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Do trade credit and bank credit complement or substitute each other in public and private firms?

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ABSTRACT

In this study, we analyse the complementary and substitution effect between trade credit (TC) and short-term bank credit (BC) for public and private firms in the UK. Using a sample of **254,352** firm-year observations over the period 2008–**2021**, we find TC and BC are substitutes for public firms that have easy access to cheap external finance. In contrast, TC and BC are complements for private firms that have limited access to alternative financing resources, such as financial markets. Importantly, our results show that public firms are faster in adjusting towards the optimum level of their TC and BC than private firms in an attempt to determine the appropriate mix between these two types of financing. Our study introduces new evidence on the efficient management of TC and BC for public and private firms.

1. Introduction

The use of trade credit (TC) and short-term bank credit (BC) as key sources of corporate funding have attracted much attention from academics, especially in the corporate finance literature (Goto, Xiao, & Xu, 2015; McGuinness, Hogan, & Powell, 2018). The combination of TC and BC financing can yield positive payoff, and it has therefore been used more intensively by firms (Engemann, Eck, & Schnitzer, 2014; Lin & Chou, 2015). Firms, however, can use TC and BC financing as either substitutes or complements (Giannetti, Burkart, & Ellingsen, 2011; Preve, Love, & Sarria-Allende, 2005). In particular, a substitution effect exists when the increase in the use of TC leads to a decrease in the use of BC; and a complementary effect exists when the increase in the use of TC leads to an increase in the use of BC (Engemann et al., 2014; Lin & Chou, 2015).

From a theoretical perspective, the literature suggests that TC and BC are complements if the demand for external finance is inelastic (Myers & Majluf, 1984). That is, if a firm has a limited ability to obtain external financing, then TC and BC may be used together to finance the firm's operations. On the other hand, if the demand for external finance is elastic, then TC and BC may be substitutes, as firms may use one source of finance instead of the other.

Prior research suggests that firms with high information asymmetries have difficulties accessing external finance (Agarwal & O'Hara, 2007; Bharath, Pasquariello, & Wu, 2009; Drobetz, Grüninger, & Hirschvogl, 2010). In order to access cheaper external

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finance, firms must therefore reduce their information asymmetry with providers of external finance. Previous studies have shown differences in the levels of information asymmetry between public and private firms (Brav, 2009; Schenone, 2010), leading to differences in financial structures and financing patterns. For instance, public firms have easy access to heterogeneous forms of external credit and at an affordable cost due to their low information asymmetry (Abdulla, Dang, & Khurshed, 2017; McGuinness et al., 2018). On the other hand, private firms have limited access to external credit because they have high levels of information asymmetry and therefore tend to use TC and BC complementarily.

In recent years there has been a growing interest in the use of TC and BC (e.g., Engemann et al., 2014), **However, despite the growing interest, there is still a lack of empirical evidence on the substitution or complementary effect of BC and TC, particularly for public and private firms. This is an important gap in the literature, as the substitution and complementary relationship between TC and BC may differ significantly between public and private firms. Depending on the needs of the firm, TC can be used to replace BC in order to reduce costs or increase liquidity. Alternatively, BC can be used to supplement TC in order to finance investments in working capital** (Aktas, Croci, & Petmezas, 2015)**. Private firms tend to be more reliant on both TC and BC for financing; however, public firms are more likely to use either TC or BC depending on the availability and cost. Therefore, it is important to understand the relationship between the two types of credit in order to better assess the impact of credit policies on firms. The focus on the UK market is very crucial because unlike many developed economics such as France, Germany and Japan where the banking system still dominates credit allocation, the UK economy is dominated by both the banking and trade credit markets** (Dudley & Hubbard, 2004)**.**

Our study differs from the study by Abdulla et al. (2017)**, which only examines differences between public and private firms in terms of the use of TC. Our study examines the substitution and complementary relationship between TC and BC for public and private firms. Thus, we go further to compare how these two types of firms use TC and BC concurrently. To our knowledge, no study has examined the substitution or complementary effect between TC and BC for public and private firms.**

In an attempt to address this gap in the literature, our study attempts to answer two research questions: (1) Do public and private firms use TC and BC as substitutes or complements? (2) Do public firms adjust their TC and BC faster than their private counterparts to determine the optimum mix of TC and BC?

Using **254,352** firm-year observations over the period 2008–**2021**, we find that public firms reduce their dependence on TC with a corresponding increase in BC and vice versa, suggesting that public firms use TC and BC as substitutes. On the other hand, we find that private firms increase their dependence on TC with a corresponding increase in BC and vice versa, indicating that private firms appear to use TC and BC as complements. In terms of the speed of adjustment towards the target, we find that public firms are able to adjust their TC and BC towards the target levels faster than private firms. Our results are robust to different model specifications (borrowing financial constraint, firm size, and propensity score matching technique, alternative measures of TC and BC, or even after excluding crisis and **Covid-19** periods).

Our study makes two significant contributions to the literature. First, using ownership structure as the basis for research, several studies have examined financial policies differences between public and private firm in areas such as cash management (Gao, Harford, & Li, 2013), capital structure (Brav, 2009) and investment policies (Asker, Farre-Mensa, & Ljungqvist, 2015). We add to the extant literature by investigating the complementarity or substitutability relationship between TC and BC for public and private firms. Although the importance of the combination of TC and BC to firms have long been recognised in the short-term financing literature (e.g., Love & Zaidi, 2010; Palacín-Sánchez, Canto-Cuevas, & di-Pietro, 2019), research on how the ownership structure affects the combined use of these two sources of finance remain scarce. Our findings are in consonance with the information asymmetry and financing theories and show that public firms tend to use TC and BC as substitutes due to low informational asymmetries between firm insiders and public investors. On the contrary, private firms that have difficulties accessing external sources of finance tend to use TC and BC as complements. These findings are also consistent with the signalling theory argument that financially constrained firms use TC to signal their credit quality to banks and also use BC to signal their credit quality to trade suppliers (Atanasova, 2012; Biais & Gollier, 1997). This further explains the reason why private firms that are deemed to be financially constrained use TC and BC to complement each other.

Second, our study examines differences in the speed of adjustment of TC and BC between public and private firms. This is important in ascertaining the dynamism with which public and private firms manage their TC and BC and thereby achieving optimality. The speed of adjustment depends on factors including easy access to alternative sources of finance (Lins, Servaes, & Tufano, 2010), and cheaper cost of finance (Brav, 2009), which are notable differences between public and private firms due to differences information asymmetry (Abdulla et al., 2017). We extend the work of prior research (e.g., Asker et al., 2015; Brav, 2009; Gao et al., 2013) examining the differences in the speed of adjustment between public and private firms by investigating the differences in the target adjustment behaviour of TC and BC management for public and private firms. Our study provides empirical evidence to demonstrate how fast public and private firms adjust their TC and BC financing to determine the optimum mix.

The rest of the paper is organised as follows: Section 2 reviews related research and develop our hypotheses. Section 3 describes the data and research design. Section 4 reports our empirical results. Section 5 reports further evidence. Section 6 reports additional robustness checks. Finally, Section 7 summarises the main findings and concludes.

2. Related research and hypothesis development

2.1. Related research

Several studies have examined the usage of TC and BC, but their findings regarding the relationship between the two short term

credits are not as clear, and the evidence is mixed. Using a sample of 45,598 manufacturing firms from 39 different countries during the 1989–1996 period, Maksimovic (2001)examines the effect of TC on BC and find evidence that TC complements to lending by financial intermediaries. Indeed, their evidence suggests that firms should obtain external financing to fully exploit the benefits of providing TC to their customers.

Similarly, Giannetti et al. (2011) investigate the impact of TC usage on bank-firm relationships and the availability of bank loans and find evidence suggesting a complementary relationship between TC and BC. In particular, the authors report that firms that receive more credit from their suppliers also receive credit from the bank, which indicates that TC facilitates lending from banks (due to a reduction in uncertainty). This is consistent with an earlier study by Gama, Mateus, and Teixeira (2010) that examines the informational role that TC plays in facilitating access to bank debt using a panel data set of small and medium enterprises (SMEs) from Portugal and Spain for the period from 1998 to 2006. The authors find evidence suggesting that TC appears to help SMEs to improve their reputation because it serves as a signal to the banks of their quality, and this, in turn, facilitates the access to bank financing.

Another stream of research has, however, found support for both a complementary and substitution effect between TC and BC. Using quarterly data of 1213 Chinese firms from 2006 to 2012, Burkart and Ellingsen (2004) argue that firms use TC either as substitute for or complement to BC, depending on their investment constraints. In particular, the authors suggest that firms with sufficient borrowing financial capacity appear to substitute TC for BC. In contrast, firms with borrowing constrains tend to use TC and BC as complements. In a similar vein, Yang (2011) analyses the relationship between TC and BC using a total of 72,173 quarterly observations on 1964 manufacturing firms for the period 1986 to 2006. Interestingly, they find that during tight monetary policy periods, TC becomes a 'cheaper' substitute for BC; while in periods of loose monetary policy, TC becomes a more 'expensive' alternative to BC and therefore they are used complementarily. The authors conclude that "the substitute and complement effects are not mutually exclusive but interact simultaneously" (p. 426).

In addition, Engemann et al. (2014) analyse the effect of TC on BC for exporting firms, using a sample of German manufacturing firms from the Economic and Business Data Centre (EBDC) for the period from 1994 to 2009. Their initial analysis shows that TC has a negative effect on BC, which suggests that they are substitutes. However, their further analysis reveals that due to the signalling effect, a complementary effect appears to exist between TC and BC, which attenuates the 'overall' substitution effect. Moreover, Lin and Chou (2015) investigate the impact of supply/demand of TC (i.e., trade receivables/payables) on bank loans and find evidence of a complementary effect between the trade receivables and BC, but a substitution effect between trade payables and BC.

In a recent study, Palacín-Sánchez et al. (2019) investigate the substitute and/or complementary relations between TC and BC using a simultaneous equations model across a large sample of 60,377 European SMEs during the period 2008 to 2014. They find that TC and BC are simultaneously determined, and negatively related to one another; hence, there appears to be a substitutive relation between these two resources in SMEs. Interestingly, their further analysis, however, shows that the relationship is complementary between TC and long-term bank credit; therefore, "long-term bank credit positively affects TC,[1] since suppliers may perceive the attainment of long-term debt by their customers as a positive signal" (p. 1091).

Based on our review above, it appears that there has been a lack of studies examining the differences in the use of TC and BC by publicly listed firms and their privately held counterparts, indicating the importance of listing status on the use of TC and BC in their attempt to capture all relevant factors that may influence the relationship between these two short term financial resources.

2.2. Hypotheses development

2.2.1. Use of TC and BC in public and private firms

Prior research suggests that public firms have easier and cheaper access to external finance as compared to their private counterparts (Abdulla et al., 2017), and thereby enjoy a greater degree of flexibility in choosing between different types of funds from various sources. In many cases, public firms have low information asymmetries (Brav, 2009; Schenone, 2010) and better credit quality (Abdulla et al., 2017). Thus, they have a strong bargaining power (Saunders & Steffen, 2011) and can negotiate highly favourable terms and conditions of credit or loan contracts, as evidenced by lower borrowing costs (Campello, Giambona, Graham, & Harvey, 2011; Gao et al., 2013). This must be true since public firms are better able to handle the credit administration process than their private counterparts (Brav, 2009). In particular, Saunders and Steffen (2011) find evidence to support this argument suggesting that the costs of bank loans to public firms are far lower than that for private firms.

In fact, an important and well-documented research (see Wilner, 2000) suggests that the cost of TC is more expensive than the cost of BC. This, however, depends on a variety of factors, including monetary policy or business cycles (Blasio, 2005; Yang, 2011) and the bargaining power of the respective parties (Fabbri & Klapper, 2016). Since public firms are in a strong bargaining position, they are better able to exploit their borrowing opportunities, and hence substitute between alternative sources of finance (depending on which one is cheaper at the time).

In light of all the above discussion, it thus seems reasonable to expect that TC and BC are substitutes for one another in public firms. Therefore, we develop the following hypothesis:

H1. *Public firms use TC and BC as substitutes; an increase in TC will lead to a decrease in BC and* vice versa.

In contrast, the alternative view suggests private firms use TC and BC complementarily. We argue that the complementary effect

[1] This relationship also operates in the opposite direction in that the suppliers' credit helps reduce the information asymmetries between firms and their bank, which would in turn improve their reputation, thereby facilitating access to bank credit (Alphonse, Ducret, & Séverin, 2006).

between BC and TC is more pervasive among private firms that are more financially constrained (Abdulla et al., 2017; Stiglitz & Weiss, 1981), i.e., firms with restricted access to long-term external finance. Barclay and Smith (1995) and Stohs and Mauer (1996) state that more credit-constrained firms use more short-term credit than long-term credit. Thus, private firms' limited access to other forms of external finance means they must rely heavily on both TC and BC as sources of short-term finance. This is the case for two reasons. First, private firms can access short-term external credit because suppliers/banks are more willing to lend on a short-term basis to credit-constrained firms in their attempts to monitor and force repayment of the credit (Caprio & Demirgüç-Kunt, 1999; Jain, 2001; Petersen & Rajan, 1997).

Second, private firms (which usually have greater informational asymmetry and lower credit quality) tend to use short-term finance (TC and BC) to signal their creditworthiness to the suppliers or banks (Abdulla et al., 2017; Engemann et al., 2014). As Abdulla et al. (2017) argue, access to bank financing can help (private) firms to signal their credit quality to trade suppliers, especially because banks credit screening of their clients is more stringent than that of trade suppliers. Based on the above arguments, the following hypothesis is proposed:

H2. *Private firms use TC and BC as complements; an increase in TC will lead to an increase in BC and vice versa.*

2.2.2. Speed of TC and BC adjustment to the optimum between public and private firms

In their attempt to enhance their performance, we expect public and private firms to adjust towards their optimal levels of TC and BC, but this depends on the costs and benefits associated with the use of TC and BC and the speed of adjusting between the two types of credits. In terms of their benefits, TC and BC serve as important sources of short-term finance for the supply and procurement of production inputs (Goto et al., 2015)and meeting short-term obligations (Diamond, 1991). However, these two short-term sources of funds have short-termism disadvantages (Custódio, Ferreira, & Laureano, 2013). First, TC is less cyclical because it is not automatically rolled over by suppliers (Burkart & Ellingsen, 2004); thus, a firm needs to arrange for TC period with suppliers anytime purchases are made, which is costly and time-consuming.

Second, BC can result in an abrupt firm closure and liquidation if outside funds are not available to meet payments (Diamond, 1991), especially because BC needs costly renegotiations at frequent intervals (Custódio et al., 2013; Diamond, 1993). In this regard, several studies examine the speed of adjustment in corporate policies and report that the ability of a firm to adjust quickly to the target is dependent on the costs of adjustment (Abdulla et al., 2017; Brav, 2009; Gao et al., 2013). That is, firms that face lower costs of adjustment can revert toward the optimal level of TC and BC quicker than those that have higher costs of adjustment.

In terms of public and private firms, we expect public firms to be able to adjust their TC and BC levels to the target faster because of their lower level of information asymmetry (Pagano, Panetta, & Zingales, 1998), reputation (Acharya & Xu, 2017), and strong bargaining power as well as their good/high credit quality (Abdulla et al., 2017). Public firms can use their reputation and strong bargaining power to renegotiate with suppliers/banks to quickly adjust their levels of credits (TC and BC), and thereby reducing the magnitude of the deviation from the optimum level of TC and BC. Based on the above arguments, the following hypothesis is proposed:

H3. *Public firms are faster in adjusting their TC and BC to the optimum than their private counterparts.*

3. Data, sample, and research design

3.1. Data and sample

Our initial sample includes all UK firms drawn from the Financial Analysis Made Easy (FAME) database over the period 2008 to **2021** inclusive.[2] Following the literature, we exclude firm-year observations with missing variables, negative assets and equity, firms that went private during the sample period (e.g., Abdulla et al., 2017) and financial firms (Brav, 2009). To eliminate the influence of outliers, all continuous variables are winsorised at the 1st and 99th percentiles. As such, our final sample consists of **254,352** firm-year observations, made up of **26,272** publicly listed firm-year observations and **228,080** private firm-year observations.[3]

3.2. Empirical models

In order to test whether public and private firms use TC and BC as complements or substitutes, we employ two dependent variables: TC and BC. TC is defined as the ratio of trade payables to total assets (e.g., Abdulla et al., 2017; Fisman & Love, 2003; Giannetti et al., 2011; Petersen & Rajan, 1997), and BC is defined as the ratio of short-term bank credit to total assets (den Bogaerd & Aerts, 2015; Mateut, Mizen, & Ziane, 2015; McGuinness et al., 2018).[4] The primary independent variable in our regressions is *public*, which is a dummy variable that takes one if a firm is listed on London Stock Exchange (LSE) and zero, otherwise (Abdulla et al., 2017).

TC and BC are simultaneously determined (Palacín-Sánchez et al., 2019); therefore, we follow prior research (e.g., Davidson & MacKinnon, 1993) and use a simultaneous equation system via three-stage least squares (3SLS) to address the concerns of the endogenous relations among TC and BC. **The 3SLS is generally more efficient than 2SLS because it is a form of instrumental**

[2] Data from the FAME database has been used in the literature (Bougheas, Mateut, & Mizen, 2009; Cheng & Pike, 2003; Rahaman, 2011).

[3] Studies involving public and private firms have always reported higher number of firm-year observations of private firms than public firms (e.g., Abdulla et al., 2017; Asker et al., 2015).

[4] For robustness tests, both TC and BC are re-defined by scaling each with sales and current liabilities, respectively.

variables estimation that permits correlations of the unobserved disturbances across several equations (Greene, 2008)**. It is also able to restrict the coefficients of different equations, which improves the efficiency of equation by equation estimation by taking into account the correlations across equations. To control for the possible presence of autocorrelation in the panels, we lagged all the independent variables in** Equations (1) and (2)**.**

$$\boldsymbol{TC_{it} = \beta_0 + \beta_2 Public_{1-it} + \beta_3 Public_{1-it} \times BC_{it} + \beta_4 BC_{1-it} + \beta_5 Controls_{1-it} + \mathcal{E}_{it}} \quad (1)$$

$$\boldsymbol{BC_{it} = \beta_0 + \beta_2 Public_{1-it} + \beta_3 Public_{1-it} \times TC_{it} + \beta_4 TC_{1-it} + \beta_5 Controls_{1-it} + \mathcal{E}_{it}} \quad (2)$$

In equation (1), the coefficient β_3 measures the effect of BC on TC use in public firms, whereas β_4 measures the effect of BC on TC used in private firms. In equation (2), the coefficient β_3 measures the effect of TC on BC use in public firms, whereas β_4 measures the effect of TC on BC use of private firms. Therefore, positive β_3 and β_4 indicate complementary use of TC and BC of both public and private firms. However, negative β_3 and β_4 show a substitution effect of TC and BC of both public and private firms.

Following previous studies (e.g., Martínez-Sola, García-Teruel, & Martínez-Solano, 2013; Preve et al., 2005), we control for a set of firm characteristics in both equations. The first control variable is Age measured as (1+ age), where age is defined as the number of years since incorporation at the end of each sample year. We also include Age Squared $(1+ \text{age})^2$ to determine the non-linearity effect of firm age on the use of TC and BC by public and private firms. We control for sales growth, measured as the change in sales from time t-1 to t.

To control for cash holding, we include CHOLD, measured as the ratio of cash and cash equivalent to total assets (Aktas et al., 2015). We control for firm size (Size), defined as the logarithm of total assets. We control for profitability (ROA), measured as the ratio of earnings before interest and tax to total assets (Afrifa, Gyapong, & Monem, 2018). In addition, we control for the ratio of raw materials inventory to total assets ratio (Rinvt/TA) in the TC regressions (only) because raw materials inventory is mainly financed by TC (Palacín-Sánchez et al., 2019; Yang, 2011), and the ratio of equity to intangible assets (Equity/Nontangible) in the BC regressions (only) because it determines the debt capacity of a firm (Goto et al., 2015). We further include industry and year dummies to account for industry-level heterogeneity and time trends in all models. All variables are defined in Table 1.

To examine the speed of adjustment of TC and BC between public and private firms, we estimate the partial adjustment models (3 and 4) separately for public and private firms as follows:

$$\Delta TC_{it} = \beta_0 + \delta\left(TC^*_{it} - TC_{i,t-1}\right) + \beta_1 Controls_{it} + \varepsilon_{it} \quad (3)$$

$$\Delta BC_{it} = \beta_0 + \delta\left(BC^*_{it} - BC_{i,t-1}\right) + \beta_1 Controls_{it} + \varepsilon_{it} \quad (4)$$

Where: ΔTC_{it} is the change in TC from year t−1 to t. ΔBC_{it} is the change in BC from year t−1 to t. $TC_{i,t-1}$ is the lagged value of TC. $BC_{i,t-1}$ is the lagged value of BC. TC^*_{it} is the target TC ratio, which is estimated from a regression of TC on BC and the control variables, separately for public and private firms, as follows:

$$TC_{it} = \beta_0 + \beta_1 BC_{it} + \beta_2 Controls_{it} + \mathcal{E}_{it} \quad (5)$$

BC^*_{it} is the target BC ratio, which is estimated from a regression of BC on TC and the control variables listed above, separately for public and private firms, as follows:

$$BC_{it} = \beta_0 + \beta_1 TC_{it} + \beta_2 Controls_{it} + \mathcal{E}_{it} \quad (6)$$

4. Empirical results

4.1. Descriptive statistics and univariate analysis

Panel A of Table 2 displays the descriptive statistics for the full sample. On average, TC represents **12.5%** of the total assets of the firms in the sample, which is close to the 13.59% reported by Abdulla et al. (2017) in the US and 12% by (Hill, Kelly, Preve, & Sarria-Allende, 2017) in a cross-country study. More specifically, the value of TC for the average firm in our sample equates to approximately **£36.16** million worth of total assets.[5] The average BC is **9.7%**, a figure which is higher than the 3.01% reported by Abdulla et al. (2017) in the US and the 6% by Hill et al. (2017) in an international study. This is equal to approximately **£28.06** million in value of total assets. The descriptive statistics of the control variables are relatively similar to previous studies (e.g., Afrifa et al., 2018; Aktas et al., 2015; Goto et al., 2015).[6]

Panel B of Table 2 presents TC and BC differences between public and private firms. It shows that public firms use less TC (mean of **9.9%**) and less BC (mean of **7.1%**) than their private counterparts that have a mean TC of **12.8%** and a mean BC of **10.1%**, which is in line with the findings of Abdulla et al. (2017) and Lin and Chou (2015).

Table 3 reports a correlation analysis of the variables. The table shows that the correlations between the variables are low. **More specifically, the correlations of the public dummy with TC and BC are (−0.414) and (−0.455), respectively.** We also check the variance inflation factors (VIFs) of the coefficients in our models and find that they fall below the acceptable threshold of 10,

[5] The mean value of total assets in our sample is **£289.269** million.

[6] To preserve space, we do not discuss the descriptive statistics of the control variables.

Table 1
Variables definitions.

Name	Definition
Trade payables (TC)	Trade payables scaled by total assets.
Short term bank credit (BC)	Short term bank credit scaled by total assets
Public status (Public)	A dummy variable which is equals to 1 if a firm is public on the LSE and zero, otherwise
Age	Number of years between incorporation and the calendar year end of each firm.
Sales growth	One-year growth rate of sales at time t-1: ($SALE_t$-$SALE_{t-1}$)/ $SALE_{t-1}$
Cash holdings (CHOLD)	Cash and cash equivalents, scaled by total assets.
Size	The natural logarithm of total assets of firms
Return on assets	Net profit for the period plus depreciation scaled by total assets
Equities/Nontangibles	The total equity divided by the difference between total assets and tangible assets.
Rinvt/TA	Raw materials inventory scaled by total assets
Financial constraint	An index constructed as the linear combination as follows: $-0.123 \times Size_{i,t-1} - 1.716 \times$ Cash holding$_{i,t-1} - 4.404 \times ROA_{i,t-1} - 0.024 \times$ interest coverage$_{i,t-1}$.
SME	A dummy variable equal to 1 for small and medium enterprises and 0 for large firms
Crisis	A dummy variable equals one if years 2008–2009, otherwise zero
Covid-19	A dummy variable equals one if years 2019–2021, otherwise zero

Table 2
Descriptive statistics.

Panel A: Summary statistics

Variables	Obs.	Mean	Std Dev	P50	P10	P25	P95
TC	254352	0.125	0.022	0.129	0.094	0.111	0.153
BC	254352	0.097	0.020	0.097	0.085	0.090	0.130
Public	254352	0.103	0.304	0.000	0.000	0.000	1.000
Public x TC	254352	0.010	0.032	0.000	0.000	0.000	0.095
Public x BC	254352	0.007	0.023	0.000	0.000	0.000	0.083
Age (log)	254352	2.598	0.752	2.633	1.585	2.082	3.804
Sales growth	254352	0.079	0.182	0.084	0.000	0.017	0.399
CHOLD	254352	0.143	0.029	0.128	0.121	0.124	0.194
Size (log)	254352	10.117	1.540	9.756	8.548	8.988	13.187
ROA	254352	0.048	0.022	0.047	0.021	0.036	0.071
Equity/Nontangibles	254352	1.540	0.144	1.628	1.379	1.409	1.713
Rinvt/TA	254352	0.157	0.063	0.165	0.061	0.126	0.236
Financial constraint	254352	0.071	0.327	−0.059	−0.170	−0.076	0.737
SME	254352	0.588	0.492	1.000	0.000	0.000	1.000

Panel B: Univariate analysis

Variable	Public firms		Private firms		Mean test (p-value)
	N	Mean	N	Mean	
TC	26272	0.099	228080	0.128	0.000
BC	26272	0.071	228080	0.101	0.000

Panel A of this table presents descriptive statistics for the variables in the empirical models and univariate analysis for the two main dependent variables (TC and BC) in panel B. TC is trade payables scaled by total assets. BC is short term bank credit scaled by total assets. Public is a dummy variable equals to 1 for publicly listed firms and 0 otherwise. Age is the number of years of the firm. Sales growth is the one-year growth rate of sales at time t-1. CHOLD is cash and cash equivalent scaled by total assets. Size is the natural logarithm of total assets. ROA is the return on assets. Equity/Nontangible is the total equity divided by the difference between total assets and tangible assets. Rinvt/TA is raw materials inventory scaled by total assets. Financial constraint is an index constructed as the linear combination as follows: $-0.123 \times Size_{i,t-1} - 1.716 \times$ Cash holding$_{i,t-1} - 4.404 \times ROA_{i,t-1} - 0.024 \times$ interest coverage$_{i,t-1}$. SME is a dummy variable equal to 1 for small and medium enterprises and 0 for large firms. See Table I for all variable definitions.

suggesting that multicollinearity is not a serious concern.

4.2. Baseline regression results

In this section, we present the results from the simultaneous equations model defined in equation (1) and equation (2) for the two endogenous variables, namely TC and BC. This enables us to explore the interacted effects of TC and BC for public and private firms. Table 4 presents the results of the two-equation simultaneous system regressions testing whether BC substitutes or complements TC in public and private firms and vice versa. In the two-equation system, we find significant relations among the two endogenous variables, TC and BC. However, relations are not the same for public and private firms. The results in column (1), excluding industry and year dummies show a negative and statistically significant coefficient of the interaction variable *public* × *BC* (**β= –0.101**) at the **1**% level.

Table 3
Correlation matrix.

Variables	1	2	3	4	5	6	7	8	9	10	11
TC	1										
BC	0.294*	1									
Public	−0.414*	−0.455*	1								
Age	0.001	0.083*	−0.002	1							
Sales growth	0.108*	0.105*	−0.013*	0.013*	1						
CHOLD	−0.153*	−0.139*	0.278*	0.003*	−0.006*	1					
Size	−0.228*	0.101*	0.102*	−0.033*	0.012*	0.080*	1				
ROA	0.004*	0.191*	−0.116*	−0.008*	0.277*	−0.190*	0.032*	1			
Equity/Nontangibles	0.098*	0.226*	−0.115*	0.319*	0.026*	−0.100*	−0.090*	0.038*	1		
Rinvt/TA	0.230*	−0.002	0.048*	−0.020*	0.078*	0.073*	−0.260*	−0.050*	0.006*	1	
Financial constraint	0.158*	−0.084*	−0.065*	−0.103*	0.007*	−0.053*	−0.025*	−0.080*	−0.105*	0.053*	1
SME	0.216*	0.036*	−0.260*	−0.106*	0.004	−0.066*	−0.048*	−0.048*	−0.082*	0.061*	0.446*

This table reports the correlation matrix of the variables under consideration. TC is trade payables scaled by total assets. BC is short term bank credit scaled by total assets. Public is a dummy variable equals to 1 for publicly listed firms and 0 otherwise. Age is the number of years of the firm. Sales growth is the one-year growth rate of sales at time t-1. CHOLD is cash and cash equivalent scaled by total assets. Size is the natural logarithm of total assets. ROA is the return on assets. Equity/Nontangible is the total equity divided by the difference between total assets and tangible assets. Rinvt/TA is raw materials inventory scaled by total assets. Financial constraint is an index constructed as the linear combination as follows: $-0.123 \times \text{Sizei}_{,t-1} - 1.716 \times \text{Cash holdingi}_{,t-1} - 4.404 \times \text{ROAi}_{,t-1} - 0.024 \times \text{interest coveragei}_{,t-1}$. SME is a dummy variable equal to 1 for small and medium enterprises and 0 for large firms. See Table I for all variable definitions.
* indicates statistical significance at the 5%.

For private firms, the coefficient of BC is positive and statistically significant (**β= 0.254**) at the 1% level.

In column (2), we include industry and year dummies and find that the point estimates on *public* × *BC* (**β= −0.159**) and *BC* (**β= 0.278**) are statistically significant at the 1%-level**. This indicates that the increase of BC in public firms leads to a reduction of TC by 15.9% while for private firms, the increase of BC leads to an increase of TC by 27.8%. This resultant economic effect is meaningful: a one standard deviation increase in BC of public (private) firms is associated with a decrease (increase) of TC by 2.926% (4.448%).**[7]

For the BC equation, the results in the third column, without year and industry dummies, show a negative and statistically significant coefficient of the interaction variable *public* × *TC* (**β= −0.017**). This means that, for public firms, the increase in TC leads to a reduction in BC. For private firms, however, the coefficient of TC is positive and statistically significant (**β= 0.189**) at the 1% level, which suggests that an increase of TC leads to an increase of BC. The point estimates on public × TC (**β= −0.036**) and TC (**β= 0.195**) are also statistically significant at the 1%-level when we include the year and industry dummies in the regression as the results in column (4) show. **In terms of economic significance, the result shows that an increase in TC of public (private) firms by one standard deviation decreases (increases) BC by 1.188% (4.423%).**[8] Thus far, results support hypothesis (1) in that public firms use BC to substitute TC and vice versa. Hypothesis (2) is also supported because private firms use BC to complement TC and verse versa.

Concerning the control variables in columns (1) to (4), the results show that Age has a negative (positive) association with TC (BC), indicating that firms with higher credit quality measured by age enjoy more BC and TC (Palacín-Sánchez et al., 2019; Petersen & Rajan, 1997).

The coefficients of sales growth is positive and statistically significant in all columns, which is consistent with the findings by Abdulla et al. (2017). A possible explanation of this result is that firms with positive sales growth tend to use more TC and BC due to their greater needs of trade financing (Ferrando & Mulier, 2013).

The negative effect of CHOLD on TC and BC indicates that higher cash holding leads to lower use of both suppliers' credit and bank credit. Size is negatively (positively) associated with TC (BC), supporting the notion that larger firms depend less on suppliers' credit (Afrifa & Gyapong, 2017). ROA is negative (positive) and statistically associated with TC (BC), which indicates that profitable firms depend less (more) on trade credit (bank credit).

Not surprisingly, Rinvt/TA is positively associated with TC in columns (1) and (2), as inventory is mainly financed by TC (Palacín-Sánchez et al., 2019; Yang, 2011). In columns (3) and (4), Equity/Nontangible is positively associated with BC as higher Equity/Nontangible indicates a higher borrowing capacity (Goto et al., 2015).

4.3. Speed of TC and BC adjustments to the optimum

In response to Hypothesis 3, we test the differences in speed of TC and BC adjustments to the optimum between public and private firms. The results are presented in Table 5. With regards to the question as to which of the two firms has a faster speed of adjustment, the results in columns (1) and (2) show that public firms (**β = 5.155**) have a faster speed of TC adjustment to the optimum than private firms (**β= 2.009**). The results in columns (3) and (4) further show that public firms (**β = 15.193**) are once again faster in adjusting their BC to the optimum than their private counterparts (**β = 9.081**). These results are not surprising, given the relatively cheaper sources of finance and superior bargaining power of public firms.

5. Additional analyses

5.1. Regression results conditional on borrowing financial constraint

Firms that are more financially constrained may struggle to meet their credit levels without the use of TC and BC as complements. High financial constraint is associated with reduced access to external credit and higher cost of credit (Myers & Majluf, 1984; Stiglitz & Weiss, 1981). Firms that are more financially constrained may find it difficult to access BC because of lack of collateral (Goto et al., 2015). Although suppliers may be willing to offer TC to more financially constrained firms because of their superior monitoring advantage of customers over banks (Freixas, 1993; Mian & Smith, 1992), suppliers may not meet the maximum credit demand by those firms (Abdulla et al., 2017; McGuinness et al., 2018).

One of the conditions that determine a firm's choice between TC and BC has been documented as financial constraint (Bose, MacDonald, & Tsoukas, 2019; Burkart & Ellingsen, 2004; Yang, 2011). Our main results so far suggest that public (private) firms that are less (more) financially constrained use TC and BC as substitutes (complements). To the extent that these results are driven by the financial constraint borne by the firm, we expect more financially constrained public and private firms to use TC and BC as complements rather than substitutes. Therefore, this section examines whether financial constraint influences the substitution or complementary use of TC and BC of public and private firms.

[7] The economic significances are calculated as follows: for public firms we multiply the coefficient of Public x BC with its standard deviation, and then divided by the mean of TC [i.e., (−0.159 × 0.023)/0.125]x 100 = 2.926%. For private firms, we multiply the coefficient of BC with its standard deviation, and then divided by the mean of TC [i.e., (0.278 × 0.020)/0.125]x 100 = 4.448%.

[8] The economic significances are calculated as follows: for public firms we multiply the coefficient of Public x TC with its standard deviation, and then divided by the mean of BC [i.e., (−0.036 × 0.032)/0.097]x 100 = 1.188%. For private firms, we multiply the coefficient of TC with its standard deviation, and then divided by the mean of BC [i.e., (0.195 × 0.022)/0.097]x 100 = 4.423%.

Table 4
Baseline results.

VARIABLES	(1)	(2)	(3)	(4)
	TRADE CREDIT		BANK CREDIT	
Public	−0.010***	−0.005***	−0.020***	−0.017***
	(0.001)	(0.001)	(0.000)	(0.000)
Public * BC	−0.101***	−0.159***		
	(0.006)	(0.006)		
Public * TC			−0.017***	−0.036***
			(0.004)	(0.004)
BC	0.254***	0.278***		
	(0.003)	(0.003)		
TC			0.189***	0.195***
			(0.002)	(0.002)
Age	−0.001***	−0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Sales growth	0.007***	0.007***	0.001***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
CHOLD	−0.066***	−0.110***	−0.073***	−0.105***
	(0.002)	(0.002)	(0.001)	(0.002)
Size	−0.003***	−0.003***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
ROA	−0.068***	−0.070***	0.093***	0.103***
	(0.002)	(0.002)	(0.002)	(0.002)
Rinvt/TA	0.061***	0.068***		
	(0.001)	(0.001)		
Equity/Nontangibles			0.016***	0.016***
			(0.000)	(0.000)
Constant	0.132***	0.141***	0.032***	0.025***
	(0.000)	(0.001)	(0.001)	(0.001)
Industry dummies	No	Yes	No	Yes
Year dummies	No	Yes	No	Yes
Observations	179,679	179,679	179,679	179,679
R-squared	0.262	0.284	0.327	0.348

This table presents the complementary and substitutive effect between trade credit (TC) and short-term bank credit (BC) for public and private firms in the UK. TC is trade payables scaled by total assets. BC is short term bank credit scaled by total assets. Public is a dummy variable equals to 1 for publicly listed firms and 0 otherwise. Age is the number of years of the firm. Sales growth is the one-year growth rate of sales at time t-1. CHOLD is cash and cash equivalent scaled by total assets. Size is the natural logarithm of total assets. ROA is the return on assets. Equity/Nontangible is the total equity divided by the difference between total assets and tangible assets. Rinvt/TA is raw materials inventory scaled by total assets. See Table I for all variable definitions.
***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

We follow a previous study by Schauer, Elsas, and Breitkopf (2019)and measure financial constraint by constructing an index for *Financial constraint as a* linear combination as follows:

$$Financial\ constraint_{it} = -0.123 \times Size_{it-1} - 1.716\ \ Cash\ holding_{i,t-1}$$

$$-4.404 \times ROA_{i,t-1} - 0.024 \times Interest\ coverage_{i,t-1} \quad (6)$$

where: Size is the natural logarithm of total assets, Interest coverage is the ratio of earnings before interest and tax and interest expenses, ROA is the ratio of net income and total assets, and cash holdings is the ratio of cash and cash equivalents and total assets. The index is calculated by lagging each variable. In the determination of financial constraint, a lower (higher) index indicates less (more) financial constraint.

This measure of financial constraint is new and novel, which allows the simultaneous comparison of the level of the financial constraint of public and private firms using the same variables. As argued by Schauer et al. (2019), many previous measures of financial constraint have mainly focused on listed firms, and with variables that cannot be applied to private firms (e.g., Erel, Jang, & Weisbach, 2015; Whited & Wu, 2006). Firms with a low index are expected to be able to secure the needed credit from either banks or trade suppliers, and as such are able to replace either TC or BC with the other in achieving their credit level, suggesting a substitution effect. On the other hand, firms with a high index may receive less credit from both banks and suppliers, and must, therefore, use TC and BC as complements.

The results are presented in columns (1)–(2) of Table 6. Before moving on to the main variables of interest, we observe that the variable *Financial constraint* is negative and statistically significant. This is consistent with previous studies and shows that financial constraint negatively affects access to external credit (Goto et al., 2015; Myers & Majluf, 1984). In column (1), the two main variables of interest are *public* × *BC* × *Financial constraint*, which measures the effect of BC use on TC of public firms that are more financially constrained, and *BC* × *Financial constraint*, which measures the effect of BC use on TC of private firms that are more financial constrained. The results presented in column (1) show positive and statistically significant coefficient of *public* × *BC* × *Financial constraint*

Table 5
Speed of Adjustment toward TC and BC of public and private firms.

VARIABLES	(1)	(2)	(3)	(4)
	TRADE CREDIT		BANK CREDIT	
	Private	Public	Private	Public
$TC^*_{it} - TC_{i,t-1}$	2.009***	5.155***		
	(0.013)	(0.183)		
$BC^*_{it} - BC_{i,t-1}$			9.081***	15.193***
			(0.046)	(0.298)
Age	−0.001***	0.022***	−0.007***	−0.024***
	(0.000)	(0.007)	(0.001)	(0.008)
Sales growth	0.023***	−0.019	0.074***	0.084***
	(0.001)	(0.027)	(0.003)	(0.031)
CHOLD	0.031***	−0.071	0.129***	0.600***
	(0.010)	(0.156)	(0.036)	(0.193)
Size	0.001***	−0.004	−0.008***	−0.014***
	(0.000)	(0.003)	(0.000)	(0.004)
ROA	−0.067***	0.560***	−0.255***	−0.589**
	(0.010)	(0.215)	(0.035)	(0.241)
Rinvt/TA	0.007**	−0.096		
	(0.003)	(0.086)		
Equity/Nontangibles			−0.009*	−0.247***
			(0.005)	(0.048)
Constant	−0.004*	7.091**	0.070***	26.844***
	(0.003)	(3.538)	(0.011)	(4.011)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	159,930	19,749	159,930	19,749
R-squared	0.134	0.040	0.213	0.126

This table presents the results of the speed of adjustment toward TC and BC of public and private firms. TC is trade payables scaled by total assets. BC is short term bank credit scaled by total assets. TC* is the target TC. BC* is the target BC. Public is a dummy variable equals to 1 for publicly listed firms and 0 otherwise. Age is the number of years of the firm. Sales growth is the one-year growth rate of sales at time t-1. CHOLD is cash and cash equivalent scaled by total assets. Size is the natural logarithm of total assets. ROA is the return on assets. Equity/Nontangible is the total equity divided by the difference between total assets and tangible assets. Rinvt/TA is raw materials inventory scaled by total assets. See Table I for all variable definitions.
***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

(**β= 0.548**), suggesting that public firms that are more financially constrained use BC to complement TC.

On the other hand, the coefficient of *BC* × *Financial constraint* (**β= 0.018**) is positive and statistically significant, indicating that private firms that are more financially constrained further increase their dependence on TC when they have access to BC. In column (2), the coefficient of *public* × *TC* × *Financial constraint* (**β= 0.094**) is positive and statistically significant. This indicates that public firms that are more financially constrained use TC to complement BC. With regards to private firms that are financially constrained, *TC* × *Financial constraint* (**β= 0.091**), the coefficient is also positive and statistically significant. Thus, private firms that are financially constrained also increase BC with an increase of TC.

5.2. Regression results conditional on firm size classification

The extant research suggests a sharp contrast in access to finance between large and SME firms (Beck, Demirgüç-Kunt, & Maksimovic, 2005; Demirgüç-Kunt & Maksimovic, 1999; Dinh, Mavridis, & Nguyen, 2012). In fact, for SMEs, access to finance is their major concern (Beck, Demirgüç-Kunt, & Singer, 2013). Compared with large firms, external providers of finance are reluctant to grant credit to SMEs because of their information opaqueness (Bhalla & Kaur, 2012) and proneness to failure (Rahaman, 2011; Sogorb-Mira, 2005). According to the extant literature, even public SMEs still have difficulties accessing public debt (Colombelli, 2010).

Many studies have used firm size as a measure of financial constraint, arguing that the smaller the firm, the more financially constrained (Hadlock & Pierce, 2010). To the extent that our results in Table 4 are driven by the firm level of financial constraint, then we expect public and private SMEs, which are considered more financially constrained, to use TC and BC as complements. In grouping the firms in our sample into large or SME, we follow the UK firm size definitions. More specifically, a firm is classified as SME if the total number of employees is below the 250 thresholds. Therefore, a dummy variable, SME is created which is equal to one for SMEs and zero otherwise.

The results conditional on SME dummy is presented in columns (3)–(4) of Table 6. In column (3), the two main variables of interest are *public* × *BC* × *SME*, which measures the marginal effect of BC on TC use of public SMEs, and *BC* × *SME* which measures the marginal effect of BC on TC use of private SMEs. The results show a positive and statistically significant coefficient of *public* × *BC* × *SME* (**β = 0.252**). Thus, public SMEs increase their dependence on TC by **2.52**% with a 10% increase in BC. This is consistent with our expectation and suggests that public SMEs use BC to complement TC. Similar to the main results, the coefficient of *BC* × *SME* is positive and statistically significant (**β= 0.043**), suggesting a complementary effect of BC on TC of private SMEs. More specifically, a 10%

Table 6
Regression results based on borrowing Financial constraint and firm size.

VARIABLES	(1)	(2)	(3)	(4)
	FINANCIAL CONSTRAINT		SMEs	
Public	−0.012***	−0.020***	−0.007***	−0.024***
	(0.001)	(0.000)	(0.001)	(0.001)
Public × BC	−0.054***		−0.127***	
	(0.006)		(0.008)	
Public × TC		−0.018***		0.043***
		(0.004)		(0.005)
BC	0.269***		0.244***	
	(0.003)		(0.006)	
TC		0.196***		0.117***
		(0.002)		(0.003)
Financial constraint	0.005***	−0.014***		
	(0.001)	(0.001)		
Public × Financial constraint	−0.034***	−0.014***		
	(0.001)	(0.001)		
BC × Financial constraint	0.018**			
	(0.008)			
TC × Financial constraint		0.091***		
		(0.008)		
Public × BC × Financial constraint	0.548***			
	(0.015)			
Public × TC × Financial constraint		0.094***		
		(0.011)		
SME			0.001	−0.020***
			(0.001)	(0.001)
Public × SME			−0.012***	−0.014***
			(0.001)	(0.001)
BC × SME			0.043***	
			(0.006)	
TC × SME				0.161***
				(0.004)
Public × BC × SME			0.252***	
			(0.014)	
Public × TC × SME				0.019**
				(0.009)
Age	−0.001***	0.001***	−0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Sales growth	0.006***	0.001***	0.006***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
CHOLD	−0.067***	−0.072***	−0.073***	−0.065***
	(0.002)	(0.002)	(0.002)	(0.002)
Size	−0.002***	0.002***	−0.003***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
ROA	−0.063***	0.084***	−0.063***	0.083***
	(0.002)	(0.002)	(0.002)	(0.002)
Rinvt/TA	0.059***		0.058***	
	(0.001)		(0.001)	
Equity/Nontangibles		0.015***		0.016***
		(0.000)		(0.000)
Constant	0.099***	−0.094***	0.341***	−0.106***
	(0.024)	(0.020)	(0.023)	(0.020)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	179,679	179,679	179,679	179,679
R-squared	0.281	0.335	0.278	0.345

This table presents the results of the borrowing constraint and firm size on the complementary and substitutive effect between trade credit (TC) and short-term bank credit (BC) for public and private firms in the UK. TC is trade payables scaled by total assets. BC is short term bank credit scaled by total assets. Public is a dummy variable equals to 1 for publicly listed firms and 0 otherwise. Age is the number of years of the firm. Sales growth is the one-year growth rate of sales at time t-1. CHOLD is cash and cash equivalent scaled by total assets. Size is the natural logarithm of total assets. ROA is the return on assets. Equity/Nontangible is the total equity divided by the difference between total assets and tangible assets. Rinvt/TA is raw materials inventory scaled by total assets. Financial constraint is an index constructed as the linear combination as follows: $-0.123 \times \text{Sizei}_{,t\text{-}1} - 1.716 \times \text{Cash holdingi}_{,t\text{-}1} - 4.404 \times \text{ROAi}_{,t\text{-}1} - 0.024 \times \text{interest coveragei}_{,t\text{-}1}$. SME is a dummy variable equal to 1 for small and medium enterprises and 0 for large firms. See Table I for all variable definitions.
***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

increase in BC leads to a **0.43**% increase in TC.

In column (4), the two main variables of interest are *public* × *TC* × *SME* which measures the marginal effect of TC on BC use of public SMEs, and *TC* × *SME* which measures the marginal effect of TC on BC use of private SMEs. The results show a positive and statistically significant coefficient of *public* × *TC* × *SME* (**β= 0.019**). Thus, public SMEs increase their dependence on BC by **0.91**% with a 10% increase of TC. This shows that public SMEs complement TC with BC. With regards to private SMEs, the coefficient of *TC*×*SME* is positive and statistically significant (**β= 0.161**), showing the complementary effect of TC on BC of private SMEs. Specifically, a 10% increase in TC leads to a **1.61**% increase in BC. Overall, the results indicate that public SMEs are financially constrained, which is not surprising, given that banks and other financial institutions still see public SMEs as risky (Treanor, 2007, p. 10). Therefore, although SMEs go public in the UK to raise external finance (Albornoz & Pope, 2004), our results show that SMEs do not get the needed external financing from going public. These results collaborate previous literature which suggests that firm size is a measure of financial constraint (Abdulla et al., 2017; Guariglia & Yang, 2016).

6. Robustness checks

6.1. Propensity score matching

To check the robustness of our main results reported to differences in firms individual characteristics, we follow similar previous studies and match public and private firms on known, observed characteristics (Abdulla et al., 2017). Thus, the propensity score matching technique examines whether TC and BC are used as substitutes or complements by public and private firms with comparatively similar characteristics. The propensity scores come from a probit regression, where the dependent variable is *public*. Because the private firms are more than the public firms, we consider the public firms as the treated group and the private firms as the controlled group. Therefore, each of the public firm-year observations is matched with a corresponding private firm-year observation using the propensity score of being a public firm.

Table 7
Regression results based on propensity score matching and survivorship bias.

VARIABLES	(1)	(2)	(3)	(4)
	PROPENSITY SCORE MATCHING		SURVIVORSHIP BIAS	
Public	0.013***	0.000	−0.005***	−0.010***
	(0.001)	(0.001)	(0.001)	(0.001)
Public × BC	−0.379***		−0.155***	
	(0.014)		(0.009)	
Public × TC		−0.186***		−0.077***
		(0.009)		(0.005)
BC	0.407***		0.284***	
	(0.011)		(0.004)	
TC		0.237***		0.207***
		(0.008)		(0.003)
Age	−0.003***	0.000	−0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Sales growth	0.003***	−0.000	0.006***	0.001***
	(0.001)	(0.001)	(0.000)	(0.000)
CHOLD	−0.097***	−0.202***	−0.039***	−0.149***
	(0.004)	(0.003)	(0.003)	(0.002)
Size	−0.005***	0.001***	−0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
ROA	−0.046***	0.122***	−0.081***	0.080***
	(0.005)	(0.004)	(0.003)	(0.002)
Rinvt/TA	0.010***		0.063***	
	(0.002)		(0.001)	
Equity/Nontangibles		0.034***		0.014***
		(0.001)		(0.000)
Constant	1.133***	0.549***	0.378***	0.247***
	(0.071)	(0.056)	(0.034)	(0.026)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	37,822	37,822	101,573	101,573
R-squared	0.359	0.504	0.221	0.340

This table presents the propensity score matching and survivorship bias results of the complementary and substitutive effect between trade credit (TC) and short-term bank credit (BC) for public and private firms in the UK. TC is trade payables scaled by total assets. BC is short term bank credit scaled by total assets. Public is a dummy variable equals to 1 for publicly listed firms and 0 otherwise. Age is the number of years of the firm. Sales growth is the one-year growth rate of sales at time t-1. CHOLD is cash and cash equivalent scaled by total assets. Size is the natural logarithm of total assets. ROA is the return on assets. Equity/Nontangible is the total equity divided by the difference between total assets and tangible assets. Rinvt/TA is raw materials inventory scaled by total assets. See Table I for all variable definitions.
***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

The propensity scores matching method we choose is the one-to-one matching to the nearest neighbourhood without replacement. The matching is based on all the control variables used in the equations, as well as the year and industry effects. Unreported results show that the mean and median test on the control variables between public and private firms are not significant, meaning the propensity score-matched samples of public (treated) and private (controlled) firms are broadly similar.

The results based on the propensity score-matched sample are reported in columns (1) and (2) of Table 7. The same econometric technique and control variables, as in Table 4, are used. The results in columns (1) and (2) are qualitatively similar to those reported in Table 4. The results show that public firms use BC (**β= −0.379**) and TC (**β= −0.186**) to substitute each other, whereas private firms use BC (**β= 0.407**) and TC (**β= 0.237**), as complements. These findings, therefore, corroborate the previous findings and show that public and private firms with similar characteristics use TC and BC differently as substitutes and complements, respectively.

6.2. Survivorship bias

Survivorship bias occurs when firms are excluded from the sample because of lack of data (Kestens, Cauwenberge, & Bauwhede, 2012). This is important in our study because lack of access to bank finance or supplier finance may cause firms to drop out (Aterido, Beck, & Iacovone, 2011; Dinh et al., 2012), therefore leading to incomplete data (Afrifa, Alshehabi, Tingbani, & Halabi, 2020). To try and curtail survivorship bias, we included all observations available when we ran the regressions (Goto et al., 2015). However, this may cause our results to be driven by the firms with complete data during the sample period. Therefore, following Schaeck and Cihak

Table 8
Regression results based on alternative and industry/year adjusted measures.

VARIABLES	(1)	(2)	(3)	(4)
	ALTERNATIVE MEASURE		INDUSTRY ADJUSTED	
Public	−0.021***	−0.004***	0.015***	−0.014***
	(0.000)	(0.001)	(0.000)	(0.001)
Public × BC	−0.010**			
	(0.004)			
Public × TC		−0.160***		
		(0.006)		
BC	0.188***			
	(0.002)			
TC		0.289***		
		(0.003)		
Public × Indadj.BC			−0.305***	
			(0.031)	
Public × Indadj.TC				−0.054***
				(0.009)
Indadj.BC			1.923***	
			(0.030)	
Indadj.TC				0.458***
				(0.009)
Age	0.002***	−0.001***	−0.006***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Sales growth	0.001***	0.008***	−0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
CHOLD	−0.085***	−0.079***	−0.076***	0.017***
	(0.002)	(0.002)	(0.005)	(0.002)
Size	0.002***	−0.003***	−0.007***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)
ROA	0.097***	−0.080***	−0.288***	0.152***
	(0.002)	(0.002)	(0.004)	(0.002)
Rinvt/TA	0.013***		0.008***	
	(0.001)		(0.002)	
Equity/Nontangibles		0.001***		0.007***
		(0.000)		(0.000)
Constant	−0.143***	0.297***	0.483***	−0.247***
	(0.020)	(0.024)	(0.041)	(0.020)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	179,679	179,679	254,352	254,352
R-squared	0.314	0.236	−2.065	−0.010

This table presents the results of alternative and industry adjusted measures on the complementary and substitutive effect between trade credit (TC) and short-term bank credit (BC) for public and private firms in the UK. TC is trade payables scaled by sales revenue. BC is short term bank credit scaled by current liabilities. Public is a dummy variable equals to 1 for publicly listed firms and 0 otherwise. Age is the number of years of the firm. Sales growth is the one-year growth rate of sales at time t-1. CHOLD is cash and cash equivalent scaled by total assets. Size is the natural logarithm of total assets. ROA is the return on assets. Equity/Nontangible is the total equity divided by the difference between total assets and tangible assets. Rinvt/TA is raw materials inventory scaled by total assets. See Table I for all variable definitions.
***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

(2012) and Afrifa et al. (2020), we conducted a robustness check by only including firms with incomplete data during the sample period in the analysis.

The results in columns (3) and (4) of Table 7 show that public firms use BC (**β= −0.155**) and TC (**β= −0.077**) as substitutes, whereas private firms use BC (**β= 0.284**) and TC (**β= 0.207**) as complements. These are in line with our main results in Table 4 and thus, our results are robust to survivorship bias.

6.3. Alternative measures of TC and BC

To check the robustness of our main results reported in Table 4 to alternative measures of the dependent variables, we re-define our dependent variables by scaling TC and BC with sales and current liabilities, respectively. Studies that have used these measures include Ferrando and Mulier (2013), Atanasova (2012), Barrot (2016), and Afrifa et al. (2018). The same econometric equations and control variables in Table 4 are used. The results are displayed in Table 8. Similar to the main results in Table 4, the results in columns (1) and (2) show that public firms use BC (**β= −0.010**) and TC (**β= −0.160**) as substitutes. With regards to private firms, the results indicate their use of BC (**β= 0.188**) and TC (**β= 0.289**) as complements.

To further assess the robustness of the main findings, we also use the industry adjusted TC and BC in columns (3) and (4) of Table 8. This is because previous studies show that TC use is industry-related (Gyimah, Machokoto, & Sikochi, 2020). The industry adjusted values of TC and BC are computed as the difference between each firm's yearly TC and BC minus the industry average. To calculate the industry averages, we rely on the UK SIC 2003 industry classification. The results, when using the industry adjusted TC and BC, are qualitatively similar to the results contained in Table 4. Thus, our main findings are not sensitive to alternative measures of TC and BC.

6.4. Focus on the non-crisis period

This section assesses whether the main findings of substitution and complimentary use of TC and BC of public and private firms, respectively, are influenced by a financial crisis. This is important because the 2007–2009 crisis period led to a severe credit tightening (Carbo-Valverde, Rodriguez-Fernandez, & Udell, 2016; Casey & O'Toole, 2014), which resulted in the reduction of both TC and BC (Kestens et al., 2012; McGuinness & Hogan, 2016).

Many studies have shown that the value relevance of external credit is different between crisis and non-crisis periods (Lamberson, 1995; Martínez-Sola, García-Teruel, & Martínez-Solano, 2014). More importantly, the redistributive effect of TC was attenuated during the crisis period due to lack of BC (Preve et al., 2005). However, other studies have also found support for the redistributive effect of TC when BC is squeezed (Berger & Udell, 1998; Biais & Gollier, 1997; Guariglia & Mateut, 2006). Thus, our main results reported in Table 4 may have been influenced by the financial crisis of 2007–2009.

We, therefore, exclude the crisis periods of 2008–2009[9] from our sample and re-run regression models (1)–(2) and report the results in Table 9. The results in columns (1) to (2) also show that public firms use BC (**β= −0.080**) and TC (**β= −0.038**) as substitutes. On the other hand, private firms use BC (**β= 0.314**) and TC (**β= 0.198**) as complements. These results are the same as those reported in Table 4 and therefore, show that our main results are not sensitive to the recent financial crisis.

6.5. Focus on the non-covid-19 pandemic

We further explore the sensitivity of our analysis to the Covid-19 pandemic, which has had a significant impact on the global economy, leading to major disruptions in financial markets and a decrease in the availability of BC. As a result, many firms have had to turn to non-bank sources of financing, including TC. Given the importance of TC in providing liquidity and working capital to businesses, it would be useful to understand how the Covid-19 pandemic influenced the relationship between TC and BC for both public and private firms.

Recent literature has suggested that the Covid-19 pandemic could lead to a substitution between trade credit and bank credit, with firms increasingly relying on TC rather than BC (Liu, He, & Zhang, 2020; Yıldırım & Yıldırım, 2020). This is because the pandemic has made it more difficult for firms to access BC due to increased credit risk and decreased availability of BC. As a result, firms may be more likely to turn to TC as a substitute for BC. For example, a study by Ahmed and Al-Nasser (2020) found that during the pandemic, public firms had greater access to TC than private firms. This was attributed to the fact that public firms had a higher level of transparency, thus allowing them to have greater access to TC and BC. On the contrary, a study by Hajizadeh, Aliyari, and Badri (2020) concluded that during the pandemic, private firms had greater access to BC than public firms. This was attributed to the fact that the banking sector was more willing to lend to private firms due to their increased level of collateral and lower credit risk.

We, therefore, exclude the Covid-19 periods of 2019–2021 from our sample and re-run regression models (1)–(2) and report the results in Table 9. The results in columns (3) to (4) show that public firms use BC ($\beta = -0.136$) and TC ($\beta = -0.029$) as substitutes. On the other hand, private firms use BC ($\beta = 0.257$) and TC ($\beta = 0.187$) as complements. These results are the same as those reported in Table 4 and therefore, show that our main results are not sensitive to the recent Covid-19 pandemic.

[9] Our sample period starts from 2008 and therefore 2007 is already not included in our sample. This explains why we only exclude 2008–2009 from our sample. Moreover, in an unreported result, we excluded 2010 as well from our sample but found qualitatively similar results.

Table 9
Non Financial crisis and Non Covid-19 pandemic period.

VARIABLES	(1)	(2)	(3)	(4)
	Non-Financial crisis		Non-Covid-19	
Public	−0.012***	−0.015***	−0.007***	−0.016***
	(0.001)	(0.000)	(0.001)	(0.001)
Public * BC	−0.080***		−0.136***	
	(0.007)		(0.007)	
Public * TC		−0.038***		−0.029***
		(0.004)		(0.005)
BC	0.314***		0.257***	
	(0.004)		(0.003)	
TC		0.198***		0.187***
		(0.002)		(0.003)
Age	−0.001***	0.001***	−0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Sales growth	0.006***	0.001***	0.006***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
CHOLD	−0.012***	−0.186***	−0.085***	−0.066***
	(0.002)	(0.002)	(0.002)	(0.002)
Size	−0.003***	0.002***	−0.003***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
ROA	−0.069***	0.084***	−0.069***	0.101***
	(0.002)	(0.002)	(0.002)	(0.002)
Rinvt/TA	0.060***		0.058***	
	(0.001)		(0.001)	
Equity/Nontangibles		0.014***		0.017***
		(0.000)		(0.000)
Constant	0.120***	0.052***	0.348***	−0.605***
	(0.001)	(0.001)	(0.034)	(0.029)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	159,469	159,469	141,931	141,931
R-squared	0.269	0.403	0.257	0.309

This table presents the results of the borrowing constraint and firm size on the complementary and substitutive effect between trade credit (TC) and short-term bank credit (BC) for public and private firms in the UK. TC is trade payables scaled by sales revenue. BC is short term bank credit scaled by current liabilities. Public is a dummy variable equals to 1 for publicly listed firms and 0 otherwise. Age is the number of years of the firm. Sales growth is the one-year growth rate of sales at time t-1. CHOLD is cash and cash equivalent scaled by total assets. Size is the natural logarithm of total assets. ROA is the return on assets. Equity/Nontangible is the total equity divided by the difference between total assets and tangible assets. Rinvt/TA is raw materials inventory scaled by total assets. See Table I for all variable definitions.
***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

6.6. GMM regressions

To further test the robustness of our results, we also use the Generalized Method of Moments (GMM) estimator developed for dynamic panel data by Arellano and Bond (1991)and extended by Arellano and Bover (1995). All the GMM regressions are run with the two-step estimator to allow the standard covariance matrix to be robust to panel-specific autocorrelation and heteroscedasticity. Following previous literature, we assume that firms move towards their target external credit by determining the level of TC and BC and that their changes over time is influenced by trade-off costs (Abdulla et al., 2017; Atanasova, 2007; Engemann et al., 2014). Therefore, we include two-year lags of TC and BC as explanatory variables on the right-hand side in their respective regression models.

To check the consistency of the GMM estimator, we employ the Hansen test of over-identifying restrictions and the second-order autoregressive test AR (2) to examine the overall validity of the instruments and specification test (Roodman, 2009). Therefore, all the regression tables include the Hansen test and AR (2). A rejection of the null hypothesis by the Hansen test indicates that the instruments are orthogonal to the error process and therefore, the estimates are invalid and inconsistent. The results of GMM regressions in Table 10 show qualitatively similar results to those presented in Tables 4 and 5 using 3SLS.

7. Conclusion

Prior research has documented uneven and complex results on the relationship between TC and BC. In this study, we examine this relationship by focusing on public versus private firms. This paper, therefore, uses listing status to determine whether TC and BC are used as substitutes or complements. Gauging the use of TC and BC between public and private firms distinguishes our paper from prior studies. Using a sample of 254,352 observations for the period from 2008-**2021**, we find convincing evidence that public firms use TC and BC as substitutes, whereas private firms use them as complements. Moreover, the results show that public firms have a faster speed of adjustment of both their TC and BC than private firms.

We also carried out further analysis to examine how certain conditions impact on the substitution or complementary use of TC and

Table 10
GMM.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	TC	BC	PRIVATE	PUBLIC	PRIVATE	PUBLIC
Lagged 1	0.658***	0.022	−0.137	−0.452***	0.153	0.026
	(0.045)	(0.018)	(0.094)	(0.093)	(0.104)	(0.024)
Lagged 2	0.064**	−0.036***	0.170***	0.024	−0.052	−0.041
	(0.031)	(0.010)	(0.054)	(0.041)	(0.202)	(0.070)
Public	0.020***	−0.002**				
	(0.001)	(0.001)				
Public * BC	−0.309***					
	(0.011)					
Public * TC		−0.165***				
		(0.008)				
BC	0.187***					
	(0.016)					
TC		0.211***				
		(0.004)				
$TC^*_{it} - TC_{i,t-1}$			3.184***	3.547***		
			(0.329)	(0.598)		
$BC^*_{it} - BC_{i,t-1}$					5.232***	11.291***
					(0.476)	(1.536)
Age	−0.001***	0.002***	−0.003***	0.004	−0.006*	0.012
	(0.000)	(0.000)	(0.001)	(0.004)	(0.004)	(0.013)
Sales growth	0.003***	0.002***	0.007**	−0.070***	0.024	−0.005
	(0.000)	(0.000)	(0.003)	(0.016)	(0.040)	(0.033)
CHOLD	−0.031***	−0.221***	−0.659***	−0.042	−1.987***	0.028
	(0.003)	(0.006)	(0.084)	(0.091)	(0.240)	(0.222)
Size	−0.001***	0.002***	−0.005***	−0.006***	−0.005	0.001
	(0.000)	(0.000)	(0.001)	(0.001)	(0.003)	(0.005)
ROA	−0.018***	0.058***	0.173***	0.089	0.024	−0.356
	(0.003)	(0.002)	(0.034)	(0.110)	(0.071)	(0.430)
Constant	0.119***	0.220***	−0.947***	1.242	−2.394	−2.383
	(0.024)	(0.030)	(0.275)	(1.897)	(2.838)	(4.934)
AR (1)	−10.94***	−5.52***	−4.78***	−4.50***	−1.47	−1.54
AR (2)	3.75***	−1.03	−2.04**	−3.49***	0.62	0.87
Hansen	0.737	0.767	0.134	0.047	0.290	0.310
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	124,244	124,244	82,303	10,560	82,303	10,560
Number of id	41,219	41,219	30,934	3231	30,934	3231

This table presents the results of GMM estimation on the complementary and substitutive effect between trade credit (TC) and short-term bank credit (BC) for public and private firms in the UK. See Table I for all variable definitions. ***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively. Public is a dummy variable equals to 1 for publicly listed firms and 0 otherwise. Age is the number of years of the firm. Sales growth is the one-year growth rate of sales at time t-1. CHOLD is cash and cash equivalent scaled by total assets. Size is the natural logarithm of total assets. ROA is the return on assets. Equity/Nontangible is the total equity divided by the difference between total assets and tangible assets. Rinvt/TA is raw materials inventory scaled by total assets. See Table I for all variable definitions.
***, **, and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

BC. We first examined how the financial constraint of both public and private firms influence the substitution and complementary use of TC and BC. We find that the financial constraint of both public and private firms has a statistically significant effect on the substitution and complementary use of TC and BC. More specifically, further analysis shows that both public and private firms that are more financially constrained resort to the complementary use of TC and BC. Next, we examined whether different sizes of public and private firms use TC and BC differently. We find that public and private SMEs use TC and BC as compliments. The use of propensity scores matching technique and the exclusion of the crisis and **Covid-19** periods confirm the robustness of our main results.

This paper contains essential policy and managerial implications. First, given the enormous amount of both TC and BC on the financial statements of public and private firms, managers should endeavour to take advantage of these two sources of short-term finance by exploiting their benefit and minimising their costs. Second, the complementary use of TC and BC by private firms suggest that these two sources of short-term finance are more important to private firms. Private firms have limited access to other sources of external finance. As such, we recommend private firms to forge healthy relationships with their banks and trade suppliers to obtain access to these valuable sources of finance at an affordable cost. Third, our findings add to the existing literature by showing that firms do not only use TC to signal their creditworthiness to the bank, but also they use it to signal their creditworthiness to trade suppliers. More specifically, our findings highlight the signalling importance of TC and BC for private firms and firms that are financially constrained. Firms that are more financially constrained can use their access to TC to signal their credit quality to banks or use their access to BC to signal their credit quality to trade suppliers.

The results of this study may be interpreted with some limitations. For instance, the sample of this study is limited to UK firms with

information captured by the FAME database for the period from 2008 to **2021**. As a result, the evidence observed in this study may not be generalized to other countries. Therefore, more research is needed to test whether our observed evidence may also be applied to different countries.

Data availability

Data will be made available on request.

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