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ANALYSIS OF THE EFFECT OF ENVIRONMENTAL MANAGEMENT ACCOUNTING COSTING TECHNIQUES ON ENERGY CONSUMPTION IN SOUTH AFRICAN MANUFACTURING COMPANIES

Abstract. *Manufacturing companies are widely recognised for their intensive energy consumption, which significantly contributes to global environmental degradation. These challenges are further exacerbated by the limitations of traditional costing techniques, which often fail to measure environmental and energy-related costs accurately. In response to these shortcomings, environmental management accounting (EMA) has emerged as an important managerial tool aimed at addressing environmental challenges and improving the quality of decision-making. This paper aims to examine the effect of EMA costing techniques on energy consumption in South African manufacturing companies listed on the Johannesburg Stock Exchange. In the empirical model, EMA costing techniques represent the independent variables and are proxied by activity-based costing (ABC), material flow cost accounting (MFCA), and life cycle costing (LCC). Energy consumption serves as the dependent variable. The study adopts a quantitative research design based on secondary data collected from the annual, integrated, and sustainability reports of selected companies over a ten-year period (2013–2022). Multivariate regression analysis was employed to assess the relationship between the study variables. Additionally, diagnostic tests, including normality, heteroscedasticity, and multicollinearity tests, were conducted to ensure compliance with the assumptions underlying regression analysis and to validate the robustness of the empirical results. The findings reveal a positive and statistically significant relationship between ABC and energy consumption. A positive, though statistically insignificant, relationship was identified between MFCA and energy consumption. Furthermore, the results indicate a negative and statistically significant relationship between LCC and energy consumption, suggesting that the application of life cycle*



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costing may contribute to improved energy efficiency. This study contributes to the EMA literature by integrating ABC, MFCA, and LCC within a single analytical framework and by identifying the costing techniques that are more effective in reducing energy consumption. The results provide practical implications for manufacturing companies, encouraging them to enhance the adoption and strategic application of EMA costing techniques in order to unlock potential environmental and economic benefits associated with their implementation.

Keywords: Activity-based costing, costing techniques, energy consumption, environmental management accounting, life cycle costing, material flow cost accounting.

JEL Classification: M41, Q56, Q41

Absztrakt. A termelő (ipari) szektor vállalatai közismerten magas energiateljesítéssel működnek, ami jelentős mértékben hozzájárul a globális környezeti degradációhoz. E kihívásokat tovább erősíti a hagyományos kalkulációs módszerek korlátozottsága, amelyek gyakran nem teszik lehetővé a környezeti és energetikai költségek pontos mérését. A fenti hiányosságokra válaszul a vezetői környezeti számvitel (Environmental Management Accounting, EMA) olyan fontos menedzsmenteszközzé fejlődött, amely a környezeti problémák kezelését és a vezetői döntések minőségének javítását szolgálja. A tanulmány célja annak vizsgálata, hogy az EMA keretében alkalmazott kalkulációs módszerek milyen hatást gyakorolnak a Dél-afrikai Köztársaság azon termelő vállalatainak energiateljesítésére, amelyek részvényeit a Johannesburgi Értéktőzsdén jegyzik. Az empirikus modellben az EMA-kalkulációs módszerek független változóként szerepelnek, és a tevékenység alapú költségvetés (ABC), az anyagáram-költségvetés (MFCA), valamint az életciklus-költségvetés (LCC) segítségével kerülnek operacionalizálásra. A függő változó az energiateljesítés szintje. A kutatás kvantitatív megközelítésen alapul, és másodlagos adatok felhasználásával készült, amelyek a kiválasztott vállalatok éves, integrált és nem pénzügyi (fenntarthatósági) jelentéseiből származnak egy tízéves időszakra (2013–2022). A változók közötti kapcsolat értékelésére többváltozós regressziós elemzést alkalmaztunk. Emellett diagnosztikai tesztekre is sor került – többek között a normalitás, a heteroszkedaszticitás és a multikollinearitás vizsgálatára – annak érdekében, hogy a regressziós elemzés feltételei teljesüljenek, és a kapott eredmények megbízhatósága igazolható legyen. Az eredmények pozitív és statisztikailag szignifikáns kapcsolatot jeleztek az ABC alkalmazása és az energiateljesítés szintje között. Ezzel szemben az MFCA és az energiateljesítés között pozitív, de statisztikailag nem szignifikáns összefüggés mutatkozott. Továbbá az LCC és az energiateljesítés között negatív és statisztikailag szignifikáns kapcsolatot azonosítottunk, ami arra utal, hogy az életciklus-költségvetés érdemben hozzájárulhat a vállalatok energiateljesítésének növeléséhez. A kutatás tudományos újdonsága abban áll, hogy az ABC, az MFCA és az LCC módszereit egyetlen egységes analitikai modellben integrálja, valamint azonosítja azokat a kalkulációs eszközöket, amelyek hatékonyabbak az energiateljesítés mérséklésében. Az eredmények gyakorlati jelentősége, hogy a termelő vállalatok számára megalapozzák az EMA-módszerek aktívabb bevezetésének és stratégiai alkalmazásának célszerűségét, elősegítve az alkalmazásukból származó környezeti és gazdasági előnyök kiaknázását.

Kulcsszavak: tevékenység alapú költségvetés (ABC), kalkulációs módszerek, energiateljesítés, vezetői környezeti számvitel (EMA), életciklus-költségvetés (LCC), anyagáram-költségvetés (MFCA).

Анотація. Підприємства виробничого сектору широко відомі значним рівнем енергоспоживання, що суттєво спричиняє глобальну деградацію довкілля. Ці виклики посилюються обмеженістю традиційних методів калькулювання, які часто не забезпечують точного вимірювання екологічних та енергетичних витрат. У відповідь на зазначені недоліки управлінський екологічний облік (Environmental Management Accounting, EMA) сформувався як важливий управлінський інструмент, спрямований на вирішення екологічних проблем та підвищення якості управлінських рішень.



Метою статті є дослідження впливу методів калькулювання в межах ЕМА на рівень енергоспоживання виробничих компаній Південно-Африканської Республіки, акції яких котируються на Йоганнесбурзькій фондовій біржі. В емпіричній моделі методи калькулювання ЕМА виступають незалежними змінними та апроксимуються за допомогою калькулювання на основі діяльності (ABC), обліку витрат матеріальних потоків (MFCA) та калькулювання за життєвим циклом (LCC). Залежною змінною визначено рівень енергоспоживання.

Дослідження ґрунтується на кількісному підході з використанням вторинних даних, отриманих із річних, інтегрованих та нефінансових (сталого розвитку) звітів відібраних компаній за десятирічний період (2013–2022 рр.). Для оцінювання взаємозв'язку між змінними застосовано багатofакторний регресійний аналіз. Додатково проведено діагностичні тести, зокрема перевірку на нормальність розподілу, гетероскедастичність та мультиколінеарність, з метою забезпечення відповідності припущенням регресійного аналізу та підтвердження надійності отриманих результатів. Результати дослідження засвідчили наявність позитивного та статистично значущого зв'язку між застосуванням ABC та рівнем енергоспоживання. Водночас між MFCA та енергоспоживанням виявлено позитивний, проте статистично незначущий зв'язок. Крім того, встановлено негативний і статистично значущий зв'язок між LCC та енергоспоживанням, що свідчить про потенціал калькулювання за життєвим циклом щодо підвищення енергоефективності підприємств. Наукова новизна дослідження полягає в інтеграції методів ABC, MFCA та LCC у межах єдиної аналітичної моделі та у визначенні тих інструментів калькулювання, які є більш ефективними для зниження рівня енергоспоживання. Отримані результати мають практичне значення для виробничих підприємств, оскільки обґрунтовують доцільність активнішого впровадження та стратегічного використання методів ЕМА з метою отримання екологічних і економічних переваг від їх застосування.

Ключові слова: калькулювання на основі видів діяльності (ABC), методи калькулювання, енергоспоживання, управлінський екологічний облік (ЕМА), калькулювання за життєвим циклом (LCC), облік витрат матеріальних потоків (MFCA).

Problem statement. The global energy crisis calls for efficient energy use across all sectors [1, 2]. South Africa is not immune to energy challenges, as seen from the recent power cuts due to demand exceeding supply, disrupting businesses and individuals. Higher usage of non-renewable energy, such as electricity, remains a key challenge in manufacturing companies [3, 4]. Despite efforts to move to renewable energy, many manufacturing companies are still over-relying on the grid for electricity generation [4, 5]. Higher non-renewable EC, such as electricity made from fossil fuels, contributes to natural resource depletion and negative environmental consequences [6-8]. These challenges require different role players to contribute to environmental sustainability by changing their actions. Accounting professionals are among the stakeholders that are critical in reducing environmental impact by implementing costing techniques to ensure resource efficiency [9]. Environmental management accounting (EMA) costing techniques such as activity-based costing (ABC), material flow cost accounting (MFCA), and life cycle costing emerged to tackle environmental challenges, amongst others [10]. ABC is known for its accurate allocation of costs to products based on activities that drive the cost [9]. MFCA measures material, energy flows, and waste output in physical and monetary terms [11, 12]. Similarly, LCC measures product costs over their life cycle [13]. While there is awareness about EMA costing techniques in South Africa, studies conducted in the



South African context remain limited [5, 12, 14, 15]. Moreover, most previous studies did not combine ABC, MFCA, and LCC in one study. Also, it remains unknown which EMA costing technique is most efficient in reducing energy consumption in manufacturing companies. Therefore, this study aims to contribute to filling the existing gap in the literature by evaluating the effect of EMA costing techniques on EC in South African manufacturing companies.

Literature review. This section discusses the theoretical foundation and the empirical literature related to this paper. This paper is based on shareholder and stakeholder theories.

Shareholder theory. The shareholder theory posits that a company's primary objective is to increase profits that maximize shareholder wealth [16-18]. Under this theory, corporate executives are responsible for making more profits for the business while complying with the basic rules of society as required by law and ethical custom [16]. The law may include having techniques to enable energy consumption preservation.

Stakeholder theory. On the other hand, stakeholder theory requires companies to consider not only the interest of shareholders, but also other stakeholder groups affected by the companies' operations [19, 20]. Stakeholders are categorized into internal and external, and include consideration of the environment in the form of non-renewable energy preservation [20]. The adoption of these two theories is made because the ability to make profits by companies as required by the shareholders theories is critical to satisfy other stakeholders such as environmental under the stakeholder theory.

Activity-based costing and energy consumption. [5] evaluated the role of EMA in assisting dirty industries to become greener in South Africa. The author followed a qualitative research method with secondary data collected from integrated and sustainability reports of the top 10 JSE-listed manufacturing companies. The findings show that companies implementing ABC, would reduce their EC by identifying inefficiencies in resource flow. Reducing EC by applying the ABC technique could encourage its adoption. Likewise, [21] used an Indonesian manufacturing company to calculate the cost per unit of Rub oil product. Data was collected using interviews, observation, and analysing documents. The author split the factory overhead costs into indirect material, wages, and electricity costs. The findings show that 504 kilowatts per hour electricity were used for the month of April. The electricity usage was further split into production, warehousing, and office use. Exposing electricity consumption amount used into different departments through ABC's application may stimulate its adoption to manage electricity consumption. [22] used an Italian wine-producing company to evaluate its economic and environmental results using an integrated methodology that incorporates ABC. The authors collected primary and secondary data over 5 years (2015- 2019). The findings revealed that transformation activity had the highest electricity cost, at 19% of the total cost, compared to packaging and bottling activity, at 4% of the total cost. Exposing areas of high electricity costs in the manufacturing process using ABC could encourage management to implement it to



manage EC. [23] assessed the effect of applying EMA costing techniques in the Zimbabwean Gold mining companies and evaluated ABC on assigning manufacturing overhead costs. The findings show ABC's ability to identify activities that drive cost, resulting in improved environmental performance, such as EC. Reducing EC by applying ABC may encourage its use. [14] assessed the role of EMA costing techniques towards responsible resource consumption in South Africa. The author followed a qualitative research method through a systematic literature review of South African studies in EMA. The study found that ABC could assist in responsible consumption of resources by revealing environmental, non-value-adding, and expensive activities during production. Saving environmental resources such as non-renewable energy through ABC application may encourage its usage. Since many previous studies found that applying ABC reduces EC, this paper proposes the following hypothesis to evaluate if ABC influence EC in South African manufacturing companies.

H₁: A negative and significant relationship exists between ABC and EC in South African manufacturing companies.

Material flow cost accounting and energy consumption. [15] used a case study of the Doordraail Water Treatment Scheme, a South African water utility, to determine actual water loss through MFCA implementation. The findings revealed that the filtration cost centre was the highest electricity consumer, with 12 384 kWh of electricity per day. Exposing activities with higher electricity consumption using MFCA may encourage its adoption to reduce EC. [24] analysed the impact of EMA costing techniques, such as MFCA, on the economic and environmental performance of a Zimbabwean gold mining company. The findings show that MFCA application reduces energy consumption. Minimizing EC through MFCA implementation could inspire its adoption in different companies. [25] evaluated the relationship between MFCA and environmental performance in Japan. Data was collected from 225 Japanese companies listed on the Tokyo Stock Exchange in 2014 using research questionnaires. The findings show that MFCA application reduces EC. Reducing EC through MFCA application may encourage its adoption in various companies. [26] analysed the cost of bread manufacturing before and during the Russia-Ukraine conflict using an integrated methodology that incorporates MFCA. The findings indicate that the highest input cost for bread manufacturing was electricity, at 54%, before the Russia-Ukraine conflict, which increased to 83% during the conflict. Revealing areas of high energy costs through the MFCA application may encourage EC reduction. Likewise, [27] evaluated the effect of applying MFCA on green productivity and sustainability in an Iraqi state-owned company. The findings show that applying MFCA assists in minimizing EC. Decreasing EC through MFCA application could encourage its use. [28] applied MFCA in a brick manufacturing company in Iraq. The manufacturing process was split into four quantity centres: preparation, mixture, burning and cutting, burning and packing. The findings show that burning and packing has the highest energy costs. Revealing activities with high energy costs may assist companies in reducing energy consumption. Since many



previous studies found that applying MFCA reduces EC, this paper proposes the following hypothesis to evaluate if MFCA influence EC in South African manufacturing companies.

H₂: A negative and significant relationship exists between MFCA and energy consumption in South African manufacturing companies.

Life cycle costing and energy consumption. [29] compared the cost of a green and traditional industrial building using LCC in Sri Lanka. The findings indicate that green buildings consume 50% less energy compared to traditional buildings. Revealing products that saves EC by the application of LCC may encourage its application. Dong, et al. [30] used a concrete manufacturer in China, to analyse the environmental and economic performance of four products (Baseline, S-I, S-II, and S-III) by integrating life cycle assessment (LCA) and LCC. The findings exposed high electricity consumption in the production stage. Revealing high areas of electricity consumption using LCC may encourage its adoption to reduce EC. Similarly, [31] used LCC technique to analyse a Brazilian office building. The findings show that the office buildings consumed high electric energy (295 000 kWh per year) through heating and cooling. Exposing areas of high EC through LCC could encourage its adoption to minimise EC. Likewise, [26] used the LCC technique to analyze bread costs in an Italian manufacturing company before and during the Russia-Ukraine conflict. Major stages of bread manufacturing include wheat farming, transportation, milling, and the actual bread manufacturing by artisans. The findings show that milling and bread manufacturing consumes more energy than other processes. Divulging activities that consume a lot of energy by applying LCC may encourage its use. Similarly, [22] assessed the economic costs of an Italian wine-making company using LCC. The findings indicate that the transformation activity was the highest electricity consumer at 19% of the total activity costs. Revealing areas of high electricity costs through LCC technique may encourage its use to minimize EC. [23] evaluated the effect of applying EMA costing techniques on Zimbabwean gold mining companies. The findings show that LCC was used less frequently in the gold mining. Low application of LCC could result in missing opportunities derived from the technique. In addition, [32] assessed the environmental and economic performance of a case study of an Italian wine producer using an integration methodology that includes LCC. The findings revealed savings in electric energy through LCC applications. Saving EC using the LCC technique may stimulate its adoption. Since many previous studies found that applying LCC reduces EC, this paper proposes the following hypothesis to evaluate if LCC influence EC in South African manufacturing companies.

H₃: A negative and significant relationship exists between LCC and EC in South African manufacturing companies.

Research aim and objectives. This study aims to evaluating the effect of EMA costing techniques on energy consumption (EC) in South African manufacturing companies. EMA costing techniques is represented by ABC, MFCA and LCC as independent variables while EC reflect a dependent variable. This paper has 3 objectives: 1. to analyse the effect of ABC on EC in South African manufacturing



companies, 2. to evaluate the effect of MFCA on EC in South African manufacturing companies and 3. to determine the effect of LCC on EC in South African manufacturing companies.

Methodology. This paper followed a positivist research paradigm and quantitative research method. A correlational research design was adopted to evaluate the relationship between independent variables (ABC, MFCA and LCC) and dependent variables (EC). Total sales revenue (TSR) was used as a control variable. The population for this study was 22 consumer goods manufacturing companies listed on the Johannesburg Stock Exchanges (JSE). A sample size of 12 manufacturing companies was selected using purposive sampling and supported by Slovin's sample size calculation formula [33]. The sampling criteria include that the company should have: (i) operated for at least 5 years during the study period; (ii) tracked and displayed EC in their reports; (iii) tracked EC information for at least 5 years; (iv) involved in the manufacturing of consumer goods. Companies not meeting the set criteria were excluded from the study. Figure 1 illustrates sample size based on Slovin's sample size calculation formula.

$$n = \frac{N}{(1 + N e^2)}$$

Where n = final sample size
N = representing the sub-population after purposive selection
1 = constant
e = the allowed level of error (0.05 significance level)

$$n = \frac{N}{(1 + N e^2)}$$
$$12 = \frac{N}{(1 + N e^2)}$$
$$12 = \frac{12}{(1 + 12 \times 0.05^2)}$$

=11.65 =12 sample size

Figure 1: Slovin's sample size calculation formula

Source: Authors' construction

The selected companies were studied for a period of 10 years (2013-2022). Secondary data relating to EC and TSR was collected from the sampled companies' annual, integrated, and sustainability reports for 10 years, giving 120 observations. EC was measured using the amount of non-renewable energy (electricity) in companies consume. TSR was recorded in Millions. Information relating to ABC, MFCA, and LCC adopted in the selected manufacturing companies was collected through questionnaires administered by emails to research participants and incorporated in the secondary data. The questionnaires were sent to the sampled companies' Finance managers, Chief Financial Officers, Environmental managers, Production Managers, and Human Resource Managers.

The researchers used a five-point Likert scale to evaluate the application of EMA costing techniques (ABC, MFCA, and LCC) and energy consumption in selected companies represented as follows: 1. Strongly disagree, 2. Disagree, 3. Neither agree nor disagree, 4. Agree, and 5. Strongly agree. The numeric primary data information was incorporated into the secondary data collected. The data was classified as a panel and was analysed using multivariate regression analysis. The following regression model was used to capture the study variables.

$$y_{it} = \alpha_{it} + \beta_1 x_{1it1} + \beta_2 x_{2it2} + \beta_3 x_{3it3} + \beta_4 x_{4it4} + \varepsilon (1)$$

Where: y = EC; α = constant; β_1 - β_4 = regression coefficient; x_1 = ABC; x_2 = MFCA; x_3 = LCC; x_4 = TSR; it = time and ε = error term (to represent accounted variables).

Results and discussions. Descriptive statistics for model 1. Table 1 indicates the description of the study variables covering number of observations, mean, standard deviation, minimum and maximum. Table 1 shows an ABC mean of 4.09 and a maximum of 5, showing that most sampled companies used it. ABC standard deviation of 0.96 depicts that data is clustered next to the mean. MFCA has a mean of 3.525 and a maximum of 5, indicating usage above 50% among the observed companies. MFCA standard deviation of 1.39 suggests that data is dispersed next to the mean. LCC has a mean of 2.65 and a maximum of 4, indicating less usage than ABC and MFCA. LCC standard deviation of 1.03 suggests that data is centered across the mean. TSR has a mean of 16 539.51 and a maximum of 57 786, showing different revenues earned by the sampled companies. TSR standard deviation was 1349.5, indicating that data is disbursed far from the mean. EC has a mean of 0.042 and a maximum of 0.35. EC standard deviation of 0.82 indicates that data is distributed evenly across the mean.

Table 1.

Descriptive statistics for model 1

Variable	Observations	Mean	Std. Dev	Min	Max
ABC	120	4.091667	0.9614051	2	5
MFCA	120	3.525	1.390015	1	5
LCC	120	2.675	1.038442	1	4
TSR	120	16539.51	13588.92	1349.5	57786
EC	120	0.0422216	0.817935	0.0036579	0.3504036

Source: Stata outcomes

Normality test for model 1. Many statistical regressions require data to be normally distributed or close to normal. This study tested normal distribution using skewness and kurtosis as reflected in Table 2. Table 2 indicates numerous skewness and kurtosis values that are zero (0), indicating that data follows a normal distribution.



Table 2.

Skewness and kurtosis test for normality model 1

Variable	Obs	Pr (Skewness)	Pr(kurtosis)
ABC	120	0.0012	0.2545
MFCA	120	0.0612	0.0000
LCC	120	0.2950	0.0000
TSR	120	0.0000	0.0370
EC	120	0.0000	0.0000

Source: Stata outcomes

Multicollinearity test for model 1. Multicollinearity exists in a dataset if the independent variables are closely related. This study used Pearson correlation matrix and variance inflation factors (VIF) to test multicollinearity. Table 3 shows multicollinearity test based on Pearson correlation. Table 3 indicates that all variables are less than 80%, indicating the absence of multicollinearity.

Table 3.

Pearson correlation matrix for model 1

	EC	ABC	MFCA	LCC	TSR
EC	1.0000				
ABC	0.2503	1.0000			
MFCA	0.2702	0.4793	1.0000		
LCC	0.3184	0.2910	0.5384	1.0000	
TSR	0.6970	-0.0154	-0.0577	0.3271	1.0000

Source: Stata outcomes

Table 4 shows multicollinearity test based on VIFs. Table 4.3 indicates that all the independent variables have VIFs of less than 10, suggesting the absence of multicollinearity between the independent variables.

Table 4.

Variance inflation factors for model 1

Variance	VIF	1/VIF
ABC	1.30	0.768699
MFCA	1.81	0.553268
LCC	1.72	0.580358
TSR	1.23	0.815955
Mean VIF	1.51	

Source: Stata outcomes

Heteroscedasticity test for model 1. The absence of homoscedasticity implies that heteroscedasticity exists. Table 5 indicates heteroscedasticity results based on the Wald test. Table 5 shows results that are insignificant, as demonstrated by a p-value of greater than 5%. Hence, this study rejects the null hypothesis, suggesting the presence of heteroscedasticity, and accepts the alternative for homoscedasticity.

Table 5.

Heteroscedasticity (Wald test) for model 1

(1)	ABC - MFCA	0	
(2)	ABC - LCC	0	
(3)	ABC - TSR	0	
	χ^2 (3)		2.44
	Prob> χ^2		0.4868

Source: Stata outcomes

Findings presentation for model 1 EMA costing techniques and EC. Table 6 shows results for the effect of applying EMA costing techniques (ABC, MFCA, and LCC) on energy consumption (EC). EC represents the dependent variable, while ABC, MFCA, and LCC represent the independent variables. Table 6 shows a positive (coefficient 0.0128) and significant relationship between ABC and EC at a 5% significance level, depicted by two stars. The findings imply that applying the ABC technique increases EC materially. Again, the findings indicate a positive (coefficient 0.0190) and significant effect between MFCA and EC at a 1% significance level, indicated by three stars. The findings suggest that applying MFCA increases EC substantially. Moreover, the findings show a negative (coefficient -0.0119) and significant effect between LCC and EC, at a 10% significance level shown by one star. The findings show that applying LCC decreases EC materially. Furthermore, TSR shows a positive and significant relationship with EC at a 1% significance level, depicted by three stars. Thus, the findings demonstrate that an upsurge in TSR increases EC substantially. The researcher anticipated TSR would affect this study's variables. Hence, the TSR is used as a control variable.

Table 6.

Effect of EMA costing techniques on energy consumption

Variables	Results (1)
	EC
ABC	0,0128** (0,0056)
MFCA	0,0190*** (0,0046)
LCC	-0,0119* (0,0060)
TSR	0,0000*** (0,0000)
cons	-0,1220*** (0,0222)
Number of observations	120
R-squared	0,6119

Standard errors in parenthesis *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; ABC=activity-based costing; LCC=life cycle costing; MFCA=material flow cost accounting; TSR=total sales revenue; and EC=energy consumption.

Source: Stata outcomes



Findings discussion. *Effect of applying activity-based costing on energy consumption.* Table 6 shows a positive (coefficient 0.013) and significant relationship between ABC and EC, as depicted by a positive coefficient variable of 0.013. The relationship is significant at a 5% significance level, reflected by two stars. The findings indicate that applying the ABC increases EC materially. The findings contradict previous literature that found that applying ABC reduces energy consumption, suggesting a positive relationship [21-23, 34]. The findings indicate that ABC did not assist the observed companies in reducing EC. The ABC's failure to reduce energy is attributable to limited application of the techniques in the observed companies. This is because ABC is advocated for its ability to reduce energy consumption [5, 24, 35, 36] by exposing products with higher EC [21, 22], allowing for energy efficiency. Therefore, the author fails to reject the null hypothesis, indicating a significant and positive relationship between ABC and EC in South African manufacturing companies.

Effect of material flow cost accounting on energy consumption. Table 6 shows a positive (coefficient 0.0190) and significant relationship between MFCA and EC at the 1% level, as indicated by three stars. The findings denote that applying the MFCA results increases EC materially. The findings contradict previous studies that found that applying MFCA reduces EC, suggesting a positive relationship [15, 27, 28, 37]. The findings indicate that MFCA did not assist the observed companies in reducing EC. The MFCA's failure to reduce EC is associated with limited application of the technique consistent with prior studies [23]. The findings are aligned with the shareholder's theory, which indicate that companies' primary objective is to make profits that maximize shareholders' wealth [16, 17]. Hence, the focus on maximizing shareholders wealth is associated with lack of improvement of environmental factors such as EC. On the other hand, the findings are not aligned with the stakeholder theory that requires multiple stakeholders' consideration, including the environment [19, 20]. Therefore, the author fails to reject the null hypothesis, indicating a significant and positive relationship between MFCA and EC in South African manufacturing companies.

Effect of life cycle costing on energy consumption. Table 6 shows a negative (coefficient -0.0118) and significant relationship LCC and EC, at a 10% significant level, as indicated by one star. The findings show that applying the LCC decreases EC substantially. The findings support previous literature, which found that applying LCC reduces EC, suggesting a negative relationship [29, 32]. The ability to reduce EC with LCC application is made possible by its capability to divulge activities with high EC [22, 30, 31]. The findings are not aligned with the shareholder's theory, which indicate that companies' primary objective is to make profits that maximize shareholders' wealth [16, 17]. However, the findings are aligned with the stakeholder theory that requires multiple stakeholders' consideration, including the environment [19, 20]. Therefore, the author rejects the null hypothesis indicating a significant and positive relationship between LCC and EC and accepts the alternative hypothesis indicating a significant and negative relationship between LCC and EC in South African



manufacturing companies. Furthermore, the findings suggest that LCC is the most efficient in reducing EC. The ABC and MFCA were considered inefficient as they failed to reduce EC due to their limited application.

Conclusions and prospects for further research. This paper assessed the effect of EMA costing techniques on EC in South African manufacturing companies following quantitative research methods. The paper used a sample size of 12 manufacturing companies listed on the JSE. Primary and secondary data were collected to reach this paper objectives. Multivariate regression analysis was used to analyse the data. The study covered three objectives: to analyse the effect of ABC on EC in South African manufacturing companies; to evaluate the effect of MFCA on EC in South African manufacturing companies and to determine the effect of LCC on EC in South African manufacturing companies. The findings reveal a positive and significant relationship between ABC and EC. In addition, the findings show a positive and significant relationship between MFCA and EC. Furthermore, the findings indicate a negative and significant relationship between LCC and EC. The findings suggest that ABC and MFCA did not assist the sampled companies in reducing EC which is aligned with the shareholder theories. Moreover, the findings show LCC enabled reduced EC, which is aligned with the stakeholder theory. This paper supports the stakeholder theory that requires the balancing of profits for shareholders with consideration of environmental factors such as EC. At the theoretical level, this paper contributes to filling the gap in the literature by combining the 3 EMA costing techniques (ABC, MFCA and LCC) in one study and evaluating its effect on EC. At the practical level, this paper encourages consumer goods manufacturing companies to increase the extent of applying EMA costing techniques to reap the potential benefits such as resource efficiency, which would lead to EC savings. The limitations of this paper include focusing on South African JSE-listed consumer goods manufacturing companies. Future studies can use the same variables for this paper in different sectors.

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