



# Analyzing the Efficiency of Working Capital Management: A New Approach Based on DEA-Malmquist Technology

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## Abstract

In this study, we analyze the efficiency of working capital management (WCME) for Gulf companies before and during the coronavirus crisis, then explore the influence of the coronavirus crisis on WCME. This study uses several techniques to achieve its goals, including the Malmquist index (MI), data envelopment analysis (DEA), and Tobit regression. The results demonstrate that most firms (approximately 84%) adopt a conservative strategy for their WCM. The WCME results revealed a statistical difference in the technological and pure efficiency scores for companies before and during the coronavirus crisis, while the results revealed no statistical difference in the technical, scale, and total factor productivity scores. Tobit's results show that the coronavirus crisis had no significant influence on companies' WCM performance. Finally, our results indicate that firms that are efficient in terms of WCM have higher sales returns and net income. The findings of this study have important implications for stakeholders to increase their awareness of companies' WCM performance before and during a crisis. In addition, the results could have implications for trading strategies as investors and financiers seek to invest in companies with good WCM. The implications of WCM performance on social interests would cause decision-makers to use the best strategies and procedures to enhance WCM activities to improve their investments and image in the community in which it operates. We advance a novel contribution to the literature by analyzing and appraising the WCME for companies before and during the coronavirus crisis using a new approach based on DEA-Malmquist technology and then examining whether the coronavirus crisis has affected the WCME.

**Keywords** Working capital management · Data envelopment analysis · Malmquist index · Optimization · Coronavirus

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## 1 Introduction

Businesses strive to make the best use of their limited resources. Resource allocation theory states that firms choose the most cost-effective distribution and allocation of resources for various productive activities [1, 2]. As a result, firms that strive for excellence manage their WC to achieve best practices. The WC term arose from corporate finance and was initially mentioned at the inception of the twentieth century [3, 4]. The WC is one of the most confusing accounting concepts. The lack of clarity concerning the employment of WC may be excused by the fact that there is no analogous classification of WC in firms' balance sheets. WCM appears to have been primarily disregarded in businesses, even though bad WC decisions are responsible for a considerable portion of business failures, and WCM is essential for corporate financial management because it directly affects a firm's profitability [5]. This is more striking as a large share of past firm bankruptcies was created by ineffective or inadequate WCM [6]. As WC significantly influences a firm's operational and financial security, the literature confirms that it is necessary to develop an optimal WC strategy for a firm [7, 8]. The literature suggests three strategies for managing WC: conservative, moderate, and aggressive [8–10]. The conservative strategy is safe for a firm and provides a high level of liquidity as it keeps current assets at high levels compared to current liabilities. In contrast, the aggressive strategy keeps current assets at low levels compared to current liabilities. Finally, the moderate strategy is considered a sensible method as it aims to minimize the drawbacks of the aforementioned methods and maximize their benefits. Exploring the suitable linkages between the items of current assets and liabilities will help a firm to adopt a good WC strategy. Therefore, a firm should adopt and manage its WC strategy on a solid and secure basis to achieve best practices.

The literature on corporate finance recognizes the significance of short-term business decisions on firm profitability. WCM is a recurring topic on a global scale because it is critical to ensure a business's optimal path. WC is essential during economic downturns because it acts as a liquidity buffer [11, 12]. Additionally, WC practices benefit firm profitability by facilitating solid sales and income growth [13, 11]. While inventory stockpiling protects businesses from price fluctuations, trade credit increases sales and strengthens customer relationships. In addition, short-term debt related to financing the WC has low interest rates and is unaffected by inflation [14]. In contrast, the PricewaterhouseCoopers (PwC) Global report notes that promoting WC could free up €1.3 trillion in cash, allowing for a 55% increase in capital investment [15]. Furthermore, the report identifies new calls for global publicly traded firms' business performance over the last 5 years as capital expenses have decreased, cash has shifted to be more costly and tough to convert, and the WC has slightly improved. Firms must cultivate and enhance their WC practices to improve business performance. On the other hand, excessive investment in WC necessitates financing and, as a result, additional payments, which may produce negative consequences and sacrifices for stockholders [13, 16]. Kieschnick et al. [17] argue that an increase in WC financing increases the likelihood of bankruptcy because it requires additional financing requirements and financing expenses.

Moreover, various components of WCM contribute significantly to its effectiveness. Firms must make critical decisions about how much stock to keep on hand as having a large inventory protects them from costly stockouts and manufacturing process interruptions. Customers who are given more credit are more likely to use and verify products before making a payment, which benefits the company [18]. According to de Almeida and Eid [19], WC is a critical component of operational cash flow and is used to calculate the free cash flow. Effective WCM reduces a firm's reliance on external funding, frees up cash for additional investments, and increases its financial flexibility. Business administration is constantly striving to maintain optimal WC volume. Increased WC investment energizes the sales process and provides discounts to suppliers for prompt payments at low WC levels. Nonetheless, once a certain level of WC investment is reached, additional interest costs are incurred, eroding firm value [20].

Two approaches have been used to assess a firm's efficiency in terms of WCM. The first approach for assessing the WCME is to use ratio analysis as a parametric method. For example, quick and current ratios have been used to assess a firm's liquidity [21]. In addition, Zimon and Tarighi [8] explored the WCM strategies of small- and medium-sized firms in Poland using liquidity and turnover ratios, cash conversion cycle (CCC), and other ratios. This approach has been criticized for its inherently static nature as a parametric method [22]. The CCC proposed by Richards and Laughlin [23] was also criticized for being mathematically incorrect, failing to focus on the total amount of funds committed, and lacking differentiation in the weights assigned to each component of WC [24]. According to Goel and Sharma [24], other measurement ratios, such as weighted CCC, have calculation issues owing to a lack of relevant data. Accordingly, researchers have developed alternative methods for measuring the WCME to overcome the weaknesses of the traditional approach. DEA is one such measure that has been used to calculate WCME as a non-parametric method in previous studies [25–30].

The DEA approach is distinguished by its ability to capture relationships between multiple outputs and inputs [31–33]. Additionally, DEA is a non-parametric technique that does not require prior assumptions about the distribution form of data or its residuals, and does not require any previous knowledge of the variable weights [34–36]. In addition, DEA is distinguished by its powerful benchmark in assessing the efficiency of firms, as it focuses on the best practices of firms rather than traditional methods, such as ratios and regression analyses, which rely on measures of average and central tendencies as criteria for evaluation, as it benchmarks a firm's performance with maximum relative performance or best practices [37, 38]. Therefore, DEA is considered a powerful approach for the continuous improvement process as it provides critical benchmark information for inefficient firms in achieving the best practices [33, 38].

Empirical evidence shows that WCM has garnered substantial interest in accounting and finance research. Considering the Gulf firms, WCM is vital to firms' economic development. Gulf member states are monarchies with distinct legal structures, and their public corporations operate in distinct institutional, economic, and political environments [39]. To integrate with the global economy, they shifted their focus from an oil-based economy to a knowledge-based one [40]. Gulf firms outrank the Middle East and North Africa (MENA) regions but not other regions

with comparable per capita income levels. Thus, inefficient employment of assets and WC impedes progress toward sustainable and equitable growth. Gulf firms should invest in balancing their assets and WC to alleviate this trend. In addition, the existing literature on WCM has rarely focused on this crucial phenomenon in Gulf firms. Therefore, more research is needed to analyze the WCME for firms operating in the Gulf and investigate the influence of the coronavirus crisis on WCM performance, which is considered a novel contribution to the literature. Therefore, this study analyzes the efficiency of WCM by integrating the data envelopment analysis approach and the Malmquist productivity index in the context of a unique Gulf setting. The objective of this study was to investigate data from 2018 to 2020. The DEA-Malmquist analysis is extended to capture the efficiency of WCM in terms of technical efficiency (effch), technological efficiency (techch), pure efficiency (pech), scale efficiency (sech), and total factor productivity (tfpch) before and during the coronavirus crisis. The efficiency of the WCM results revealed a statistical difference in the technological and pure efficiency scores before and during the coronavirus crisis. Tobit's results show that the coronavirus crisis had no significant influence on Gulf firms' WCM performance. The findings of this study have important implications for stakeholders to increase their awareness of companies' WCM performance before and during a crisis. In addition, the results could have implications for trading strategies as investors and financiers seek to invest in companies with good WCM. The implications of WCM performance on social interests would cause decision-makers to use the best strategies and procedures to enhance WCM activities to improve their investments and image in the community in which it operates.

The motivation for the study stems from market characteristics and the economic prospects of the Gulf. Most Gulf countries experienced increased inflation during the study period, resulting in higher interest rates, influencing a firm cost of capital. The Gulf Statistics Centre recently released a report on the Gulf countries' inflation rates, which were 3.5% in April 2021, up from 3.5% the previous year. In April 2021, Saudi Arabia had the highest inflation rate in the Gulf, at 5.3%, up from 3.1% in April 2020, followed by Kuwait (3.1%), Oman (1.6%), and Qatar (1.6%). In the United Arab Emirates and Bahrain, inflation decreased about 0.5% and 0.1%, respectively. Besides, the coronavirus epidemic, on the other hand, had a tremendous impact on the entire world, as every country, industry, and civilization were affected in some way [41]. Many activities have been restricted because of the pandemic to slow the spread of the virus. We should turn everything off to limit the negative impact. When public authorities take decisive action to address the emerging health threat of coronavirus, business leaders are faced with the challenge of channeling their WCM through the issue. Recognizing the crisis impact on the people who drive the firm's operations is critical. That highlights the importance of a resilient leader in a fast-changing environment and working differently. Also, the author has not found any research by reviewing previous studies on WCM in the context of the coronavirus pandemic. Using MI and DEA, this study is thought to be one of the earliest attempts to analyze and appraise the WCM performance of the firms. Moreover, Gulf firms were adversely impacted by the numerous issues that arose because of the outbreak. Based on these arguments and evidence, this study investigates the following:

*RQ1. Are there, on average, significant differences in firms' WCME over the study period?*

*RQ2. Has coronavirus crisis affected firms' WCME over the study period?*

The remainder of this paper is organized as follows. Section 2 presents a literature review and hypotheses formulation. Section 3 clarifies the data and the methodology used. Section 4 presents the empirical results. Finally, Sect. 5 presents a summary and conclusions of the study.

## 2 Literature Review and Hypotheses Formulation

WCM is a critical component of a firm's success [42, 43]. Furthermore, the WCM can help with risk management and increase the value of a business [44]. Furthermore, a conservative approach to WCM necessitates increased inventory and accounts receivable investment, which has the advantage of lowering supply-chain costs and price fluctuations, posing less risk to businesses [21, 45]. Increased sales and market share generate profits [46]. Firms that take a proactive approach to WCM reduce risk exposure by reducing inventory investment and credit terms with customers [13]. Besides, a study of Indian industrial firms between 2004 and 2013 revealed continuous growth in WCME. The DEA-based approach effectively overcame the limitations associated with traditional WCME measures [26, 27]. Furthermore, an examination of Indian industrial firms revealed a high degree of efficiency volatility among manufacturing firms, with those operating at 50 to 60% efficiency lacking liquidity management expertise [28, 29]. According to Ukaegbu [47], there is a negative relationship between WCM and Egyptian manufacturing firm profitability. According to a study conducted in 46 countries, lowering CCC could increase business profitability and value [16]. Furthermore, publicly traded European hospitals with a low leverage ratio show that increasing WCM increases profitability [48].

Prior research in developed countries revealed various WCME and firm performance outcomes [49]. While these studies have been extensive in developed countries, they have only recently been extended to developing countries. In developing countries, the relationship between WCME and profitability has been documented using a variety of proxies. Over 10 years, Akinlo [50] investigated the relationship between WCME and non-financial sector firm profitability in Nigeria. Inventory days, average payment period accounts receivable, and WCM efficiency were all calculated by WCME. The data were analyzed using fixed effects and a pooled ordinary least squares model. Nigerian businesses' return on assets (ROA) decreases as accounts receivable, accounts payable, and inventory turnover days increase, but increases as CCC decreases. Altaf [51] investigated the effect of WCME on the performance of the Indian hospitality sector using a two-step efficient GMM (generalized method of moments). WC financing is calculated using the short-term debt-to-working-capital ratio. The results were a non-monotonic relationship with ROA and

Tobin Q. That means that a low level of short-term debt benefits the performance of the business.

Wasiuzzaman [49] calculated the WC using inventory, receivables, payables, and WC balance. According to this study, WC is negatively correlated with ROA in Malaysian manufacturing firms. The payables and hypothesized relationships were incompatible. Soukhakian and Khodakarami [52] investigated whether WCME could significantly improve the ROA and economic performance of publicly traded Iranian industrial firms. Even though CCC was negatively associated with ROA, there was no significant relationship between WCM and refined economic value added when endogeneity was considered. Wang et al. [46] investigated the corporate relationships of non-financial listed firms in Pakistan over their existence. According to the findings, an increase in WCME (as measured by the net trade cycle) decreased ROA regardless of the life cycle stage. Zimon [10] analyzed WCM in small firms in Poland using a sample of 96 commercial firms operating in the construction industry from 2015 to 2017. The results demonstrate that firms operating within purchasing groups focus on financial safety and adopt a moderate-conservative strategy. Lyngstadaas [53] investigated the link between WCM packages and financial performance using a sample of 589 firms in the USA from 2012 to 2019. The results indicate that out of the 11 effective packages in terms of WCM, six are significant. Additionally, the results confirm that the six packages systematically relate to operational and financial WC performance.

In addition, Chamberlain and Aucouturier [54] explore the influence of WCM on the performance of publicly traded companies in Europe from 2004 to 2016. The results indicate that the links between WCM, profitability, and firm value are positive and significant. This study suggests that directors should take a nuanced view of WCM's influence on performance. Zimon [7] reviewed prior research on WCM. This study shows that higher WC levels enable firms to increase their sales volume. The study concludes that directors should base their WCM strategies on high sales volumes to enhance firms' WCM efficiency, profitability, and financial security. Aldubhani et al. [55] explored the linkage between WCM policies and profitability of manufacturing firms in Qatar from 2015 to 2019. The results reveal that firms with a shorter duration of receivables and CCC, and a longer duration of accounts payable and inventory turnover are more profitable. Jaworski and Czerwonka [56] explored the linkage between WCM measures using a sample of 326 Polish firms from 1998 to 2016. The results revealed a significant nonlinear linkage between working capital, liquidity, and profitability. Mazanec [57] explored the influence of WCM on a firm's performance using 3828 transport firms in the Visegrad Group in the European Union in 2019. The results indicate that cash ratio affects firm performance in all models, excluding the Polish and Czech models. In addition, small firms are at a disadvantage in terms of WCM compared to medium-sized firms in Slovakia and the Czech Republic. Zimon and Tarighi [8] examined the influence of the COVID-19 crisis on WCM using a sample of 61 Polish firms from 2015 to 2020. The results demonstrate that firms manage a moderately conservative strategy for their WCM. Additionally, the results indicated that the COVID-19 crisis did not significantly alter firms' WCM strategies. Tarkom [58] investigates the influence of the COVID-19 crisis on firms' WCM using a sample of 2542 US-publicly traded US

firms from 2019 to 2021. The results show that firms with more investment options and government incentives operate at lower levels during cash-conversion cycles. Additionally, the results demonstrated a significant negative influence of COVID-19 on WCM. This finding suggests that the influence can be mitigated by increasing government incentives and investment opportunities. Struwig and Watson [59] critically examined the WCM research conducted during the COVID-19 crisis in South Africa. The study concludes that during a crisis, the WC examination focuses on workforce safety and demand volatility. This suggests that effective cash management and digital transformation shifts are necessary to relieve undesirable changes in supply chains. Based on these arguments and evidence, this study hypothesizes the following:

*H<sub>1</sub>. On average, there were significant differences in firms' WCME over the study period.*

*H<sub>2</sub>. The coronavirus crisis has affected the firms' WCME over the study period.*

### 3 Data and Methodology

The sample size included 459 publicly traded companies in the following industries: communication services, consumer discretionary, consumer staples, energy, health care, industrials, materials, real estate, and utilities. These companies are located in Oman, Qatar, Saudi Arabia, Kuwait, Bahrain, and the United Arab Emirates. According to Pastor and Ruiz [60] and Portela et al. [61], negative data values would limit the capacity of the DEA model to perform the analysis. As a result, 273 firms were excluded due to negative values in some cases and a lack of data in others. As a result, the final decision-making units (DMUs) are 186 firms. The primary data sources were based on the annual reports of the selected firms. These firms' annual reports were obtained from the standard and poor's DataStream, the platform of Mubasher-info, and firms' websites.

Among the numerous approaches available for assessing DMU efficiency scores, the DEA approach was chosen to evaluate the efficiency of the firms under study because of its unique characteristics. First, as Mourad et al. [31], Shahwan and Habib [32], and Tone [33] argue, DEA is a versatile and powerful technique for capturing the relationship between specific outputs and inputs. Furthermore, DEA can provide critical information for continuous improvement, assisting inefficient DMUs in achieving best practices. Second, like Cooper et al. [37] and Habib and Shahwan [38] argued, DEA stands out as a benchmark technique that focuses on the best practices of DMUs rather than traditional methods that rely on measures of central tendencies. Finally, as demonstrated by Habib and Kayani [36], Mourad et al. [31] and Tuskan and Stojanovic [35], DEA distinguishes itself as a non-parametric technique that does not require prior assumptions about the distribution form of data (or its residuals). Furthermore, DEA does not require any previous knowledge of the variable weights.

To calculate efficiency using DEA, we require a set of inputs and outputs pertinent to the analysis’s primary objective [36, 37, 62]. DMUs are expected to provide outputs based on their possible inputs related to the primary objective under analysis. According to prior research, e.g., Gill and Biger [25], Goel and Sharma (24, 26, 27, and Seth et al. [30], the inputs for calculating the WCME should include those items that account for a significant portion of WC investments. Additionally, each firm invests in WC to maintain consistency and increase sales. Thus, firms that generate more sales while supporting the same WC can be considered more efficient. As a result, net sales should be chosen as an output variable. Almost all prior research has overlooked the significance of net income as a by-product of WCM. A business that generates a higher net income while investing the same WC is more efficient. Following a review of the prior literature, the current DEA-WCME model used inventory, accounts receivable, accounts payable, and cost of goods sold as inputs and net sales and net income as outputs. Finally, the radial Malmquist DEA model is obtained by solving the next linear optimization problem:

$$\begin{aligned}
 \frac{1}{\delta^s(X_n^t, Y_n^t)} &= \max_{\lambda \in \mathbb{R}_+^N} (\theta_n) \\
 \text{St } -\theta_n y_{rn}^t + \sum_{j=1}^N \lambda_j y_{rj}^s &\geq 0, \quad r = 1, \dots, m_o \\
 x_{in}^t - \sum_{j=1}^N \lambda_j x_{ij}^s &\geq 0, \quad i = 1, \dots, m_I \\
 \lambda_j &\geq 0
 \end{aligned}
 \tag{1}$$

where  $x_{in}^s$  (resp.  $y_{rn}^s$ ) is the value of the  $i$ -th input (resp.  $r$ -th output) of the  $n$ -th DMU observed in period  $s$ , the  $(\lambda_n)_{\{1 \leq n \leq N\}}$  are the weights corresponding to the DMUs. The DMU is considered relatively efficient in period  $s$  measured by frontier technology  $t$  if  $\delta^s(X_n^t, Y_n^t) = 1$ ; otherwise it is inefficient. It should be noted that,  $e_n^1 = \frac{1}{\delta^1(X_n^1, Y_n^1)}$  (resp.  $e_n^2 = \frac{1}{\delta^2(X_n^2, Y_n^2)}$ ) is the constant return to scale (CCR) efficiency score for the  $n$ -th DMU in the first (resp. second) period.

Following the evaluation of the firms’ WCME using the DEA approach, the current study used the Tobit regression analysis to identify the potential statistical effect of the coronavirus on firms’ WCME. This model is a valuable tool for assessing the relationships between variables when the dependent variable contains censored data or has a range constraint [38], Verbeek 2008). The equation represents the Tobit linear regression relationship:

$$\begin{aligned}
 \text{WCME}_{it} &= \beta_0 + \beta_1 v_1 + \beta_2 v_2 + \beta_3 v_3 + \beta_4 v_4 \\
 &+ \beta_5 v_5 + \beta_6 v_6 + \beta_7 v_7 + \beta_8 v_8 + \beta_9 v_9 \\
 &+ \beta_{10} v_{10} + \beta_{11} v_{11} + \beta_{12} v_{12} + \varepsilon_{it}
 \end{aligned}
 \tag{2}$$

where  $e_i$  represents each firm’s WCME;  $v_1$  is the coronavirus as an independent variable defined by a dummy variable. To put it another way, if the time is related to the time before the coronavirus crisis, this indicator variable equals 1, and if it is associated with the time before the coronavirus crisis, it equals 0. Furthermore,



to improve the accuracy of the analyses, the study used various control variables such as size, age, and leverage. Thus,  $v_2$  represents the firm size as defined by the natural logarithm of total assets;  $v_3$  represents the firm age as defined by the natural logarithm of firm age from the start of the activity until the end of the current year;  $v_4$  represents firm leverage as defined by dividing a firm's total liabilities by shareholders' equity;  $v_5$  refers to the communication services sector;  $v_6$  refers to the consumer discretionary sector;  $v_7$  refers to the consumer staples sector;  $v_8$  refers to the energy sector;  $v_9$  refers to the health care sector;  $v_{10}$  refers to the industrials sector;  $v_{11}$  refers to the materials sector;  $v_{12}$  refers to the real estate sector.  $\beta_0$  is a constant;  $\beta_i$  represents the Tobit regression coefficients; and  $\varepsilon_i$  are known by the Gaussian noises or errors.

## 4 Results and Discussion

### 4.1 Results of the Efficiency Model

Table 1, panel A, shows the Malmquist index summary for the top ten DMUs under analysis ( $\text{tfpch} > 1$ ) over the study period (2018–2020) in terms of WCME changes. In terms of improvement, the KWSE:HUMANSOFT achieved the best results (2.331), followed by the SASE:9510 (2.100), the DSM:NLCS (1.960), and so on. Table 1, panel B, displays the Malmquist index summary for all DMUs under consideration during the study period (2018–2020) regarding WCME changes. According to the Malmquist index summary, technological efficiency or frontier-shift ( $\text{techch}$ ) was the primary source of the increasing efficiency of the total factor productivity index of the DMUs under study, rather than technical efficiency or catch-up changes ( $\text{effch}$ ). In terms of improvement ( $\text{tfpch} > 1$ ), 100 DMUs out of 186 under investigation achieved the best results ( $\text{tfpch} > 1$ ). Only 86 DMUs appeared to be inefficient, and they should reconsider operating processes and improve performance through necessary corrective actions to achieve best practices and improve overall factor productivity.

The DEA-Malmquist index summary of annual means in terms of WCME changes over the study period is shown in Table 2, panel A. The Malmquist index increased by about 1.002 (0.2%) from the base year in the first period (2018–2019) before the coronavirus crisis. This increase is the result of an increase in technological efficiency or frontier-shift changes ( $\text{techch}$ ) of about 1.083 (8.3%) multiplied by a decrease in technical efficiency or catch-up changes ( $\text{effch}$ ) of about 0.926 (7.4%). Similarly, the situation has not changed significantly during the crisis; the Malmquist index for the second period (2019–2020) increased by about 1.034 (3.4%), with this increase attributed to the rise in technological efficiency changes of about 1.135 (13.5%) multiplied by a decrease in technical efficiency changes of about 0.911 (8.9%). Over the study period, the Malmquist index increased by about 1.018 (1.8%), the technological efficiency increased by approximately 1.108 (10.8%), and the technical efficiency decreased by about 0.918 (8.2%).

Table 2, panel B, shows a complementary statistical test for confirming significant differences in firm efficiency scores regarding WCM over the study period using

**Table 1** DEA-Malmquist index summary of firm means

Panel A: DEA-Malmquist index summary (top ten DMUs)											
DMU: Ticker	MI summary					DMU: Ticker	MI summary				
	effch	techch	pech	sech	tfpch		effch	techch	pech	sech	tfpch
KWSE:HUMANSOFT	1.000	2.331	1.000	1.000	2.331	SASE:3040	1.115	1.365	1.318	0.846	1.523
SASE:9510	1.555	1.351	1.500	1.036	2.100	SASE:1301	1.296	1.174	1.325	0.978	1.521
DSM:NLCS	1.911	1.025	1.978	0.966	1.960	KWSE:KRE	1.094	1.260	1.316	0.831	1.378
SASE:2170	1.000	1.839	1.000	1.000	1.839	DSM:WDAM	1.284	1.064	1.589	0.808	1.366
SASE:3050	1.146	1.445	1.387	0.827	1.657	MSM:SUWP	1.078	1.201	1.000	1.078	1.294
Panel B: Total factor productivity change summary											
Mean							effch	techch	pech	sech	tfpch
No. of DMUs (tfpch ≥ 1):							0.918	1.108	1.01	0.909	1.018
No. of DMUs (tfpch < 1):							100				
							86				

All Malmquist index averages are geometric means

effch technical efficiency change, techch technological change, pech pure technical efficiency change, sech scale efficiency change, tfpch total factor productivity (TFP) change

**Table 2** DEA-Malmquist index summary of annual means

Panel A: DEA-Malmquist index summary of annual means		Panel B: results of Wilcoxon test			
Year	effch	techch	pech	sech	tfpch
Year 2 (2018–2019)	0.926	1.083	1.026	0.902	1.002
Year 3 (2019–2020)	0.911	1.135	0.995	0.915	1.034
Mean	0.918	1.108	1.010	0.909	1.018
Efficiency scores	Wilcoxon signed ranks test	Null hypothesis			Decision on the null hypothesis
Technical efficiency change (year 2 vs. year 3)	Z-statistic	p-value			
Technological efficiency change (year 2 vs. year 3)	-1.946	0.052*	The median of differences between effch-Y1 and effch-Y2 equals 0		Retain
Pure efficiency change (year 2 vs. year 3)	-4.016	0.000**	The median of differences between techch-Y1 and techch-Y2 equals 0		Reject
Scale efficiency change (year 2 vs. year 3)	-2.523	0.012**	The median of differences between pech-Y1 and pech-Y2 equals 0		Reject
Total factor productivity change (year 2 vs. year 3)	-0.674	0.500	The median of differences between sech-Y1 and sech-Y2 equals 0		Retain
	-0.400	0.689	The median of differences between tfpch-Y1 and tfpch-Y2 equals 0		Retain

All Malmquist index averages are geometric means

effch technical efficiency change, techch technological change, pech pure technical efficiency change, sech scale efficiency change, tfpch total factor productivity (TFP) change

\*  $p < 0.1$ ; \*\*  $p < 0.05$

Wilcoxon tests (via IBM-SPSS ver26). The results showed no statistical difference in technical efficiency scores at a 5% significance level before and during the coronavirus crisis. Similarly, at a 5% significance level, there was no statistical difference in scale efficiency scores and total factor productivity scores. As a result, we retain the null hypothesis that the median of differences between  $effch$  (before the crisis) and  $effch$  (during the crisis) equals 0;  $sech$  (before the crisis) and  $sech$  (during the crisis) equal 0;  $tfpch$  (before the crisis) and  $tfpch$  (during the crisis) equal 0. Furthermore, the results revealed a statistical difference in technological efficiency scores and pure efficiency scores at a 5% significance level before and during the crisis. As a result, we reject the null hypothesis that the median of differences between  $techch$  (before the crisis) and  $techch$  (during the crisis) equals 0;  $pech$  (before the crisis) and  $pech$  (during the crisis) equals 0. All previous results indicate that H1 is partially supported.

## 4.2 Results of the Tobit Regression Model

Following the evaluation of the firms' WCM performance using the DEA approach, it is helpful to identify some of the factors that affect WCM performance. In this section, the following factors are investigated for their impact on performance: the coronavirus crisis, size, age, leverage, and sector classification.

Tobit regression analysis was used to investigate factors influencing WCM performance using Stata/MP ver16. Table 3 depicts the effect of the variables under investigation on the WCM performance of the firms over the study period. Table 3 shows that firm size and sector (Sec1, the communication services sector; Sec2, the consumer discretionary sector) have a significant favorable influence at the 0.10 significance level or less. Furthermore, at the 0.10 significance level or less, the leverage and the industry sector (whether Sec5, the health care sector; Sec7, the materials sector) negatively influence.

The current study's findings revealed that the coronavirus crisis had no significant influence on WCM performance. As a result, the H2 hypothesis is unsupported. This findings are consistent with Zimon and Tarighi [8] study as they reveal that the COVID-19 crisis did not significantly alter firms' WCM strategies. In contrast, the findings are inconsistent with Tarkom [58] study, as they demonstrate a significant negative influence of the COVID-19 crisis on WCM. In contrast, the findings revealed that firm size and leverage significantly impact WCM performance. Moreover, the results showed that the sector category (whether Sec1, the communication services sector, Sec2, the consumer discretionary sector; Sec5, the health care sector; Sec7, the materials sector) have a significant influence on the WCM performance at the same time the sector category (whether Sec3, the consumer staples sector; Sec4, the energy sector; Sec6, the industrials sector; Sec8, the real estate sector) have no significant influence on the WCM performance.

**Table 3** The results of Tobit regression

Tobit regression			Num. of obs = 558			
			$F(12, 546) = 28.25$			
			Prob > $F = 0.0000$			
Log pseudolikelihood = -147.95353			Pseudo R2 = 0.3969			
Independent variables	Coef	Robust std. err	$t$	$P >  t $	[95% conf. interval]	
Cov	0.0042342	0.0240661	0.18	0.860	-0.0430392	0.0515076
Size	0.054534	0.0077672	7.02	0.000***	0.0392768	0.0697912
Age	-0.0004944	0.0096836	-0.05	0.959	-0.0195162	0.0185273
Leverage	-0.0302935	0.0139484	-2.17	0.030**	-0.0576926	-0.0028944
Sec1	0.1817935	0.0851139	2.14	0.033**	0.0146028	0.3489843
Sec2	0.1368425	0.0825054	1.66	0.098*	-0.0252244	0.2989095
Sec3	-0.0712983	0.0817635	-0.87	0.384	-0.2319079	0.0893112
Sec4	0.1268625	0.0873644	1.45	0.147	-0.044749	0.2984739
Sec5	-0.2485024	0.0760406	-3.27	0.001***	-0.3978703	-0.0991345
Sec6	-0.1187937	0.079931	-1.49	0.138	-0.2758037	0.0382162
Sec7	-0.1354647	0.0775438	-1.75	0.081*	-0.2877854	0.016856
Sec8	0.0774234	0.088747	0.87	0.383	-0.096904	0.2517508
_cons	-0.0359543	0.1206739	-0.30	0.766	-0.2729963	0.2010877

\* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$

### 4.3 Sensitivity Analysis and Model Validation

Internal and external validity can be used to analyze findings. Internal validity investigates whether the methods utilized to change the results are valid, whereas external validity explores whether could generalize the results away from the present data [63, 38, 64]. Sensitivity examinations are helpful for both types of evaluations. Thus, the internal validity is appraised by utilizing various variables' combinations. Table 4, panel A, presents the results of sequentially removing different variables used from the basic model. The current study adopted the Mann–Whitney U test to examine the efficiency scores of the modified DEA-WCME models to the original efficiency scores via the basic DEA-WCME model to verify if the removal of variable occurred a significant difference in the relative efficiency scores. Besides, the correlations of Spearman rank were computed as well.

It is exposed in Table 4, panel A, that the accounts payable removal significantly decreased the model's efficiency distinction by diminishing the average of firms' efficiency scores of 0.61 to 0.51 and the rate of the efficient DMUs of 12.9 to 9.1%. Similarly, removing either input accounts receivable, cost of goods sold, or inventory significantly influenced the model results concerning the efficiency score distribution and the rate of the efficient DMUs. Moreover, the high correlations of Spearman

**Table 4** Sensitivity analysis and model validation

Panel A: sensitivity analysis of the DEA model

Variables/removed	Average scores	DMUs efficient (%)	<i>p</i> -value (Mann–Whitney)	Spearman rank correlation (sig.)
None	0.61	12.9%	–	–
Accounts payable	0.51	9.1%	$3 \times 10^{-13}$	0.832 (0.000)
Accounts receivable	0.54	7.5%	$3 \times 10^{-6}$	0.886 (0.000)
Cost of goods sold	0.51	8.6%	$2 \times 10^{-10}$	0.899 (0.000)
Inventory	0.57	8.1%	0.0226	0.938 (0.000)
Panel B: the distribution variance of efficiency scores				
Year	<i>p</i> -value (Mann–Whitney)	<i>p</i> -value (Kruskal–Wallis)	Spearman rank correlation (sig.)	
(2018–2019)	0.497	0.814	0.812 (0.000)	
(2019–2020)	0.944		0.876 (0.000)	
(2018–2020)	0.684		0.738 (0.000)	

ranks suggest that the firms' rankings were not significantly altered through the efficiency models. It is not surprising that removing either input impacted the model results because they blend various resource kinds. Therefore, excluding each would occur significant information removal.

Finally, the current study used the consistency of the results over time to assess the external validity of the firms' efficiency model. The firms' efficiency model was re-applied utilizing 2018 data in this analysis and then matched the relative efficiency scores to the 2019 and 2020 results (Table 4, panel B). The Mann–Whitney U test revealed no statistically significant variance in the efficiency score distribution for the study years 2018–2019 ( $p=0.497$ ), 2019–2020 ( $p=0.944$ ), and 2018–2020 ( $p=0.684$ ). The Kruskal–Wallis H test revealed no statistically significant variation in the efficiency score distribution over the study ( $p=0.814$ ). The correlation of Spearman rank between each year was also highly significant. As a result, the general distribution of efficiency scores and the rate of the efficient DMUs not appear to change significantly from period to period, and the firms ranked as efficient remain mostly harmonious from period to period.

## 5 Summary and Conclusion

Empirical evidence shows that WCM has garnered substantial interest in accounting and finance research. Tewolde [5] shows that inadequate WC decisions are responsible for a considerable portion of business failures, and that WCM affects a firm's profitability. This is striking because an ineffective WCM strategy creates a large share of past firm insolvencies [6]. As WC significantly influences a firm's operational and financial security, the literature confirms that it is necessary to develop a good strategy for a firm's WCM [7, 8]. Drawing on this, there are increasing concerns regarding the coronavirus crisis toward firms that adopt WCM strategies, which may harm their performance and value. Using a unique Gulf setting, this study analyzes the efficiency of WCM before and during the coronavirus crisis using an integration between the data envelopment analysis approach and the Malmquist productivity index, and then explores the influence of the crisis on WCME using Tobit regression. To the best of our knowledge, the current study is the first to develop and apply the data envelopment analysis methodology using the Malmquist productivity index to evaluate WCME. Besides, the authors advanced a novel contribution to the literature by examining whether the coronavirus crisis has affected the WCM for firms under investigation. This study is essential for regulators, management, and investors to increase their awareness of firms' WCM performance before and during a crisis. In addition, it provides insight into how the coronavirus crisis affects firms' WCM, which is likely to strengthen firms' financial policy and improve their strategies. These findings are consistent with Zimon and Tarighi [8] study as they reveal that the COVID-19 crisis did not significantly alter firms' WCM strategies. In contrast, the findings are inconsistent with Tarkom [58] study, as they demonstrate a significant negative influence of the COVID-19 crisis on WCM.

The results show that 157 firms (approximately 84%) adopt a conservative strategy as a safe strategy for their WCM, while 29 firms have adopted an aggressive strategy,

suggesting that most firms strive to provide a high level of liquidity and maintain current assets at high levels compared to current liabilities. In addition, the results of the DEA-Malmquist analysis revealed that the annual means of WCME increased by approximately 0.2% before the coronavirus crisis due to technological efficiency or frontier-shift changes. The results did not change significantly during the coronavirus crisis, with only a 3.4% increase due to technological efficiency or frontier-shift changes. Furthermore, at the 5% significance level, the Wilcoxon test revealed no statistical difference in the efficiency scores of technical and scale efficiency, and total factor productivity before and during the coronavirus crisis. In contrast to previous findings, the results revealed a statistical difference in technological efficiency and pure efficiency scores at a 5% significance level. In addition, the current study's findings showed that the coronavirus crisis and firm age have no significant influence on WCM performance. By contrast, the findings reveal that firm size and leverage substantially impact WCM performance. Furthermore, the results indicate that sector category (communication services, consumer discretionary, healthcare, and materials) significantly influences WCM performance. Finally, our results indicate that firms that are efficient in terms of WCM have higher sales returns and net income, as the sales and net income averages of firms with relative efficiency in terms of WCM are approximately 11 and 30 times higher, respectively, than inefficient firms in terms of WCM.

Given the study findings, decision-makers and WC managers of firms should develop the necessary means and schemes to ensure the best practices of WCME and address the inefficiency aspects in terms of technical efficiency and scale efficiency to ensure that a firm operates efficiently, which would likely positively reflect on the firm and the confidence of many stakeholders. These findings highlight the need to disclose WCM practices within traditional firm reports or integrated reporting, where conventional statements alone would be insufficient to appraise firm performance, especially given the current ecosystem's rapid and consecutive development. The findings would also pique the interest of decision-makers and WC managers, who could use the DEA methodology to investigate and identify weaknesses in firm performance, and then take significant actions to optimize performance and achieve best practices.

This study has some limitations. This study focuses on 186 firms (558 firm-year observations) in the Gulf Cooperation Council (GCC), and the findings are limited to the period 2018–2020. Based on the findings of the sensitivity analysis and model validation, the findings can be generalized to other firms in GCC and Middle Eastern countries, and future research may include all non-financial sector firms for broader applicability. Managerial ability, intellectual capital, real earnings management, ESG criteria, and the likelihood of financial distress are also important elements of financial policy that are not considered in this study but can be investigated in future studies. Despite these limitations, our study contributes to the literature by providing empirical evidence that most firms adopt conservative WCM strategies. Additionally, the WCME results revealed a statistical difference in firms' technological and pure efficiency scores before and during the coronavirus crisis. The study also shows that the coronavirus crisis had no significant influence on firms' WCM performance. Finally, this study may have implications for many stakeholders,



including decision-makers, WCM managers, financiers, investors, financial consultants, researchers, and others, in increasing their awareness of firms' WCM performance before and during a crisis. In addition, the results could have implications for trading strategies as investors and financiers seek to invest in companies with good WCM. The implications of WCM performance on social interests would cause decision-makers to use the best strategies and procedures to enhance WCM activities to improve their investments and image in the community in which it operates.

**Author Contribution** The first author conceived the project and planning; fundamental analysis; the framework and statistical models; collected data and analyzed it; wrote the abstract, introduction, literature review and hypotheses formulation, data and methodology, results and analyses, and conclusions and implications; reviewed and edited the manuscript; responding to coming reviewers' comments. The second author conceived the project and planning; results and analyses; reviewed the manuscript.

## Declarations

**Conflict of Interest** The authors declare no competing interests.

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