



Latin American J. of Management for Sustainable Development

ISSN online: 2052-0344 - ISSN print: 2052-0336

<https://www.inderscience.com/lajmsd>

Analysis of factors associated with ESG performance of Brazilian cities

John Cesar de Souza, Vanderly Janeiro, George Lucas Moraes Pezzott

DOI: [10.1504/LAJMSD.2025.10073828](https://doi.org/10.1504/LAJMSD.2025.10073828)

Article History:

Received:	20 August 2024
Last revised:	10 November 2024
Accepted:	18 February 2025
Published online:	12 January 2026

Analysis of factors associated with ESG performance of Brazilian cities

John Cesar de Souza

Department of Production Engineering,
State University of Maringá, Brazil
Email: johncesa@gmail.com

Vanderly Janeiro and
George Lucas Moraes Pezzott*

Department of Statistics,
State University of Maringá, Brazil
Email: vjaneyro@uem.br
Email: glmpezzott@uem.br
*Corresponding author

Abstract: Environmental, social and governance (ESG) criteria emerged in 2004 as a way to assess the performance of corporations in terms of environmental sustainability, social equity, and effective governance. Since then, many companies have embraced these criteria as a way to demonstrate their sustainable development. On the other hand, ESG criteria can be replicated in cities in order to contribute to a better quality of life for citizens, generate environmental sustainability, improve resilience, and attract investors to the city. In this context, this paper aims to analyse the sustainable performance of cities according to ESG criteria. The data are from Brazilian cities and they were constructed by the Competitiveness Ranking of Municipalities of the Center for Public Leadership. We analysed three editions (2021, 2022 and 2023) between 409 and 415 municipalities and applied a mixed-effects model for each index (ESG, E, S and G). The results show that the geographic region, the predominant economic sector, whether the city is a capital or not, per capita revenue, per capita companies and average salary are significant variables in defining the positioning of cities in the indicators, offering the profile of the cities with the best and worst performance in sustainable development.

Keywords: environmental, social and governance; ESG; sustainable cities; regression model; mixed effects models.

Reference to this paper should be made as follows: de Souza, J.C., Janeiro, V. and Pezzott, G.L.M. (2025) 'Analysis of factors associated with ESG performance of Brazilian cities', *Latin American J. Management for Sustainable Development*, Vol. 6, No. 4, pp.374–391.

Biographical notes: John Cesar de Souza holds a Bachelor's degree (2017) and a Master's degree (2024) in Production Engineering from the State University of Maringá (UEM), and an MBA in Project Management from the Maringá University (UNICESUMAR) (2019). He has professional experience working on projects for the socioeconomic development of municipalities, regions and their economic sectors.

Vanderly Janeiro is a Professor in the Department of Statistics at the State University of Maringá (DES/UEM), Brazil. He holds a degree in Mathematics from UEM (1995), a Master's degree in Computer Science and Computational Mathematics from the University of São Paulo – São Carlos (1998–2000), and a PhD in Statistics and Agricultural Experimentation from ESALQ/University of São Paulo – Piracicaba (2006–2010). His academic work focuses on applied statistics, statistical modelling, and statistics education, with an emphasis on the use of computational technologies for data analysis, experimental and analysis of design, mixed models, and nonlinear models.

George Lucas Moraes Pezzott holds a PhD in Statistics from the Interinstitutional Graduate Program in Statistics from the University of São Paulo and Federal University of São Carlos (2014–2018), a Master's degree in Statistics from the Federal University of São Carlos (2012–2014), and a Bachelor's degree in Statistics from the State University of Maringá (2008–2011). He is currently a Professor in the Department of Statistics at the State University of Maringá (DES/UEM). His research focuses on Probability and Statistical Inference, particularly the analysis of sustainability indicators, Bayesian analysis and the estimation of population size using capture-recapture models.

1 Introduction

The environmental, social and governance (ESG) criteria were created in 2004 by the UN Global Pact, through the 'Who Cares Wins' document. Since then, ESG has been used as one of the criteria for investors to analyse the conduct and future financial performance of companies and is being practiced in developed countries (Li et al., 2021). This has led financial institutions around the world to evaluate ways of associating environmental, social and governance aspects in the financial market, becoming a stimulus for the adoption of measures with positive impacts in these three areas.

One way to measure the ESG performance of organisations is through assessment models. Some of these models are proposed by organisations, such as the ESG Refinitiv score, Thomson Reuters ASSET4/EIKON and Bloomberg. In Brazil, there is the ISEB3 Index, an index developed by Brazilian Stock Exchange (B3) of the performance of the prices of the assets of selected Brazilian companies (ISEB3, 2024). In addition, at the end of 2022, the Brazilian Association of Technical Standards (ABNT) published the ABNT PR 2030 standard, which aims to conceptualise, guide how to implement and evaluate ESG in organisations (Associação Brasileira De Normas Técnicas, 2022). These ESG models and indexes are built based on institutional performance indicators. In general, to obtain an ESG index for an institution, data is collected that can be obtained from questionnaires or indicators related to environmental, social and governance aspects, an appropriate standardisation is carried out so that they are on the same scale, and the ESG score is calculated. The higher the index, the better the performance of the institutions in the aspects evaluated.

Many studies evaluate the performance of companies in the ESG index by relating it to other factors and variables of interest (Halbritter and Dorfleitner, 2015; Triyani et al., 2020; Arsin, 2023; Firmansyah et al., 2023; Qureshi et al., 2021; Buallay, 2019; Rao et al., 2023; Naimy et al., 2021). For example, Almeyda and Darmansyah (2019) used

multiple regression to analyse whether there is a correlation between the ESG score and the financial results of real estate companies in the seven largest economies in the world. Junius et al. (2020) used multiple regression and analysed the impact of ESG performance on the market value performance of 271 companies from Thailand, Singapore, Malaysia and Indonesia. The study used return on assets, return on equity and Tobins's Q variables. De Lucia et al. (2020) used a combined machine learning and logistic regression approach to analyse the accuracy of financial indicators of public companies in Europe, assess whether ESG factors affect their financial performance and how these factors can contribute to the advancement of corporate social responsibility policies. Data from 1,038 public companies available in the Thomson Reuters ASSET4/EIKON database were used, being for the environmental axis: use of resources, emissions and innovation; for the social axis: workforce, human rights, community and product responsibility; and for the governance axis: management, shareholders, CSR strategy; in addition to data on return on equity (ROE) and return on assets (ROA). Alareeni and Hamdan (2020) analysed whether an organisation's ESG performance brings returns to shareholders and whether it can withstand crisis situations. To this end, multiple regression was used to find the causal relationship between ESG indicators, accounting, financial indicators, and market indicators, from a sample of 969 companies, during the COVID-19 pandemic. The authors conclude that companies with better ESG performance can recover more quickly from crisis situations. Quintiliani (2022) analysed the relationship between company value and the ESG score of 115 companies in Europe. Cash flow indicators, return on equity, and liquidity ratios were used as variables. The study used a linear regression model and concluded that the variables have a significant positive relationship.

In fact, ESG theory was initially used for corporate governance. However, many factors of corporate governance are similar to urban governance, and therefore ESG theory provides excellent research perspectives and solutions for city management. For example, Xu and Zhao (2023) analysed that the integration of environmental, social and governance factors contributes to the construction of strategies to overcome disasters in cities and, thus, make them more resilient, thus favouring their sustainable development in the long term. Esmailpour et al. (2021) say that good urban governance occurs through the integration of public managers and citizens in search of better environmental, social and economic performance, and indicate that this is achieved through participation and evaluation of indicators. Hiremath et al. (2013), state that methods are needed to assess the level of sustainability of cities and suggest using indicators as a method. Kusakci et al. (2022) contribute that the indicators, in addition to helping governments in decision-making, also provide transparency for the population, motivating society to be more participatory. The cities of the future can be built by companies with ESG at the forefront and innovation (Buallay et al., 2021)

Regarding sustainable city analyses, Zhou et al. (2021) estimated a regression model to estimate carbon emissions from land use at the city level by assessing the relationship between urbanisation and carbon emissions. For this purpose, data from 13 cities in the Beijing-Tianjin-Hebei (BTH) urban agglomeration in China were used. The results show that Beijing showed a reduction in carbon emissions due to its optimisation and industrial upgrade, while other cities showed an increase. The regression analysis between urbanisation and carbon emissions from land use shows low carbon emissions in cities with high and low urbanisation, high carbon emissions in cities with medium urbanisation. The authors indicate the need to control urban expansion and excessive land

development. Sharma et al. (2021) used quantile regression to analyse the relationship between greenhouse gas emissions and gross domestic product, gross domestic product, value added in agriculture, forestry and fishing, pesticide use, renewable energy consumption and human capital. The study was conducted in the six BIMSTEC countries (Bangladesh, India, Myanmar, Nepal, Sri Lanka and Thailand). The results indicate that limiting agriculture to small-scale production can contribute to environmental quality, but as production increases, it can increase greenhouse gas emissions. It was also analysed that renewable energies have an insignificant effect on greenhouse gas emissions, showing an inefficiency of the use of this technology in agricultural production. There is no significant effect between the human capital variables and greenhouse gas emissions from pesticide use. The use of renewable energies can offset the effect of pesticides.

Liu et al. (2022) evaluated the transition to sustainable energy in the ten countries that emit the most CO₂ in relation to the energy trilemma (environmental sustainability, energy security, and access to equitable energy). The authors used random effects panel GLS regression and used economic growth, environmental quality, energy data, and investment as variables. Based on the results, the authors conclude that economic growth is positively influenced by the transition to sustainable energy, the energy trilemma, investments in fixed assets, and energy consumption. The transition to sustainable energy and the energy sector trilemma negatively influences the environment. They also conclude that the countries analysed are more prosperous and have better environmental performance when they transition to sustainable energy.

For Bonab et al. (2023), a smart city is also a sustainable city and suggest that public managers reflect on the uncontrolled growth of the population of cities. The authors estimated a regression model to analyse the relationship between population and the level of smart city and ecology of all cities with more than one million inhabitants in the world. The results show that the size of a city's population negatively impacts its ecology and, conversely, positively impacts its intelligence. They also suggest a balance in population size so that the city is both ecological and intelligent.

However, although the ESG index is widely used in companies, few studies apply it to assess the sustainable performance of cities, leaving a research gap in the area of sustainable cities. In fact, studies of socio-environmental aspects and indicators, aligned with ESG guidelines, are necessary for the sustainable development of cities (Dias et al., 2023). In this sense, this study aims to study which profile variables can explain a better or worse performance of cities in the ESG ranking and characterise the profile of a city in sustainable performance, according to ESG criteria, based on data from Brazilian cities.

The work is structured as follows. This section introduces the subject. Section 2 presents the data from the ESG indexes and the factors analysed. This section also discusses the regression model for longitudinal data for data analysis. Section 3 presents the descriptive and inferential analyses via regression model for the data considering four models respectively for the ESG, E, S and G indexes. Section 4 presents the discussions of the results found and, finally, Section 5 presents the conclusions of this study.

2 Materials and methods

2.1 Data

This article analysed data from three editions (2021, 2022 and 2023) of the Ranking de Competitividade dos Municípios of Centro de Liderança Pública (CLP, 2021, 2022, 2023). This ranking analyses the performance of Brazilian municipalities through indicators. The 2021 edition evaluated 411 municipalities, the 2022 edition evaluated 415 municipalities, and the 2023 edition evaluated 409 Brazilian cities. The 2022 sample represents 7.45% of the total cities in Brazil, and the cities in the study together have 127.9 million inhabitants (59.96% of the country's population). To construct the ranking, 65 indicators were used, organised into 13 thematic pillars and three dimensions.

2.2 Factors analysed

This study used the general ESG scores developed by CLP, which ranked the largest Brazilian cities in terms of sustainable development, to assess factors associated with Brazilian municipalities that contribute to better or worse performance in the sustainable development ranking. To this end, data related to profile variables that characterise the municipalities were used: year (2021, 2022 and 2023); capital (yes or no); region (central-west, northeast, north, southeast and south); predominant economic sector (industry + agriculture, services and public sector); average salary in R\$; population size; companies per capita; and municipal revenue per capita (IBGE, 2022).

The selection of the factors analysed was based on the following criteria:

- a not being part of the list of indicators that make up the ranking
- b they must be indicators or indexes available in public sources
- c the data must be available for all Brazilian cities.

2.3 Regression model

In order to study the relationship between the variables, we propose in this article to adjust four regression models considering as response variables the ESG, E, S and G indices, and as covariates the independent variables presented in Section 2.2. The model was proposed based on the following linear mixed effects structure (Pinheiro and Bates, 2006; Gałęcki et al., 2013; West et al., 2022):

$$\begin{aligned}
 y_{ijk} = & \beta_0 + \beta_1 Year_k + \beta_2 CapitalYes_i + \beta_3 RegionNortheast_i \\
 & + \beta_4 RegionNorth_i + \beta_5 RegionSoutheast_i + \beta_6 RegionSouth_i \\
 & + \beta_7 PredominantEconomicSectorServices_{ik} \\
 & + \beta_8 SPredominantEconomicSectorPublicSector_{ik} \\
 & + \beta_9 AverageSalary_{ik} + \beta_{10} Population_{ik} \\
 & + \beta_{11} Companiespercapita_{ik} + \beta_{12} MunicipalRevenuepercapita_{ik} \\
 & + \beta_{13} AverageSalary_{ik}^2 + \beta_{14} Companiespercapita_{ik}^2 \\
 & + \beta_{15} MunicipalRevenuepercapita_{ik}^2 + u_i + \varepsilon_{ijk}
 \end{aligned}$$

$$i = 1, \dots, n_k, j = 1, \dots, 5, k = 1, 2, 3$$

where

- y_{ijk} represents the value of the dependent variable (ESG, E, S or G scores) for municipality i nested in region j in year k
- β_0 to β_{15} represent the fixed intercept and the fixed effects of the covariates
- u_i is the random effect associated with the intercept for the i^{th} municipality
- ε_{ijk} represents the residual error.

For random effects, the following distributions will be considered:

$$u_i \sim^{iid} \text{Normal}(0, \sigma_{city}^2) \text{ and } \varepsilon_{ijk} \sim^{ind.} \text{Normal}(0, \sigma_j^2)$$

where

- σ_{city}^2 represents the random variation of the municipality-specific intercepts
- σ_j^2 represents the variances of the residual error, with heterogeneity between regions.

We adjusted the models considering restricted maximum likelihood estimates. In this case, we used the 'lme' function from the 'nlme' package of the R software (R Core Team, 2022). Initially, the saturated model is adjusted (with all covariates) and then the selection model is run by removing one by one the covariates whose p-value of the t-test in the model was less than 5% significance. If there is a significant decrease in the AIC of the model without the covariate, then the covariate is removed from the model. In all models, we tested $H_0 : \sigma_{city}^2 = 0$ versus $H_1 : \sigma_{city}^2 > 0$ for the presence of the random effect μ_i in the model. In this scenario, it is recommended to use the test statistic by a mixture of chi-square tests because the parameter is on the edge of the parametric space (West et al., 2022). Additionally, an F test from analysis of variance is adopted to test $H_0 = \sigma_1^2 = \dots = \sigma_5^2$ for the components of the residual variance. The quality of the model fit will be assessed through R^2 (Nakagawa and Schielzeth, 2013; Nakagawa et al., 2017) and residual analysis.

3 Results

3.1 Descriptive analysis

Table 1 presents the categorical variables analysed, the amount of observed data, the mean, the standard deviation, minimum and maximum in each of them, for the ESG and E, S and G indexes separately. From Table 1, it is possible to analyse that among cities that are not capitals, the average ESG score decreased in the period of -3.57% . The

lowest score in the sample was in 2023, with a value of 3.89, which represents a decrease in the period of -57.59% compared to the minimum score in 2021, which was 9.18. The highest score in the sample was 94.79 in 2021. The maximum score also decreased in the period, with a value of -3.87% . Among the capitals, the ESG average decreased by -8.06% in the period, going from a score of 66.15 in 2021 to 60.82 in 2023. On the E axis (environmental), considering cities that are not capitals, the samples showed a decrease in the average value of -6.72% . Among capital cities, the average score on the E axis decreased by -11.75% , going from a score of 67.23 in 2021 to 59.34 in 2023. The minimum score on the axis in the period was 8.81 in 2023 and the maximum was 86.10 also in 2023. On the S axis (social), considering cities that are not capitals, the average decreased in the period of -1.66% , where there was a score of 53.27 in 2021 and 52.39 in 2023. Among capital cities, the decrease in the average score was -5.67% , going from 58.77 in 2021 to 55.43 in 2023. Among capital cities, the lowest minimum score on the social axis was 20.80 in 2023 and the highest maximum score was 89.72 in 2022. Analysing axis G (governance), the average among cities that are not capitals decreased by -1.98% , going from a score of 62.85 in 2021 to 61.60 in 2023. Among capitals, the average score on axis G decreased by -6.57% . Among capital cities, the lowest minimum score was 22.98 in 2022 and the highest maximum score was 99.02 in 2021. In general, on all axes, cities that are not capitals had growth in 2022 and a decrease in 2023, even having a lower score than in 2021. Cities that are capitals, on the other hand, had a decrease in 2022 and 2023. In all years, the minimum values in capitals are much higher than the minimum values in non-capitals. Furthermore, no maximum value equal to 100.00 was observed among the capitals in the period analysed, while among the non-capitals, maximum values equal to 100.00 were observed in all years for the E, S and G axes.

Regarding the predominant sector in the cities analysed, following the analysis in Table 1, in general, all sectors had a decrease in the score in all axes during the period. The industry + agriculture and public sector sectors had a small growth in the indexes in 2022, but in 2023 they had a decrease, with some indexes falling below the initial year (2021). Analysing the general ESG index, the services sector had a decrease of -3.85% , the industry + agriculture sectors had a growth of 0.59% and the public sector had the highest growth with 2.69% . In the environmental axis, all sectors showed a decrease, with the public sector having the highest value (-7.47%). Evaluating the social axis, the industry + agriculture sector grew by 1.40% , the services and public sector sectors showed a decrease, with the public sector showing the largest decrease (-3.51%). In the governance axis, the public sector showed significant growth with a value of 22.41% , the industry + agriculture sector achieved a 3.75% growth in the axis score, while the services sector showed a decrease of -2.65% . Evaluating the average scores of the sectors, in the ESG axis, the public sector presented the lowest average (28.28), a value observed in 2021. In the environmental axis, the lowest average was in 2023 for the public sector (33.13). In the social axis, the lowest average was in the public sector in 2022, with an average of 21.75. In the governance axis, the lowest average was also in the public sector (25.78) in 2021.

Table 1 Descriptive analysis of ESG, E, S and G scores by categorical variables

Variable/levels	Year	n	ESG		E		S		G	
			Mean ± desv. pad.	[min – max]	Mean ± desv. pad.	[min – max]	Mean ± desv. pad.	[min – max]	Mean ± desv. pad.	[min – max]
Capital										
No	2021	385	59.96 ± 16.41	[9.18 – 94.79]	63.76 ± 18.02	[0.00 – 100.00]	53.27 ± 16.07	[0.00 – 100.00]	62.85 ± 18.44	[0.00 – 100.00]
	2022	389	60.29 ± 16.15	[9.21 – 91.56]	65.42 ± 16.12	[0.00 – 100.00]	52.41 ± 18.33	[0.00 – 100.00]	63.05 ± 17.45	[0.00 – 100.00]
	2023	383	57.82 ± 17.15	[3.89 – 91.13]	59.47 ± 19.07	[0.00 – 100.00]	52.39 ± 18.74	[0.00 – 100.00]	61.60 ± 18.08	[0.00 – 100.00]
Yes	2021	26	66.15 ± 12.69	[41.33 – 87.49]	67.23 ± 13.12	[27.48 – 86.02]	58.77 ± 12.86	[38.97 – 84.54]	72.44 ± 15.00	[40.58 – 99.02]
	2022	26	64.50 ± 14.58	[33.23 – 87.01]	66.39 ± 15.11	[14.37 – 85.49]	57.61 ± 14.85	[28.21 – 89.72]	69.48 ± 16.89	[22.98 – 98.25]
	2023	26	60.82 ± 16.64	[24.02 – 87.24]	59.34 ± 18.76	[8.81 – 86.10]	55.43 ± 17.06	[20.80 – 87.42]	67.68 ± 17.18	[30.31 – 98.49]
Predominant sector										
Services	2021	366	62.17 ± 14.71	[14.48 – 94.80]	65.89 ± 16.06	[9.76 – 100.00]	55.22 ± 14.80	[16.03 – 100.00]	65.40 ± 16.70	[8.42 – 100.00]
	2022	360	62.08 ± 15.17	[14.10 – 91.56]	66.83 ± 15.03	[0.00 – 100.00]	54.48 ± 17.20	[12.89 – 100.00]	64.93 ± 16.75	[18.29 – 100.00]
	2023	360	59.77 ± 15.89	[4.43 – 91.13]	61.34 ± 17.92	[4.20 – 100.00]	54.31 ± 17.51	[2.31 – 100.00]	63.67 ± 16.98	[0.00 – 100.00]
Industry + agriculture	2021	33	51.83 ± 19.06	[9.34 – 80.78]	53.06 ± 23.62	[0.00 – 83.88]	46.91 ± 16.91	[11.88 – 77.98]	55.51 ± 19.62	[4.13 – 81.99]
	2022	40	57.29 ± 15.56	[21.77 – 81.71]	62.39 ± 17.83	[17.95 – 90.56]	48.68 ± 18.25	[2.23 – 77.23]	60.79 ± 14.87	[21.82 – 85.33]
	2023	34	52.13 ± 18.92	[3.89 – 82.05]	51.24 ± 20.74	[1.91 – 83.20]	47.57 ± 20.99	[0.00 – 80.58]	57.59 ± 18.32	[1.04 – 82.36]
Public sector	2021	12	28.28 ± 12.97	[9.18 – 54.87]	35.81 ± 15.11	[6.38 – 66.69]	23.26 ± 11.48	[0.00 – 40.44]	25.78 ± 18.78	[0.00 – 59.34]
	2022	15	32.64 ± 11.85	[9.21 – 52.50]	41.18 ± 15.05	[7.42 – 63.09]	21.75 ± 9.25	[0.00 – 35.56]	34.99 ± 16.33	[0.00 – 60.27]
	2023	15	29.05 ± 12.26	[9.07 – 52.98]	33.13 ± 17.36	[0.00 – 59.07]	22.45 ± 10.35	[6.18 – 42.14]	31.56 ± 14.68	[8.02 – 57.74]

Table 1 Descriptive analysis of ESG, E, S and G scores by categorical variables (continued)

Variable/levels	Year	n	ESG			E			S			G		
			Mean ± desv. pad.	[min – max]		Mean ± desv. pad.	[min – max]		Mean ± desv. pad.	[min – max]		Mean ± desv. pad.	[min – max]	
Region Central-West	2021	28	58.94 ± 10.06	[41.92 – 76.36]		64.47 ± 11.75	[39.08 – 83.42]		50.10 ± 10.41	[34.29 – 70.01]		62.25 ± 12.48	[37.32 – 80.66]	
	2022	28	57.99 ± 10.80	[35.82 – 74.41]		64.55 ± 10.91	[39.92 – 84.20]		48.03 ± 12.70	[26.74 – 71.50]		61.38 ± 12.74	[38.96 – 79.30]	
	2023	31	52.52 ± 10.44	[33.51 – 70.52]		52.17 ± 13.05	[29.04 – 74.82]		46.55 ± 11.30	[26.90 – 65.16]		58.85 ± 12.65	[38.60 – 79.06]	
Northeast	2021	90	47.59 ± 11.51	[14.48 – 73.83]		52.39 ± 16.58	[9.76 – 86.95]		41.20 ± 9.47	[16.03 – 64.01]		49.18 ± 12.44	[8.42 – 73.99]	
	2022	90	46.26 ± 10.99	[14.26 – 74.06]		55.01 ± 16.36	[0.00 – 92.42]		36.83 ± 10.50	[16.03 – 60.38]		46.95 ± 11.31	[18.29 – 71.34]	
	2023	89	44.35 ± 11.62	[7.69 – 69.73]		48.58 ± 17.32	[1.78 – 87.18]		37.43 ± 11.34	[10.28 – 61.35]		47.04 ± 12.25	[2.92 – 71.84]	
North	2021	38	37.96 ± 15.47	[9.18 – 74.26]		42.76 ± 17.97	[0.00 – 81.74]		31.92 ± 13.80	[0.00 – 63.68]		39.22 ± 19.38	[0.00 – 77.37]	
	2022	38	39.73 ± 13.42	[9.21 – 70.74]		46.07 ± 14.99	[9.32 – 74.03]		29.87 ± 14.38	[0.00 – 63.80]		43.25 ± 15.66	[0.00 – 74.40]	
	2023	38	34.52 ± 13.79	[3.89 – 63.69]		35.10 ± 17.10	[0.00 – 70.21]		28.16 ± 13.64	[0.00 – 54.56]		40.28 ± 15.43	[0.00 – 66.19]	
Southeast	2021	187	68.33 ± 12.13	[26.50 – 94.80]		72.00 ± 13.26	[20.62 – 100.00]		61.44 ± 12.80	[20.18 – 100]		71.53 ± 14.03	[15.92 – 100]	
	2022	189	68.5 ± 12.18	[26.10 – 91.56]		72.41 ± 11.80	[25.30 – 100.00]		61.75 ± 14.65	[12.10 – 100.00]		71.34 ± 13.17	[21.42 – 100.00]	
	2023	184	66.79 ± 13.15	[17.39 – 91.13]		68.04 ± 14.78	[13.39 – 100.00]		62.42 ± 15.09	[6.18 – 100.00]		69.91 ± 14.35	[11.98 – 98.49]	
South	2021	68	68.39 ± 10.67	[36.84 – 87.49]		68.89 ± 14.21	[24.47 – 96.01]		62.11 ± 10.33	[35.45 – 89.72]		74.15 ± 11.77	[45.79 – 98.32]	
	2022	70	69.83 ± 8.98	[50.12 – 87.96]		71.12 ± 11.76	[48.01 – 96.05]		63.17 ± 10.85	[35.46 – 89.72]		75.18 ± 10.31	[55.81 – 98.25]	
	2023	67	67.92 ± 9.83	[44.33 – 90.29]		67.58 ± 13.88	[31.38 – 96.24]		62.33 ± 12.03	[34.63 – 87.42]		73.85 ± 12.07	[39.55 – 100.00]	

Furthermore, according to Table 1, analysing the scores of the cities by region, all had a decrease in the average score of the ESG axis in the analysed period. The central-west region had the largest decrease, with a value of -10.88% , followed by the north region with a decrease of -9.10% , the northeast with a decrease of -6.82% , and the southeast with -2.25% . The south region had the smallest decrease, with a value of -0.68% . Analysing the environmental axis (E), there was again a decrease in all regions. The central-west region had the smallest decrease (-19.07%), followed by the north region (-17.92%), the northeast region (-7.29%), the southeast (-5.51%), and the south (-1.89%). In the social axis (S), three regions had a decrease in the average score of the cities: north (-11.78%), northeast (-9.16%), and central-west (-7.09%). In this social axis, the southeast and south regions had growth in the average score in the period with values of 1.59% and 0.34% , respectively. In the governance axis (G), only the north region showed growth in the average score, with growth of 2.70% . The others showed a decrease: central-west (-5.45%), northeast (-4.35%), southeast (-2.27%), south (-0.41%). Analysing the minimum values in the ESG axis among the regions, the minimum value observed in the entire period was in the north region in 2023 with a value of 3.89. In the environmental axis, the lowest minimum value was observed in the northeast in 2022 and in the north in 2021 and 2023, with a value of 0.00. In the social and governance axes, the north had the lowest value (0.00) in the three years analysed. The south and central-west regions had the highest minimum values in the periods and axes evaluated. Regarding maximum values, the southeast region presented the highest maximum values in all axes in the period analysed. The south region also performed well in maximum scores in the three axes in the period.

Table 2 Descriptive analysis of numerical variables

<i>Variable</i>	<i>Year</i>	<i>n</i>	<i>Minimum</i>	<i>Mean</i>	<i>Maximum</i>	<i>Corr. ESG</i>	<i>Corr. E</i>	<i>Corr. S</i>	<i>Corr. G</i>
Companies per capita	2021	411	0.0056	0.0389	0.1074	0.7321	0.5347	0.7864	0.7451
	2022	415	0.0064	0.0404	0.1177	0.7392	0.5100	0.7914	0.7498
	2023	409	0.0075	0.0397	0.3497	0.2089	0.1022	0.2538	0.2244
Average salary	2021	411	1,382.18	2,500.77	5,956.72	0.4109	0.2937	0.4347	0.4301
	2022	415	1,602.71	2,782.53	6,260.42	0.3887	0.2364	0.4272	0.4120
	2023	409	1,780.66	2,882.87	6,578.88	0.4212	0.2898	0.4438	0.4342
Population	2021	411	78,728	305,151.7	12,252,023	0.1556	0.1298	0.1192	0.1842
	2022	415	78,239	302,968.7	12,252,023	0.1405	0.1121	0.1094	0.1713
	2023	409	56,789	305,909.4	12,252,023	0.1378	0.1025	0.1128	0.1674
Municipal revenue per capita (×1,000)	2021	411	1.4539	3.9134	16.5869	0.4232	0.2844	0.4607	0.4492
	2022	415	1.2483	4.5405	27.3288	0.3255	0.1769	0.3734	0.3477
	2023	409	2.2490	5.6583	95.3822	0.1933	0.0777	0.2223	0.2375

Table 3 Parameter estimates of mixed effects models fitted to the data

	ESG		E		S		G	
	Estimate (std. error)	p-value	Estimate (std. error)	p-value	Estimate (std. error)	p-value	Estimate (std. error)	p-value
Intercept	1.942.91 (344.8)	<0.0001	3.156.09 (508.4)	<0.0001	812.01 (384.5)	0.0350	2.629.00 (427.4)	<0.0001
Year	-0.94 (0.2)	<0.0001	-1.54 (0.3)	<0.0001	-0.37 (0.2)	0.0474	-1.28 (0.2)	<0.0001
Capital (yes)	11.23 (1.9)	<0.0001	7.75 (2.6)	0.0031	12.47 (2.4)	<0.0001	12.05 (2.2)	<0.0001
Northeast Region	-6.42 (1.9)	0.0010	-5.51 (2.6)	0.0373	-7.52 (2.3)	0.0010	-7.91 (2.1)	0.0001
North Region	-14.47 (2.3)	<0.0001	-14.38 (3.2)	<0.0001	-16.38 (2.7)	<0.0001	-14.89 (2.5)	<0.0001
Southeast Region	12.38 (1.8)	<0.0001	11.88 (2.4)	<0.0001	14.15 (2.1)	<0.0001	10.62 (1.9)	<0.0001
South Region	10.59 (2.0)	<0.0001	7.62 (2.7)	0.0047	13.95 (2.3)	<0.0001	10.88 (2.1)	<0.0001
Predominant sector (services)	2.96 (0.9)	0.0013	3.31 (1.5)	0.0283	0.78 (0.8)	0.3473	2.59 (1.0)	0.0117
Predominant sector (public sector)	-3.52 (1.9)	0.0657	-3.36 (3.1)	0.2711	-6.02 (1.8)	0.0009	-4.16 (2.0)	0.0401
Companies per capita	2.37 (0.3)	<0.0001	2.15 (0.4)	<0.0001	1.15 (0.2)	<0.0001	2.80 (0.3)	<0.0001
Municipal revenue per capita	0.63 (0.2)	0.0002	-0.16 (0.07)	0.0255	0.64 (0.2)	0.0001	0.98 (0.2)	<0.0001
Companies per capita ²	-0.06 (0.01)	<0.0001	-0.05 (0.01)	0.0054	-0.035 (0.008)	0.0001	-0.082 (0.01)	<0.0001
Municipal revenue per capita ²	-0.006 (0.01)	0.0001			-0.006 (0.002)	0.0004	-0.001 (0.002)	<0.0001
Average salary					-0.004 (0.002)	0.0402	0.0014 (0.0006)	0.0219
Average salary ²					0.000 (0.000)	0.0110		
R ² (conditional)	0.8376		0.6324		0.9363		0.8175	
R ² (marginal)	0.5588		0.3072		0.5602		0.5569	

Analysing Table 2 of descriptive analysis of continuous data, the company per capita variable presents a strong correlation with the ESG, S and G axis index score for 2021 and 2022. It also presents an average correlation for axis E in 2021 and 2022. For 2023, this variable presents a low correlation in all axes. The population variable presents a low correlation in all axes for all years. The revenue per capita variable presents an average correlation with the ESG, S and G axes in 2021 and 2022 and presents a low correlation with axis E in all years and in 2023 for all axes. The average salary variable presents an average correlation with the ESG, S and G axes in all years and a low correlation with axis E in all years.

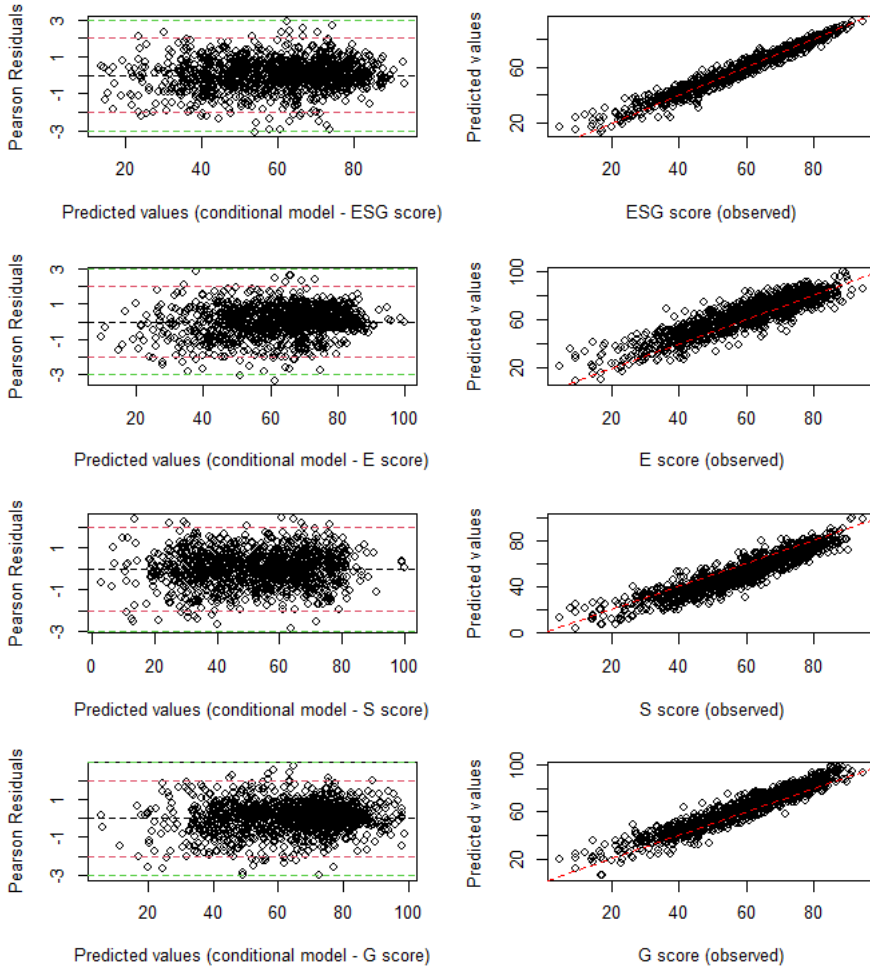
3.2 Mixed effect models

The mixed effects model was adjusted to the data and the results were obtained as shown in Table 3. Among the variables analysed, the population size had no influence and is therefore not shown in the model. The industry and agriculture sectors were combined into a single set due to their low sample size. In all models, the random effect in the municipality-specific intercepts ($p\text{-value} < 0.0001$) and for the different components of the residual variance between region ($p\text{-value} < 0.0001$) were significant. The R^2 values for the conditional model were high, com 0.8376, 0.6324, 0.9363 and 0.8175 for ESG, E, S and G models, respectively, demonstrating good fit of the models.

According to Table 3, the 'year' variable had a negative effect on all axes, with the environmental axis having the greatest negative effect and the social axis having the smallest negative effect. The capital variable has a positive influence on all axes, compared to cities that are not capitals. This variable has the greatest influence on the social axis, followed by governance. Among the regions, the central-west region was defined as the reference category. The north and northeast regions have a negative effect on all axes. For the north region, the social axis has the greatest negative effect, while in the northeast region the governance axis has the greatest negative effect. The southeast and south regions have a positive effect on all three axes. In both cases, the social axis presents the greatest positive effect. As for the predominant sector variable, the set that united the industrial and agricultural sectors is what was defined as the reference. The service sector has a positive influence on all axes, and the environmental axis has the greatest impact. The public sector, on the other hand, has a negative influence on all axes. The social axis has the greatest negative impact. The companies per capita variable has a positive influence on all axes. It is on the governance axis that this variable has the greatest impact. The per capita revenue variable has a negative influence on the environmental axis and a positive influence on the others. The greatest positive influence is on the governance axis. The average salary variable had a positive influence only on the social axis, and had no significant influence on the other axes.

Figure 1 shows the residual plots for the models. On the left side of the figure are the plots of values predicted by the conditional model versus Pearson residuals, showing no apparent pattern. On the right side are the predicted values versus observed values, where we observe good predictive power of the model since the points follow very close to the $x = y$ line. These graphs together with the R^2 show a satisfactory fit of the models.

Figure 1 Plot of predicted values versus residuals (graphs on the left) and observed values versus predicted values (graphs on the right) for four models (ESG, E, S and G) (see online version for colours)



4 Discussion

Analysing the data in Table 2, the capital variable has a greater influence on the ESG, S and G axes and a slightly smaller influence on the E axis. This may be justified by the fact that these are larger, more planned and organised cities, which may mean better management and allocation of resources, while they face great difficulties in environmental management combined with urban growth. Considering that capital cities are, in general, highly urbanised, and making a proxy for the environmental axis with carbon emission indicators, the results found in this study contrast with those found by Zhou et al. (2021), who analysed that there are low carbon emissions in cities with high and low urbanisation and high carbon emissions in cities with medium urbanisation. The

authors indicate the need to control urban expansion and excessive land development. Regarding the variable related to the region in which the city is located, the result reflects the already known development of the southeast and south regions of Brazil as more developed regions and the north and northeast regions as less developed. Analysing the predominant sector variable, we note the better performance of cities that have the services sector as predominant. This sector is actually the main sector of many Brazilian cities and is very important for the country's economy. It contributes to municipal revenue since it generates taxes that are collected by the municipalities themselves. However, it is worth noting that in order to develop a sustainable economy, a complete production chain composed of all sectors is necessary. It cannot be said that a city with only companies in the service sector would be the most suitable for better performance in an ESG index. As for the companies per capita variable, according to the model, it contributes positively to the performance of the index in all axes. This can be justified by the fact that companies contribute to income generation for the population and the municipality, especially the service sector, as already mentioned. Having a greater number of companies per capita can mean a more diversified economy and therefore less vulnerable to sectoral crises. Regarding the role and importance of companies in building sustainable cities, Jin et al. (2024) argue that companies are the main link between consumers and the government. Companies can promote the sustainable development of cities through transformation and innovation in their products and services, making them more sustainable and environmentally friendly. The municipal revenue per capita variable had a negative influence on the environmental axis, which may be a sign that even Brazilian cities are not allocating resources to improve their environmental issues and, therefore, have not improved their indicators related to this axis. The governance axis, on the other hand, has a greater positive impact for this variable, which may indicate the efforts of managers to raise resources for their cities. However, it is worth highlighting the importance of correctly allocating these resources, thinking about the sustainability of the municipality in environmental, social and economic issues. This thought is reinforced by the conclusions of the study developed by Kutty et al. (2020) in which they argue that investments are necessary to promote a smart and sustainable city, and that a shared policy and governance structure with the public and private sectors, civil society and other stakeholders is also necessary, with transparent strategies. The average salary variable was the only one that had an influence on only one axis, a positive influence on the social axis. The population did not show any relationship with the ESG indexes, contradicting Bonab et al. (2023), who analysed that the size of a city's population negatively impacts its ecology and positively impacts the intelligence of cities.

Six of the seven variables that are part of the model have influences on all axes. This represents the relevance of these variables in sustainable development, according to ESG criteria. The influence of companies on development is noticeable, generating jobs and income for citizens. At the same time that having companies positively impacts the ESG index, these companies need to offer fair wages and preserve the local community where they are located so as not to generate losses on the environmental and social axis.

One point that draws attention in the model is the negative influence of municipal revenue per capita on the environmental axis. As previously mentioned, this can be justified by the way in which resources are allocated, but a more in-depth study on the subject is necessary to confirm this hypothesis.

5 Conclusions

To perform efficient management, it is necessary to use indicators that indicate the scenario and the performance of processes and improvements. This cannot be different for the management of sustainable development, including the sustainable development of cities. ESG criteria emerged as a way to evaluate the performance of companies regarding their sustainable development and their environmental, social and governance impacts. Using these ESG criteria to evaluate cities can also be a good practice since the whole world must be concerned about future generations. Using ESG criteria in city management contributes to more efficient, transparent management and demonstrates care for the community that is impacted by the decisions of the public manager.

In this sense, this study aims to study which profile variables can explain a better or worse performance of cities in the ESG ranking and characterise the profile of a city in sustainable performance, according to ESG, E, S and G indices, based on data from Brazilian cities. This work therefore contributes with a statistical model capable of defining the ESG index of cities, which makes it possible to compare how far a city has moved towards sustainable development. In conclusion, the findings indicate that capital cities outperform others across all ESG dimensions. The southeast region leads in ESG, E, and S indices, while the south excels in G. Conversely, the north consistently shows the lowest performance. Cities with a service-based economy perform better, whereas those reliant on the public sector perform worse. Contrary to expectations, ESG indices declined over time. A higher number of companies per capita is associated with better performance across all axes. As for municipal revenue per capita, higher values improve ESG, S, and G indices but are linked to lower scores on the E axis. These results highlight the importance of understanding the socioeconomic and regional characteristics that influence sustainable development at the municipal level. By identifying the factors associated with better ESG performance, public managers can adopt targeted strategies that enhance the strengths and address the weaknesses of their municipalities. The proposed statistical model serves as a useful tool to support decision making, guide public policies, and foster transparency and accountability. Furthermore, by encouraging the adoption of ESG principles in the public sector, this study contributes to aligning urban development with global sustainability goals, ensuring that cities become more inclusive, resilient, and sustainable for current and future generations.

This work is limited in terms of data availability. This made it difficult to analyse more covariates. In Brazil, there are several sources of public data on cities, but they are often not easily accessible and are not concentrated in one or a few data portals, which would facilitate collection. In Brazil, there are still few analyses related to ESG criteria for cities. As future work, we suggest expanding the number of cities analysed and also evaluating other cities and countries around the world.

References

- Alareeni, B.A. and Hamdan, A. (2020) 'ESG impact on performance of US S&P 500-listed firms', *Corporate Governance: The International Journal of Business in Society*, Vol. 20, No. 7, pp.1409–1428 [online] https://unipub.lib.uni-corvinus.hu/6734/1/Green_Financial_Perspectives.pdf#page=55 (accessed 13 May 2024).
- Almeyda, R. and Darmansyah, A. (2019) 'The influence of environmental, social, and governance (ESG) disclosure on firm financial performance', *IPTEK Journal of Proceedings Series*, <http://dx.doi.org/10.12962/j23546026.y2019i5.6340>.
- Arsin, M. (2023) 'A structured literature review of the impact of ESG activities on firm performance', *SCIENTIA MORALITAS – International Journal of Multidisciplinary Research*, Vol. 8, No. 1, pp.34–45 [online] <https://scientiamoralitas.com/index.php/sm/article/view/224> (accessed 2 March 2024).
- Associação Brasileira De Normas Técnicas (2022) *Prática Recomendada: ABNT PR 2030: Ambiental, Social e Governança (ESG) – conceitos, diretrizes e modelo de avaliação e direcionamento para organizações*, Rio de Janeiro.
- Bonab, A.B., Bellini, F. and Rudko, I. (2023) 'Theoretical and analytical assessment of smart green cities', *Journal of Cleaner Production*, Vol. 410, p.137315, <https://doi.org/10.1016/j.jclepro.2023.137315>.
- Buallay, A. (2019) 'Is sustainability reporting (ESG) associated with performance? Evidence from the European banking sector', *Management of Environmental Quality: An International Journal*, Vol. 30, No. 1, pp.98–115, <https://doi.org/10.1108/MEQ-12-2017-0149>.
- Buallay, A., El Khoury, R. and Hamdan, A. (2021) 'Sustainability reporting in smart cities: a multidimensional performance measures', *Cities*, Vol. 119, p.103397, <https://doi.org/10.1016/j.cities.2021.103397>.
- Centro De Liderança Pública (CLP) (2021) *Ranking de Sustentabilidade dos Municípios – ESG e ODS – Um outro olhar a partir dos indicadores de competitividade do CLP* [online] <https://municipios.rankingdecompetitividade.org.br/camadas-esg-e-ods> (accessed 21 March 2023).
- Centro De Liderança Pública (CLP) (2022) *Ranking de Sustentabilidade dos Municípios – ESG e ODS – Um outro olhar a partir dos indicadores de competitividade do CLP* [online] <https://municipios.rankingdecompetitividade.org.br/camadas-esg-e-ods> (accessed 21 March 2023).
- Centro De Liderança Pública (CLP) (2023) *Ranking de Sustentabilidade dos Municípios – ESG e ODS – Um outro olhar a partir dos indicadores de competitividade do CLP* [online] <https://municipios.rankingdecompetitividade.org.br/camadas-esg-e-ods> (accessed 21 March 2023).
- De Lucia, C., Pazienza, P. and Bartlett, M. (2020) 'Does good ESG lead to better financial performances by firms? Machine learning and logistic regression models of public enterprises in Europe', *Sustainability*, <https://doi.org/10.3390/su12135317>.
- Dias, F.T., Dutra, A.R.d.A., Cubas, A.L.V., Henckmaier, M.F.F., Courval, M. and Guerra, J.B.S.O.d.A. (2023) 'Sustainable development with environmental, social and governance: strategies for urban sustainability', *Sustainable Development*, Vol. 31, No. 1, pp.528–539, <https://doi.org/10.1002/sd.2407>.
- Esmailpour, N., Goodarzi, G. and Zanjani, S.E. (2021) 'O modelo de boa governança urbana sustentável baseado em conceitos ESG', *Journal of Urban Management and Energy Sustainability*, Vol. 2, No. 4, DOI: 10.22034/jumes.2021.249506.
- Firmansyah, E.A., Umar, U.H. and Jibril, R.S. (2023) 'Investigating the effect of ESG disclosure on firm performance: the case of Saudi Arabian listed firms', *Cogent Economics & Finance*, Vol. 11, No. 2, p.2287923, <https://doi.org/10.1080/23322039.2023.2287923>.
- Gałecki, A., Burzykowski, T., Gałecki, A. and Burzykowski, T. (2013) *Linear Mixed-Effects Model*, pp.245–273, Springer, New York.

- Halbritter, G. and Dorfleitner, G. (2015) 'The wages of social responsibility — where are they? A critical review of ESG investing', *Review of Financial Economics*, Vol. 26, pp.25–35, <https://doi.org/10.1016/j.rfe.2015.03.004>.
- Hiremath, R.B., Balachandra, P., Kumar, B., Bansode, S.S. and Murali, J. (2013) 'Indicator-based urban sustainability – a review', *Energy for Sustainable Development*, <https://doi.org/10.1016/j.esd.2013.08.004>.
- IBGE (2022) *Cidades e Estados* [online] <https://www.ibge.gov.br/cidades-e-estados.html> (accessed 22 January 2024).
- ISEB3 (2024) [online] <https://indicadores.iseb3.com.br> (accessed 12 May 2024).
- Jin, H., Wang, Q. and Wu, L. (2024) 'Sustainable city development from the perspective of corporate green innovation and governance', *Sustainable Cities and Society*, Vol. 102, p.105216, <https://doi.org/10.1016/j.scs.2024.105216>.
- Junius, D., Adisurjo, A., Rijanto, Y.A. and Adelina, Y.E. (2020) 'The impact of ESG performance to firm performance and market value', *Jurnal Aplikasi Akuntansi*, <https://doi.org/10.29303/jaa.v5i1.84>.
- Kusakci, S., Yilmaz, M.K., Kusakci, A.O., Sowe, S., Nantembelele, F.A., (2022) 'Towards sustainable cities: a sustainability assessment study for metropolitan cities in Turkey via a hybridized IT2F-AHP and COPRAS approach', *Sustainable Cities and Society*, <https://doi.org/10.1016/j.scs.2021.103655>.
- Kutty, A.A., Abdella, G.M., Kucukvar, M., Onat, N.C. and Bulu, M. (2020) 'A system thinking approach for harmonizing smart and sustainable city initiatives with United Nations sustainable development goals', *Sustainable Development*, Vol. 28, No. 5, pp.1347–1365, <https://doi.org/10.1002/sd.2088>.
- Li, T.T., Wang, K., Sueyoshi, T. and Wang, D.D. (2021) 'ESG: research progress and future prospects', *Sustainability*, Vol. 13, No. 21, p.11663, <https://doi.org/10.3390/su132111663>.
- Liu, H., Khan, I., Zakari, A. and Alharthi, M. (2022) 'Roles of trilemma in the world energy sector and transition towards sustainable energy: a study of economic growth and the environment', *Energy Policy*, Vol. 170, p.113238, <https://doi.org/10.1016/j.enpol.2022.113238>.
- Naimy, V., El Khoury, R. and Iskandar, S. (2021) 'ESG versus corporate financial performance: evidence from East Asian firms in the industrials sector', *Studies of Applied Economics*, Vol. 39, No. 3, <https://doi.org/10.25115/eea.v39i3.4457>.
- Nakagawa, S. and Schielzeth, H. (2013) 'A general and simple method for obtaining R² from generalized linear mixed-effects models', *Methods in Ecology and Evolution*, Vol. 4, No. 2, pp.133–142, DOI: 10.1111/j.2041-210x.2012.00261.x.
- Nakagawa, S., Johnson, P.C.D. and Schielzeth, H. (2017) 'The coefficient of determination R² and intra-class correlation coefficient from generalized linear mixed-effects models revisited and expanded', *Journal of The Royal Society Interface*, Vol. 14, No. 134, p.20170213, <https://doi.org/10.1098/rsif.2017.0213>.
- Pinheiro, J. and Bates, D. (2006) *Mixed-Effects Models in S and S-PLUS*, Springer Science & Business Media, <https://doi.org/10.1007/b98882>.
- Quintiliani, A. (2022) 'ESG and firm value', *Accounting and Finance Research*, Vol. 11, No. 4, p.37, <https://doi.org/10.5430/afr.v11n4p37>.
- Qureshi, M.A., Akbar, M., Akbar, A. and Poulova, P. (2021) 'Do ESG endeavors assist firms in achieving superior financial performance? A case of 100 best corporate citizens', *Sage Open*, Vol. 11, No. 2, <https://doi.org/10.1177/21582440211021598>.
- R Core Team (2022) *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria [online] <https://www.R-project.org/> (accessed 2 July 2024).
- Rao, A., Dagar, V., Sohag, K., Dagher, L. and Tanin, T.I. (2023) 'Good for the planet, good for the wallet: the ESG impact on financial performance in India', *Finance Research Letters*, p.104093, <https://doi.org/10.1016/j.frl.2023.104093>.

- Sharma, G.D., Tiwari, A.K., Erkut, B. and Mundi, H.S. (2021) 'Exploring the nexus between non-renewable and renewable energy consumptions and economic development: evidence from panel estimations', *Renewable and Sustainable Energy Reviews*, Vol. 146, p.111152, <https://doi.org/10.1016/j.rser.2021.111152>.
- Triyani, A., Setyahuni, S.W. and Kiryanto, K. (2020) 'The effect of environmental, social and governance (ESG) disclosure on firm performance: the role of CEO tenure', *Jurnal Reviu Akuntansi Dan Keuangan*, Vol. 10, No. 2, pp.261–270, <https://doi.org/10.22219/jrak.v10i2.11820>.
- West, B.T., Welch, K.B. and Galecki, A.T. (2022) *Linear Mixed Models: A Practical Guide Using Statistical Software*, Chapman and Hall/CRC, <https://doi.org/10.1201/9781003181064>.
- Xu, Y. and Zhao, Z. (2023) *Resilient Cities Governance When Encountering External Turbulence in the Greater Bay Area of China: An ESG Perspective*, SSRN 4591271, <http://dx.doi.org/10.2139/ssrn.4591271>.
- Zhou, Y., Chen, M., Tang, Z. and Mei, Z. (2021) 'Urbanization, land use change, and carbon emissions: quantitative assessments for city-level carbon emissions in Beijing-Tianjin-Hebei region. *Sustainable Cities and Society*, Vol. 66, p.102701, <https://doi.org/10.1016/j.scs.2020.102701>.