Austin, 2004).

ii. ***Unsupervised learning*** – the use of algorithms that include statistical methods, density-based models, isolation, and unsupervised learning methods such as K-means, DBSCAN, deep learning algorithms, or neural networks that "reconstruct" data and can detect significant differences as anomalies (Goodfellow, Bengio, & Courville, 2016).

iii. ***Anomaly investigation*** – analyzing behaviors that are significantly outside the norm (determined by a set limit) to determine whether they represent fraud or other suspicious activities (Chandola et al., 2009).

Deep learning models can detect unusual transactions or inappropriate accounting records, which helps auditors analyze areas of real risk. In the detection of anomalies, often spontaneous and without predefined patterns, through such techniques there is still a risk of false alarms (false positives), which may require additional human intervention for verification (Chandola et al., 2009).

Contract analysis, natural language processing (NLP) communication extracts relevant information by understanding and interpreting the content of legal texts and other documents or communications, reducing manual effort and improving the accuracy of analysis (Liu et al., 2020). Unstructured text processing is based on pre-trained machine learning and language models, syntactic analysis, entity recognition, and classification (Yu, Xu, & Wang, 2021):

i. ***Contract analysis –*** **by** using NLP, algorithms automatically identify key clauses, payment terms, obligations of the parties, and can highlight potential conflicts or risks (Yu, Xu & Wang, 2021).

ii. ***Communication analysis –*** the processing of dialogues, emails or other documents has the role of emphasizing intentions, feelings or to clarify the context of a conversation. In business, this technique helps automate customer support, and in the legal field, it allows for quick analysis of documents and correspondence (Liu et al., 2020).

Automated contract analysis makes it easier to verify compliance with accounting policies and identify suspicious or inappropriate clauses, thus reducing the auditor's time and manual effort. AI agents can play a decisive role from the stage of planning discussions, questioning the management of the audited unit, including written statements and other communications, in the sense of detecting keywords or procedural deficiencies within the organization. Beyond the advantages

determined by the **speed of operations and the prevention of legal risks, the application of NLP techniques can run into ambiguity or complexity of language, thus requiring specialized models for the legal or commercial field (Liu et al., 2020).**

Detecting complex patterns through neural networks uses deep learning algorithms to identify complicated structures and relationships in data that are difficult to detect by traditional methods. Neural networks are capable of interpreting nonlinear and complex patterns, being highly efficient in image recognition, natural language processing, and implicitly fraud detection (Goodfellow, Bengio, & Courville, 2016).

i. ***Functioning of neural networks*** **-** consisting of layers of artificial neurons connected to each other, neural networks can learn high-level representations and complex relationships between variables, being able to detect subtle patterns that are difficult to capture by classical algorithms (LeCun, Bengio & Hinton, 2015).

ii. ***Complex pattern detection*** – networks identify hidden patterns and relationships, extract automated features, recognize suspicious activity or fraud in financial data, can make accurate predictions, even in the case of incomplete data (Goodfellow, Bengio & Hinton, 2016).

In an audit engagement, these techniques allow the interpretation of a mixture of data from multiple sources and different formats (e.g. SQL databases, XML files, text documents, images, etc.). But although neural networks are successfully used in financial prediction and complex fraud detection, in the case of computer systems they require large volumes of data, considerable computing power, and can be difficult to interpret in terms of explicit logic, which is a challenge in applications where decision-making transparency is critical (LeCun, Bengio & Hinton, 2015).

From a regulatory point of view, the ISA 240 Standard encourages the use of advanced information technologies and suggests several lines of action to auditors:

- *the use of data analytics technologies for* processing large volumes of information and for the automatic reporting of suspicious activities;
- *applying anomaly detection and machine learning techniques* to detect deviations from the norm in financial data or suspicious transactions;
- *document and communication analysis* for the rapid and automatic extraction of relevant information from large volumes of documents;
- *implementing real-time monitoring systems for* financial flows and transactions on an ongoing basis, in order to provide a prompt response to possible fraudulent activities.
- *documenting and justifying the use of information technologies*, including methodologies, tools and results obtained, in order to ensure transparency and substantiation of audit opinions.

In essence, ISA Standard 240 emphasizes the auditor's responsibility to plan and execute appropriate audit procedures for fraud detection, understanding the auditee's environment and acting prudently in identifying suspicious activities in order to issue an accurate opinion on the financial statements. In relation to the rigors of the standard and the advantages of the available intelligent systems, the implementation of AI agents in fraud detection, from our point of view, can be done in 5 distinct phases:

1. **Collection and analysis of financial-accounting data.** Accounting journals, transaction books, bank statements, data from ERP systems and other electronic documents are automatically collected, pre-processed to be compatible for analysis and integrated through AI agencies. Unsupervised learning techniques are applied to model the normal behavior of financial activities (Hodge & Austin, 2004).
2. **Detection of deviations**. AI agents identify, through advanced algorithms, financial transactions or activities that differ significantly from normal models. For example, transactions with unduly large amounts, transfers to offshore accounts, or operations in unusual times (outside normal hours, for example) may be considered.
3. **Fraud risk assessment**. Each activity gets a risk score based on the severity of the deviation from previously learned patterns. This score helps auditors prioritize checks and focus on the most suspicious transactions, according to the requirements of ISA 240, relating to the identification and response to fraud risks (IAASB, 2025).
4. **Reporting and documentation**. Suspicious transactions are automatically documented in system-generated reports, which include explanations of the

reasons for each block or flag, in accordance with the transparency and justification requirements of ISA 240.

5. **Involvement in the final phase of the human factor**. The results and conclusions are drawn by the auditors, following the analysis of suspicious transactions; if it is determined that it is explicit fraud, according to ISA 240, further reports and investigations are triggered.

Thus, we believe that compliance with the procedural and justification requirements of the ISA 240 Standard is achieved by streamlining the identification of fraud risks in a large volume of processed data, while increasing the detection rate of complex and sophisticated frauds.

4.3 Case study

JPMorgan Chase, a global leader in banking, has invested heavily in AI technology with the aim of improving financial fraud detection systems and strengthening its own security and compliance systems (JPMorgan Chase, 2023). The focus was on real-time monitoring of transactions and the automatic identification of suspicious activity so that audit and security teams could intervene quickly.

The solution implemented by JPMorgan Chase, **Fraud Intelligence,** is part of its own suite - *Optimization & Protection* within the *J.P. Morgan Payments* platform and has the following main features:

- Real-time detection of fraudulent transactions
- Built-in protection for merchants and customers
- No additional integration required for activation
- Includes AI functionalities such as machine learning, NLP, and anomaly detection.

This solution, being developed and operated in-house by JPMorgan, allows the organization to quickly adapt to market needs and evolving cyber threats. It is used both for the protection of online transactions and for optimizing authorization rates and reducing losses caused by fraud. The technological architecture is based, in this case, on the following components:

- *Machine learning* - JPMorgan Chase uses ML models to analyze millions of daily transactions. The algorithms are trained on historical datasets, identifying fraud patterns and anomalous behaviors (GetEasy.ai, 2024).
- *Anomaly detection* – AI systems monitor account activity in real-time, flagging transactions that deviate from the client's usual behavior (McKinsey & Company, 2023).
- *NLP and textual analysis* - are used to analyze emails, messages, and internal documents, detecting phishing attempts, legal risks, or suspicious activity (Deloitte, 2022).
- *Automation* – AI optimizes identity verification processes and monitoring suspicious activity, reducing processing time and the risk of human error (Amity Solutions, 2023).

The results of the AI system developed and implemented at JP Morgan Chase are presented in Table no. 3.

Table no. 3. Results of the AI system developed and implemented at JP Morgan

RESULTS		CHALLENGES	
Indicator	**Estimated value/result**	**Indicator**	**Observations**
Loss reduction	Over 50% in high-risk segments (JPMorgan Chase, 2023)	*Algorithmic bias*	Models can reflect biases in historical data, affecting accuracy (Chen & Zhang, 2021)
Detection accuracy	80% increase over rule-based methods (Chen & Zhang, 2021)	*Legal complexity*	Adapting AI to international regulations requires interdisciplinary collaboration (Deloitte, 2022)
Reaction time	Reduction from hours to minutes (McKinsey & Company, 2023)	*Organizational Acceptance*	AI Integration Involves Cultural Shifts and Staff Training (McKinsey & Company, 2023)
False alarm	60% decrease, improving customer experience (Deloitte, 2022)		
Regulatory Compliance	Effective Automation of Audit and Reporting Processes (Amity Solutions, 2023)		

Source: own processing from the mentioned sources

In the initial phases of AI implementation, JPMorgan worked with **Microsoft** and other companies specializing in cloud infrastructure and artificial intelligence models, then the bank began developing its own AI platforms, such as ***OmniAI*** – the in-house platform for developing and scaling AI models across all JPMorgan (Sirimaya, 2025) and ***Account Confidence Score (ACS)*** divisions – a proprietary AI system that analyzes more than 15 billion transactions to assess the risk of beneficiary accounts before payments are made (Silicon Digest, 2024). The transition from external solutions to in-house development demonstrates the strategic option of **having superior control over data, increased security and** personalized AI models.

5. Conclusions

The contribution of artificial intelligence agents in audit missions is remarkable in terms of advantages related to processing speed, accuracy of the information obtained, ability to adapt and self-improve in the conditions of an increasingly digitized context. The complications of artificial intelligence created by information over-dimensioning, the increasingly sophisticated technologies behind transactions and hidden identities are difficult to manage, but possible to be solved by precisely the same set of tools. The auditor is once again in a position to reinvent himself, to invest in his own professional training and in emerging technologies in order to acquire capabilities for detecting, reporting and even combating financial fraud.

Although AI-based technologies have the potential to considerably improve audit processes, the application of AI agents in the analysis of financial and accounting data faces various significant limitations that can affect the accuracy, reliability and acceptability of automated systems. To summarize, these shortcomings are determined by:

- ✓ **Training data**

In this case, it is the quality of the data as well as the insufficient volume of training examples that can lead to weak algorithms that can generate low model performance, as well as increased rates of false negatives and false positives (Hodge & Austin, 2004). In addition, in the absence of proper management of data, especially financial data, it can be incomplete, noisy or manipulated, affecting the accuracy of AI models.

- ✓ **Lack of transparency and explainability**

Advanced algorithms such as deep neural networks are often "black boxes", i.e. their decisions become difficult to explain and justify in front of those interested (auditors, shareholders, etc.). This limits the acceptability of AI in auditing, which often requires clear and transparent justifications for decisions made (LeCun, Bengio & Hinton, 2015; Miller, 2019).

- ✓ **Complexity and ambiguity of legal and financial language**

The interpretation of the language used can lead to incorrect conclusions or omissions in the identification of risks as written documents of any type – contracts, financial documents, official communications, etc. often present ambiguous expressions or difficult to interpret by AI algorithms, especially in the case of natural language processing techniques (Liu et al., 2020).

- ✓ **Taking responsibility**

The consequences of using AI agents in fraud detection can raise issues related to accountability for automated decisions or their consequences. It is uncertain who is liable in the event of decision-making errors, which can lead to reluctance to widely adopt these technologies in auditing (Miller, 2019).

- ✓ **Inadequate resources for the implementation and maintenance of systems**

The deployment, development and maintenance of AI systems require allocations of considerable financial funds and human resources prepared and with specialised expertise. Auditors must become experienced users of such technologies, have the skills to operate and interpret the information obtained, and be keen observers of signals in the system that can warn of potential fraudulent transactions. Such a level of expertise is obtained through experience but also through professional training in the field of dedicated smart technologies. At the same time, vendor prices for such systems are per use, but due to the fact that AI agents are usually frequently used on a large scale, the costs can quickly rise. Obviously, in the case of unknown or limited benefits and values, the use of AI agents within small organizations or for certain industries involves costs that can be prohibitive and not always justified (Nguyen et al., 2020). Moreover, the lack of a robust technical infrastructure (cloud, own equipment, etc.) and integration with other internal or external systems through application programming interface (API)

leads to the annihilation of the efficiency of AI agents (Gartner, 2025).

✓ **Legal and ethical challenges**

There are concerns about privacy, data protection, and the ethics of using AI in the audit process, as complying with legislation and ensuring transparency in automated decisions are major challenges in implementing these technologies (Morris & Lee, 2023).

✓ **Unsuitable AI agents**

There may be situations where AI agents are inadequate for the needs of the organization or for the size of a financial audit. There are two antagonistic situations in which the implementation of such systems turns out to be an unrealistic investment: *Agents that are too sophisticated* for situations that can be solved by simple automations and with fixed rules or *weak agents* which are overvalued in a context that is far too risky and complex. At the same time, certain suppliers do not have the necessary experience and do not have in their portfolio systems that are mature enough and ready to be delivered to the market (Gartner, 2025).

In conclusion, The use of AI agents in fraud detection is a significant development in the current audit field, but also a real challenge. On the one hand, these systems have advanced capabilities for quickly and accurately identifying suspicious activity through the ability to process large volumes of data, analyze complex patterns, and monitor transactions in real time. All these elements contribute to the efficiency and reliability of the audit process as well as to the strengthening of the integrity and transparency of the financial statements. On the other hand, however, the implementation of AI technologies requires a responsible approach, which ensures compliance with ethical and legal norms, international standards such as ISA 240 in fraud detection. It can be said that these technologies have not yet reached full maturity because they have not yet shown their true potential and because the audit is not yet ready to fully adopt such systems. At the same time, there are sufficient research directions still unexplored, especially in the area of practical applicability and concrete solutions aimed at transforming the AI agent into a reliable partner in carrying out audit mission.

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Bibliometric Analysis of Sustainability Reporting Assurance:

A Comprehensive Review of Global Research Trends and Emerging Topics

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Abstract

This paper analyses the intellectual structure of research on the audit and assurance of extra-financial reports, with the dual objective of mapping the intellectual structure of the field and identifying avenues for further inquiry. Employing bibliometric techniques and co-word analysis on data extracted from the Scopus database, the study maps the field's evolution from 2010 to the present. The findings reveal a thematic shift toward regulatory compliance, audit quality, and integrated reporting, reflecting a growing global demand for accountability. However, the analysis uncovers a significant geographical and institutional bias: the current literature is heavily dominated by Western contexts, with a marked underrepresentation of Africa and the Arab world. This limitation hinders the development of inclusive theoretical models capable of addressing the challenges of emerging markets. The study's contribution lies in identifying the need to investigate audit firm constraints in contexts where sustainability standards are still in a developmental phase, such as Tunisia. By highlighting these neglected areas, the research provides a strategic agenda for scholars and policymakers to design governance frameworks that are effective across diverse regulatory environments.

Cuvinte cheie: *sustainability reporting assurance; bibliometric analysis; performance analysis; science mapping; co-word analysis;*

Clasificarea JEL: *M42, C80, Q56*

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1. Introduction

The assurance of sustainability reports has evolved from a niche voluntary practice into a critical area of scientific inquiry and corporate governance. As stakeholders, ranging from investors to regulatory bodies, increasingly demand "investor-grade" environmental, social, and governance (ESG) data, the role of external assurance in validating this information has become paramount. This shift has precipitated a surge in academic research exploring diverse themes, such as audit methodologies, the credibility of non-financial disclosures, and the impact of assurance on firm value. However, as the volume of literature expands exponentially, the field risks becoming fragmented, with isolated studies offering deep insights into specific jurisdictions while lacking a cohesive global perspective.

Despite the growing importance of this domain, systematic assessments of its intellectual structure remain scarce. Existing reviews often rely on qualitative methods, which, while valuable, can be limited by subjective interpretation and a narrow scope of selected papers. Furthermore, the current body of knowledge is heavily skewed toward developed economies, principally Europe, North America, and Australia. This geographic concentration obscures the unique challenges faced by auditors in emerging markets, particularly in the Arab world and African continent, where regulatory frameworks for sustainability are still in a developmental phase. Understanding these regional disparities is not merely an academic exercise; it is essential for developing inclusive theoretical models that reflect the global reality of audit practices.

This paper addresses these limitations by employing a comprehensive bibliometric analysis to map the evolution of sustainability reporting assurance. Unlike traditional literature reviews, bibliometric analysis offers a quantitative, objective means to synthesize large volumes of data, revealing structural patterns, influential networks, and thematic shifts that may not be immediately apparent through qualitative reading (Zupic and Čater, 2015). By utilizing the Scopus database and advanced science mapping techniques, this study aims to firstly, visualize the conceptual structure of the field, then, identify the migration of research topics from voluntary disclosure to mandatory compliance, and finally pinpoint critical geographical and thematic gaps that require urgent scholarly attention.

The originality of this research is twofold. First, it provides the first bibliometric mapping that explicitly contrasts the well-established Western discourse with the nascent research emerging from developing contexts. Second, it responds to the specific calls by Habib (2022) for increased bibliometric inquiry in accounting, and by Ding *et al.* (2001) for mapping the conceptual boundaries of disciplines. By identifying the disconnection between global theoretical models and local audit realities in emerging markets, this study offers a strategic roadmap for researchers seeking to position their work in high-impact areas and for policymakers striving to harmonize global assurance standards.

This paper is organized as follows: Section 2 presents the theoretical background and reviews prior relevant studies. Section 3 outlines the bibliometric methodology and data selection process. Section 4 reports the results of the performance analysis and science mapping. Finally, Section 5 discusses the implications, acknowledges limitations, and proposes a future research agenda.

2. Theoretical background

The academic literature on sustainability reports has undergone a significant transformation over the past two decades, evolving from a niche interest into a mainstream accounting discipline. Early studies primarily focused on the technical and normative aspects of the field, with researchers such as Farooq and de Villiers (2017) examining the diverse standards and methodologies employed to audit extra-financial information. As the practice matured, the thematic focus broadened to encompass the strategic implications of assurance, exploring how verification mechanisms influence stakeholder perception and corporate value. In this context, studies began to position auditors not merely as verifiers of data but as critical agents of legitimacy; for instance, Handoko *et al.* (2020) demonstrated how external assurance serves to bolster a company's responsible image and secure reputational capital in an increasingly competitive global market. More recently, the proliferation of regulatory frameworks has introduced a new dimension to the literature, shifting attention from voluntary adoption to mandatory compliance. This trend is exemplified by recent works, such as that of Legenzova and Raudoniene (2025), which investigate the complexities arising from the European Union's directive imposing mandatory audits for sustainability reports. Despite this rich accumulation of empirical studies, efforts to systematically map the field's intellectual terrain remain fragmented. While recent reviews, such as that by Oware and Moulya (2023), have synthesized findings on specific sub-topics, there remains a paucity of comprehensive

bibliometric analyses that capture the global structural evolution of the discipline. This gap is particularly acute regarding the visualization of cross-jurisdictional trends and the identification of under-represented regions, highlighting the urgent necessity for a quantitative, network-based approach to decipher the complex interactions between emerging thematic clusters and the geographic distribution of knowledge.

3. Research methodology

Bibliometric research has been widely used for a variety of purposes (Kılıç and Uyar, 2022), including mapping the thematic and conceptual structure of a research field (Ding *et al.,* 2001) and providing deeper insight into future research trends (Faraji *et al.,* 2022). As part of this bibliometric study of sustainability reports and their audits, a literature search of the Scopus database was adopted (Chadegani *et al.,* 2013).

To address the research objectives, this study adopts a systematic bibliometric workflow that aligns specific bibliometric techniques with targeted research questions to ensure robust results. **Table no. 1** details this methodological framework.

Table no. 1. Research model

Objectives	Research questions	Methodological Approach
Study the latest scientific developments in auditing sustainability reports	How is the scholarly community structured in terms of influential authors, high-impact journals, and geographic distribution?	Performance Analysis: Citation metrics, H-index, and production volume analysis using *Biblioshiny*.
Identify Networks & Themes	What are the dominant conceptual clusters in sustainability assurance, and how have these themes evolved from voluntary reporting to regulated compliance?	Science Mapping: Co-word analysis and network visualization using *VOSviewer*.
Gap Analysis & Future Agenda	What specific institutional and regional gaps exist that hinder a global understanding of audit practices?	Qualitative Synthesis: Critical content analysis of under-represented clusters and recent debate.

Source: own projection

3.1. Data collection

Following previous research (Ecim and Maroun, 2022), we used the Scopus database to extract documents related to the audit of sustainability reports as it covers different disciplines and high-quality journals. Scopus was selected over Web of Science due to its broader coverage of Social Sciences and business-related journals, which allows for a more comprehensive mapping of the accounting and business literature (Mongeon and Paul-Hus, 2016).

To ensure data homogeneity and analytical rigor, we constructed a search string that intersects two conceptual domains: the subject matter (employing terms such as "non-financial reporting," "ESG," and "CSR") and the assurance function (employing terms such as "audit" and "assurance"). This combination was designed to capture the full evolutionary arc of the field, ensuring the inclusion of both early voluntary disclosure studies and recent mandatory compliance research. The search, conducted in March 2025, yielded an initial dataset of 505 documents based on the specific query detailed in **Figure no. 1**. To strictly maintain data homogeneity and ensure the reliability of the trend analysis, several filters were applied. We limited the scope to peer-reviewed "Articles" in English within the "Business, Management, and Accounting" and "Economics" subject areas. Crucially, we excluded 14 documents published in the current incomplete year (2025) to avoid time-lag bias in the annual growth calculations. This rigorous filtering process resulted in a final homogeneous sample of 491 documents (spanning 2000–2024) for the bibliometric analysis.

The systematic selection process, detailing the initial identification and the subsequent exclusion of incomplete data, is illustrated in the PRISMA flow diagram (**Figure no. 2**).

Figure no. 1. Advanced query in Scopus

```
TITLE-ABS-KEY ("non-financial reporting" OR "ESG reporting" OR "sustainability reporting" OR "extra-financial disclosure" OR "CSR reporting" OR "CSR disclosures" OR "ESG disclosure" OR "non-financial information" OR "sustainability reporting" ) AND TITLE-ABS-KEY ( "Audit" OR "Assurance" OR "auditor*" OR "Audit firms" OR "sustainability reporting assurance" ) AND ( LIMIT-TO ( PUBSTAGE , "final" ) ) AND ( LIMIT-TO ( SUBJAREA , "BUSI" ) OR LIMIT-TO ( SUBJAREA , "ECON" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) ).
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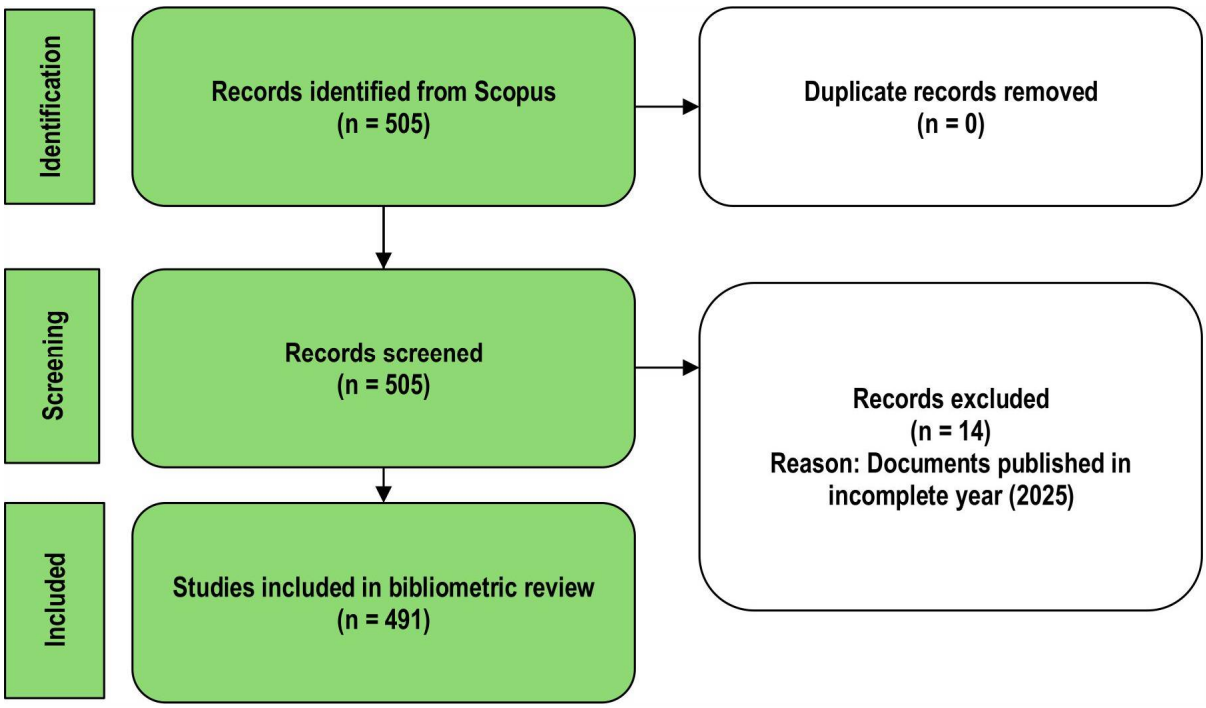
Source: own projection

Figure no. 2. Prisma flow diagram



Source: own projection

3.2. Database analysis

The first search was carried out on 8 March 2025. 491 articles were selected from the Scopus database. A total of 491 documents were analysed using Bibliometrix software, version 4.4.3, and its Biblioshiny function. This enabled bibliometric analysis to be carried out by identifying the authors, journals and frequently cited references. In addition, the use of Bibliometrix made it possible to identify the main players and influencers in the research field, based on quantitative measurements, publication trends and citation patterns (Alkathiri *et al.,* 2024). Second, to visualize the intellectual structure and thematic evolution of the field, we employed VOSviewer (version 1.6.20). To enhance the replicability of the network analysis, specific technical parameters were applied: we utilized the full counting method to assign equal weight to co-occurrences and established a minimum threshold of 5 for keyword frequency. This threshold was selected to filter out marginal terms and reduce noise, ensuring that the visualized clusters represent significant and recurring research themes within the literature.

Table no. 2 presents the general bibliometric information for this database. The documents studied were published

between 2000 and 2024 in 201 sources, including journals and books. The database includes a total of 491 documents, with an average annual growth rate of 20.16%. In addition, the database includes a total of 26,895 bibliographic references and 1,086 keywords defined by the authors.

Table no. 2. Metric data

Description	Results
Timespan	2000 : 2024
Sources (Journals, Books, etc.)	201
Documents	491
Annual Growth Rate %	20.16
Document Average Age	5.2
Average citations per doc	45.63
References	26895
DOCUMENT CONTENTS	
Keywords Plus (ID)	247
Author's Keywords (DE)	1086
AUTHORS	
Authors	1086
Authors of single-authored docs	53
AUTHORS COLLABORATION	
Single-authored docs	58
Co-Authors per Doc	2.84
International co-authorships %	31.57

Source: own projection

In addition, the analysis highlights an average of 2.84 co-authors per document, underlining an international collaborative dynamic, with 31.57% of documents resulting from international collaborations.

4. Results of bibliometric analysis

4.1. Metrics and scientific production: performance analysis

Performance analysis examines the contributions of different research components to a specific field of knowledge (Cobo *et al.,* 2011). A wide range of indicators is commonly employed for this purpose, among which the most frequently used are the number of publications and citations per year or per author. The number of publications is generally interpreted as a proxy for scientific productivity, while citation counts reflect scholarly impact and influence. Composite indicators, such as citations per publication and the h-index, combine both dimensions and are widely used to assess the performance of journals, authors, or institutions (Donthu et al., 2021). Additional indices, including the m-index and the g-index, further refine this evaluation.

In this context, the number of published articles represents an indicator of scientific production, whereas the number of citations reflects the impact of this production on the advancement of knowledge within the field (Tiberius and Weyland, 2022).

4.1.1. Publication trends

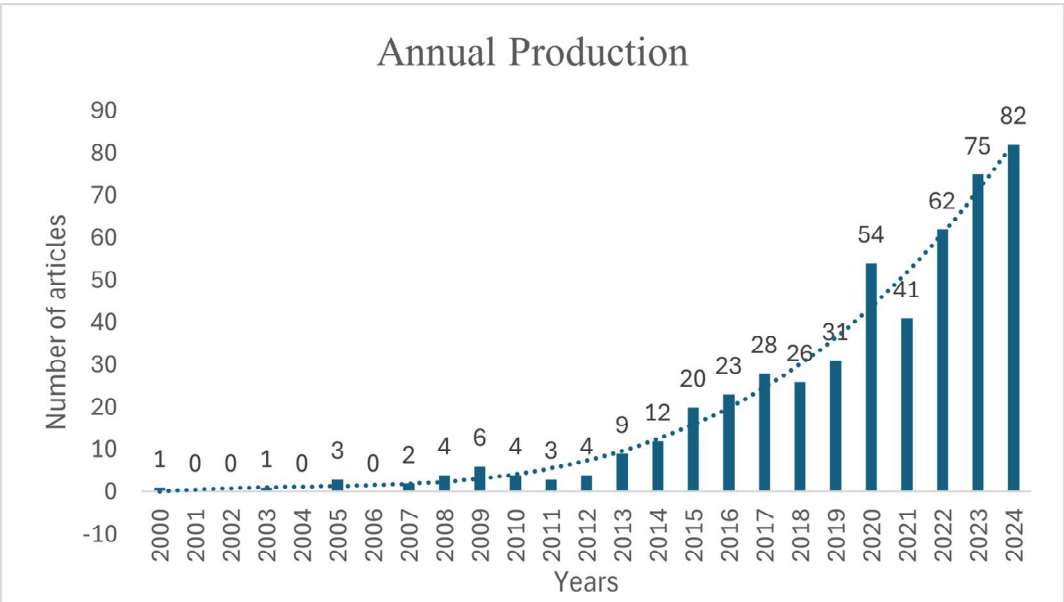
Figure no. 3 illustrates the annual evolution of scientific output between 2000 and 2024. The results reveal a significant upward trend, with an estimated annual growth rate of approximately 20.16%. This evolution can be divided into three distinct phases. Before 2010, scientific

production remained marginal, rarely exceeding five articles per year. This period corresponds to the early stage of sustainability reporting research, when disclosure practices were largely voluntary and confined to a limited academic niche.

From 2015 onwards, a clear acceleration in publication activity is observed, with output exceeding 15 articles per year. This shift correlates with the institutionalization of the field, driven by the introduction of integrated reporting frameworks (IIRC) and early discussions on European directives.

The most substantial increase occurred after 2020, peaking at over 80 articles in 2024. While Demers et al. (2020) attribute part of this surge to the COVID-19 pandemic, where researchers investigated ESG as a resilience factor, our analysis suggests a structural driver: the transition from voluntary disclosure to mandatory assurance. The proliferation of regulations, such as the EU's CSRD and the formation of the ISSB, has forced the academic community to pivot from normative discussions to technical investigations of audit quality and compliance.

Figure no. 3. Articles annual production



Source: own projection

4.1.2. Average number of article citations per year

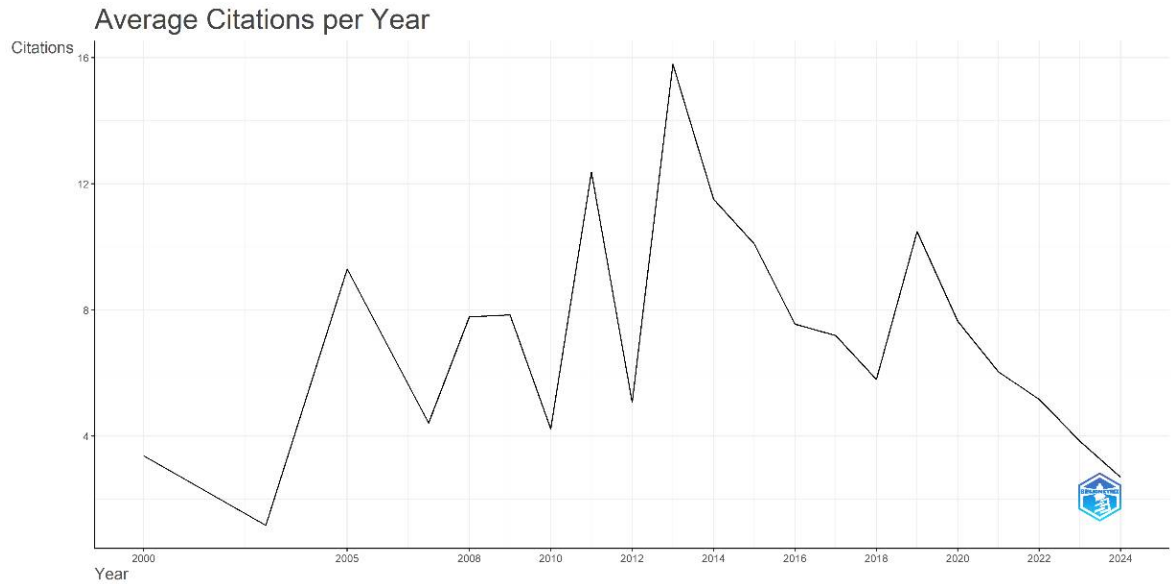
As with the number of publications, the average number of citations per paper initially increased, as shown in **Figure no. 4**. A notable peak in citations was recorded in 2013, with each paper being cited an average of 15.8 times.

In more recent years, however, the average number of citations per paper has fallen, despite the increase in the number of publications (see **Figure no. 4**). This decline can be attributed to several factors, including an increase in the volume of research, which can lead to a dispersion of citations, resulting in a dilution effect whereby individual articles receive fewer citations on average. In addition, recent publications may not yet have had the time to accumulate citations, as the impact of citations tends to increase over time.

4.1.3. Literature sources

Table no. 3 identifies the most relevant sources that have published work, based on the number of publications focusing on extra-financial reporting and auditing. The Corporate Social Responsibility and Environmental and Management, Sustainability Accounting Management and Policy Journal stands out as the most significant source, with 28 and 27 estimated publications respectively, representing the most substantial contribution in the dataset examined.

Figure no. 4. Average number of citations per year



Source: own projection

Table no. 3. The 10 most relevant sources

Sources	Articles
Corporate Social Responsibility and Environmental Management	28
Sustainability Accounting, Management and Policy Journal	27
Journal of Business Ethics	21
Business Strategy and The Environment	16
Journal of Cleaner Production	15
Meditari Accountancy Research	14
Managerial Auditing Journal	13
Social Responsibility Journal	12
Journal of Applied Accounting Research	10
Cogent Business and Management	9

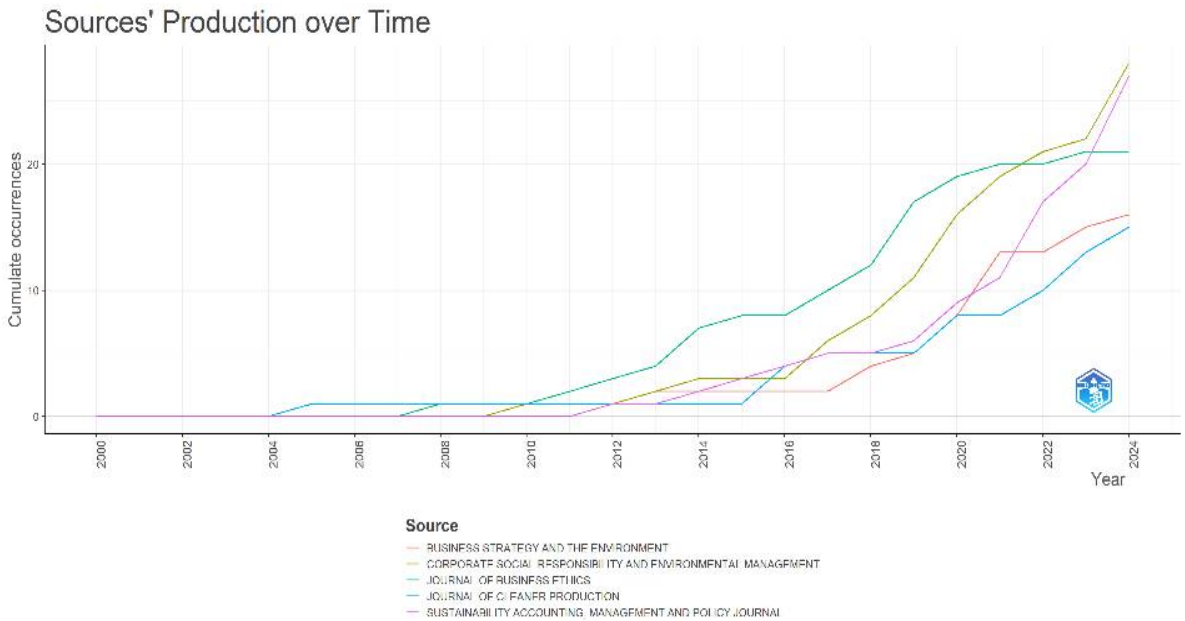
Source: own projection

The Journal of Business Ethics ranks third with approximately 21 publications (4.3%), followed by Business Strategy and the Environment and the Journal of Cleaner Production which rank fourth and fifth, with 16 (3.2%) and 15 articles (3.1%) respectively. It should be noted that 33.6% of the 491 articles examined were published in the top ten journals on the list.

In addition, **Figure no. 5** illustrates the trend in the production of sustainability research articles in five specialist journals between 2000 and 2024. It should be noted that during the period 2000-2012, the number of publications was relatively low, with journals such as the Journal of Business Ethics and Business Strategy and the Environment publishing fewer than five articles each. There was a gradual increase in output between 2013 and 2020, led by the Journal of Cleaner Production, with around 10 articles published, and Corporate Social Responsibility and Environmental Management, with around 8 articles. From 2021 onwards, there will be a significant increase in output, with the Sustainability

Accounting, Management and Policy Journal becoming the main source of information, with around 20 publications between 2021 and 2024, representing around 33% of the total output tracked. Business Strategy and the Environment and Journal of Cleaner Production will publish between 15 and 18 articles respectively. Newer journals began contributing after 2020, reflecting a broader academic interest in sustainability. These trends suggest that institutions and researchers are paying increasing attention to integrating sustainability and extra-financial reporting into their studies.

Figure no. 5. Trends in scientific output in journals time



Source: own projection

In addition, the data reflects the dynamics of global research and how it is distributed across regions, highlighting the main centers of knowledge and the geographical diversity of academic contributions.

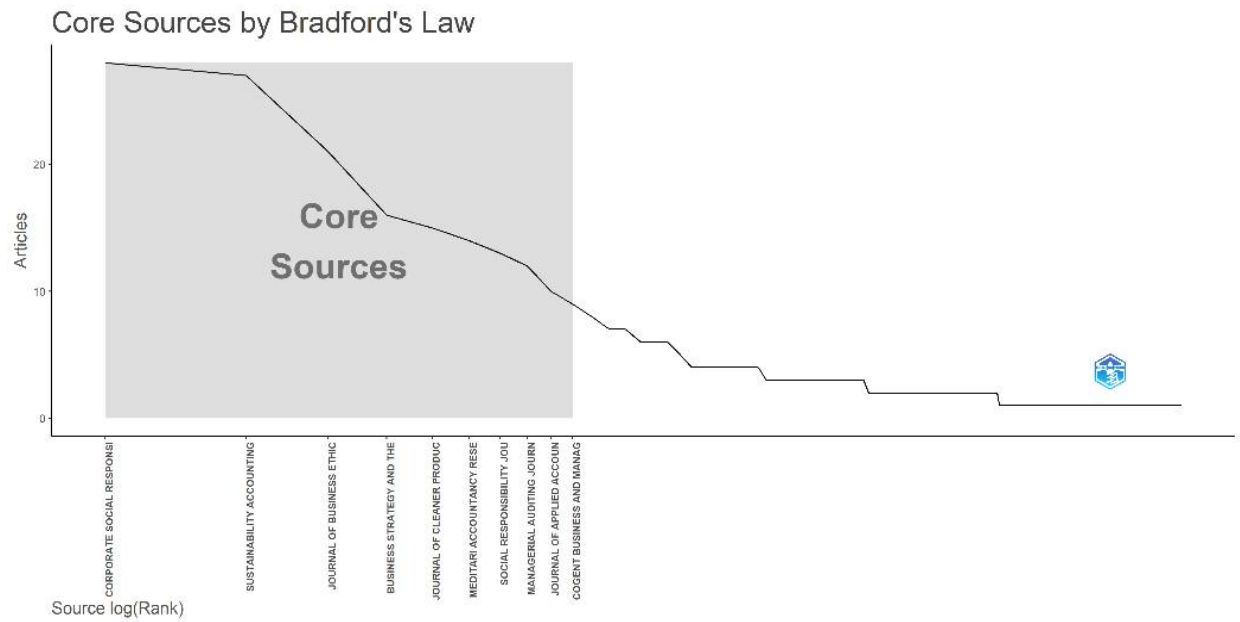
4.1.4. Bradford's Law

Bradford's law, introduced by Samuel C. Bradford in 1934, describes the unequal distribution of scientific articles in academic journals. This law highlights the fact that a small number of 'core' journals publish a significant proportion of articles in each field, while the majority of the remainder are scattered across a network of less active journals (Naranan, 1970). Bradford's law has made it possible to identify the journals that form the central core of a theme, occupying around a third of publications (Ben Said *et al.*, 2024). In this study's sample of 201 journals, only 10 belong to zone 1 (see **Figure no. 6**), which corresponds to the journals that are published most frequently on the subject. These ten journals published a total of 165 articles out of a sample of 491 articles, illustrating a significant concentration of scientific production and representing most of the high-impact research. The three most influential journals in this field are: Corporate Social Responsibility and Environmental Management, Sustainability Accounting, Management and Policy Journal and Journal of Business Ethics.

4.1.5. Sources' local impact

Analysis of the local impact of sources makes it possible to determine the most influential sources within the corpus selected. Unlike the analysis of the most relevant sources, which ranks journals according to the number of publications, this measure assesses the qualitative impact of sources by considering indicators based on citations. These indicators include the local h-index, the g-index and the m-index, defined in the previous section.

Figure no. 6. Bradford's law



Source: own projection

Table no. 4 shows the classification of journals according to the h-index. This index summarizes two distinct but complementary aspects of the journal: the number of articles, reflecting quantity, and the impact or citations of these articles, reflecting quality, (Chadegani *et al.*, 2013). The Journal of Business Ethics stands out in first place in terms of h-index (21), attributable to the significant breadth of dissemination of its publications in terms of citations. In second place, the Corporate Social Responsibility and Environmental Management Journal also stands out, with an h-index of 20. The Sustainability Accounting, Management and Policy Journal came third with a h-index of 18.

Table no. 4. Top 10 most productive sources ranked by h-index

Source	h_index	Total Citations	Number of items
Journal of Business Ethics	21	3676	21
Corporate Social Responsibility and Environmental Management	20	1727	28
Sustainability Accounting, Management and Policy Journal	18	1003	27
Business Strategy and The Environment	15	1681	16
Journal of Cleaner Production	10	1066	15
Social Responsibility Journal	10	870	13
Journal of Applied Accounting Research	9	445	10
Meditari Accountancy Research	8	228	14
Accounting, Auditing and Accountability Journal	7	296	8

Source: own projection

4.1.6. The most relevant authors and their impact

The analysis of the most relevant authors (**Table no. 5**) indicates that Uyar A (12), Kuzey C (11) and Karaman AS (10) have the largest number of publications. However, their split score, which evaluates the relative contribution of an author by considering the total number of co-authors (Bu *et al.*, 2020), suggests that their individual impact on these publications is split between several co-authors. **Table no. 5** also presents the ten most productive authors. In this context, productivity is evaluated in terms of the number of citations and the h-index, a major indicator for assessing the impact and quality of scientific work (Diwan, and Amarayil Sreeraman, 2023). The most productive researchers in this field are Uyar A, Kuzey C, Martínez-Ferrero J, García-Sánchez I-M, Hussainey K, Karaman As, Al-Shaer H, Boiral O, Comfort D, De Villiers C. The author Boiral O was one of the first who contribute to this field, with his article "*Sustainability reports as simulacra? A counter-account of A and A+ GRI reports*" which examines "the extent to which sustainability reports can be seen as a simulacrum used to mask real sustainability issues and project an idealised view of how companies are doing" (Boiral, 2013). His article has been widely cited in subsequent studies on green accounting and sustainability (519 citations), which explains the high number of citations for this author.

Analysis of the data presented in **Table no. 5** reveals a hierarchy of authors based on their h-index. Statistical analysis reveals that author Uyar A has the highest h-index, with a score of 8, supported by a body of 12 publications and an accumulation of 428 citations. With 256 citations, his paper, "*Determinants of Sustainability Reporting and its Impact on Firm Value: Evidence from the Emerging Market of Turkey*," investigated "factors influencing Global Reporting Initiative (GRI)-based sustainability reporting, adoption of assurance statements in sustainability reporting, and levels of implementation of sustainability reporting." (Kuzey and Uyar, 2017). This article was co-authored by Kuzey C, who comes next with an h-index of 7. In third place, Martínez-Ferrero J holds a total citation count of 403, with his article "*Impact of Disclosure and Assurance Quality of Corporate Sustainability Reports on Access to Finance*" receiving 125 citations. This article "investigates the impact of the quantity and quality of corporate social responsibility disclosure and external validation on capital constraints" (García-Sánchez *et al.*, 2017).

Table no. 5. Classification of authors according to the h index

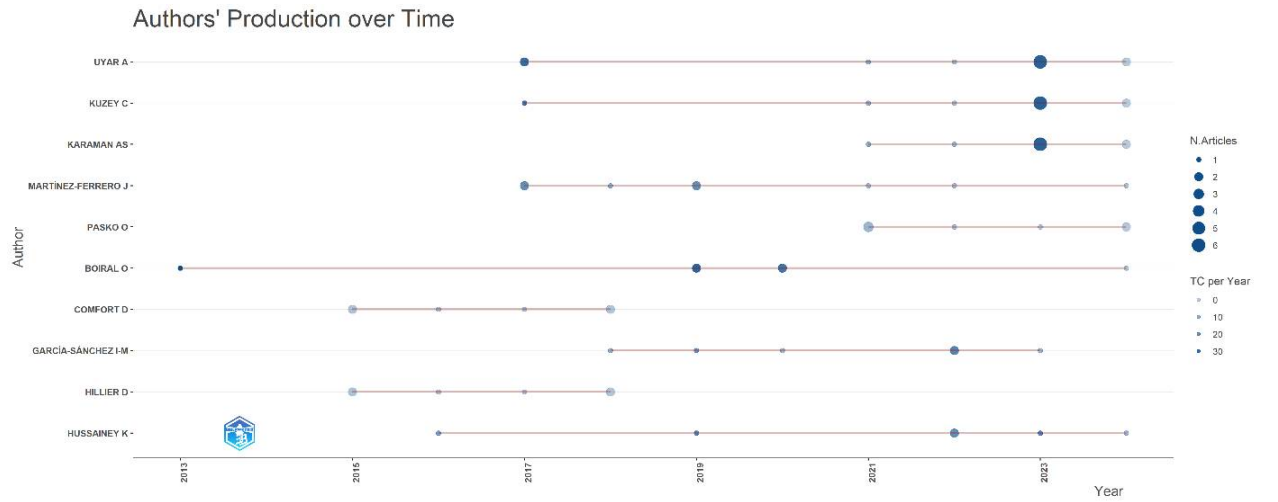
Auteurs	h_index	Total Citations	Number of items	Year of publication	Articles fractionalized
Uyar A	8	428	12	2017	3,85
Kuzey C	7	417	11	2017	2,85
Martínez-Ferrero J	7	403	8	2017	3,08
García-Sánchez I-M	6	331	6	2018	2,42
Hussainey K	6	444	6	2016	2,08
Karaman As	6	161	10	2021	2,35
Al-Shaer H	5	465	5	2018	2,67
Boiral O	5	916	6	2013	2,75
Comfort D	5	83	6	2015	2,00
De Villiers C	5	211	5	2018	1,92

Source: own projection

4.1.7. Authors' production over time

Figure no. 7 illustrates the evolution of authors' output over time. Over the years, several authors have emerged, with notable peaks in research output around 2021. Among the most productive authors, Uyar A., Kuzey C. and Karaman AS show a significant increase in the number of articles published, particularly in recent years. The greatest concentration of publications appears between 2019 and 2023, when several authors have reached their production peak.

Figure no. 7. The most productive authors over time



Source: own projection

4.1.8. Corresponding authors' countries

The analysis highlights a marked concentration of academic research on non-financial information in developed economies. Spanish and American researchers stand out with 38 articles each, representing 7.7% of the 491 total publications. This preponderance can be explained by the presence of cutting-edge research infrastructure in Spain and the United States, substantial institutional financial support and expertise rooted in the fields of sustainability (Altın and Yılmaz, 2023). British (7.1%) and Australian (6.5%) researchers are in second place, reflecting the significant influence of Anglo-Saxon and European academia in the development of global corporate transparency standards. In Europe, German (3.1%) and Italian (4.7%) researchers illustrate a regulatory-driven research landscape, stimulated by initiatives such as the European Union's Corporate Sustainability Reporting Directive (CSRD) and the Global Reporting Initiative (GRI), which encourage academic scrutiny of reporting mechanisms (Effah *et al.*, 2023).

Although emerging economies remain under-represented, researchers from China (5.3%) and Indonesia (3.9%) report a significant increase in ESG disclosure engagement in Asia, driven by global supply chain pressures and investor demands for accountability. South African researchers, with 2.4% of publications, are the only African contributors to the top 10, highlighting the challenges specific to their region, particularly in relation to resource governance and climate vulnerability. They are thus in line with international agendas, such as the Sustainable Development Goals (SDGs) set by the UN.

However, a closer analysis of the data reveals a significant imbalance. The top ten nations account for 51.3% of total publications, a trend dominated by the developed economies. This disparity highlights the bias of the 'global North' in sustainable development research, which could lead to the marginalisation of local perspectives from emerging markets. For example, while European researchers focus on regulatory alignment, their counterparts in Indonesia or South Africa explore issues specific to national contexts (such as deforestation or social equity), which are under-represented in the dominant discourse. In addition, the preponderance of American and Australian researchers highlights the influence of voluntary market-oriented frameworks, such as the Task Force on Climate-related Financial Disclosures (TCFD), on research programmes. This dynamic contrasts with the regulatory rigour observed in Europe (**Table no. 6**).

The dominance of Western developed economies observed in our sample aligns with the findings of recent bibliometric reviews. Specifically, Oware and Moulya (2023), and Pasko et al. (2021) similarly identified a hegemony of US and European contexts in sustainability research. Pasko et al. (2021) notably identified 2011 as a "bifurcation point" marking the maturity of sustainability reporting, a trend mirrored in our data regarding assurance. However, a nuanced difference emerges in

our results: while previous studies found a broader distribution for general ESG reporting, our mapping reveals a sharper concentration of assurance-specific research in Europe (notably Spain, UK, Italy). This divergence is likely driven by the distinct regulatory landscape in Europe (e.g., the long-standing audit requirements of the NFRD), which has generated a specific demand for assurance research that is less pronounced in the purely market-driven US context.

Table no. 6. Ranking of countries by affiliation of corresponding authors

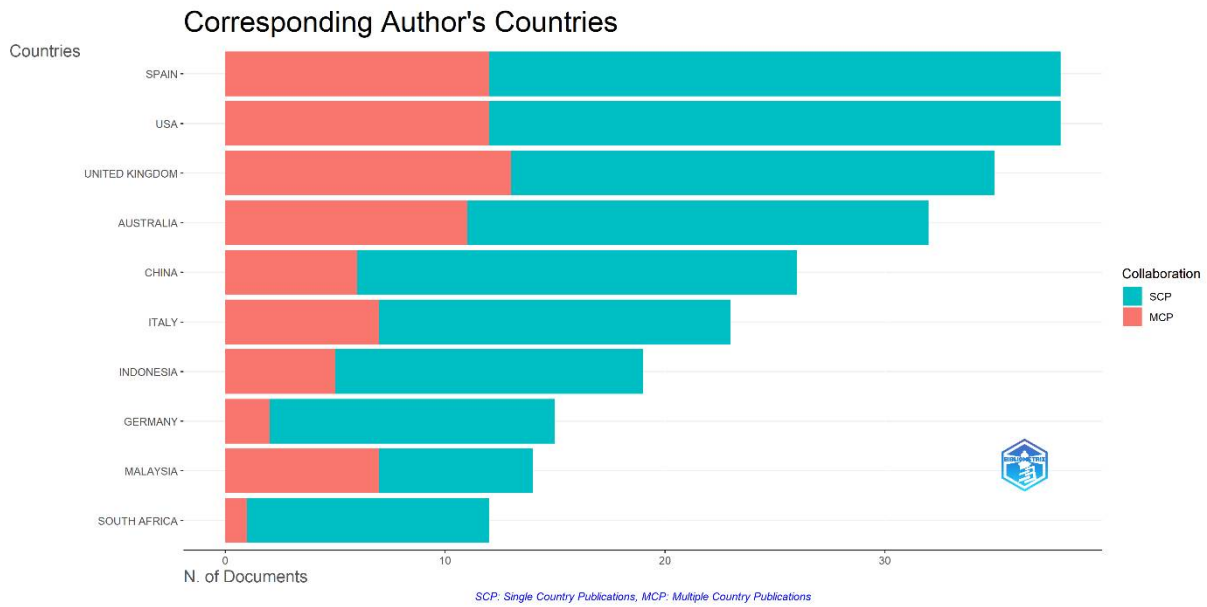
Country	Articles	Articles %
Spain	38	7.7
United States	38	7.7
United Kingdom	35	7.1
Australia	32	6.5
China	26	5.3
Italy	23	4.7
Indonesia	19	3.9
Germany	15	3.1
Malaysia	14	2.9
South Africa	12	2.4

Source: own projection

Figure no. 8 illustrates trends in collaboration between the countries of the corresponding authors, measured using publications from a single country (SCP, research involving only national authors) and publications from several countries (MCP, collaborations with international co-authors). While Spain and the United States maintain a balance between national (SCP) and cross-border (MCP) collaborations, Malaysia stands out with 50% of its publications involving multinational partnerships, the highest rate among the main contributors. This contrasts sharply with South Africa (8.3% of MCPs) and Germany (13.3% of MCPs), where research results remain largely anchored at national level. The UK (37.1% CPG) and Australia (34.4% CPG) also emphasize their propensity to establish global partnerships, in line with their close links with international university networks.

Collectively, these top 10 countries account for around half of all publications, reflecting a geographically diverse but unevenly collaborative research landscape. While Western countries dominate in terms of volume, the inclusion of Malaysia and South Africa highlights the growing participation of Asian and African regions. The data highlights a dichotomy in research priorities: some countries leverage international networks to amplify their reach, while others focus on localised outcomes, a dynamic that is shaping the global discourse on non-financial reporting.

Figure no. 8. Authors collaboration from different countries

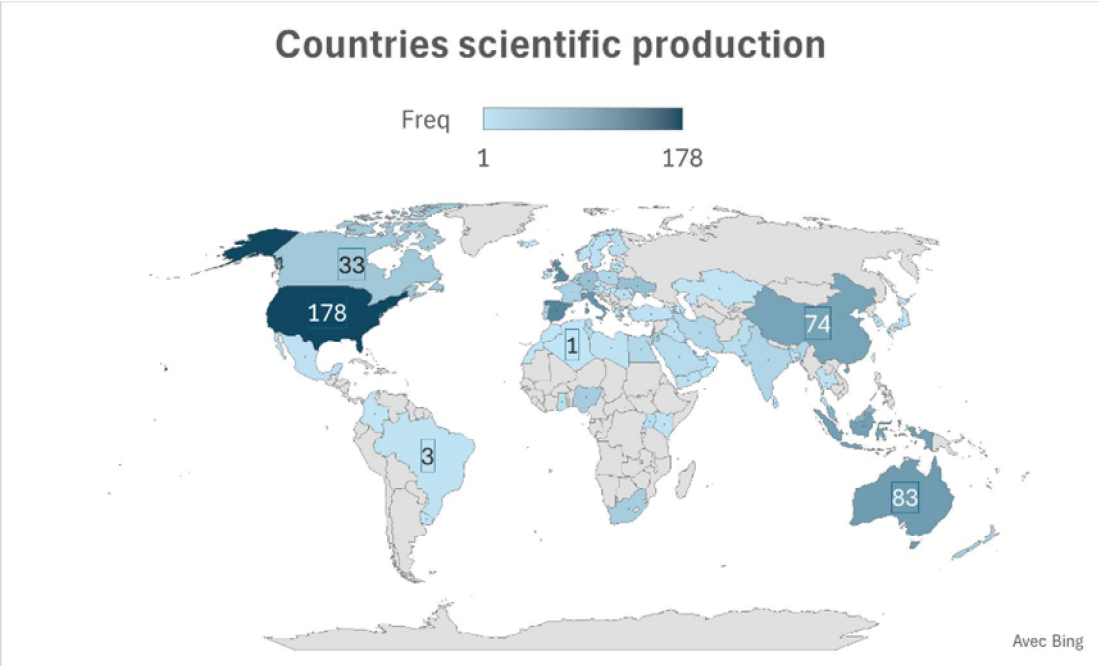


Source: own projection

4.1.9 Countries' scientific production

Figure no. 9 shows the distribution of scientific output by country. The United States leads the way with 178 publications, followed by Spain (108), the United Kingdom (104), Italy (91), Australia (83) and Indonesia (79). This trend highlights the preponderance of developed countries in research production, a phenomenon attributable to their systemic advantages in terms of funding and infrastructure. The inclusion of Indonesia in this ranking reveals the gradual emergence of emerging economies in the concert of international scientific contributions. The data reveals a research landscape that is both progressive and evolving, characterized by increasing participation.

Figure no. 9. Countries scientific production



Source: own projection

4.2. Science mapping

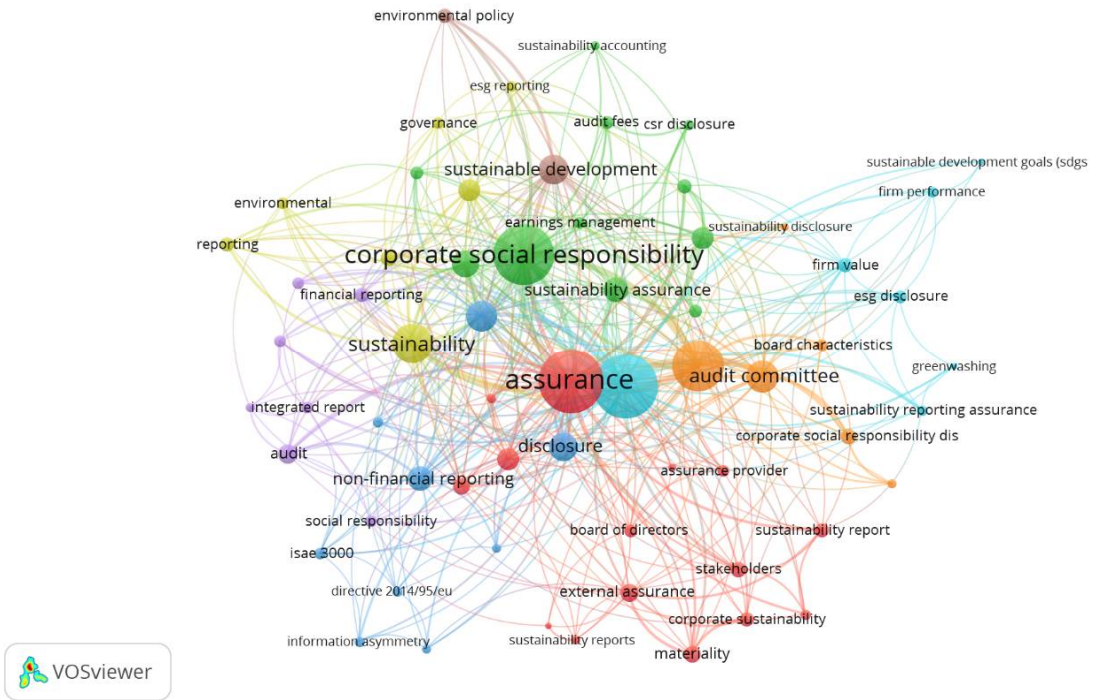
4.2.1. Co-word analysis

Various bibliometric methods are used to quantitatively map the relationships between concepts, ideas and themes. To refine our study, we are going to use one of the most important methods, which is co-word analysis. By analysing a large number of research papers over several periods, co-word analysis provides a precise view of the evolution of a research field (Ding *et al.*, 2001). In addition, it improves the objectivity of traditional literature analysis approaches (Zupic and Cater, 2015).

The co-word analysis highlights a research environment characterized by its dynamism and interdisciplinarity, with a focus on the themes of sustainability, governance and corporate responsibility. Within this landscape (**Figure no. 10**), 'sustainability reporting' (cluster 6) plays a central pivotal role, linking themes such as ESG integration (cluster 4), regulatory compliance (cluster 3) and CSR disclosure (cluster 2), reflecting its role as the linchpin of modern corporate transparency. The close links between 'corporate governance' (cluster 1) and 'CSR reporting' highlight the interaction between internal governance structures and external communication on sustainable development. The emergence of specific terms such as 'greenwashing' (cluster 8) and 'sustainability reporting assurance' highlights the increased importance attributed to ethical responsibility and verification, driven by regulatory frameworks such as European Directive 2014/95/EU. Furthermore, the spatial proximity of the Sustainable Development Goals (SDGs) and

environmental policy highlights efforts to align corporate strategies with global agendas. However, despite this interconnectedness, the weaker links with 'financial performance' suggest underexplored synergies between profitability and sustainability. Thus, the mapping highlights a sector in flux, shifting from a communications model focused on regulatory compliance to a more holistic, stakeholder-focused approach. This transition is accompanied by the emergence of sustainability assurance and anti-greenwashing mechanisms, which are positioning themselves as crucial control mechanisms at a time when environmental and social issues are coming under greater scrutiny.

Figure no. 10. Co-words analysis



Source: own projection

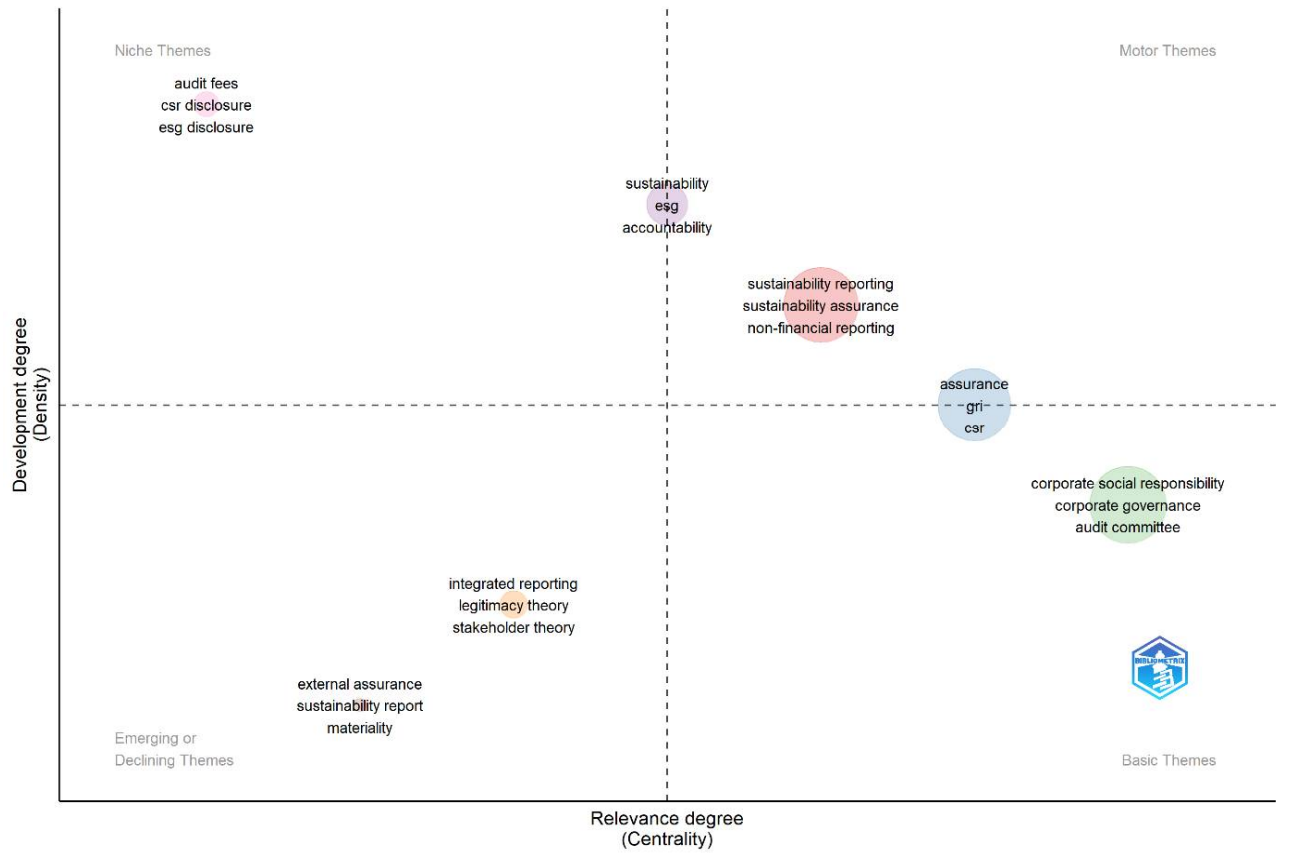
4.2.2. Thematic map

As illustrated in **Figure no. 11**, a thematic map is projected onto a plane composed of the axis of centrality on the abscissa and the axis of density on the ordinate (Alkathiri *et al.,* 2024). The analysis of the provided map will facilitate the identification of the following: driving themes, basic or transversal themes, emerging or declining themes, and niche themes. This classification, established by Della Corte *et al.* (2019), helps to structure research in the field of sustainability reporting assurance. The aim of this thematic map is to highlight the main trends in research into sustainability reporting assurance. It classifies concepts according to two criteria: their centrality, which corresponds to their relevance to the field as a whole, and their density, which corresponds to their level of internal development within the theme. This visualization makes it possible to identify the key areas that structure academic discussions and to assess their evolution over time.

The concepts identified as drivers, located in the top right quadrant, include sustainability reporting, sustainability assurance and non-financial reporting. These themes are not only well developed, but also strongly interconnected with other central concepts in the field. This prominence highlights the increasing importance of assurance mechanisms applied to non-financial information, reflecting the growing demand for transparency and

accountability on the part of companies. At the same time, core topics such as corporate social responsibility (CSR), corporate governance and audit committees form a major pillar of the literature on sustainability reporting assurance. Although these topics are essential, they remain less studied in the specific context of sustainability audit practices. On the other hand, niche topics such as audit fees, CSR disclosure and ESG disclosure, although enriched, remain of lesser importance. This suggests that they provide specialist knowledge in specific sub-areas, do not exert a significant influence on the wider sustainability assurance debate. In addition, emerging or declining themes in the bottom left quadrant include concepts such as external assurance, materiality, legitimacy theory and stakeholder theory. These ideas have historically played a crucial role in justifying the increasing attention paid by companies and regulators to sustainability reporting. However, their current positioning suggests that they are at a crossroads, either regaining relevance as sustainability reporting becomes more regulated, or losing ground to more standardized and compliance-focused approaches. The evolution of these themes points to a gradual institutionalization of sustainability assurance practices. Indeed, evolving regulatory frameworks is redefining expectations for non-financial reporting, and the role of audit firms in ensuring the reliability of sustainability information is becoming increasingly crucial. This poses new technical and organizational challenges for audit firms, and it is therefore essential to assess their readiness to integrate sustainability assurance into their service offering. By understanding their perspectives and readiness, we can not only gain valuable insights into the evolving audit landscape but also anticipate the key drivers and barriers to the adoption of sustainability assurance practices.

Figure no. 11. Thematic map



Source: own projection

An analysis of the literature in our sample reveals a constant diversity and evolution of approaches related to environmental, social and governance (ESG) issues, extra-financial reporting and their audit. In terms of empirical studies, quantitative analyses, and more specifically regression models, predominate in research that focuses on the influences of corporate governance structures, such as audit committees and board characteristics, on ESG information and company performance (Moussa *et al.*, 2024). In academic literature, theoretical frameworks such as legitimacy and stakeholder theory are frequently used to understand these relationships (Poulsen and Sigurjonsson, 2024). However, recent qualitative studies suggest that the effectiveness and credibility of assurance processes could be compromised, revealing a potential for managerial capture, greenwashing and a disconnect between reported information and actual impact (Hsueh, 2018). The emergence of mandatory sustainability reporting requirements and the application of artificial intelligence (AI) to ESG assurance are considered recent trends, which require further investigation of their implications (Pantazi, 2024; Li *et al.*, 2024). Our literature review reveals a trend towards a more integrated and strategic approach to sustainability reporting certification. This evolution is driven by changing market expectations and increasingly complex regulatory frameworks, which challenge traditional audit practices. By synthesising these themes, the review not only clarifies the current intellectual landscape but also highlights opportunities for future research to explore how audit firms can adapt to and advance this transformation.

4.2.3. Future research directions

Based on the structural gaps and thematic disconnects identified in our bibliometric mapping, we propose a comprehensive research agenda that explicitly links these empirical findings to critical avenues for future inquiry. First, our spatial analysis highlighted a significant hegemony of Western contexts, with a critical paucity of research emerging from the Arab world and North Africa. This geographic imbalance implies that existing theoretical frameworks, often rooted in developed institutional settings, may not fully capture the complexities of emerging markets. Consequently, future scholarship must prioritize the investigation of assurance adoption in transitional economies, such as Tunisia. Researchers should specifically examine how local audit firms navigate "institutional voids", such as fragmented regulations and limited technical expertise and whether their motivations are driven by genuine ethical commitment or merely the pressure to signal legitimacy to foreign investors. Second, the thematic map revealed that topics such as "Audit Fees" and "Financial Performance" remain niche clusters with low centrality, suggesting that the tangible economic benefits of assurance are not yet clearly established in the literature. To address this, future studies should rigorously investigate the cost-benefit dynamics of assurance services, exploring whether high-quality assurance actually reduces the cost of capital in developing markets or if it simply represents a compliance cost without financial return. Finally, acknowledging that the field is currently dominated by quantitative regression analyses using archival data, we argue that a methodological shift is required to deepen our understanding of the field. We strongly recommend the adoption of mixed-method research designs that combine large-scale data analysis with qualitative inquiries, such as in-depth practitioner interviews. Such an integrated approach is essential to open the "black box" of the assurance process, allowing researchers to triangulate findings and better understand the behavioral and organizational nuances of auditors that statistical correlations alone cannot reveal.

5. Conclusions

The primary objective of this study was to review the existing literature to identify key findings and define future research areas. By employing a quantitative bibliometric method, this study overcomes the subjective biases often associated with qualitative reviews (Zupic and Čater, 2015), offering an objective and global representation of the sustainability reporting assurance field. Our analysis reveals a significant resurgence of interest since the 2010s, with a thematic evolution from voluntary "CSR disclosure" to mandatory "regulatory compliance" and "audit quality." This shift reflects the global priority placed on transparency and accountability in ESG approaches. However, despite this growth, our findings highlight a critical geographical bias: the literature is heavily dominated by Western contexts, with minimal representation of Africa and the Arab world. The unique contribution of this research lies in identifying this gap as a major obstacle to the development of inclusive theoretical models. Specifically, we argue that the current literature fails to address the motivations and restrictions of audit firms in transitional economies, such as Tunisia, where sustainability standards are still in a developmental phase.

This insight offers practical relevance for policymakers in emerging markets, suggesting that governance frameworks must be adapted to local institutional contexts rather than simply importing global standards. Furthermore, utilizing science mapping methods (Donthu et al., 2021), we visualized the intellectual interactions within the field. The co-word analysis demonstrated that while topics like corporate governance are central, the link between assurance and financial performance remains underexplored. These findings provide a strategic roadmap for future research. While this study is limited by its exclusive reliance on the Scopus database, it establishes a necessary foundation for the next phase of scholarship. Future research should aim to merge multiple databases and employ mixed-method designs to deeply investigate the operational challenges of assurance in under-researched emerging markets.

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