Evaluating the Super-Efficiency of Working Capital Management Using Data Envelopment Analysis: Does COVID-19 Matter?

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Abstract

This study evaluates the working capital management (WCM) super-efficiency in UAE firms and determines how the COVID-19 crisis may affect WCM super-efficiency from a statistical perspective. Data envelopment analysis (DEA), difference tests, and Tobit regression techniques are used. Integration of DEA with Tobit regression is required to recognize the potential statistical consequence of COVID-19 on the super-efficiency of WCM. The results show that WCM super-efficiency is moderate and requires decision-makers' corrective measures to attain best practices. The study results show no significant difference in WCM super-efficiency, and COVID-19 does not significantly influence WCM super-efficiency. The results would rouse decision-makers' interests, who would look into the firm's efficiency and weak spots. They would then take major steps to improve efficiency and achieve the best practices. Stakeholders such as managers, financiers, and investors may need these results to monitor how firms manage their assets and liabilities. We contribute to the literature by investigating and evaluating firms' WCM super-efficiency pre and post the COVID-19 pandemic employing a unique technique based on DEA super-efficiency and examining whether COVID-19 has affected WCM super-efficiency to extend the scope of knowledge and stressing the importance of sound WCM, especially in periods of economic distress.

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1 Introduction

In December 2019 and the beginning of 2020, COVID-19 was discovered, which caused the economies of most countries to suffer [1–5]. In January 2020, the World Health Organization (WHO) stated that there was a worldwide public health emergency and that there would be a pandemic in March 2020. Since 2021, various types of viruses have emerged in different countries. The most dangerous versions are the delta, alpha, and beta versions. As of August 2021, there have been over 215 million confirmed cases and 4.49 million confirmed deaths, making it one of the deadliest pandemics in history [6–8]. Ding et al. [9], and He [10] showed that the financial crisis caused by COVID-19 is different from other financial crises in terms of its cause, scope, and severity. Because of this, many economists and financial experts worldwide have focused on the COVID-19 effects on capital. The most important thing to remember is that, according to Habib and Mourad [11], Habib and Kayani [12], and Salehi et al. [13], one of the best ways to solve financial problems during a financial emergency is to make good decisions about WCM approaches. WCM discusses an arrangement that allows organizations to use short-term assets and obligations while keeping enough cash to meet short-term costs and obligations [14]. Salehi et al. [13] say that in today's unpredictable business world, the choices for WCM approaches are usually important and challenging for corporate leaders. This is because they can make a big difference in an organization's finances during an emergency. During emergencies or times of financial crisis, WCM needs to be given greater attention because the least attention may result in liquidity issues and cash management for a firm [15–17].

The COVID-19 pandemic has highlighted the importance of firms' continuous improvement practices. The pandemic disrupted supply chains worldwide, making it difficult for firms to obtain financing. This shows the importance of a firm's WCM strategy in protecting its financial health [11]. When considering firms in UAE, WCM is crucial to economic growth. Firms in UAE operate in unique organizational, financial, and political contexts. UAE is trying to join the global economy by switching to a knowledge-based one [12, 18]. Since efficient practices are important for long-term growth and firm performance in a knowledge-based economy, companies in UAE should place them at the top of their WCM strategies.

Moreover, the recent pandemic has significantly affected WCM in UAE, as firms are under greater pressure than ever to manage their cash flows. Many firms have been affected by supply chain disruptions, reduced demand, and delayed payments, causing liquidity challenges and cash flow constraints. UAE government has implemented measures to help firms address these problems. These include loan deferrals, financial support programs, and other financial assistance that have helped many firms continue running during the pandemic and have supported their WCM initiatives [19]. Overall, COVID-19 has highlighted the importance of effective WCM for firms in UAE and has demonstrated the need for firms to be agile and responsive to changing market conditions. By implementing good WCM practices, firms can better manage their cash flow and keep running during crises [11]. Accordingly, the main goal of this research is to adopt a DEA model to evaluate the WCM

super-efficiency of listed firms in UAE. Next, we use Tobit regression analysis to determine how the COVID-19 pandemic might affect the WCM super-efficiency of listed firms from a statistical point of view. The results would rouse decision-makers' interests, who would look into the firm's efficiency and weak spots. They would then take major steps to improve efficiency and achieve the best practices. Stakeholders such as managers, financiers, and investors may need these results to monitor how firms manage their assets and liabilities.

The rest of this paper is arranged in the following order: Section 2 introduces a related literature review. Section 3 clarifies the research method. Section 4 illustrates the outcomes. Finally, Section 5 concludes the research.

2 Literature Review

WCM is an essential strategy that focuses on maintaining a sufficient balance between a firm's existing assets and liabilities and significantly affects firms' operational and financial security [11, 20, 21]. Additionally, effective WCM helps firms cover their financial obligations and boost their performance [16, 22–28]. According to available literature, WCM efficiency has been examined using different measures. Habib [16] evaluated efficiency of WCM at US firms using a sample of 964 firm-year observations from 2016 to 2019 and the DEA technique. The results demonstrated that WCM was relatively inefficient and required correctional efforts by decision-makers. The results also reveal that WCM efficiency has a significantly positive influence on firm value. Habib and Mourad [11] analyzed the WCM employing a selection of 459 firms in GCC countries from 2018 to 2020. This study adopted the Malmquist index using DEA technology. The outcomes indicate that most firms operate conservative practices regarding WCM. Seth et al. [29] analyzed the WCM efficiency of Indian companies using the DEA approach. This study employed a selection of 212 Indian companies from 2008 to 2019. The outcomes reveal that WCM efficiency was unsatisfactory during the analysis period. The average mean WCM efficiency scores range between 0.623–0.654, highlighting that Indian companies only operate at approximately 60% of efficiency regarding WCM. Satoto et al. [30] examined the differences in firms' WCM efficiency measures before and during COVID-19 employing a selection of 143 Indonesian companies from 2017 to 2021. The outcomes reveal significant differences in receivable and inventory turnover before and during the crisis. By contrast, working capital and cash turnover show no differences before and during the crisis.

Motivated by the limited research from UAE perspective and to extend the scope of knowledge by investigating firms' WCM super-efficiency practices before and during the crisis, the following hypothesis is proposed:

H1. There were statistically significant differences in firms' WCM super-efficiency before the COVID-19 crisis compared to the crisis period.

In addition, Habib and Kayani [12] examined the WCM efficiency of Emirati firms to explore the potential statistical influence of WCM efficiency on the probability of

bankruptcy employing a selection of 57 companies from 2018 to 2020. The outcomes demonstrate that efficiency of WCM negatively influences the likelihood of a firm's bankruptcy, whereas the crisis positively influences the probability of a company's bankruptcy. Lyngstadaas [24] examined the relationship between efficiency of WCM and a company's performance by employing a selection of 589 US companies during 2012–2019. These outcomes suggest that WCM efficiency is essential for improving a firm's performance. Prasad et al. [25] analyzed efficiency of WCM and investigated WCM efficiency influence on Indian firms' performance. The results reveal that efficiency of WCM and asset structure determine firms' financial performance. This study confirms that firms with highly efficient WCM are less exposed to liquidity risk and are less dependent on external financing. Such firms eventually produce more value for their shareholders. Moussa [31] examined the impact of WCM efficiency on firms' performance and value utilizing a selection of 68 Egyptian firms from 2000 to 2010. The outcomes reveal that firms with better performance and value measures will likely pay less attention to WCM efficiency. Therefore, the study confirms that stock markets in emerging economies such as Egypt fail to realize the optimum WCM efficiency.

Furthermore, Filbeck et al. [32] analyzed the relationship between WCM efficiency and shareholder return utilizing a selection of US companies from 1997 to 2012. The outcomes reveal that companies with superior WCM efficiency provide significant returns for shareholders regardless of the market cycle, confirming that shareholders reward firms with superior WCM efficiency. Kasiran et al. [23] analyze efficiency of WCM in Malaysian firms using a sample of 24 SMEs from 2010 to 2013. The results reveal that SMEs were less efficient in WCM. Additionally, the outcomes show that WCM efficiency is critical for ensuring firms' sustainability in maintaining business and improving performance. Tahir and Anuar [27] examined the relationship between WCM efficiency and firm profitability utilizing a selection of 127 Pakistani textile companies from 2001 to 2012. The outcomes reveal that WCM plays an essential role in improving profitability. Singhania et al. [26] investigated the connection between WCM efficiency and firms' gross operating profits as a proxy of profitability by employing a selection of 82 Indian manufacturing companies from 2005 to 2012. The outcomes reveal that WCM efficiency plays an essential role in improving profitability. Gill and Biger [33] investigated the relationship between corporate governance and WCM efficiency utilizing a selection of 180 US manufacturing companies from 2009 to 2011. The outcomes revealed that corporate governance plays a role in improving WCM efficiency. Ashraf [34] examined the relationship between WCM efficiency ratio measures and net operating profit as a proxy for profitability utilizing a selection of 16 Indian companies from 2006 to 2011. The outcomes reveal that WCM efficiency improves a company's net operating profit. Baños-Caballero et al. [22] analyzed the relationship between WCM and profitability utilizing a selection of 1008 Spanish SMEs from 2002 to 2007. The outcomes reveal that SMEs with better WCM will likely maximize their profitability. Fiador [35] investigated the relationship between corporate governance and WCM efficiency utilizing a selection of 13 Ghanaian companies from 2001 to 2012. The outcomes show that sound corporate governance structures improve WCM efficiency. Valipour and Jamshidi [28] examined the relationship between WCM

efficiency and asset efficiency utilizing a selection of 72 Iranian companies from 2000 to 2011. The outcomes reveal that WCM efficiency is vital in improving a company's asset efficiency. Den and Oruc [36] investigated the connection between WCM efficiency and return on assets (ROA) for profitability utilizing a selection of 49 Turkish companies from 1993 to 2007. The results show that WCM efficiency is essential for improving a company's profitability. Ganesan [37] analyzed efficiency of WCM in the telecommunications equipment industry to investigate the connection between WCM efficiency and performance utilizing a selection of 349 US companies from 2001 to 2007. The outcomes show that WCM efficiency is essential for improving profitability and liquidity.

Moreover, Ahmad et al. [38] investigated the impact of COVID-19 on efficiency of WCM compared with the 2008 financial crisis using a sample of 577 firms from three developing Asian countries from 2004 to 2020. The results reveal that WCM efficiency was more significantly and negatively influenced during the COVID-19 crisis than during the financial crisis of 2008. Hamshari et al. [39] investigated the impact of COVID-19 on efficiency of WCM utilizing a selection of 101 Jordanian companies from 2012 to 2021. The outcomes reveal that COVID-19 negatively impacts a company's WCM efficiency. Tarkom [40] examined the impact of COVID-19 on efficiency of WCM utilizing a selection of 2542 US companies from 2019 Q1 to 2021 Q2. The outcomes reveal that COVID-19 negatively impacts a company's WCM efficiency. Zimon and Tarighi [21] investigated the impact of COVID-19 on WCM efficiency utilizing a selection of 61 Polish SMEs during 2015–2020. The outcomes reveal that COVID-19 does not change SMEs' WCM efficiency.

Motivated by the limited research from UAE perspective and to extend the scope of knowledge by investigating the potential statistical influence of COVID-19 on WCM super-efficiency, the following hypothesis is proposed:

H2. COVID-19 has not significantly influenced firms' WCM super-efficiency during the study period.

3 Data and Methodology

3.1 Data Description

The empirical aspect of the present study consists of data collection, the identification of study inputs and outputs, the development of the connection between variables utilizing the DEA technique to evaluate the WCM super-efficiency of decision-making units (DMUs), which are companies, and finally, recognize the probable statistical consequence of COVID-19 on the super-efficiency of WCM utilizing Tobit regression. All companies recorded on UAE Stock Exchange across nine industries during 2018–2020 were included in the initial sample. According to Pastor and Ruiz [41], Habib [16], Habib and Kayani [12], and Habib and Mourad [11], missing values diminish DEA model's efficacy. Consequently, the final sample consisted of 50 firms with 150 firm-year observations. The study sample description is presented in Table 1.

Table 1 The study sample description

Entity Name	Sector	Exchange: Ticker	Entity Name	Sector	Exchange: Ticker
Abu Dhabi Aviation	Industrials	ADX:ADAVIATION	Foodco Holding PJSC	Consumer Staples	ADX:FOODCO
Abu Dhabi National Company for Building Materials PJSC	Materials	ADX:BILDCO	Fujairah Building Industries P.J.S.C	Materials	ADX:FBI
Abu Dhabi National Hotels Company PJSC	Consumer Discretionary	ADX:ADNH	Fujairah Cement Industries P.J.S.C	Materials	KWSE:FCEM
Abu Dhabi National Oil Company for Distribution PJSC	Consumer Discretionary	ADX:ADNOCDIST	Gulf Cement Company P.S.C	Materials	ADX:GCEM
Abu Dhabi Ship Building PJSC	Industrials	ADX:ADSB	Gulf General Investments Co. (P.S.C)	Financials	DFM:GGICO
Agthia Group PJSC	Consumer Staples	ADX:AGTHIA	Gulf Medical Projects Company (PJSC)	Health Care	ADX:GMPC
Air Arabia PJSC	Industrials	DFM:AIRARABIA	Gulf Navigation Holding PJSC	Industrials	DFM:GULFNAV
Al Waha Capital PJSC	Financials	ADX:WAHA	Gulf Pharmaceutical Industries P.S.C	Health Care	ADX:JULPHAR
Al Yah Satellite Communication Company PJSC	Communication Services	ADX:YAHSAT	International Holding Company PJSC	Consumer Staples	ADX:IHC
Aldar Properties PJSC	Real Estate	ADX:ALDAR	Lamprell plc	Energy	LSE:LAM
Arkan Building Materials Company (ARKAN) PISC	Materials	ADX:ARKAN	Manazel PJSC	Real Estate	ADX:MANAZEL
Aster DM Healthcare Limited	Health Care	NSEI:ASTERDM	National Cement Company (Public Shareholding Co.)	Materials	DFM:NCC
Damac Properties Dubai Co. PJSC	Real Estate	DFM:DAMAC	National Central Cooling Company PJSC	Industrials	DFM:TABREED
Dana Gas PJSC	Energy	ADX:DANA	National Corporation for Tourism and Hotels	Consumer Discretionary	ADX:NCTH
Depa PLC	Industrials	DIFX:DEPA	Orascom Construction PLC	Industrials	DIFX:OC
Deyaar Development PJSC	Real Estate	DFM:DEYAAR	R.A.K. Ceramics P.J.S.C	Industrials	ADX:RAKCEC

Table 1 (continued)

Entity Name	Sector	Exchange: Ticker	Entity Name	Sector	Exchange: Ticker
Dubai Investments PJSC	Industrials	DFM:DIC	RA International Group PLC	Industrials	AIM:RAI
Dubai Refreshment (P.J.S.C.)	Consumer Staples	DFM:DRC	RAK Properties PJSC	Real Estate	ADX:RAKPROP
Emaar Development PJSC	Real Estate	DFM:EMAARDEV	Ras Al Khaimah Cement Company P.S.C	Materials	ADX:RAKCC
Emaar Malls PJSC	Real Estate	DFM:EMAARMALLS	Ras Al Khaimah Co. for White Cement & Construction Materials P.S.C	Materials	ADX:RAKWCT
Emaar Properties PJSC	Real Estate	DFM:EMAAR	Ras Al Khaimah Poultry & Feeding Co. P.S.C	Consumer Staples	ADX:RAPCO
Emirates Driving Company P.J.S.C	Consumer Discretionary	ADX:DRIVE	Sharjah Cement and Industrial Development Co. (PJSC)	Materials	KWSE:SCEM
Emirates Integrated Telecommunications Company PJSC d/b/a du	Communication Services	DFM:DU	Union Properties Public Joint Stock Company	Real Estate	DFM:UPP
Emirates Refreshments (P.S.C.)	Consumer Staples	DFM:ERC	United Foods Company (PSC)	Consumer Staples	DFM:UFC
Emirates Telecommunications Group Company PJSC d/b/a Etisalat UAE	Communication Services	ADX:ETISALAT	Zee Stores PJSC	Consumer Staples	ADX:ZS

This study was conducted in two stages. The first stage incorporates DEA, in which a model is adopted to assess WCM super-efficiency. The second stage incorporates Tobit regression to examine the probable influence of COVID-19 on WCM super-efficiency. Figure 1 shows the study framework and describes the steps taken for analysis.

3.2 WCM Model

In this study, a model was adopted to assess the WCM super-efficiency. The model is based on advanced slack-based models (SBM), which were suggested by Tone [42] and Tone [43] to assess the WCM super-efficiency of the selected firms. In terms of benchmarking and evaluating efficiency of firms, the DEA technique has several important characteristics. First, Tone [44], Mourad et al. [45], Habib [16], and Habib and Shahwan [46] confirm that DEA is a powerful non-parametric technique for analyzing the nexus between inputs and outputs. Second, Dalwai et al. [47], Shahwan and Habib [48], Habib and Mourad [11], and Shahwan and Habib [49] confirm that the DEA technique delivers critical information for continual improvement. Finally, Habib and Mourad [11], Shahwan and Habib [49], Cooper et al. [50], Mourad [51], and Mourad et al. [52] confirm that the DEA technique focuses on the best practice concept as a base of benchmarking, that is, the relatively efficient firm (located on the efficient frontier curve), on the efficiency frontier curve, as opposed to conventional techniques that focus on central tendencies.

Typically, the DEA efficiency scores of firms range from zero to one, where a score of "one" indicates a relatively efficient firm (located on the efficient frontier curve), and a score less than "one" indicates a relatively inefficient firm [11, 16, 45, 51, 52]. Moreover, the DEA super-efficiency scores of firms may exceed "one" as the super-efficiency technique involves further ranking for the efficient firms located on
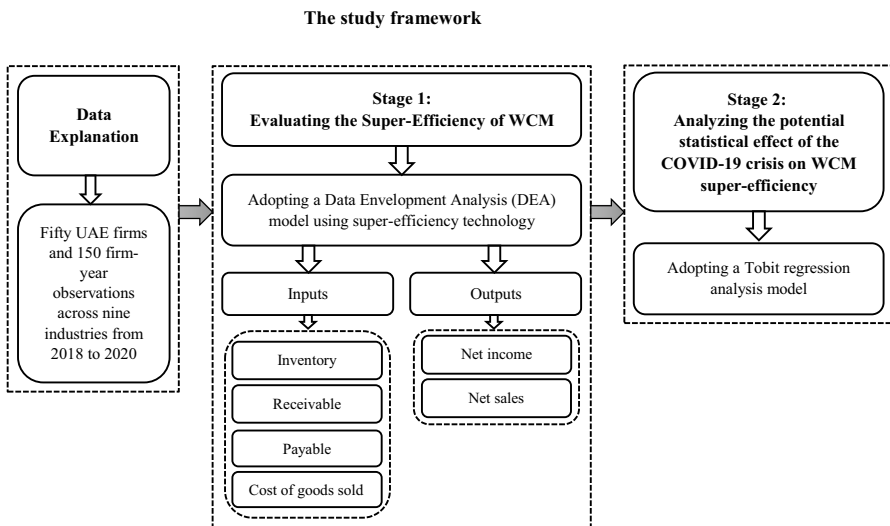
The study framework

Fig. 1 The study framework

the efficient frontier curve [53]. According to Tone [42], and Tone [43], the relative super-efficiency of a firm can be calculated from a statistical perspective utilizing the following DEA model:

$$\delta_o^* = \underset{\lambda, s^-, s^+}{min} \frac{1 + \frac{1}{m} \sum_{i=1}^{m} \frac{s_i^-}{x_{io}}}{1 - \frac{1}{s} \sum_{r=1}^{s} \frac{s_r^+}{y_{ro}}}$$

subject to

$$x_{io} = \sum_{f=1, j \neq 0}^{n} x_{if} \lambda_f - s_i^- \quad (i = 1, \dots, m) \tag{1}$$

$$y_{ro} = \sum_{f=1, j \neq 0}^{n} y_{rf} \lambda_f + s_r^+ \quad (r = 1, \dots, s)$$

$$\lambda_f \geq 0, \ s_i^- \geq 0, s_r^+ \geq 0.$$

where $f = 1, \dots, n$ is a set of firms, $r = 1, \dots, s$ (resp. $i = 1, \dots, m$) is the set of outputs (resp. inputs) of the n-th *firm* spotted in period s, y_{rj} (resp. x_{ij}) is the amount of the r-th outputs (resp. i-th inputs), y_{ro} $\left(resp. x_{io}\right)$ is the r-th outputs (resp. i-th inputs) of a *firm_o*, λ_j is a vector loadings, δ is the best possible practices, s_r^+(resp. s_i^-) is r-th outputs shortfall (resp. i-th inputs excess). Moreover, past research lends credence to the choice of variables applied in analogous situations, which helps ensure that the measurements are accurate. Hence, to evaluate efficiency of the WCM, the DEA model variables confirmed by Habib and Mourad [11] and Habib and Kayani [12] for evaluating the super efficiency of WCM in the context of UAE firms were considered. As a result, the study considered firms' sales and income as outputs. In contrast, firms' cost of goods sold, inventory, payable, and receivable were considered inputs of the model.

3.3 Tobit Regression Model

Following the assessment of WCM super-efficiency, this research utilized the Tobit regression to recognize the probable statistical consequence of COVID-19 on WCM super-efficiency. When the dependent variable comprises range constraint, the Tobit regression is a worthwhile technique for estimating connections between variables [11, 45, 54]. In the context of our study, the WCM efficiency estimates are between 0–1, while the WCM super-efficiency estimates are between 0–4.48. A summary of the descriptive statistics of the dataset is presented in Table 2. The Tobit regression model can be expressed as follows:

Table 2 Descriptive statistics summary of the data set

Variables	Obs	Mean	Std. dev.	Minimum	Maximum
Net sales	150	3723.3	8543.1	17.784	52,388
Net income	150	521.16	1564.5	-1381.1	9026.5
Accounts payable	150	557.23	1276.9	1.030	7748.1
Accounts receivables	150	2088.5	6690.3	0.829	47825
Cost of goods sold	150	2371.4	4756.3	14.40	25738
Inventory	150	874.42	2498.5	1.572	14739
WCM super-efficiency	150	0.565	0.768	0.000	4.483
COV	150	0.333	0.473	0.000	1.000
SIZE	150	8.119	1.616	3.798	11.80
AGE	150	3.322	0.485	2.398	4.248
LEV	150	1.141	1.604	0.054	10.52

$$
\begin{aligned}
WCM\ efficiency_{i,t} = \ & \beta_0 + \beta_1 COV_{i,t} + \beta_2 SIZE_{i,t} \\
& + \beta_3 AGE_{i,t} + \beta_4 LEV_{i,t} + \beta_5 \sum Year_t \\
& + \beta_6 \sum Industry_i + \epsilon_{i,t}
\end{aligned} \tag{2}
$$

$WCM\ efficiency_{i,t}$ represents a firm's working capital management efficiency. $COV_{i,t}$ is defined by a a dummy variable. If time is connected to the period pre the crisis, it takes "zero" and "one" otherwise. In addition, to enhance the exactness of the model, we employed several control variables, including size, age, leverage, year-fixed effects, and industry-fixed effects. $SIZE_{i,t}$ denotes the size of a firm as determined by the natural logarithm of total assets. $AGE_{i,t}$ is the firm's age as expressed by the period's natural logarithm from the activity's beginning to the end of the current year. $LEV_{i,t}$ describes firm leverage, calculated by dividing total liabilities over equity. Furthermore, the model controls year and industry-fixed effects (FE). β_0 is a constant. β_i explained the model coefficients, and ε_i explained the Gaussian noises.

4 Results and Discussion

4.1 WCM Model Results

Table 3 displays the WCM super-efficiency estimates of firms. The outcomes indicate that UAE firms operated at approximately 57.9%, 56.1, and 55.4% (on average) WCM efficiency in 2018, 2019, and 2020, respectively, which is a primary concern for UAE firms. Only 11, 12, and 13 firms were relatively efficient (out of 50) during the study period from 2018 to 2020. The average WCM super-efficiency score during the study period was 0.565. This indicates that the WCM super-efficiency of the firms under investigation is moderate and requires decision-makers' corrective measures to attain best practices. These outcomes are compatible with those of prior researches such as [11, 16, 29]. For instance, Habib [16] demonstrated that WCM in US

Table 3 WCM super-efficiency scores summary

Exchange: Ticker	WCM super-efficiency scores				Exchange: Ticker	WCM super-efficiency scores			
	2018	2019	2020	mean		2018	2019	2020	mean
ADX:ADAVIATION	0.171	0.247	0.507	0.308	ADX:FOODCO	0.376	0.043	0.518	0.312
ADX:BILDCO	0.094	0.076	0.005	0.058	ADX:FBI	0.223	0.260	0.340	0.274
ADX:ADNH	0.678	0.565	0.870	0.704	KWSE:FCEM	0.026	0.022	0.002	0.017
ADX:ADNOCDIST	1.164	1.099	1.289	1.184	ADX:GCEM	0.034	0.024	0.002	0.020
ADX:ADSB	1.339	0.052	0.005	0.465	DFM:GGICO	0.026	0.022	0.004	0.017
ADX:AGTHIA	0.153	0.130	0.114	0.132	ADX:GMPC	0.473	0.337	0.275	0.362
DFM:AIRARABIA	1.451	4.483	0.002	1.979	DFM:GULFNAV	0.096	0.032	0.003	0.044
ADX:WAHA	0.568	0.019	1.056	0.548	ADX:JULPHAR	0.013	0.012	0.002	0.009
ADX:YAHSAT	0.156	1.050	1.125	0.777	ADX:IHC	0.050	0.376	1.221	0.549
ADX:ALDAR	0.690	0.827	1.800	1.106	LSE:LAM	0.012	0.008	0.002	0.007
ADX:ARKAN	0.062	0.062	0.002	0.042	ADX:MANAZEL	0.302	0.338	0.088	0.243
NSEI:ASTERDM	0.112	0.121	0.176	0.136	DFM:NCC	0.046	0.414	0.007	0.156
DFM:DAMAC	0.457	0.006	0.000	0.154	DFM:TABREED	0.788	0.912	1.711	1.137
ADX:DANA	0.013	1.146	0.001	0.387	ADX:NCTH	0.373	0.366	0.562	0.434
DIFX:DEPA	0.027	0.015	0.002	0.015	DIFX:OC	0.191	0.160	0.123	0.158
DFM:DEYAAR	0.376	0.237	0.002	0.205	ADX:RAKCEC	0.129	0.119	0.001	0.083
DFM:DIC	0.344	0.348	0.462	0.385	AIM:RAI	0.224	0.255	0.228	0.236
DFM:DRC	0.102	0.192	0.354	0.216	ADX:RAKPROP	1.190	0.347	0.530	0.689
DFM:EMAARDEV	1.358	1.101	0.788	1.082	ADX:RAKCC	0.081	0.033	0.005	0.040
DFM:EMAARMALLS	4.240	2.740	1.482	2.821	ADX:RAKWCT	0.074	0.111	0.114	0.100
DFM:EMAAR	2.074	1.779	1.209	1.687	ADX:RAPCO	0.999	1.000	0.999	0.999
ADX:DRIVE	1.000	1.000	1.000	1.000	KWSE:SCEM	0.046	0.038	0.004	0.029
DFM:DU	1.234	1.100	1.988	1.441	DFM:UPP	0.546	0.039	1.012	0.532
DFM:ERC	0.999	0.483	0.999	0.827	DFM:UFC	0.138	0.195	0.353	0.229
ADX:ETISALAT	2.587	2.631	3.335	2.851	ADX:ZS	1.039	1.077	1.038	1.051
Mean						0.579	0.561	0.554	0.565

firms was relatively inefficient and required correctional efforts by decision-makers. Habib and Mourad [11] demonstrated that most firms in GCC countries adopt a conservative strategy for their WCM. Seth et al. [29] demonstrated that Indian firms' WCM efficiency was unsatisfactory during the analysis period and required correctional efforts by decision-makers. Generally, these corrective actions in the context of UAE firms are directly related to their output. Therefore, they can concentrate on increasing revenue and income by developing strategies to improve sales and profitability, such as offering sales promotions to boost the volume of sales, refining pricing plans, changing sales incentive structures, surveying customers to understand the market, developing a public reputation for quality and expertise, developing new products or service lines, finding new customers, growing geographic reach by selling in new markets, adding new payment forms, and avoiding any sources of extravagance within the business. Undoubtedly, searching for ways and strategies for continuous improvement is the basis of growth and excellence in the current business environment (Habib & Dalwai [55], Habib & Mourad [56]).

Table 4 shows a complementary statistical test to verify whether there is a significant difference in firms' super-efficiency practices before and during the COVID-19 crisis using the sign and Wilcoxon tests. The outcomes demonstrated no significant difference in WCM super-efficiency estimates at an important level of 0.05. Thus, the previous outcomes suggst that H1 is not supported. Hence, there were no statistically significant differences in firms' WCM super-efficiency before the COVID-19 crisis comparing the crisis period. These outcomes are compatible with [30] findings, which did not reveal significant differences in firms' working capital before and during COVID-19. Additionally, the results show that UAE government's enforced measures to help firms during the COVID-19 crisis were efficient. These measures included loan deferrals, financial support programs, and other financial assistance that have helped many firms continue operating during the pandemic and have supported their WCM initiatives [19].

4.2 Tobit Regression Results

Table 5 shows the statistical effects of COVID-19 on firms' WCM super-efficiency during the study period. The outcomes show that COVID-19 did not significantly influence WCM super-efficiency at a significance level of 0.05. Thus, H2 is not supported. This finding is consistent with previous findings, such as those of Zimon and Tarighi [21], which confirmed that COVID-19 does not significantly influence WCM efficiency in Polish firms. Moreover, these outcomes are inconsistent with prior findings, such as those of Ahmad et al. [38], which confirm that WCM efficiency was more significantly and negatively influenced by COVID-19. Hamshari et al. [39] indicate that COVID-19 negatively impacts WCM efficiency in Jordanian firms. Tarkom [40] indicates that COVID-19 negatively impacts WCM efficiency in US firms. Besides, firm size positively influences WCM super-efficiency at a significance level of 0.05. These findings suggest that large firms are likelier to have better WCM super-efficiency. Firm age positively influences WCM super-efficiency, but is not significant at the significance level of 0.05. Firm leverage negatively influences WCM super-efficiency but is insignificant. These results may be necessary for researchers to recognize the potential statistical effect of COVID-19 on WCM super-efficiency in UAE context. These results may be necessary for researchers to recognize the probable statistical consequence of COVID-19 on the super-efficiency of WCM in UAE context. The outcomes may be essential for stakeholders to evaluate the firms utilize of existing assets and liabilities.

4.3 Additional Analyses Results

4.3.1 Robustness Tests for WCM Model

Table 6 presents the results of robustness tests for the WCM super-efficiency model. Robustness tests were conducted using various combinations. Panel A shows the outcomes of consecutively extracting the variables from the primary model. The present study embraced Mann–Whitney U and Kruskal–Wallis analyses to explore the

Table 4 Test results of the differences using Wilcoxon and sign tests

Super-efficiency scores	Sign test		Wilcoxon signed ranks test		Null hypothesis	Decision
	z-statistic	p-value	z-statistic	p-value		
Super-efficiency change from 2018 to 2019.	-1.143	0.253	-1.179	0.238	The median of differences equals zero.	Retain the null hypothesis.
Super-efficiency change from 2019 to 2020.	-0.857	0.391	-0.592	0.554		
Super-efficiency change from 2018 to 2020.	-1.143	0.253	-0.005	0.996		

Table 5 Tobit regression results

Num. of obs =	150	Pseudo R^2 =	0.3254		
LR chi^2 =	81.53	Log pseudolikelihood =	-84.521		
Prob > chi^2 =	0.000				

Independent Variables	Coefficient	Std. err.	t	P > |t|	[95% conf. interval]	
COV	0.024	0.080	0.30	0.767	-0.135	0.182
SIZE	0.065	0.031	2.11*	0.037	0.004	0.127
AGE	0.050	0.032	1.56	0.120	-0.013	0.114
LEV	-0.041	0.025	-1.61	0.110	-0.091	0.009
_cons	0.598	0.367	1.63	0.105	-0.128	1.323
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimations from the Tobit regression model. The dependent variable is a firm's WCM efficiency level. The independent variables include the coronavirus crisis (COV), firm size (SIZE), firm age (AGE), and leverage (LEV). The model controls year and industry-fixed effects (FE)

*Denotes statistical significance at the 0.05 level

super-efficiency estimates of the further super-efficiency models compared to the primary estimates to ascertain if extracting the variables resulted in a considerable difference in primary estimates. As shown in Panel A, removing accounts payable decreases the average of WCM super-efficiency estimates from 0.565 to 0.490 and the rate of efficient firms from 14 to 12%. It is likewise, extracting the other variables relatively altered the WCM super-efficiency estimates and rate of efficient firms. Mann–Whitney U analysis does not indicate a statistically considerable variance in WCM super-efficiency estimates distribution for all models. Kruskal–Wallis analysis does not indicate a statistically considerable variance in WCM super-efficiency estimates distribution among all models. These findings support robustness of the super-efficiency model used in this study. Moreover, the high Spearman rank correlations indicate that WCM super-efficiency rankings were not significantly changed when modified super-efficiency models were used.

To examine the external validity of the WCM super-efficiency model, this study also utilized the consistency analysis of outcomes across time (Panel B). In addition, Mann–Whitney U analysis does not indicate a statistically considerable variance in the distribution of WCM super-efficiency estimates across the periods. Additionally, Kruskal–Wallis analysis does not indicate a statistically considerable variance in the distribution of WCM super-efficiency estimates over the analysis period. Furthermore, highly significant was the Spearman rank correlation between years. Consequently, the WCM super-efficiency distribution and the set of efficient firms do not alter significantly over the analysis period. Firms classified as relatively efficient continue mostly harmonious over the analysis period. Thus, all prior findings enhance the coherence of the WCM super-efficiency model adopted in this study.

Table 6 Robustness tests for the WCM model

Panel A: Sensitivity analysis

Variables/removed	Average Efficiency Score	Percentage of DMUs efficient	p-value (Mann–Whitney)	p-value (Kruskal–Wallis)	Spearman rank correlation (sig.)
None	0.565	14%	-	0.783	-
Accounts payable	0.490	12%	0.520		0.972* (0.000)
Accounts receivable	0.509	8%	0.469		0.970* (0.000)
Cost of goods sold	0.483	2%	0.204		0.947* (0.000)
Inventory	0.504	12%	0.507		0.983* (0.000)

Panel B: Distribution variance of super-efficiency scores

Year	p-value (Mann–Whitney)	p-value (Kruskal–Wallis)	Spearman rank correlation (sig.)
(2018–2019)	0.572	0.492	0.643* (0.000)
(2019–2020)	0.420		0.662* (0.000)
(2018–2020)	0.278		0.630* (0.000)

This table reports robustness tests estimates for the WCM super-efficiency model. This study examines whether shifts in the WCM super-efficiency model variables using various combinations of variables result in significant differences in relative super-efficiency scores

*Denotes statistical significance at the 0.01 level

4.3.2 Robustness Tests for Tobit Regression Model

Table 7 presents robustness tests for the Tobit regression model. These tests examined whether different estimates resulted in considerable differences in the basic model. Regression estimates were employed with robust standard errors, random effects, generalized least squares (GLS), ordinary least squares (OLS), and logistic model estimates. The results indicate that even when different estimates are used, the coefficient for the COVID-19 pandemic is in the identical direction and insignificant. These outcomes were compatible with the outcomes shown in Table 5. All prior findings enhance the coherence of the Tobit regression model adopted in this study.

Table 7 Robustness tests for the Tobit regression model

Independent Variables	Tobit regression (robust)	Tobit regression (random-effects)	GLS regression	OLS regression	Logistic regression
COV	0.024 (0.081)	0.016 (0.057)	0.009 (0.045)	0.012 (0.064)	1.321 (0.754)
SIZE	0.065** (0.033)	0.096** (0.043)	0.069** (0.035)	0.043* (0.024)	1.152** (0.321)
AGE	0.050 (0.034)	0.056 (0.046)	0.033 (0.038)	0.029 (0.025)	1.241 (0.265)
LEV	-0.041 (0.021)	-0.031 (0.031)	-0.033 (0.026)	-0.042** (0.021)	0.936 (0.179)
_cons	0.598 (0.464)	0.261 (0.497)	0.185 (0.402)	0.452 (0.275)	0.083 (0.196)
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
F (Prob > F)	9.17 (0.000)	-	-	7.81 (0.000)	-
Chi^2 (Prob > chi^2)	-	49.59 (0.000)	45.68 (0.000)	-	29.17 (0.000)
Pseudo R^2	0.3254	-	-	-	0.2051
R-squared	-	-	0.4221	0.4275	-
Adj R-squared	-	-	-	0.3728	-

This table reports robustness tests estimates for the study Tobit regression model. These tests examine whether different estimations result in significant differences in the essential model. Regression estimations with robust standard errors, random effects, generalized least squares (GLS), ordinary least squares (OLS), and logistic model estimations were employed. The independent variables include the coronavirus crisis (COV), firm size (SIZE), firm age (AGE), and leverage (LEV). The model controls year and industry-fixed effects (FE)

*, ** denote statistical significance at the 0.05 and 0.10 levels, respectively

5 Conclusions

This study's primary objective is to adopt a model for evaluating the WCM super-efficiency using DEA super-efficiency technology. Following the assessment of WCM super-efficiency, this study utilized a Tobit model to recognize the probable consequence of COVID-19 on the super-efficiency of WCM. The outcomes show that WCM super-efficiency is moderate and requires decision-makers' corrective measures to attain best practices. These outcomes are compatible with those of prior studies such as Habib [16], Habib and Mourad [11], and Seth et al. [29]. Generally, these corrective actions in the context of UAE firms are directly related to their outputs. Therefore, they can concentrate on increasing revenue and income by developing strategies to improve sales and profitability, such as offering sales promotions to boost the volume of sales, refining pricing plans, changing sales incentive structures, surveying customers to understand the market, developing a public reputation for quality and expertise, developing new products or service lines, finding new customers, growing geographic reach by selling in new markets, adding new payment forms, and avoiding any sources of extravagance within the business. Undoubtedly, searching for ways and strategies for continuous improvement is the basis of growth and excellence in the current business environment (Habib & Mourad [55] and Habib & Dalwai [56]). In addition, the outcomes show no considerable difference in firms' WCM super-efficiency before COVID-19 compared to the crisis period. These outcomes are compatible with those notified by Satoto et al. [30]. In addition, the outcomes show that UAE government's enforcement of measures to help firms during the COVID-19 crisis was efficient. These measures included loan deferrals, financial support programs, and other financial assistance that have helped many firms continue operating during the pandemic and have supported their WCM initiatives [19]. Finally, the results of this study show that COVID-19 does not significantly influence WCM super-efficiency. These results are consistent with those of Zimon and Tarighi [21].

The results would rouse decision-makers' interests, who would look into the firm's efficiency and weak spots. They would then take major steps to improve efficiency and achieve the best practices. Stakeholders such as managers, financiers, and investors may need these results to monitor how firms manage their assets and liabilities. According to the theory of finance, sound WCM is Important for financial security and forthrightly affects a firm's performance [16, 22-28, 54, 57]. Moreover, based on the agency theory, managers of businesses operate as agents. They must meet the agency relationship through sound strategies regarding WCM practices.

These findings shed light on the importance of evaluating firms' WCM practices for continuous improvement and to ensure the financial security of a firm. The future investigation could look into generalizations of the outcomes in different countries. In addition, an investigation of the COVID-19 influence on other critical aspects is required, such as intellectual capital efficiency, corporate governance efficiency, corporate social responsibility practices, operational and financial performance, and managerial ability.

Author Contributions 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, data and methodology, empirical results and discussion, and conclusions; reviewed and edited the manuscript; responded to the Editor and reviewers' comments. The second author participated in writing the introduction and literature review.

Data Availability The datasets generated or analyzed during the current study are available in firms' annual reports from their websites and the Mubasher-Info platform.

Declarations

Conflicts of Interest The authors declare no conflict of interest.

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