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Stochastic frontier modelling of working capital efficiency across Europe

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ABSTRACT

This paper adopts the stochastic frontier analysis (SFA) to model working capital efficiency (WCE) on a sample of 6170 European firms from 2009 to 2018. We find: (i) larger firms are more efficient with their working capital management (WCM) than smaller firms, (ii) higher cash holding contributes to WCE, (iii) high competition is less conducive to WCE than low competition, (iv) export and sales growth potential decrease WCE and (v) WCE increases with access to bank credit. In the analysis, a distinction is made between the "old" EU countries and the "new" EU countries. The results are sensitive to the year of admission into the EU. The results are robust to omitted variable bias, using a more novel approach.

1. Introduction

Working capital represents an important source of finance for firms' growth, survival and value (Baños-Caballero et al., 2010; Ferrando and Mulier, 2013). The extant literature shows that efficient working capital management (WCM) can be used as a strategic tool to increase a firm's performance (Chambers and Cifter, 2022), and that it enhances firm value, especially in financially constrained firms (see Kieschnick et al., 2013). This is because an efficient WCM is able to reduce the financial constraints of firms through the generation of internal funds (Banerjee et al., 2021). As a result, its impact has been the focus of many recent professional and academic discourses in the last decade (Aktas et al., 2015; Ben-Nasr, 2016; Chauhan, 2019; Pirttilä et al., 2020). The growing body of evidence from these studies suggests that efficient WCM is paramount to the survival and growth of firms (Shin and Soenen, 1988; Aktas et al., 2015). For instance, anecdotal evidence from the PWC Global report in February 2019/2020[1] suggests that a significant number of firms are unlocking cash and creating value through efficient WCM policies. Similarly, the value relevance of efficient WCM during the recent COVID-19 crisis has been highlighted in recent literature (Tarkom, 2021; Zimon and Tarighi, 2021). The interruption of economic activities during the crisis affected firms' short-term capital requirement and assets value (Ji et al., 2020; Almaghrabi, 2022), thus making firms ineffective in their WCM (see Tarkom, 2021).

Although a large body of research has examined the factors that affect firms' working capital efficiency (WCE) (Baños-Caballero et al., 2010; Boisjoly et al., 2020) and its implications on firms' value (Aktas et al., 2015), key knowledge voids remain, and the focus of this study is to fill these research gaps. Key among these is the adoption and measurement of WCE. Existing studies in an attempt to capture channels through which firms WCE is determined have either adopted the traditional cash conversion cycle (CCC) (Deloof, 2003; Baños-Caballero et al., 2010; Boisjoly et al., 2020; Banerjee et al., 2021) or net working capital (NWC) (Ben-Nasr, 2016; Aktas et al., 2015; Chauhan, 2019; Pirttilä et al., 2020). However, these measures have, in recent times, attracted several criticisms from extant literature as being too over-simplistic (Preve and Sarria-Allende, 2010) and biased as they only reflect the operational side of firms' WCE (Mun and Jang, 2015).

In view of this, our study presents an alternative measure of WCE using the stochastic frontier analysis (SFA). SFA is often used to identify

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[1] https://www.pwc.com/gx/en/services/advisory/deals/business-recovery-restructuring/working-capital-opportunity.html.

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or estimate efficiency, given its reliability and accuracy (Cullinane et al., 2002; Adom et al., 2018; Lee et al., 2022). In light of this, the study adopts the SFA and proposes three channels through which this approach provides a better estimate of firms WCM compared to the traditional CCC and NWC measurements of WCE. First, rather than deducing WCE from accounting ratios, the SFA models sales generated as a function of the three working capital elements - inventory holding, trade payables and trade receivables. Second, unlike the CCC or NWC, which estimates firms' WCE independently from other firms, the SFA approach compares the differences in WCE levels between a firm and the best 'practice' firm using the three known working capital elements. Thus, this study provides a much more accurate efficiency estimate of WCM compared to the traditional approach, given that the firms' efficiency is captured through a comparison between differences in WCE levels between a firm and its best 'practice' peer with the aid of the SFA. Third, the SFA provides a more robust measure of WCE because it considers the stochastic properties of the data and decomposes the error term into random error and efficiency (Luo and Donthu, 2005). These are expected to help improve the accuracy of all parameter estimates (Kumbhakar and Lovell, 2000) used in estimating the WCE.

By employing the SFA methodology on a sample of 6170 firms (40,542 firm-year observations) from 2009 to 2018, this paper examines the effects of firm size, cash holding, industry competition, export intensity, access to short-term (ST) bank credit and sales growth on the WCE of European Union (EU) listed firms. To further strengthen the robustness of our results, we further separate our sample into the old EU countries and the new EU countries. Our results show that several factors contribute to firms' WCE in Europe. We find that larger and older firms manage their working capital more efficiently than smaller and younger firms. Moreover, higher cash holding and access to bank credit positively contribute to WCE. However, industry competition, export intensity and sales growth seem to be associated with lower WCE. The findings are robust to alternative proxies and the control of endogeneity.

This paper contributes to the existing literature in two significant ways. First, it complements the existing operational measures of WCE (Shin and Soenen, 1988; Aktas et al., 2015) by adopting a technical measure, which addresses some of the limitations ignored in the literature when it comes to inferring WCE from accounting ratios. The technical approach's benefit is that it collectively models the inputs of working capital (inventories, trade receivables, trade payables) as a function of the output (sales revenue) and compares the WCE of firms against the best-practised working capital efficient firm within the sample. This helps determine the relative efficiency of a firm's working capital inputs in generating sales revenue. This is the first time such evidence has been presented to the best of our knowledge.

The second contribution of this paper is the determination of factors that influence the technical WCE of firms across the EU. So far, previous studies have only examined factors that affect the operational WCE of firms (Baños-Caballero et al., 2010; Hill et al., 2010). For example, Baños-Caballero et al. (2010) found in their study on small and medium enterprises (SMEs) that CCC is longer for older firms and firms with greater cash flow but lower for firms with growth opportunities, higher leverage, investment in fixed assets and higher profitability. We, therefore, extend the previous literature by looking at possible firm-level factors that contribute to technical WCE using the SFA approach among EU firms. This generates new evidence on the channels through which firms' technical WCE is determined across EU firms for the first time.

The rest of the paper is structured as follows. The next section presents the literature review. Section 3 contains the modelling strategy, data and hypothesis development. Section 4 reports the main empirical findings. Further analysis and robustness tests are contained in Sections 5 and 6. Section 7 concludes the paper.

2. Existing measures of working capital efficiency – a selective literature

Existing literature has explicitly explored factors affecting firms' WCM efficiency (Baños-Caballero et al., 2010; Boisjoly et al., 2020) and their implications on firms' value (Aktas et al., 2015). The existing studies have either used the CCC or NWC to measure WCE (Chauhan, 2019). For instance, Boisjoly et al. (2020) used the CCC adopted by firms to examine the aggressive working capital practices on firms' turnover. Evidence from their study suggests a statistically significant shift in the means and the skewness of the three components of CCC (i.e., accounts receivable, inventory and payables outstanding). Specifically, the authors attribute this to stricter financial management and less risk-taking trade-credit behaviour among sample firms.

Similarly, Wang (2019) used a sample of all firms traded on NYSE, Amex, and NASDAQ from 1976 to 2015 to examine the CCC spread across different industries. Specifically, their results show stock returns of between 5 % and 7 % alphas per year for a zero-investment portfolio that buys the lowest CCC decile stocks and sells the highest CCC decile. Zeidan and Shapiro (2017) used a case study of firms over the period from 2009 to 2016. Their results show that firms generally over-invest in working capital with economically inefficient consequences. By decomposing working capital investments into CCC and growth effects in the presence of x-inefficiency, they show that reductions in CCC result in higher stock prices and profitability and increased cash flow.

Another spectrum of studies has also examined WCE using the NWC measure. Baños-Caballero et al. (2014) used the non-linear method to evaluate firms' NWC, using a sample of Spanish firms for the period from 2001 to 2007. This study found a concave relationship between NWC and firm value. Therefore, they argue that an optimal NWC exists that maximises firm value. Consequently, any over investment or underinvestment in working capital is value decreasing. Pirttilä et al. (2020) used a sample of 20,459 Russian automotive industry supply chain firms from 2010 to 2016. Their results find that firms with lower NWC are mainly the leaders and most influential players in the supply chain. Aktas et al. (2015) evaluated firms' NWC efficiency by benchmarking it against the industry average. Using a sample of data from Compustat for the period from 2010 to 2016, they examined the deviation from the average industry NWC level. Their study finds that a deviation below or above the industry average NWC reduces firm value, arguing that any deviation represents working capital inefficiency. Ben-Nasr (2016) used 719 firm-year observations of privatised multinational firms from 54 different countries to examine the impact of state and foreign ownership on the relationship between NWC and firm value. Their study first confirms a U-shaped relationship between NWC and firm value but then shows that shareholders' valuation of NWC is less (more) in government-controlled (foreign-controlled) firms with a low level of NWC when compared to their non-government-controlled (non- foreign-controlled) peers. Chauhan (2019) examined the extent of short-term financial flexibility in working capital decisions using all non-financial firms for which the data was available in Compustat over the period from 1984 to 2014. The results show systematic and persistent growth of NWC levels across different industries.

3. Modelling strategy, data and hypothesis development

What drives WCE efficiency? We will answer this question with a two-step approach using SFA. We first demonstrate how WCE is derived from the stochastic production frontier in Section 3.1. Second, we link the SFA of a firm to a selected number of firm characteristics that have been identified in the literature to influence WCE, including firm size, firm age, cash holdings, industry competition, export intensity, ST bank credit and growth opportunity in Section 3.2. Finally, we also estimate the above model according to the date of EU membership. For this purpose, we divide the sample into old EU membership and new EU membership. The classification of the countries involved in the old EU and new EU is presented in Appendix 1.

3.1. Working capital efficiency

We follow previous studies (Hanousek et al., 2015) and use the SFA measure estimation developed by Aigner et al. (1977) and Meeusen and van Den Broeck (1977) and extended to panel data by Schmidt and Sickles (1984), Kumbhakar (1990), Battese and Coelli (1995), and Greene (2005), which has its roots from the production frontier models. The SFA begins with a production function $\gamma_t = (x_t; \beta)$, which represents the effect of the inputs (x) on the resulting output (y) for the most efficient production. However, this production involves some degree of inefficiency, and therefore the function is modified as follows: $(x_t; \beta)$. TE_i. The TE represents the non-negative ratio of results and lies between (0; 1) because the firm output is assumed to be positive. The SFA is a technique used in determining differences in efficiency levels between a firm and the best 'practice' efficient firm using several known observed explanatory variables. The best 'practice' efficient firm is expected to achieve a TE = 1 by employing inputs in the most efficient way possible. Thus, a lower TE indicates that the firm is inefficient in employing inputs to produce the required outputs.

Therefore, the natural log of the production function is written as follows:

$$ln\gamma_{it} = \beta_0 + \sum_{j=1}^{k} \beta_{jit} lnx_{it} + V_{it} - \mu_{it} \quad (1)$$

Following Hanousek et al. (2015), we employ the Cobb-Douglas time-invariant function, which assumes a production function between the working capital components (inventories, trade receivables and trade payables) and sales revenue. The working capital efficiency scores are then predicted and used in the second stage. Therefore, our efficiency frontier model for a firm ($I = 1$, ……I) over a nine-year period ($T = 1$, … T) is specified as follows:

$$LnSales_{it} = \left[\beta_o + \beta_1 Ln(Invt)_{it} + \beta_2 Ln(Trec)_{it} + \beta_3 Ln(Tpay)_{it}\right] + V_{it} - u_{it} \quad (2)$$

where:Ln (*Sales*) = the natural logarithm of sales revenue of firm i at time t.Ln (Invt) = the natural logarithm of inventories of firm i at time t; Ln (Trec) = the natural logarithm of trade receivables of firm i at time t; Ln (Tpay) = the natural logarithm of trade payables of firm i at time t;V = random error.μ = represents working capital inefficiency.

3.2. Factors affecting working capital efficiency

In the second stage, to examine the firm-level determinants of WCE scores, we use the panel data approach and control for a year, industry and country effects in all regressions. We also account for heteroscedasticity by clustering the standard errors at the firm level. Therefore, the fixed effects model is employed as follows:

$$\begin{aligned} WCE_{i,t} =& \beta_0 + \beta_1 FSize_{i,t-1} + FAge_{i,t-1} + CHolding_{i,t-1} + Competition_{i,t-1} \\ &+ Export_{i,t-1} + BCredit_{i,t-1} + SGrowth_{i,t-1} + \varepsilon_{i,t} + \phi_{i,t} \end{aligned} \quad (3)$$

where:WCE = working capital efficiency. The WCE is the predicted value from an SFA regression in Eq. (2) above, where sales revenue was related to essential inputs: inventories, trade receivables and trade payables. In different research areas, studies have used the SFA regression to predict firm-level efficiency (see, Hanousek et al., 2015; Luo and Donthu, 2005).FSize = firm size, which is measured as the natural logarithm of total assets of firms (see, Aktas et al., 2015).FAge = firm age, which is defined as the difference between the date of incorporation and each calendar year-end (McGuinness et al., 2018).CHolding = cash holding, which is measured as the ratio of cash and cash equivalent to total assets (Aktas et al., 2015).Competition = degree of industry competition, calculated using the Herfindahl Index, as the sum of the squares of the firms' market share in each industry. Following Hill et al. (2010) and Molina and Preve (2009), the competitive industry is defined as one whose Herfindahl Index is below the median industry Herfindahl Index for the year; otherwise, the industry is deemed to be concentrated. Export = export intensity, which is measured as the ratio of foreign sales revenue to total sales revenue (Pla-Barber and Alegre, 2007).BCredit = ST bank credit, which is defined as the ratio of ST bank loans to total assets (McGuinness et al., 2018).SGrowth = annual sales growth, measured as the change in sales from time t-1 to t. (Abdulla et al., 2017).

The definitions of all the variables are presented in Table 1.

Table 1
Variable definitions.

Variable	Acronym	Definition
Working capital efficiency	WCE	First stage regression where inventory holding (log), trade receivables (log) and trade payables (log) on sales revenue (log).
Firm size	Size	Total assets of firms
Firm age	Age	The number of years between incorporation and the calendar year-end of each firm.
Cash holding	Cholding	Trade payables minus industry average trade payables
Industry competition	Competition	Short-term bank credit minus industry average short-term bank credit
Export intensity	Export	A dummy variable equal to one for trade credit substitute firms and zero otherwise.
Short term bank credit	ST bank credit	The ratio of short-term debt to total assets
Sales growth	Growth	One–year growth rate of sales at time t-1: (SALEt-SALEt-1)/ SALEt-1
Value-added	–	Number of years between incorporation and the calendar year-end of each firm
Standardised products	–	An indicator variable equal to one of the firm produces standard products and zero otherwise.
Services	–	Services is an indicator variable equal to one if the firm is a service provider and zero otherwise.
Differentiated products	–	An indicator variable which is equal to one if the firm produces differentiated products and zero otherwise.

3.3. Data

The firm-level data is obtained from the ORBIS database. Our sample comprises public listed firms in all 28 EU member states, for which financial data was available between 2009 and 2018. Following previous research (Deloof, 2003), we excluded firms operating in the financial industry and firm-year observations with abnormalities such as negative assets or negative sales. This left us with an unbalanced panel of 40,542 firm/year observations.

3.4. Hypothesis development

Larger firms have superior bargaining power over suppliers and customers (Abdulla et al., 2017). This may allow them to improve their overall WCE by dictating the credit agreement with suppliers and customers. Also, larger firms have easy and cheaper access to external finance (Rahaman, 2011; Martínez-Sola et al., 2014), which may allow them to improve WCE by adequately financing inventory (Guariglia, 1999) and customers (Baños-Caballero et al., 2010). Therefore, a positive relationship between firm size and WCE is expected.

Older firms have established relationships with banks and trade suppliers (Niskanen and Niskanen, 2006; Baños-Caballero et al., 2010) and are expected to achieve a higher WCE. Older firms can improve their WCE by receiving better credit terms from banks and trade suppliers (Berger and Udell, 1998; Lee et al., 2015) and extend such credit to their financially constrained customers (Love et al., 2007) in order to maximise sales and profit (Hill et al., 2012). Accordingly, a positive association between firm age and WCE is anticipated.

Firms with cash holding are expected to be more efficient with their working capital because they do not need to over-depend on suppliers' credit (Abdulla et al., 2017), decline to offer credit to customers (Abdulla et al., 2019) or experience shortages of inventory (Guariglia, 1999) for lack of financing. Furthermore, according to the pecking order theory (POT) proposed by Myers (1977), firms give priority to internally generated cash than debt or equity issues because it is cheap (Baños-Caballero et al., 2010) and allows management control over operations and assets (Shah et al., 2017). As such, we hypothesise a positive association between cash holding and WCE.

The degree of industry competition has been found in previous literature to affect firm-level working capital (Hill et al., 2010; Pirttilä et al., 2020). In a highly competitive industry, firms may experience a poor WCE because of the need to offer generous trade credit to customers to compete for market share (Molina and Preve, 2009; Hill et al., 2012). Firms operating in highly competitive industries may also have to keep excess inventories to lure customers (Boisjoly et al., 2020), which may increase the level of inventory beyond the optimal level. Therefore, this paper expects an inverse relationship between a degree of industry competition and WCE.

Firms' degree of export intensity is expected to influence WCE because, on average, it takes longer for goods to be delivered internationally (Engemann et al., 2014) and for importers to pay their debts (Paravisini et al., 2015). This will affect WCE because firms may have to keep a high buffer of inventory to meet international orders (Zhao and Chen, 2019); offer more extended credit periods to foreign customers to settle their accounts (Paravisini et al., 2015) and over depend on their suppliers for credit (Burkart and Ellingsen, 2004; Love et al., 2007; Ferrando and Mulier, 2013). Consequently, a negative relationship is expected between export intensity and WCE.

Firms with ST bank credit are expected to improve their WCE by avoiding the expensive suppliers' credit (Chen et al., 2019). Although trade credit is essential to firms, especially financially constrained firms (Fabbri and Menichini, 2010; Molina and Preve, 2012), it is also more expensive than bank credit (Kestens et al., 2012; Afrifa et al., 2018). Access to bank credit may also cause optimality in trade receivables because of the direct association between bank credit and credit to customers (Fabbri and Klapper, 2016). Therefore, a positive relationship is expected between ST bank credit and WCE.

Sales growth opportunity is expected to influence firms' WCE. This is because firms anticipating future growth hoard inventory to meet such expectations (Blazenko and Vandezande, 2003). However, sales growth opportunities may also cause working capital inefficiencies because of the accompanying generous trade receivables generally associated with it (Burkart and Ellingsen, 2004; Ferrando and Mulier, 2013). Given the need for firms to hoard a higher level of inventory with the expectation of future growth opportunities, firms may over-depend on suppliers' credit as a source of finance to purchase the required inputs to meet production (Caglayan et al., 2012; Goto et al., 2015) and credit extended to customers (Ferrando and Mulier, 2013). Therefore, a negative relationship is expected between sales growth opportunities and WCE.

4. Empirical results

4.1. Summary statistics

The results of the descriptive statistics for the base variables and those used in the regressions are presented in Table 2. In terms of the means of the absolute variables used in estimating the WCE, sales revenue is £4244.0570 million, trade receivables are £1156.1900 million, trade payables is £754.6085 million, and inventory holding is £1298.3630 million. In the first stage, the variables used in estimating the WCE are as follows: the natural logarithm of sales revenue is 8.0835, the natural logarithm of trade receivables is 6.7719, the natural logarithm of trade payables is 6.4665, and for inventory holding, the natural logarithm is 6.8513.

In the second stage, the summary statistics are as follows: the average WCE is 51.82 %, suggesting that the average firm's WCE is above 50 %. The logarithm of total assets and logarithm of the age of the average firm is 12.4137 and 3.0160, respectively. The cash holding is, on average, 17.36 %. Approximately 59 % of the industries are competitive. The average export intensity is approximately 18.04 %. The percentage of ST bank credit of the average firm is 9.05 %. Sales growth is, on average, 11.19 %; however, 25 % of the sample has a negative sales growth.

Table 3 presents country averages for WCE, firm size, firm age, cash holding, competition, export intensity, ST bank credit and sales growth. Overall, the results show wide variations in WCE and key firm-level determinants, which confirms similar studies in the EU relating to trade receivables (García-Teruel and Martínez-Solano, 2010a) and trade payables (García-Teruel and Martínez-Solano, 2010b). This justifies why we have controlled for country effects in all our regressions.

The Pearson correlation matrix results are presented in Table 4. Initial results are consistent with our hypotheses (except for sales growth, which is positive but insignificantly correlated with WCE) and show that WCE is positively correlated with firm size, firm age, cash

Table 2
Descriptive statistics.
The table provides the sample characteristics of 40,542 firm-years across 6170 unique EU firms over the period 2010–2018. All variables are defined in Table I.

Variable	N	Mean	p50	SD	p10	p25	p95
Stage 1							
Sales revenue (£m)	40542	4244.0570	3398.1020	3169.9260	1235.9730	820.2115	8169.8620
Trade receivables (£m)	40542	1156.1900	926.6338	824.1912	301.7355	193.9621	2388.9490
Trade payables (£m)	40542	754.6085	863.5087	318.5982	256.4376	157.3497	1072.1530
Inventory holding (£m)	40542	1298.3630	1020.0880	1036.8470	317.0374	205.8616	2605.7300
Sales revenue (log)	40542	8.0835	8.1310	0.8011	7.1196	6.7096	9.0082
Trade receivables (log)	40542	6.7719	6.8316	0.8236	5.7096	5.2677	7.7786
Trade payables (log)	40542	6.4665	6.7610	0.6972	5.5469	5.0585	6.9774
Inventory holding (log)	40542	6.8513	6.9276	0.8769	5.7590	5.3272	7.8655
Stage 2							
WC_efficiency	40373	0.5182	0.5146	0.1115	0.3754	0.3473	0.6644
Firm size (log)	40542	12.4137	12.3961	0.1930	12.1625	12.1177	12.6857
Firm age (years)	40325	3.0160	2.9124	0.2970	2.6733	2.6327	3.3554
Cash holding	40542	0.1736	0.1519	0.2136	0.0667	0.0451	0.2198
Competition	40542	0.5932	1.0000	0.4913	0.0000	0.0000	1.0000
Export intensity	35315	0.1804	0.2049	0.0538	0.0839	0.0835	0.2341
ST bank credit	40427	0.0905	0.0919	0.0513	0.0110	0.0043	0.1509
Sales growth	30162	0.1119	0.0392	0.1930	−0.0395	−0.2046	0.2786

Table 3
Mean value of variables across countries.
This table reports, by countries, the mean of all variables for 40,542 firm-years across 6170 unique EU firms over the period 2009–2018.

Country	WCE	Firm size	Firm age	Cash holding	Competition	Export intensity	Bank credit	Sales growth
Austria	0.5086	12.5068	2.9645	0.1504	0.7140	0.1799	0.0817	0.1238
Belgium	0.5164	12.4709	3.0666	0.1597	0.7169	0.1780	0.0924	0.1226
Bulgaria	0.5376	12.4794	3.1170	0.1551	0.1119	0.1631	0.1182	0.1235
Croatia	0.5149	12.3823	2.9205	0.1188	0.6144	0.1839	0.0874	0.1198
Cyprus	0.5589	12.4268	3.0859	0.1496	0.4873	0.1821	0.0991	0.1412
Czech Rep.	0.5078	12.6312	2.9775	0.1556	0.1324	0.1776	0.1352	0.1000
Denmark	0.5127	12.4008	3.0028	0.1634	0.7958	0.1802	0.0877	0.1290
Estonia	0.5191	12.4822	2.9766	0.1495	0.0000	0.1611	0.1178	0.1402
Finland	0.4882	12.4071	2.9649	0.1570	0.8162	0.1787	0.0737	0.1242
France	0.5055	12.3698	3.0151	0.1844	0.7458	0.1812	0.0855	0.1181
Germany	0.5372	12.3816	3.0455	0.1796	0.7441	0.1777	0.0930	0.1202
Greece	0.5164	12.3727	2.9646	0.1489	0.8102	0.1827	0.0986	0.1507
Hungary	0.5133	12.5063	3.0227	0.1329	0.1082	0.1773	0.1128	0.1175
Ireland	0.5226	12.5118	2.9423	0.1931	0.6834	0.1826	0.0916	0.1132
Italy	0.4647	12.4329	2.9490	0.1367	0.7366	0.1894	0.0673	0.1308
Latvia	0.5719	12.4180	2.9111	0.1276	0.0229	0.1533	0.1010	0.1090
Lithuania	0.4876	12.3638	2.8943	0.1188	0.8095	0.1782	0.0898	0.1265
Luxembourg	0.5178	12.5348	3.0801	0.1544	0.6199	0.1816	0.0917	0.1210
Malta	0.5466	12.3781	3.2284	0.1619	0.6168	0.1879	0.0922	0.1017
Netherlands	0.5132	12.4779	3.0291	0.1925	0.7629	0.1822	0.0869	0.1242
Poland	0.4931	12.4472	3.0666	0.1458	0.1358	0.1810	0.1099	0.0948
Portugal	0.5022	12.5235	2.9342	0.1254	0.7342	0.1852	0.0657	0.1439
Romania	0.5075	12.4851	2.9249	0.1335	0.0864	0.1640	0.1005	0.1072
Slovakia	0.5202	12.4249	2.9537	0.1047	0.0000	0.1938	0.0836	0.1760
Slovenia	0.5245	12.5126	2.9920	0.1271	0.0824	0.1752	0.1136	0.1086
Spain	0.5148	12.4782	3.0710	0.1391	0.6429	0.1789	0.0726	0.1253
Sweden	0.5284	12.3502	2.9917	0.2003	0.7400	0.1793	0.0819	0.0737
UK	0.5345	12.4103	3.0223	0.2045	0.5681	0.1842	0.0902	0.1042
Total	0.5086	12.5068	2.9645	0.1504	0.7140	0.1799	0.0817	0.1238

Table 4
Pearson correlation matrix.
The table presents the Pearson correlation coefficient for the 40,542 firm-years across 6170 unique EU firms over the period 20,009–2018. All variables are defined in Table I. *Significant at the 0.05.

Variables	1	2	3	4	5	6	7
WCE	1						
Firm size	0.1314*	1					
Firm age	0.2865*	0.0314*	1				
Cash holding	0.1061*	−0.1863*	0.0855*	1			
Competition	−0.1667*	−0.1940*	−0.2500*	−0.0309*	1		
Export intensity	−0.1583*	−0.0764*	0.0268*	0.0017	0.0093	1	
ST bank credit	0.3463*	0.1052*	0.1298*	0.0438*	−0.1461*	−0.1296*	1
Sales growth	0.0036	0.0403*	0.0164*	−0.0253*	−0.0046	0.0456*	0.0026

holding, ST bank credit and sales. On the other hand, competition and export intensity are negatively correlated with WCE.

4.2. Main results

Table 5 presents the results of the baseline firm fixed effects regression from running Eq. (3) on the key determinants of WCE among EU firms. In all regressions, we control for year, industry and country fixed effects and the standard errors are clustered at the firm level to account for heteroskedasticity and autocorrelation (Petersen, 2009; Aktas et al., 2015). Also, to mitigate any endogeneity concerns, we follow Hill et al. (2010) and lag all the key determinants used in this study.

Column 1 presents the results of the full sample. In contrast, columns (2) and (3) contain old EU and new EU memberships, respectively. The evidence presented in column (1) of Table 5 shows that the coefficient of firm size is positive and statistically significant at the 1 % level ($\beta = 0.0105$, t-statistic = 10.52). The positive coefficient of firm size is consistent with hypothesis 1. It indicates that large firms are, on average, more efficient with their working capital than small firms. Specifically, the results show that, on average, a 10 % increase in the firm's size leads to a 0.105 % higher efficiency in working capital. One plausible reason for this may be their size and bargaining power (Abdulla et al., 2017). Larger firms can influence suppliers' and customers' credit to secure favourable terms (Klapper et al., 2012). Due to their less financial constraint, larger firms may also be able to finance inventory to meet sales and give customers a variety to choose from (Preve and Sarria-Allende, 2010).

Similarly, we also find a positive relation between firm age and WCE at the 1 % significance level ($\beta = 0.0028$, t-statistic = 5.44). This is consistent with hypothesis 2 and suggests that older firms are more efficient with their working capital than younger firms. The finding suggests that a 10 % increase in a firm's age leads to a 0.028 % increase in WCE. One explanation may be that business relationships with banks and trade suppliers are established over time (Niskanen and Niskanen, 2006; Baños-Caballero et al., 2010), which may allow older firms to benefit from better bank and trade credit deals (Berger and Udell, 1998; Lee et al., 2015).

Additionally, the evidence presented in column (1) of Table 5 shows that the coefficient of the cash holding is positive and statistically significant at the 1 % level (β =0.0008, t-statistic = 3.65). The positive coefficient of cash holding is consistent with hypothesis 3. It indicates

Table 5
Determinants of working capital efficiency.
This table presents firm fixed effects regression for 40,542 firm-years across 6170 unique EU firms over the period 2009–2018. In all columns, the dependent variable is the WCE. All variables are defined in Table I. *, **, *** significant at the 10 %, 5 % and 1 % levels, respectively.

SFA dependent = sales revenue			
Variables	1	2	3
Firm size	0.0105***	0.0099***	0.0151***
	(10.52)	(9.71)	(4.02)
Firm age	0.0028***	0.0023***	0.0061***
	(5.44)	(4.26)	(4.45)
Cash holding	0.0008***	0.0008***	0.0031
	(3.65)	(3.55)	(1.04)
Competition	−0.0017***	0.0446**	−0.0012**
	(−3.58)	(2.05)	(−2.31)
Export intensity	−0.0076***	−0.0080***	−0.0032
	(−6.39)	(−6.18)	(−1.15)
ST bank credit	0.0145***	0.0146***	0.0158***
	(9.17)	(8.79)	(3.44)
Sales growth	−0.0009***	−0.0010***	−0.0002
	(−3.30)	(−3.49)	(−0.35)
Constant	0.4263***	0.3973***	0.4176***
	(23.69)	(13.56)	(7.31)
Year effects	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes
Country effects	Yes	Yes	Yes
R-squared	0.4399	0.4624	0.3538
Rho	0.9937	0.9936	0.9947
N	21,566	18,367	3199

that firms with cash holding tend to be more efficient with their working capital. Specifically, the results show that a 10 % increase in firms' cash holdings will lead to a 0.008 % increase in WCE. The plausible explanation may be that firms with cash holding do not need to over-depend on suppliers' credit, which tends to be more expensive (Abdulla et al., 2017; Afrifa et al., 2018). Moreover, firms with cash holding can easily optimise their trade payables because they have the means to pay for goods and services upfront if there is a need to reduce the level of suppliers' credit. Also, firms with cash holding can optimise trade receivables by financing credit extended to customers for sales maximisation (Martínez-Sola et al., 2014; Box et al., 2018).

Further in column (1) of Table 5, we also find a significantly negative relationship between industry competition and firms' WC (β = −0.0017, t-statistic = −3.58), suggesting that firms operating in highly competitive industries tend to be less efficient in their WCM. More specifically, a 10 % increase in industry competition leads to a 0.017 % decrease in WCE. The negative coefficient of industry competition is consistent with hypothesis 4. Firms will have to offer generous trade credit to customers in highly competitive industries to increase sales (Molina and Prev, 2009; Hill et al., 2012). Also, firms in competitive industries may have to rely more on suppliers' credit to offset some of the credit extended to customers because firms that offer more credit to their customers also depend more on suppliers' credit (Ferrando and Mulier, 2013). On the other hand, the degree of competition also affects the level of inventory firms hold. Firms operating in highly competitive industries become less efficient in their inventory control (Min and Chen, 1995; Olivares and Cachon, 2009) because of factors including delivery competition (Boisjoly et al., 2020).

Similarly, the results in column 1 of Table 5 also present evidence of the relationship between export intensity and WCE. The evidence suggests a significantly negative relationship between export intensity and WCE (β = −0076, t-statistic = −6.39). The negative coefficient of export intensity is consistent with hypothesis 5. It indicates that firms' degree of export intensity adversely affects their WCE. An explanation for this result may be that exporting firms over-depend on their suppliers due to the period it takes importers to settle their accounts (Engemann et al., 2014). Overdependence on suppliers' credit may decrease value because it is expensive compared with bank credit (Kestens et al., 2012). An alternative explanation may be that exporting firms give an extended credit period to their foreign customers because of the lead-time of freight (Zhao and Chen, 2019), which may cause a reduction in the value relevance of trade receivables.

The results in column 1 of Table 5 also show a significantly positive relation between ST bank credit and WCE (β = 0.0145, t-statistic = 9.17). The finding is consistent with hypothesis 6 and indicates that firms with access to ST bank credit tend to be more efficient with their working capital. Because ST bank credit is cheaper than trade credit, it is seen as the most value-relevant financing of trade receivables (Du et al., 2012; Hill et al., 2012). Firms that do not have access to ST bank credit may be forced to reduce their extension of trade credit to customers below the optimum, which is expected to cause working capital inefficiencies. Also, the lack of access to ST bank credit may lead to working capital inefficiencies because of the overdependence on suppliers' credit (Atanasova, 2007; Huyghebaert et al., 2007) as a substitute.

The findings also show a significantly negative relationship between sales growth and firms' WCE (β = −0.0009, t-statistic = −3.30). The negative coefficient of sales growth is consistent with hypothesis 7. We attribute the accompanying generous trade receivables usually associated with sales growth (Ferrando and Mulier, 2013) as a possible explanation for this. Studies such as Hill et al. (2012) and Ferrando and Mulier (2013) show that firms use trade credit to customers as a tool to increase sales and market share by enticing customers to buy more. However, using generous trade credit to customers as a tool to increase sales may be sub-optimal and lead to working capital inefficiencies if customers default payment (Martínez-Sola et al., 2014).

Columns (2) and (3) contain the results of the determinants of WCE differences across the two EU memberships – old EU membership and new EU membership, which show interesting trends. The results show significant variations of firms' cash holding across the two EU memberships. In particular, on average, we find higher cash holding of firms in the old EU countries to be efficient with their working capital, as demonstrated by the significantly positive coefficient presented in Column 2 in Table 4 (β = 0.0008, t-statistic = 3.55). However, in the new EU countries in Column 3, we find a relatively insignificant relationship between cash holding and WCE, which precludes us from making any further references with this evidence. Nevertheless, based on our evidence, we deduce that, in general, cash holding can be linked with high efficiency. Also, industry competition is positively related to the WCE of firms in the old EU countries, contrary to the complete set of firms in the new EU countries with a negative association between industry competition and WCE. Moreover, contrary to the complete set of firms in old EU countries, export intensity and sales growth are not associated with the WCE of firms in the new EU countries.

5. Further analysis

5.1. Results based on the nature of product classification

Several studies have shown that working capital components' management varies across the nature of the product (Giannetti et al., 2011; Mateut et al., 2015). However, the evidence of the key determinants of WCE across the nature of the product is unknown. Generally, firms' products can be classified into three, namely standard products, services and differentiated products (Hill et al., 2012; Afrifa et al., 2018). We follow a similar procedure by Hill et al. (2012) and segregate the firms in our sample into the three categories based on the Standard Industrial Classification of Economic Activities (SIC) 2003 (see, Appendix 2). To minimise the possibility of selection bias, we classify all unclassified firms as standardised products (see Hill et al., 2012). Among the three product types, the quality of differentiated products is the most difficult to verify because of their non-standard nature (Hill et al., 2012). As a result, suppliers of differentiated products may have to extend longer

Table 6
Results based on nature of product and WCM components.
The table shows the results based on the nature of product in columns (1)–(3) and individual working capital management components in columns (4)–(6) for 40,542 firm-years across 6170 unique EU firms over the period 2009–2018. The dependent variable is the WCE in all columns. T-values are in parentheses below the coefficients. All variables are defined in Table I. *, **, *** significant at the 10 %, 5 % and 1 % levels, respectively.

SFA dependent = sales revenue						
	Nature of product			WCM components		
	1	2	3	4	5	6
Firm size	0.0069***	0.0107***	0.0120***	−0.0023***	0.0196***	0.0131***
	(6.53)	(5.56)	(3.23)	(−3.22)	(11.04)	(8.57)
Firm age	0.0017***	0.0046***	0.0080***	0.0045***	0.0115***	0.0074***
	(3.32)	(4.09)	(3.21)	(11.78)	(11.30)	(10.02)
Cash holding	0.0012***	−0.0002	0.0003	−0.0006	0.0028***	−0.0017***
	(4.23)	(−0.69)	(0.12)	(−1.31)	(5.23)	(−6.47)
Competition	−0.0009	−0.0023**	−0.0021	−0.0014***	−0.0038***	−0.0013*
	(−1.43)	(−2.52)	(−0.88)	(−2.93)	(−3.52)	(−1.70)
Export intensity	−0.0103***	−0.0143***	−0.0102***	−0.0054***	−0.0029	−0.0068***
	(−6.65)	(−7.00)	(−3.01)	(−6.92)	(−1.55)	(−4.24)
ST bank credit	0.0059***	0.0280***	0.0257***	0.0060***	0.0073***	0.0161***
	(3.40)	(8.74)	(5.01)	(5.30)	(2.62)	(7.54)
Sales growth	−0.0008***	−0.0008	−0.0023**	0.0003	−0.0018***	−0.0008**
	(−2.84)	(−1.25)	(−2.01)	(1.57)	(−4.15)	(−2.29)
Constant	0.5248***	0.4969***	0.4061***	0.3519***	0.4169***	0.4454***
	(25.96)	(16.54)	(4.37)	(29.44)	(15.71)	(17.74)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.4025	0.4447	0.5206	0.5503	0.3732	0.3622
Rho	0.9941	0.9941	0.9910	0.9957	0.9851	0.9937
N	13,779	5894	1893	21,566	21,566	21,566

credit terms to their customers (Fabbri and Menichini, 2010; Giannetti et al., 2011) because of the time needed for buyers to verify the quality of products purchased (Burkart and Ellingsen, 2004; Caglayan et al., 2012). Mateut et al. (2015) show that the inventories complexity influences trade credit. This, in turn, will also cause a firm to depend more on suppliers for an extended credit on inputs purchased. Thus, on average, both trade receivables and payables may be longer for firms dealing in differentiated products than service and standard products firms. Thus, we examine how the key determinants of WCE vary across different product types.

To examine the key determinants of WCE across different product types, we re-estimating Eq. (3) separately for standard firms (column 1), service firms (column 2) and differentiated products firms (column 3) for the entire sample. The results, presented in Columns (1) to (3) of Table 6, respectively, show some differences in the key determinants of WCE across different product types. Specifically, cash holding is positively associated with the WCE of standard product firms but not related to the WCE of service or differentiated product firms. Also, WCE is not related to competition for standard products and differentiated firms. Sales growth is also not significantly associated with the WCE of service firms. These significant differences in the key determinants of WCE across different product types confirm working capital component differences across different product types (Fabbri and Menichini, 2010; Hill et al., 2012).

5.2. *WCM components*

In estimating the WCE, we have used the sum of the main three components of working capital. However, different firm characteristics may affect the individual working capital components differently (see, Deloof, 2003; García-Teruel and Martínez-Solano, 2010b). As a further analysis, we also examine the various key determinants of the efficiencies of the individual components of working capital (inventories, trade receivables and trade payables). This is important because the summation of the three main components in estimating the WCE may conceal differences in the key determinants of the individual working capital components.

Therefore, we re-estimate Eq. (2) and model sales revenue as a function of inventory holdings, trade receivables and trade payables individually. Next, we re-estimate Eq. (3) separately for inventory holding, trade receivables, and trade payables to examine the key determinants of each WCE component. The results are presented in Columns (4) to (6) of Table 6 for the full sample, respectively.[2] Interestingly, the results show significant differences in the key determinants of the three main working capital components. Specifically, firm size is positively associated with trade receivables and trade payables efficiency but negatively related to inventory holding efficiency. Cash holding is positively associated with trade receivables efficiency but negatively related to trade payables efficiency and not significantly related to inventory holding efficiency. Export intensity is negatively related to inventory holding and trade payables efficiencies but not related to trade receivables efficiency. Lastly, sales growth is negatively associated with the efficiencies of trade receivables and trade payables but is not significantly related to inventory holding efficiency. These results show that there are efficiency differences in the key determinants of the three working capital components.

6. Robustness test

6.1. *Value-added as a measure of WCE*

To evaluate the sensitivity of our WCE measure, we re-estimate Eq. (2) and model value-added (instead of sales revenue) as a function of inventory holdings, trade receivables, and payables. Next, we re-estimate Eq. (3) to examine the key determinants of each WCE component. The results in Table 7 present the empirical evidence of this relationship. Column (1) presents results of the full sample, while columns (2) and (3) summarise results on old and new EU memberships, respectively. The overall evidence presented in columns (1) to (3) are not statistically different from the results presented in Table 5 except for

[2] The separation of the sample into the new EU and old EU follow a similar pattern as in Table 4.

Table 7
Value-Added as a measure of WCE.
This table presents firm fixed effects regression for 40,542 firm-years across 6170 unique EU firms over the period 2009–2018. In all columns, the dependent variable is the WCE. All variables are defined in Table I. *, **, *** significant at the 10 %, 5 % and 1 % levels, respectively.

SFA dependent = value-added			
Variables	4	5	6
Firm size	0.0086***	0.0082***	0.0111***
	(11.63)	(10.99)	(3.93)
Firm age	0.0031***	0.0029***	0.0040***
	(9.72)	(8.71)	(4.25)
Cash holding	0.0009***	0.0009***	0.0044**
	(4.27)	(4.11)	(2.31)
Competition	−0.0012***	0.0463**	−0.0014***
	(−3.51)	(2.40)	(−3.36)
Export intensity	−0.0035***	−0.0036***	−0.0020
	(−4.18)	(−4.00)	(−0.96)
ST bank credit	0.0124***	0.0123***	0.0123***
	(11.42)	(11.05)	(3.37)
Sales growth	−0.0005***	−0.0006***	−0.0001
	(−2.64)	(−2.79)	(−0.24)
Constant	0.3948***	0.3656***	0.4245***
	(23.34)	(13.66)	(9.95)
Year effects	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes
Country effects	Yes	Yes	Yes
R-squared	0.3923	0.4109	0.3147
Rho	0.9974	0.9975	0.9968
N	21,566	18,367	3199

Table 8
Industry adjusted WCE and 3-year WCE moving average regressions.
This table presents firm fixed effects regression for 40,542 firm–years across 6170 unique EU firms over the period 2009–2018. The dependent variable is the industry-adjusted WCE in columns (1)–(3); and 3-year WCE moving average in columns (4)–(6). t-Values are in parentheses below coefficients. All variables are defined in Table I. *, **, *** significant at the 10 %, 5 % and 1 % levels, respectively.

SFA dependent = Sales revenue						
Variables	Industry adjusted WCE			3–year WCE moving average		
	1	2	3	4	5	6
Firm size	0.0104***	0.0099***	0.0148***	0.0136***	0.0126***	0.0226***
	(10.49)	(9.76)	(3.94)	(10.54)	(9.48)	(4.62)
Firm age	0.0028***	0.0023***	0.0066***	0.0036***	0.0029***	0.0086***
	(5.59)	(4.28)	(4.76)	(4.97)	(3.82)	(4.35)
Cash holding	0.0008***	0.0008***	0.0029	0.0011***	0.0010***	0.0031
	(3.63)	(3.54)	(0.98)	(3.48)	(3.42)	(0.73)
Competition	−0.0018***	−0.0010	−0.0011**	−0.0020***	0.0437***	−0.0016***
	(−3.50)	(−0.37)	(−2.01)	(−3.17)	(2.04)	(−2.26)
Export intensity	−0.0076***	−0.0080***	−0.0031	−0.0085***	−0.0091***	−0.0006
	(−6.34)	(−6.16)	(−1.14)	(−5.77)	(−5.77)	(−0.17)
ST bank credit	0.0144***	0.0146***	0.0158***	0.0165***	0.0164***	0.0207***
	(9.15)	(8.77)	(3.43)	(8.10)	(7.67)	(3.34)
Sales growth	−0.0009***	−0.0010***	−0.0002	−0.0014***	−0.0015***	−0.0008
	(−3.29)	(−3.49)	(−0.36)	(−4.05)	(−4.11)	(−0.94)
Constant	−0.0813***	−0.0744***	−0.0748	0.4148***	0.3923***	0.3481***
	(−5.01)	(−4.48)	(−1.21)	(20.25)	(12.79)	(5.09)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.3590	0.3851	0.1813	0.5110	0.5321	0.4155
Rho	0.9939	0.9937	0.9954	0.9899	0.9896	0.9910
N	21,566	18,367	3199	21,334	18,227	3107

cash holding, which is also positive and statistically significant in column (3). These imply that our results are robust to an alternative measure of WCE.

6.2. Industry adjusted WCE

WCE of firms may be industry-related (Hanousek et al., 2015). For example, Page (1984) found firm size to be associated with productivity efficiency differently across different industries. We, therefore, evaluate the sensitivity of our baseline results to industry differences. Specifically, we re-run Eq. (3) separately for each of the industries in our sample.[3] The results are contained in columns (1) to (3) of Table 8. Column (1) presents the results of the full sample, while columns (2) and (3) summarise results in old and new EU membership. Consistent with the main results in Table 5, column (1) results show that firm size, age, cash holding, and ST bank credit positively relate to industry-adjusted WCE. In contrast, industry competition, export intensity and sales

[3] Our industry classification is based on the UK SIC (2003) classification.

Table 9
Results based on survivorship bias.
The table shows the results of the survivorship bias regression for 40,542 firm-years across 6170 unique EU firms over the period 2009–2018. The dependent variable is the WCE in all columns. T-values are in parentheses below the coefficients. All variables are defined in Table I. *, **, *** significant at the 10 %, 5 % and 1 % levels, respectively.

SFA dependent = sales revenue			
Variables	1	2	3
Firm size	0.0108***	0.0104***	0.0168**
	(9.38)	(9.14)	(2.51)
Firm age	0.0024***	0.0021***	0.0073***
	(4.30)	(3.56)	(3.26)
Cash holding	0.0008***	0.0007***	0.0024
	(3.50)	(3.42)	(0.58)
Competition	−0.0022***	0.0305	−0.0006
	(−3.81)	(1.02)	(−0.75)
Export intensity	−0.0082***	−0.0084***	−0.0030
	(−5.96)	(−5.92)	(−0.60)
ST bank credit	0.0138***	0.0139***	0.0208**
	(7.59)	(7.57)	(2.37)
Sales growth	−0.0009***	−0.0010***	−0.0009
	(−2.74)	(−2.81)	(−0.59)
Constant	0.4290***	0.4021***	0.3396***
	(19.76)	(13.23)	(3.56)
Year effects	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes
Country effects	Yes	Yes	Yes
R-squared	0.4856	0.4819	0.6677
Rho	0.9934	0.9934	0.9861
N	15,960	14,999	961

growth are negative key determinants of industry-adjusted WCE. Similarly, the results in columns (2) to (3) are qualitatively similar to those presented in Table 5. These results further strengthen our main results in Table 5.

6.3. Three-year average WCE regressions

In this section, we test the sensitivity of our baseline results in Table 5 to a long-run performance measure by following studies by Box et al. (2018) and use the three-year average WCE as the dependent variable. The same econometric procedure and set of control variables are used as in Table 5. The results displayed in columns (4) to (6) of Table 8 generate consistent findings, as reported in Table 5. Thus, these results further support our baseline results and prove that the various key determinants of WCE persist through time.

6.4. Results based on survivorship bias

Survivorship bias occurs when some firms are excluded for lack of data availability (Kestens et al., 2012). In our case, the survivorship bias test is particularly important because working capital inefficiency is one of the main reasons for firm failure (Aktas et al., 2015). For example, many studies (Shin and Soenen, 1988; Aktas et al., 2015) have shown that working capital inefficiency leads to failures. One way to control for survivorship bias is to include all firms regardless of whether all data is available over the sample period or not (Goto et al., 2015). Consequently, we have not excluded firms without complete data from our sample. However, this approach may cause the results to be driven by firms with complete data throughout the sample period (Afrifa et al., 2019). We, therefore, follow a similar procedure by Schaeck and Cihák (2012) and Afrifa et al. (2019) and restrict our sample to firms without complete data throughout the sample period to investigate any possible survivorship bias.

The results are presented in Table 9 with the same econometric technique and set of determinants of firms' WCE as in Table 5. After controlling for selection bias, the regression results show qualitatively the same results as presented in Table 5 for the full sample and across the old EU and new EU. Thus, our main results are robust to survivorship bias.

6.5. Quantile regressions for the whole sample

In this section, we examine if the key determinants of WCE vary across different sample segments by dividing the sample into five different quantiles (q0.10, q0.25, q0.50, q0.75 and q0.90). We follow a similar procedure by Tchakoute-Tchuigoua (2014) and perform quantile regression with bootstrapped standard errors for the whole sample. The results are reported in Table 10. Except for industry competition at the quantile 0.10, which is positive and statistically significant, the rest of the key determinants of WCE across all five quantiles are qualitatively

Table 10
Quantile regressions for the whole sample.
This table reports the quantile regression estimates for 40,542 firm-years across 6170 unique EU firms over the period 2009–2018. The dependent variable is the WCE in all columns. T-values are in parentheses below the coefficients. All variables are defined in Table I. *, **, *** significant at the 10 %, 5 % and 1 % levels, respectively.

SFA dependent = sales revenue					
Variables	Quantile = 0.10	Quantile = 0.25	Quantile = 0.50	Quantile = 0.75	Quantile = 0.90
	1	2	3	4	5
Firm size	0.0624***	0.0446***	0.0446***	0.0438***	0.0492***
	(20.18)	(17.34)	(17.34)	(12.04)	(8.02)
Firm age	0.0671***	0.1202***	0.1202***	0.1106***	0.0901***
	(19.76)	(42.58)	(42.58)	(27.67)	(13.37)
Cash holding	0.0162***	0.0476***	0.0476***	0.0943***	0.0922***
	(6.58)	(23.29)	(23.29)	(32.58)	(18.90)
Competition	0.0043**	−0.0071***	−0.0071***	−0.0102***	−0.0117***
	(2.13)	(−4.22)	(−4.22)	(−4.28)	(−2.91)
Export intensity	−0.2490***	−0.2325***	−0.2325***	−0.2796***	−0.2566***
	(−23.14)	(−26.00)	(−26.00)	(−22.08)	(−12.03)
ST bank credit	0.1148***	0.2351***	0.2351***	0.3318***	0.4750***
	(10.18)	(25.08)	(25.08)	(25.00)	(21.24)
Sales growth	−0.0282***	−0.0265***	−0.0265***	−0.0281***	−0.0280***
	(−8.94)	(−10.08)	(−10.08)	(−7.56)	(−4.48)
Constant	−0.3982***	−0.2845***	−0.2845***	−0.2183***	−0.2262***
	(−9.90)	(−8.51)	(−8.51)	(−4.61)	(−2.84)
Year effects	Yes	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes
Pseudo R2	0.4174	0.4196	0.4196	0.3664	0.3057
N	26,624	26,624	26,624	26,624	26,624

Table 11
Coefficient stability method - omitted variable bias test.
This table presents the test results for potential omitted variables following the approach of Oster (2019). As recommended by Oster (2019). We run the methods of coefficient stability for our main regressions in Table 5. Columns (1), (2) and (3) show the coefficients, confidence intervals and the R-squared from the main regressions. Columns (5) and (6) report whether the bias-adjusted coefficient β^* in the identified set bounds meets the two robustness criteria in Oster (2019), specifically column (5) reports if the bias-adjusted coefficient moves further away from zero and column (6) reports whether the changes in the adjusted coefficient fall within the 95 % confidence intervals of the estimated coefficient β in the primary regression. All variables are as defined in Table 1.

			Controlled regression				Uncontrolled regression		Interpretation	
			1	2		3	4		5	6
Table	Regression	Variables	Coefficient from the regression	95 % confidence intervals of the estimated coefficient		R–squared of the regression	Identified set of bounds (controlled – full set)		Coefficient moves away from zero	Coefficient falls within the 95 % confidence intervals
4	Column 1	Firm size	0.0105	0.0085	0.0124	0.3754	0.0105	0.1677	Yes	Yes
	Column 1	Firm age	0.0028	0.0017	0.0037	0.3754	0.0028	0.1200	Yes	Yes
	Column 1	Cash holding	0.0008	0.0003	0.0013	0.3754	0.0008	0.0062	Yes	Yes
	Column 1	Competition	−0.0017	−0.0026	−0.0007	0.3754	−0.0017	−0.0885	Yes	Yes
	Column 1	Export intensity	−0.0076	−0.0099	−0.0053	0.3754	−0.0076	−0.0450	Yes	Yes
	Column 1	ST bank credit	0.0145	0.0113	0.0175	0.3754	0.0145	0.5695	Yes	Yes
	Column 1	Sales growth	−0.0009	−0.0014	−0.0003	0.3754	−0.0009	−0.0396	Yes	Yes

similar to the main results reported in Table 5. Overall, we conclude that the effects of the key determinants of WCE are not significantly different across different segments of the sample.

6.6. Endogeneity - omitted variable bias test

In our effort to mitigate any possible endogeneity concerns, we have lagged all the key determinants in all our regressions. This section also uses a more novel method of controlling for the endogeneity issue of omitted variables bias by performing the Oster (2019) test. This test estimates the effect of unobserved time-variant and time-invariant omitted variables on the reported results (Adams and Ferreira, 2009; Oster, 2019). This test is vital because the omission of specific key determinants may undermine our main results reported in Table 5 (Wang and Yin, 2018). As suggested by Oster (2019) and used in Afrifa et al. (2019), we determine the presence of omitted key determinants by testing the stability of the coefficients of the key determinants based on the two main assumptions. The first assumption is that the importance of both the omitted and observed key determinants is equally important. The second assumption is that by including the omitted key determinants, the R-squared of the main regressions can be improved by 1.3 times. Thus, the Oster (2019) test helps determine to what extent the unobserved key determinants make the coefficients reported in Table 5 redundant. This sensitive type of procedure determines if the inclusion of additional key determinants will cause changes in both the coefficients and their R-squared.

Therefore, we follow Oster (2019), Afrifa et al. (2019) and Wang and Yin (2018) and investigate whether the results reported in Table 5 suffer from the possible omission of any key determinant. The results are presented in Table 11 as follows. Column (1) presents the coefficients of the key determinants in Table 5. Column (2) contains the 95 % confidence intervals of the estimated coefficient of interest. Column (3) reports the R-squared of key determinants in Table 5. Column (4) contains the identified set of bounds of the coefficient for the controlled set (β) and the full set (including omitted variables). Column (5) presents the movement in the coefficients of the key determinants. Column (6) estimates whether the coefficients of key determinants are within the 95 % confidence intervals. Overall, the results presented in Table 11 suggest that our main results reported in Table 5 do not suffer from omitted variables bias. Specifically, the results in column (5) show that the coefficients of the key determinants all move away from zero. Also, the results presented in column (6) show that the coefficients of the key variables are all within the 95 % intervals.

7. Conclusion

This paper examined the effects of firm size, firm age, cash holding, industry competition, export intensity, ST bank credit, and sales growth on firm WCE using the SFA. One of our important contributions to the literature focuses on the technical efficiency of working capital instead of the standard accounting ratios. The results indicate that specific key determinants influence WCE behaviour. Specifically, the findings highlight that larger firms, older firms, cash holding and ST bank credit are characterised by higher WCE. Alternatively, industry competition, export intensity and sales growth are characterised by lower WCE. In the analysis, we also distinguish between the old EU and new EU and show differences in key determinants' influence on WCE. More precisely, the findings indicate that cash holding, export intensity and sales growth do not significantly influence the WCE of firms operating in the new EU membership.

On the other hand, industry competition has a positive influence on the WCE of firms residing in old EU membership. Using an alternative WCE outcome variable (value-added instead of sales revenue) further strengthens our results. These results are consistent after using industry-adjusted WCE, 3-year average WCE and quantile regression. The results are also robust to survivorship bias and omitted variable bias.

More importantly, further analysis shows that the key determinants of WCE behaviour depend on the products' nature. Specifically, cash holding does not influence the WCE of firms dealing in services and differentiated products. Competition is also not significantly crucial to the WCE of firms operating in standardised and differentiated products. Finally, sales growth does not affect the WCE of service firms. Further analysis of the efficiency of individual components of working capital also shows interesting trends. The results show that cash holding does not influence inventory holding efficiency but positively influences trade receivables efficiency and negatively affects trade payables efficiency. Export intensity does not influence trade receivables efficiency, whereas sales growth does not affect inventory holding efficiency.

Our study should be helpful to future research since it is the first to investigate the key determinants of WCE using the technical efficiency approach of SFA. Furthermore, these key determinants can be used as a benchmark for WCE levels. The key limitation of this study is that the above findings are only limited to the EU. The key determinants of WCE behaviour may differ from other countries/continents, especially in Africa and Asia. Unlike other countries/continents worldwide, the EU has well-developed capital markets, making financings easier and affordable for working capital components. This restricts the generalisability of our findings to other countries/continents. Due to this limitation, there is an avenue for future research to use data from countries/continents with less-developed capital markets to assess the key determinants of WCE.

Data availability

Data will be made available on request.

Appendix 1. List of old and new EU member countries

Old EU countries	New EU countries
Austria	Bulgaria
Belgium	Czech Rep.
Croatia	Estonia
Cyprus	Hungary
Denmark	Latvia
Finland	Poland
France	Romania
Germany	Slovakia
Greece	Slovenia
Ireland	
Italy	
Lithuania	
Luxembourg	
Malta	
Netherlands	
Portugal	
Spain	
Sweden	
UK	

Appendix 2. Nature of products classification using the UK SIC 2003 codes

Nature of product	Standardised products	Services	Differentiated products
Industry classification According to UK SIC 2003 code	1, 2, 7, 8–10, 12–17, 20–24, 26, 28, 29, 31, 33, 40, 43, 46, 58, 60, 62, 63, 64, 67, 70, 72, 76, 80, 81–84, 86–89, 91–97 and 99	41, 42, 44, 45, 47-57, 59, 61, 65, 73, 75, 78 and 79	25, 27, 30, 32 and 34–39

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