

## BUDGETING FOR THE FUTURE: RELATIONSHIP BETWEEN INTENSITY OF BUDGETING METHODS AND SUSTAINABILITY PERFORMANCE

Andrzej PIOSIK<sup>1</sup>, Anna KARMAŃSKA<sup>2\*</sup>

<sup>1</sup> University of Economics in Katowice, Faculty of Finance, Department of Accounting, andrzej.piosik@uekat.pl, ORCID: 0000-0003-0057-5501

<sup>2</sup> University of Economics in Katowice, Faculty of Finance, Department of Accounting; anna.karmanska@uekat.pl, ORCID: 0000-0001-5883-1243

\* Correspondence author

**Purpose:** This research empirically assesses the relationship between corporate budgeting methods and sustainable performance.

**Design/methodology/approach:** The analysis utilized Ordinary Least Squares regression, the Random Forest model, and the Explainable Artificial Intelligence technique SHAP on a global sample of 399 budgeting practitioners.

**Findings:** The findings indicate that alignment with competitive strategy is the most significant positive predictor of sustainability performance. In contrast, high environmental uncertainty exerts a significant negative influence on these outcomes. Budgeting methods serve as essential tools for implementing and monitoring organizational strategy. The results demonstrate a significant positive association between intensive use of Budgeting in a Variable Costing System, Flexible Budgeting, and Bottom-Up Budgeting, and sustainability performance. Intensive application of budgeting in Variable Costing enhances the visibility and immediate accounting of direct costs, such as materials, energy usage, and waste disposal, during production. This approach supports efficiency, discourages overproduction, and reduces environmental footprints. Bottom-Up Budgeting fosters employee engagement and uncovers specific, small-scale opportunities for cost reduction and efficiency that are often overlooked by senior management. The analysis also reveals that Activity-Based Budgeting and Budgeting using a functional cost structure may negatively impact sustainable performance, as these methods do not adequately distinguish between critical environmental costs or reflect waste discharge. However, the study provides a nuanced view of this relationship by operationalizing organizational structure quality; specifically, the findings reveal that the negative impact of Activity-Based Budgeting is significantly mitigated in organizations characterized by efficient communication channels, clear decision-making processes, well-defined role accountability, and employee empowerment. The application of the following budgeting methods demonstrates greater similarity among each other than with the remaining approaches: Bottom-Up Budgeting and Participative Budgeting, Budgeting in a Variable Costing System and Budgeting using a functional structure of costs, Rolling Budgeting and Performance-Based Budgeting, Flexible Budgeting, and Beyond Budgeting. In contrast, the intensity of usage for Static Budgeting differs substantially from all other methods.

**Research limitations/implications:** This study addresses a gap in the literature regarding the impact of budgeting methods on sustainable performance.

**Practical implications:** It provides practical insights for managers seeking to enhance sustainability through budgeting approaches.

**Originality/value:** This paper provides the first empirical evidence linking the intensity of usage budgeting methods and sustainable performance. The methodological approach is the first to employ Machine Learning (ML) techniques such as Random Forest, SHAP, and Hierarchical Clustering.

**Keywords:** budgeting, budgeting methods, management accounting, sustainability, machine learning.

**Category of the paper:** Research paper.

## 1. Introduction

Sustainability, which refers to the impact on the environment or society, has become a crucial part of organizations. In the European Union (EU), numerous initiatives are being undertaken to support the transition to a circular economy. An example is the European Green Deal (EGD), an attempt to transform the EU economy to achieve climate neutrality by 2050 (Dahl, 2021). Approved in 2020, it sets more than 175 directives and regulations that establish clean energy investment, climate tech innovation, carbon pricing, and sustainability reporting for public companies (Buysing Damsté et al., 2024).

However, reporting is the final stage of business processes. At the beginning of the road, there is always a plan for allocating resources to achieve organizational targets. A budget is a comprehensive financial plan that outlines the expected path for achieving an organization's financial and operational objectives (Yilmaz, 2018). Budgeting is the process of obtaining a budget (Obi, 2015).

Presently, the integration of sustainability considerations represents a critical emerging focus within the corporate budgeting paradigm. Although corporate strategy is the primary driver of corporate behavior, budgeting is considered a crucial tool for implementing and monitoring that strategy, as well as fulfilling various additional responsibilities (Nguyen et al., 2018). Therefore, the budgeting methods play an essential role as a facilitator or barrier to executing the adopted strategy.

The relationship between budgeting methods and attaining sustainability goals has attracted attention in contemporary management discourse. While organizations strive to reach financial profitability and environmental liability, the meaning of the budget extends beyond simply allocating resources and managing costs. Effective budget methods are essential to promoting sustainable practices that align with social and environmental objectives. Management accounting's ability to develop, implement, and perfect these budget methods positions it as a crucial facilitator of sustainability initiatives.

Previous literature emphasizes the crucial role of innovative management tools, particularly in budgeting, in achieving sustainable results. For example, Vărzaru et al. (2022) highlight how advanced frameworks, such as beyond budget, zero-based budget, and activity-based budgeting, can improve organizations' ability to respond to environmental challenges. These innovative approaches incorporate environmental and social performance metrics into their budget processes, encouraging a more holistic perspective that prioritizes sustainability and traditional financial metrics.

Empirical tests support the thesis that the various budget methods can significantly affect both financial and sustainability metrics. Kihn (2010) claims that adopting participatory budget practices, which involve the parties concerned throughout the organization, can lead to greater responsibility and the resolution of innovative problems related to allocating resources for sustainable initiatives. The findings of numerous studies also emphasize the role of particular corporate budgeting methods in supporting sustainability objectives within enterprises. These methods include flexible budgeting (Hansen et al., 2003), rolling budgeting (Håkonsson et al., 2013), incremental budgeting (Lee et al., 2016), zero-based budgeting (ZBB) (Okoh et al., 2023), budgeting under variable costing (Burritt, Schaltegger, 2001), activity-based budgeting (Hossain, Hasan, 2024), top-down budgeting (Kim, Park, 2006), bottom-up budgeting (Ugalde Vasquez, Naranjo-Gil, 2020), and beyond budgeting (Bogsnes, 2016; Matějka et al., 2021).

These findings underscore the crucial role of individual budgeting methods in advancing the Sustainable Development Goals (SDGs). However, a comprehensive evaluation is lacking — one that simultaneously examines the application of various corporate budgeting methods. Such an analysis could identify which methods most effectively support sustainability goals, determine those with the highest impact, and classify groups of budgeting methods with similar characteristics. This gap represents a significant research opportunity in management accounting, which the authors aim to address in this study.

The need for an investigation into adopting different budget methods is underlined by the transformations within corporate environments led by the imperative for sustainability. Organizations are aware of the pressure to align their operations with environmental expectations and request a critical examination of how budget methods influence their ability to achieve sustainability while maintaining financial objectives. Therefore, future research should investigate the specific budget methodologies employed in various sectors and their impact on sustainability and financial health.

The literature search, conducted using the terms “budgeting methods” and “sustainability” in the bibliographic databases Scopus, clearly confirms the research gap. The link between budgeting and sustainability in the literature is dominated by theoretical papers and case studies, with a significant lack of large-scale, quantitative survey data that tests these relationships across multiple companies, sectors, and countries.

The paper is divided into sections: Section 1 is an introduction, and Section 2 presents the literature review. Section 3 outlines the methodology employed in this research, and Section 4 presents the results. Section 5 is a discussion. Finally, Section 6 draws conclusions and recommendations for future research.

## 2. Literature Review

Understanding how budgeting aligns organizational priorities with sustainability targets bridges the gap between theoretical concepts and management practices. Derchi et al. (2013) demonstrate that integrating environmental concerns into budgeting depends on technical expertise, external pressures, and internal readiness. Christ and Burritt (2013) emphasize the need for innovation in budgeting processes to better address environmental costs. This resonates with Dunk (2012), who links budgeting's planning and control aspects to environmental performance. Schaltegger and Csutora (2012) emphasize the importance of carbon accounting, advocating for rigorous accounting practices that extend beyond compliance to proactively pursue sustainability.

Lueg and Radlach (2016) argue that robust management accounting supports financial and sustainability objectives through stronger resource allocation and performance measurement. Similarly, Lavia López and Hiebl (2015) note that incorporating sustainability considerations in management accounting can enhance overall financial performance. Digitalization further intensifies this relationship. Rikhardsson and Yigitbasioglu (2018) highlight the role of business intelligence in improving the accuracy of both financial and sustainability reporting. Table 1 provides potential advantages of budgeting for sustainable development.

**Table 1.**  
*Variable literature*

Variable	Description, literature
SD1	Budgeting fosters resource optimization and reduction (Obi, 2015; Yilmaz, 2018; Fortuna, 2021)
SD2	Budgeting drives cost reduction (Argyris, 2013; Obi, 2015)
SD3	Budgeting supports the adaptation of the business model to environmental needs (Abernethy, Brownell, 1999; Szczypa, 2016)
SD4	Budgeting helps lower carbon emissions (Goulder et al., 2010; Kotnik et al., 2017)
SD5	Budgeting extends product lifecycles (Dunk, 2012; Westkämper, 2000)
SD6	Budgeting allocates funds for green investments (Burritt, Schaltegger, 2001; Unruh et al., 2016)
SD7	Budgeting boosts productivity and curbs waste (Kotnik et al., 2017; Brink et al., 2018)

Source: own work.

Under the right conditions, even traditional budgeting can incorporate sustainability metrics to elevate environmental and social goals alongside financial targets (Baumgartner, 2014). A culture of flexibility can enable innovative sustainability projects to flourish (Hansen et al., 2003). Recent shifts also highlight a growing recognition of financial tools as catalysts for sustainable development (Balstad, Berg, 2020).

Grossi et al. (2020) observe that more rigorous budgeting can effectively integrate sustainability considerations into decision-making processes. Similarly, Burritt and Saka (2006) demonstrate that detailed environmental cost tracking leads to better resource efficiency and improved sustainability performance. However, smaller enterprises often face resource constraints that impede sophisticated budgeting (Pelz, 2019). When rigid adherence to traditional methods hinders experimentation, more flexible or rolling approaches may be more beneficial (Bogsnes, 2016; Ekholm, Wallin, 2000).

Incremental Budgeting supports gradual resource adjustments and can foster long-term environmental objectives, but it may discourage radical innovation (Weston, Nnadi, 2023). Zero-based Budgeting (ZBB) encourages strategic questioning of expenditures, thus boosting sustainability investments (Okoh et al., 2023). However, ZBB may demand significant implementation resources (Allen, Clifton, 2023). A balanced approach remains vital to align accountability with sustainable growth (Appannan et al., 2023).

Static Budgeting can limit agility and slow responses to environmental demands (Ekholm, Wallin, 2011). Flexible Budgeting adapts better to sustainability initiatives, assuming the organization can handle added financial complexity (Al-Baghdadi et al., 2021). Rolling forecasts allow organizations to refine plans regularly in line with evolving sustainability goals (Okeke et al., 2024). Flexibility is essential in sustainable services, as it allows organizations to adapt to changes in their environment, such as new regulations or changes in consumer preferences towards more sustainable products. For example, as defined by Cowell et al. (2020), flexible budgets are important for implementing biological monitoring in protected areas, which is increasingly vital as environmental concerns intensify.

Variable Costing clarifies cost structures but may mislead managers when fixed expenses are high (Burritt, Schaltegger, 2001). The analysis of variable costs can lead to increased financial services for manufacturing companies when sustainability measures are integrated into the budget. This integration enables organizations to align their budget activities with sustainability, supporting the efficient use of resources and minimizing waste. Functional Costing aids budget precision at the department level but risks siloed thinking that undermines collaboration on sustainability programs (Sanford, 2009). Activity-Based Costing (ABC) pinpoints environmental cost drivers, potentially improving both ecological and financial performance (Maiga et al., 2014; Hossain, Hasan, 2024), although implementation can be complex (Jänkälä, Silvola, 2012). Integrating advanced technology may help, but it also requires cultural shifts and a commitment from stakeholders (Al-Kawaz et al., 2023).

Top-down budgeting can expedite decision-making for sustainability but might limit lower-level inputs (Kim, Park, 2006). Bottom-up methods encourage stakeholder involvement, often leading to superior environmental outcomes and stronger innovation (Ugalde Vasquez, Naranjo-Gil, 2020). Participatory processes can also enhance employee acceptance of sustainability measures (Bartocci et al., 2023).

Performance-based Budgeting (PBB) ties funding to defined goals, potentially increasing accountability for sustainability (Huy, Phuc, 2022). However, narrow metrics can lead to data manipulation and sideline long-term ecological concerns (Mauro et al., 2021). The Beyond Budgeting model offers adaptability and transparency, encouraging local teams to act on sustainability priorities (Bogsnes, 2016; Matějka et al., 2021). Resistance to change and the need for new competencies continue to be challenges (Amini et al., 2019).

Traxler et al. (2020) find that rigorous budgeting frameworks are correlated with better environmental performance, supporting the argument that management accounting has a direct influence on sustainability practices. Vale et al. (2022) further assert that incorporating sustainability into management accounting can enhance governance structures and create shareholder value.

The literature suggests that aligning budgeting methods with sustainability amplifies organizations' capacity to balance financial efficiency with social and environmental stewardship. Integrating modern budgeting practices with a sustainability lens pushes beyond traditional cost-control paradigms, fostering long-term corporate resilience. These insights pave the way for further exploration of how diverse organizational contexts shape the role and efficacy of intensive budgeting in achieving sustainable development goals.

Enterprises employ various budgeting methods, classified according to various criteria, and may even apply multiple approaches under the same criterion. A thorough review of the literature indicates that the intensive use of diverse corporate budgeting methods — both conventional (e.g., variable costing-based budgeting, function-based cost budgeting, incremental budgeting, flexible budgeting) and modern (e.g., ZBB, participatory and bottom-up budgeting, activity-based budgeting (ABB), rolling budgeting, beyond budgeting) — supports the achievement of enterprises' sustainable development goals.

However, comprehensive studies that examine multiple budgeting methods across different classification criteria and comparative assessments of how various budgeting methods aid in achieving corporate sustainability remain scarce. Moreover, the degree of similarity in using different budgeting methods (i.e., identifying groups of budgeting methods with comparable levels of application intensity) has not been investigated. These underexplored areas are crucial for assessing how budgeting methods enable enterprises to pursue sustainability, particularly since companies often employ multiple budgeting methods concurrently. This gap in the research leads to the following questions:

- Q1: What is the relative importance and independent contribution of a firm's budgeting method in explaining its sustainability performance?
- Q2: Are there groups of corporate budgeting methods whose application intensities are similar?

According to the theory of contingencies, previous research suggests that contextual factors, including organizational structure quality, environmental uncertainty, and support for competitive and functional strategies (e.g., sales, production, procurement), influence

a company's performance (Piosik, Karmańska, 2023, 2025). Analysis of the previous studies enables the formulation of the following research question:

Q3: What is the relative importance and independent contribution of environmental uncertainty, competitive strategy, and structure quality in explaining a firm's sustainability performance?

### 3. Methods

The survey questionnaire was developed based on a literature review. It was emailed to 37600 companies between August 2023 and April 2024, targeting managers, chief accountants, and accounting specialists involved in budgeting. The base population of our study consisted of 399 respondents from 58 countries, mainly in Europe. Table 2 presents the distribution of the sample.

**Table 2.**  
*Distribution of the sample members*

<b>Company size</b>	<b>Frequency</b>	<b>Percentage</b>
Very Small micro-enterprise (less than ten employees)	89	22.3
Small enterprise (10 to 49 employees)	91	22.8
Medium-sized enterprise (50-249 employees)	91	22.8
Large enterprise (250 employees and more)	128	32.1
<b>Dominant sector of operational activity</b>	<b>Frequency</b>	<b>Percentage</b>
Trade	75	18.8
Industry	79	19.8
Service	213	53.4
Financial institution	32	8.0
<b>Localization</b>	<b>Frequency</b>	<b>Percentage</b>
Europe	306	76.7
Asia	43	10.8
North America	29	7.3
Africa	11	2.7
Oceania	7	1.7
South America	3	0.8

Source: own work.

Based on the variables described in Table 1, the study calculated a sustainable score as the sum of respondents' ratings for all the items. According to literature, for example, Warmbrod (2014), if Likert items use the same scale, the responses can be summed to create a composite score for each individual.

Control variables are usually included in regression analyses to estimate the causal effect of a treatment on an outcome (Hünernund, Louw, 2023). Specifically, in this study, the inclusion of control variables serves two primary, interrelated purposes: mitigating omitted variable bias and increasing the precision of the primary coefficient estimates. The regression model was augmented with a set of control variables, including BS - support of competitive strategy and

functional strategies, SQ - quality of the organizational structure, EU - environmental uncertainty.

To assess the relationships between variables, we employed Ordinary Least Squares (OLS) regression, with machine learning techniques, specifically the non-linear Random Forest (RF) algorithm, complemented by the SHAP method for model interpretability and explanation. All models were implemented using Python and its libraries. This hybrid approach allows for capturing both linear trends (OLS) and complex, non-linear interactions (RF).

## 4. Results

The intensity of usage of individual budgeting methods was measured using a 5-point Likert scale. The responses are coded as follows: (1) not at all - the budgeting method is not used in the company; (2) low intensity, rarely - the budgeting method is used infrequently or on a limited basis; (3) moderate intensity - the budgeting method is used occasionally but not consistently, (4) high intensity - the budgeting method is used frequently and consistently, (5) always - the budgeting methods are intensively and consistently applied in the company.

Table 3 presents the results, frequencies, and volatility measures.

**Table 3.**  
*Intensity of usage budgeting methods*

Variable		Frequency					Mode	Median	Average
		1	2	3	4	5			
Conventional budgeting method									
IB	Incremental Budgeting	53	53	124	133	36	4	3	3.115
TB	Top-Down Budgeting	50	64	100	133	52	4	3	3.183
VCB	Budgeting in the Variable Costing System	101	58	103	94	43	3	3	2.799
FSB	Budgeting using a functional structure of costs	79	52	100	115	53	4	3	3.028
STAT	Static Budgeting	107	69	94	78	51	1	3	2.742
FLEX	Flexible Budgeting	60	62	115	113	49	3	3	3.073
Modern budgeting method									
ZBB	Zero-Based Budgeting	101	69	117	82	30	3	3	2.677
BB	Bottom-Up Budgeting	107	68	87	91	46	1	3	2.752
PBU	Participative Budgeting	89	64	112	91	43	3	3	2.837
ABB	Activity-Based Budgeting	86	47	113	114	39	4	3	2.932
ROLL	Rolling Budgeting	79	55	113	102	50	3	3	2.972
BEYO	Beyond Budgeting	120	57	119	78	25	1	3	2.576
PBB	Performance-Based Budgeting	66	52	122	123	36	4	3	3.028

Source: own work.

Regarding the intensity of usage, Top-Down Budgeting (TB) emerged as the most prevalent method, recording the highest mean (3.183) and a mode of 4.0. This suggests a clear predominance of hierarchical, centralized budgeting approaches among the surveyed enterprises. Conversely, Beyond Budgeting (BEYO) demonstrated the lowest adoption level

(mean = 2.576, Mode = 1.0), indicating that this framework may be perceived by respondents as structurally difficult to implement within current organizational settings.

In the next step, the respondents were asked to indicate the extent to which budgeting in their company supports its sustainable performance. The responses in the questionnaire are coded using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

A target variable, sustainable score (SUS), was calculated as an individual's summated score of SD1-SD7 items. The results, frequencies, and volatility measures are presented in Table 4.

**Table 4.**  
*Intensity of usage budgeting methods*

Variable	Frequency					Mode	Median	Average	
	1	2	3	4	5				
SD1	26	30	82	186	75	4	4	3.637	
SD2	13	45	95	175	71	4	4	3.617	
SD3	17	47	122	144	69	4	4	3.504	
SD4	61	96	119	83	40	3	3	2.862	
SD5	32	58	131	133	45	4	3	3.253	
SD6	38	69	128	115	49	3	3	3.170	
SD7	33	81	123	109	53	3	3	3.170	
SUS								23	23.213

Source: own work.

As Table 4 shows, the respondents' top advantages of budgeting in support of sustainability were resource optimization and reduction, cost-cutting, and the adaptation of the business model to environmental needs.

The analysis further confirms that contextual factors significantly shape sustainability outcomes. Specifically, organizational structure quality (SQ), environmental uncertainty (EU), and the support for competitive and functional strategies (BS)—all measured on a 5-point Likert scale—serve as critical determinants of performance. The descriptive analysis of contextual factors reveals a sample characterized by high strategic maturity and structural stability. Business Strategy Alignment (BS) exhibits a pronounced negative skew (left-skewed distribution), with nearly 40% of respondents reporting high or very high alignment, indicating that budgeting functions primarily as a strategic execution mechanism rather than an isolated accounting task. Organizational Structure Quality (SQ) measures internal governance efficacy, characterized by efficient communication, transparent decision-making, clear accountability, and employee empowerment. The variable SQ demonstrates a strong central tendency with a mode of 3.0 (n = 182). The distribution is also negatively skewed, as 33.6% of practitioners reported high structural integrity compared to 20.8% indicating low quality. Conversely, Environmental Uncertainty (EU) presents positively skewed (right-skewed) distribution, where only 26.8% of the sample experiences high turbulence, while 35.3% operate under relatively stable conditions.

The results of OLS Regression (Table 5) demonstrate while strategic alignment across functional areas (sales, production, and procurement) acts as a robust driver of sustainability, environmental uncertainty remains a significant barrier that managers must navigate. Additionally, the model identifies specific budgeting methods that exert either a significant positive or negative influence on sustainability performance.

**Table 5.**  
*Results of OLS Regression*

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Constant	17.508	2.405	7.280	0.000***
ZBB (Zero-Based Budgeting)	0.369	0.223	1.656	0.099*
TB (Top-Down Budgeting)	0.396	0.226	1.749	0.081*
BB (Bottom-Up Budgeting)	0.541	0.215	2.516	0.012**
VCB (Variable Costing Budgeting)	0.891	0.217	4.114	0.000***
FSB (Functional Structure Budgeting)	-0.496	0.231	-2.149	0.032**
ABB (Activity-Based Budgeting)	-1.956	0.710	-2.757	0.006***
STAT (Static Budgeting)	-0.361	0.203	-1.777	0.076*
FLEX (Flexible Budgeting)	0.559	0.234	2.386	0.018**
EU (Environmental Uncertainty)	-0.610	0.237	-2.576	0.010**
BS (Business Strategy Alignment)	1.251	0.276	4.538	0.000***
SQ (Organizational Structure Quality)	-0.729	0.684	-1.065	0.288
ABB × SQ (Interaction Term)	0.654	0.210	3.117	0.002***
Model Summary				
Observations	399			
R-squared	0.299			
Adjusted R-squared	0.277			
F-statistic	13.73			
Prob (F-statistic)	< 0.001			

Note: \*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$ .

Source: own work.

Our model is highly significant, as the F-statistic of 13.73, with an associated p-value (Prob (F-statistic)) of  $1.00 \times 10^{-23}$ , provides conclusive evidence that the set of independent variables collectively explains a significant portion of the variance in the dependent variable SUS.

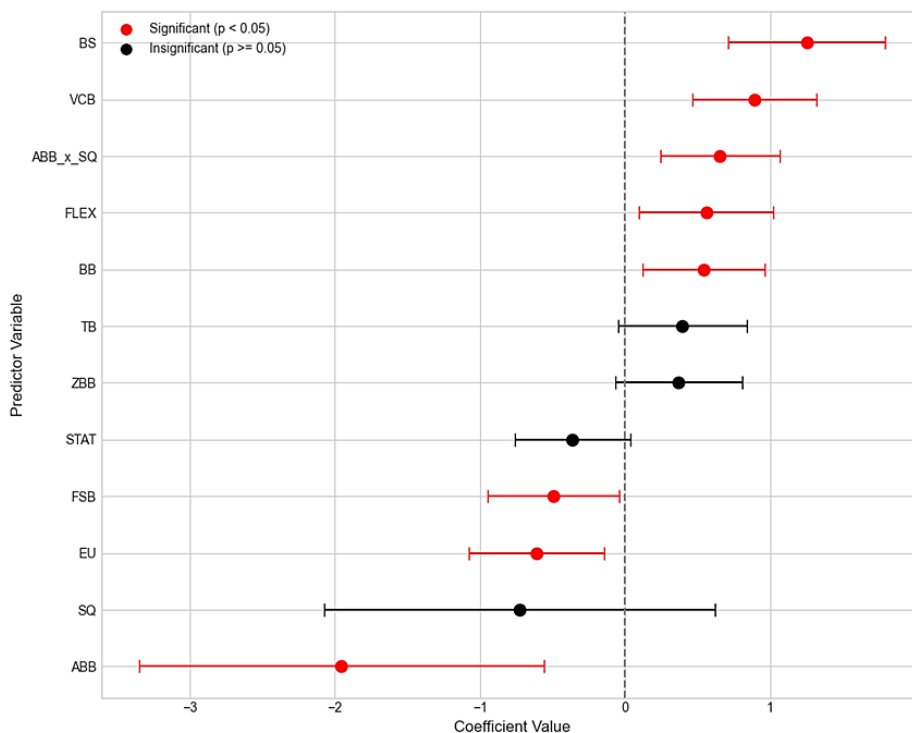
R-squared indicates that the model explains 29.9% of the variance in the target variable. While this value might appear modest, it is considered satisfactory in the context of social sciences. According to Ozili and Ozili (2022), an R-squared of at least 10% is acceptable provided that most predictors are statistically significant. This threshold acknowledges that human behavior—driven by individual self-interest, group dynamics, and emotions—is inherently complex, making it difficult, if not impossible, to predict with absolute precision.

The minimal difference between the R-squared and Adjusted R-squared of 27.7% confirms that the model is not over-specified; the included variables are meaningful contributors.

The coefficients reveal the specific significant relationships between the predictors and the dependent variable SUS. The variables BB ( $\beta = .541, p = .012$ ), VCB ( $\beta = .891, p < .001$ ), FLEX ( $\beta = .559, p = .018$ ), and BS ( $\beta = 1.251, p < .001$ ) all have a significant positive impact on the dependent variable. Support for competitive and functional strategies demonstrates the most substantial positive influence. Among budgeting methods, Variable Costing, Flexible Budgeting, and Bottom-Up Budgeting are associated with significant positive impacts on sustainability performance. We also found negative significant effects: FSB ( $\beta = -.496, p = .032$ ), ABB ( $\beta = -1.956, p = .006$ ), and EU ( $\beta = -.610, p = .010$ ). The methods Activity-Based Budgeting and Budgeting using a Functional Structure of Costs have a negative relationship with the sustainability performance. However, we found that the interaction effect ABB x SQ remains positive and highly significant ( $\beta = .654, p = .002$ ). This confirms that the organizational structure quality moderates the negative effect of ABB. As SQ increases, the negative impact of ABB on the sustainability performance diminishes. The results also indicate that environmental uncertainty EU has a negative and significant relationship with sustainability performance ( $\beta = -.610, p = .010$ ). While SQ ( $p = .288$ ) is not statistically significant as a main effect, its role is primarily confirmed as a moderator in the model.

The resulting regression model is presented with the following equation:

$$\begin{aligned}
 SUS = & 17.508 + 0.369(ZBB) + 0.396(TB) + 0.541(BB) + 0.891(VCB) \\
 & - 0.496(FSB) - 1.956(ABB) - 0.361(STAT) + 0.559(FLEX) \quad (1) \\
 & - 0.610(EU) + 1.251(BS) - 0.729(SQ) + 0.654(ABB \times SQ) + \varepsilon
 \end{aligned}$$

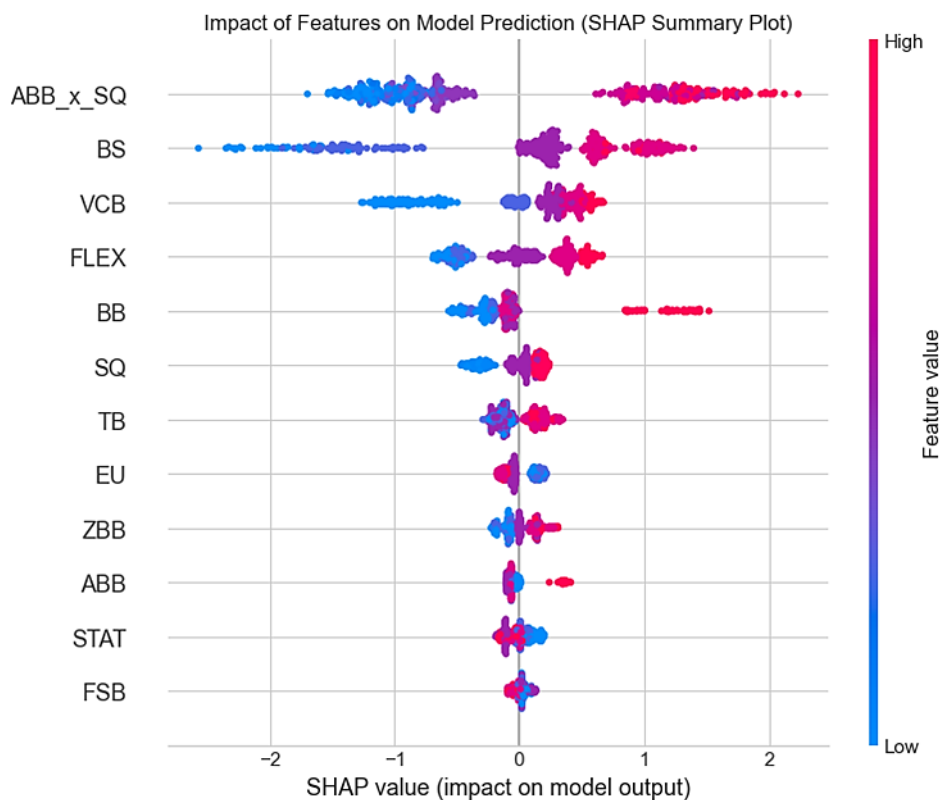


**Figure 1.** OLS Model Coefficients by Statistical Significance.

Source: own work.

The forest plot (Figure 1) visualizes the results of the OLS regression model. It displays variables, coefficient estimate (the dot) and the 95% confidence interval, that are the most important and reliable predictors in the model (the red dots,  $p < .05$ ) and which variables appear to have no statistically detectable effect (the black dots,  $p \geq .05$ ). The vertical line ( $x = 0$ ) represents a zero effect, where the predictor variable has no statistical relationship with the outcome variable SUS.

A Random Forest (RF) algorithm was also implemented; however, it exhibited lower predictive power compared to the linear model, with an R-squared value of 0.18. It suggests that the relationship between predictors and the dependent variable in the sample are predominantly linear, with a lack of substantial non-linear complexities or high-order interactions that would typically favor machine learning algorithms. In the next step, the SHAP technique explained which features were most important in driving the predictions and how they interacted to produce the final result. The beeswarm plot (Figure 2) displays an information-dense summary of how the top features in a dataset impact the model's prediction (Lundberg, 2023).

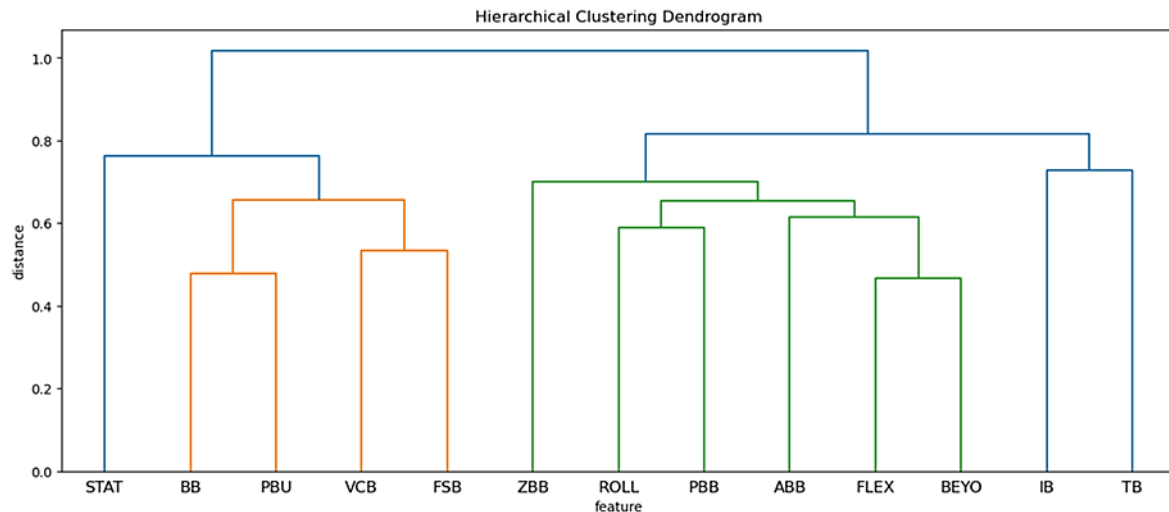


**Figure 2.** OLS Model Coefficients by Statistical Significance.

Source: own work.

It is visible that Budgeting in Variable Costing System, Flexible Budgeting, and Bottom-Up Budgeting (BB) are the three top methods that have a positive impact on the final prediction.

Subsequently, the ML algorithm Hierarchical Clustering was employed to group input variables into a tree of nested clusters of similar objects (Figure 3). In this model, we exclusively considered the intensity of use of specific budgeting methods as input variables; we did not incorporate control variables.



**Figure 3.** Hierarchical clustering of the budgeting methods.

Source: own work.

This dendrogram visually groups features (the intensity of usage specific budgeting methods) based on their informational similarity and redundancy as perceived by the model. FLEX and BEYO are clustered low. This means that the intensity of use of these two methods is highly correlated. PBU and BB, as well as VCB and FSB, also exhibit similar patterns of usage. Meanwhile, leaf STAT is substantially different from all of the other clades. It remains on a distinct branch and is only joined to the other clusters at a very high distance. This indicates that the usage pattern of STAT is not redundant with other budgeting methods.

## 5. Discussion

The first research question has been addressed positively. The results indicate that an overarching strategy exerts the most substantial positive influence on sustainability performance, whereas budgeting methods vary in their effectiveness. These findings are consistent with existing literature, as traditional budgeting methods have been criticized. For example, Qu et al. (2022) observed that such methods often fail to provide the necessary information for environmental economic management decisions.

The findings confirm that specific budgeting methods, including Budgeting within a Variable Costing system, Flexible Budgeting, and Bottom-Up Budgeting, can universally enhance sustainability performance. This effect remains robust across various strategies and

under uncertain conditions. In a Variable Costing system, fixed manufacturing overhead is excluded from the product cost of production. The primary accountability measure for managers is the contribution margin, calculated by subtracting variable costs from sales revenue. Consequently, this approach aligns financial incentives with resource efficiency, thereby reducing overproduction, minimizing material waste, and improving energy efficiency.

Extensive use of Flexible Budgeting also strongly supports sustainable strategies. This dynamic approach adapts to changes in production volume, market volatility, and environmental uncertainty, allowing for seamless adjustments. Flexible Budgeting facilitates the alignment of budget allocations with actual performance, helping to isolate waste attributable to production volume.

In Bottom-Up Budgeting, employees at the operational level, who possess detailed and practical knowledge of specific processes, resource utilization, and waste generation, are responsible for constructing the budget. In contrast to top management, who prepare Top-Down Budgeting, lower-level managers and staff can establish more realistic targets and incorporate opportunities for eco-efficiency. Furthermore, involvement in the budgeting process increases engagement and accountability, as individuals feel responsible for the execution of the budget.

The results indicate that two budgeting methods, Activity-Based Budgeting and Budgeting based on a Functional Structure of Costs, can have a negative impact on sustainability performance. Activity-Based Budgeting enables companies to divide the production process into distinct activity centers, allowing them to estimate and plan resource consumption for each center. However, this approach does not account for waste discharge or its environmental impact (Qu et al., 2022). In response, Qu et al. (2022) introduced Material Flow Cost Accounting - Activity-Based Budget, which transforms a purely operational budget into an environmental-economic budget, thereby generating both environmental and economic benefits for companies. The findings further suggest that the quality of organizational structure moderates the negative impact of Activity-Based Budgeting (ABB) on sustainability performance. Companies that extensively use ABB should therefore promote efficient communication, clear decision-making processes, well-defined roles and accountability, employee empowerment, and other elements that enhance the quality of organizational structure.

In budgeting systems that use a functional structure of costs, expenses are grouped by department, which can obscure critical environmental costs because they are not identified as distinct cost drivers, as it is possible in Variable Costing systems. Additionally, managers tend to focus solely on their departmental budgets. However, effective sustainability management requires a holistic, system-wide approach. The data suggest that respondents perceive functional costing as equivalent to absorption costing.

Effective budgeting should evolve, responding swiftly to financial and operational changes (Ekholm, Wallin, 2011). While our findings do not dismiss the importance of static budgeting (master budgets), they reinforce earlier conclusions by Sivabalan et al. (2009), which show that most organizations integrate flexible and rolling budgets alongside annual budgets, rather than replacing them.

Our findings reveal two key factors: support of the competitive strategy emerges as the most significant positive predictor of sustainability performance. Conversely, a high level of environmental uncertainty is shown to have a significant negative impact on these outcomes. Thus, we have positively addressed the third research question.

The usages of the following methods are more similar to each other than they are to the others: Bottom-Up Budgeting and Participative Budgeting, Budgeting in a Variable Costing System and Budgeting using a functional structure of costs, Rolling Budgeting and Performance-Based Budgeting, Flexible Budgeting, and beyond budgeting. Meanwhile, the intensity of usage of Static Budgeting is substantially different from all the other methods.

In this way, we have addressed the second research question. As anticipated, the usage intensity of Bottom-Up Budgeting and Participative Budgeting exhibits apparent similarities. Yet, in line with our findings from the first research question, the mere involvement of managers, employees, and potentially external stakeholders—though beneficial for sustainability outcomes (Bartocci et al., 2023)—is outweighed by the stronger influence of bottom-up information flow, i.e., decentralizing the budgeting process.

We also observed a marked resemblance between Budgeting in a Variable Costing System and budgeting that employs a functional cost structure. Identifying cost variability under variable costing (in a functional framework) rather than a process-oriented approach, such as activity-based costing, substantially improves sustainability performance. This contradicts studies emphasizing the key role of budgeting within alternative costing systems (Maiga et al., 2014; Hossain, Hasan, 2024; Al-Kawaz et al., 2023), although the limited adoption of ABC in practice may explain these discrepancies.

Corporate budgeting methods such as Rolling Budgeting and Performance-Based Budgeting also share important commonalities. However, their role appears to be mainly supportive.

Finally, we identified notable parallels between Flexible Budgeting and Beyond Budgeting. This finding aligns with other research indicating that Beyond Budgeting promotes agility and flexibility, enabling teams to align decisions with long-term objectives (Bogsnes, 2016; Matějka et al., 2021).

## 6. Conclusions

The findings suggest that sustainability cannot be achieved solely through operational instruments, such as budgeting methods; instead, it must be integrated into the firm's overall strategy. Conversely, environmental uncertainty serves as a significant barrier, demonstrating a strong negative association with sustainability performance.

The literature review and empirical results do not identify a single universal budgeting method that positively influences sustainability. Although traditional budgeting methods have been widely criticized in academic literature, they remain prevalent in practice. Consequently, organizations are advised to enhance traditional budgeting approaches rather than eliminate them (Nguyen et al., 2018). The regression analysis identifies Variable Costing Budgeting, Flexible Budgeting, and Bottom-Up Budgeting as the primary drivers of sustainability performance. Among the tested frameworks, these three methods yielded the highest significant coefficients, indicating their critical role in supporting sustainable organizational outcomes. Conversely, Functional and Activity-Based Budgeting appear to hinder performance in the studied context, suggesting that rigid or overly complex systems may impede sustainable organizational outcomes.

This study addresses a significant methodological gap in the literature regarding the impact and intensity of budgeting method usage on sustainable performance. It offers empirical evidence through a quantitative survey methodology and employs robust statistical analyses, including OLS regression, Random Forest, and SHAP.

These findings may help practitioners understand the relationship between budgeting and sustainability. Managers seeking to enhance sustainable performance should focus on direct strategies supported by flexible budgeting tools. Intensive use of Budgeting within a Variable Costing system is recommended, as it improves the visibility and immediate accounting of costs, such as direct materials, energy usage, and waste disposal, during production. This approach supports efficiency, discourages overproduction, and reduces environmental footprints. Additionally, Bottom-Up Budgeting can increase employee engagement and reveal specific, small-scale opportunities for cost reduction and efficiency that are often not apparent to senior management.

The results offer a foundation for future surveys focused on budgeting, particularly within the small and medium-sized enterprise (SME) sector. However, these results should be interpreted with caution due to several limitations, including a small sample size. Additionally, the research relies on self-reported data, which may introduce biases or inaccuracies in reported usage and beliefs, and is based on a single-source survey. The use of a 5-point Likert scale in the questionnaire further restricts the range of responses and may not capture the full nuance of respondents' attitudes.

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