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Inverted U-shaped dynamics of capital structure and firm value: Evidence from an emerging market

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ABSTRACT

This study investigates the nonlinear relationship between capital structure and firm value using data from manufacturing firms listed on Borsa Istanbul over the period 2005 to 2023. We use a novel methodology, the Method of Moments Quantile Regression (MMQR), and perform several robustness checks using the novel JKS half-panel jackknife estimation method, and the lag augmented VAR (LA-VAR) panel causality test. Our results show the presence of an inverted U-shaped nonlinear relation between the capital structure and firm value. Specifically, higher borrowing increases firm value in the lower quantiles, while excessive borrowing beyond a threshold adversely decreases it. Causality test results indicate a unidirectional causality from capital structure to firm value. The results have implications for management in manufacturing industries and policymakers, and enhance our understanding of how firms should restrict their borrowing to optimize firm value, maintain financial stability, and foster sustainable growth.

1. Introduction

How capital structure affects firm value is a fundamental debate in corporate finance (Vo & Ellis, 2017). If a financial manager makes irrational decisions to secure funding through debt financing, it may lead to higher capital costs, which can ultimately diminish firm value (Ullah et al., 2020). On the other hand, globalization provides new growth opportunities for firms in emerging markets while requiring managers to overcome financial obstacles to international expansion and make critical financing decisions (Melgarejo Duran & Stephen, 2020). However, financial crises can restrict access to external financing, encourage debt usage through interest rate changes, and increase market volatility and policy uncertainty, thereby impacting capital structure decisions (Tanin et al., 2024).

Recently, emerging markets, particularly Türkiye, have been impacted by domestic economic policies and global risks. Similar to other developed and developing countries, the Central Bank of the Republic of Türkiye (hereafter, CBRT) reduced the policy rate by 100 basis points to 9.75% on March 17, 2020, to ensure liquidity and boost economic activity during COVID-19 (Gök et al., 2023). To encourage domestic demand, policy interest rates were decreased further to 8.25% in May 2020. However, rising inflation due to currency devaluation and supply chain disruptions prompted a change to stricter measures, with the rate rising to 19% by early 2021. Later governance reforms returned growth-oriented measures, decreasing the rate to 14% in December 2021. This caused rapid currency depreciation and inflation. Rate cuts in 2022 raised inflation and devalued the lira. As inflation and risks rose in 2023, the CBRT tightened policies and raised interest rates. By 2024, the policy rate had risen to 50%, one of its highest levels in history, but commercial loan rates had risen to 63.7%, showing continued volatility (CBRT, 2024). This scenario left businesses struggling to handle excessive borrowing costs, limiting their ability to develop, expand, and retain profitability. Therefore, given the impact of recent interest rate hikes on firms' borrowing costs in Türkiye, the literature remains unclear on what the optimal level of borrowing should be to maximize firm value in borrowing strategies, how shocks such as global crises and the COVID-19 pandemic shape capital structure strategies, and to what extent these effects are determinants of firm value maximization.

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rates decrease significantly after 2008, increase sharply around 2018, and rise even more in 2023/Q4. This shows periods of monetary easing followed by tightening, likely the result of central bank policies which are adjusted in response to macroeconomic conditions. The ratio of total liabilities to total assets (green line) has an upward trend. This trend shows that companies rely more on leverage over time. The decline in 2023/Q4 may indicate companies quickly reducing leverage because borrowing costs are increasing. The blue line shows short-term obligations compared to total assets. It shows little change over time but increases sharply in 2023/Q4. This may suggest that companies are replacing short-term debt with long-term debt (brown line), which remains comparatively stable, to manage cash flow during periods of elevated interest rates.

The current literature reveals mixed findings about the relationship between the cost of capital and firm value. Some studies find a positive link, suggesting that moderate leverage enhances firm value by mitigating agency costs (Ayaz et al., 2021; Jiraporn & Liu, 2008). Tax shield benefits and low debt issuance costs further strengthen this relationship (Abdullah & Tursoy, 2021). Evidence from emerging markets shows that general debt positively impacts performance metrics such as return on assets (ROA) and Tobin's Q, though inefficiencies in long-term debt can reduce firm value (Bui et al., 2023; Chowdhury & Chowdhury, 2010; Nguyen et al., 2023). However, other strands of research suggest a negative relationship, driven by managerial self-interest and pecking order theory (Friend & Lang, 1988; Moh'd et al., 1998). Evidence from Chinese firms supports this, showing that high-profitability companies typically avoid debt (Chen, 2004). Finally, a few studies show no significant relationship between the cost of capital and firm value. For instance, El-Sayed Ebaid (2009) finds that leverage levels have minimal impact on financial performance metrics for non-financial firms in Egypt. Similarly, Phillips and Sipahioglu's (2004) research into UK hotel companies shows no significant link between debt levels and financial performance. However, these studies ignore the impact of capital structure decisions on low, medium, and high quantiles of firm value. To fill this gap in the literature, we study the nonlinear relationship and causality between capital structure decisions and firm value.

This study contributes to the literature in several ways. Firstly, we examine the nonlinear, inverted U-shaped relationship between the capital structure and firm value of firms operating in the manufacturing sector of Borsa Istanbul for the period 2005–2023 using the Method of

Moments Quantile Regression (MMQR). We focus on emerging markets as they continue to grow economically and are more sensitive to macroeconomic shocks such as inflation and interest rates. The most important motivation for selecting Borsa Istanbul for this study is to reveal how recent interest rate hikes affect the manufacturing industry, which is the primary sector of Borsa Istanbul. On the other hand, recent inflationary pressure in Türkiye's manufacturing industry differentiates Borsa Istanbul from other emerging markets. Using the MMQR methodology, we identify the effects of capital structure during periods of low, medium, and high firm value. MMQR provides robust results with bootstrap simulations for heterogeneous panel data, revealing the dynamics of the nonlinear relationship between capital structure and firm value. Secondly, we examine the causal relationship between capital structure and firm value by applying the JKS non-causality test and LA-VAR Granger causality test. These robust methods allow for accurate and reliable inferences, taking into account potential heterogeneity and cross-sectional dependence (CSD) across firms. Both tests effectively resolve the complexities inherent in firm-level data. Thirdly, we include the impact of external shocks such as the 2008 financial crisis and COVID-19 pandemic to assess how these events affect the optimal relationship between capital structure and firm value in emerging markets. Finally, our study has important implications for policy makers and corporate managers, and makes recommendations regarding the optimal capital structure and level of debt that maximizes firm value.

The rest of this paper is organized as follows. Section 2 introduces the theoretical background and literature review. Section 3 discusses the empirical methodology and the data used in the study. Section 4 reports and discusses the empirical results of the study. Section 5 presents concluding remarks and policy implications.

2. Theoretical background and literature review

2.1. Theoretical background

Durand (1952), the first to examine the effect of the cost of capital on firm value using the net income approach, argues that, as company debts increase, the cost of capital decreases and firm value increases. Building on this perspective, Solomon (1955) argues that the advantages of low leverage financing and the disadvantages of high leverage financing offset each other, thereby determining an optimum debt ratio for the

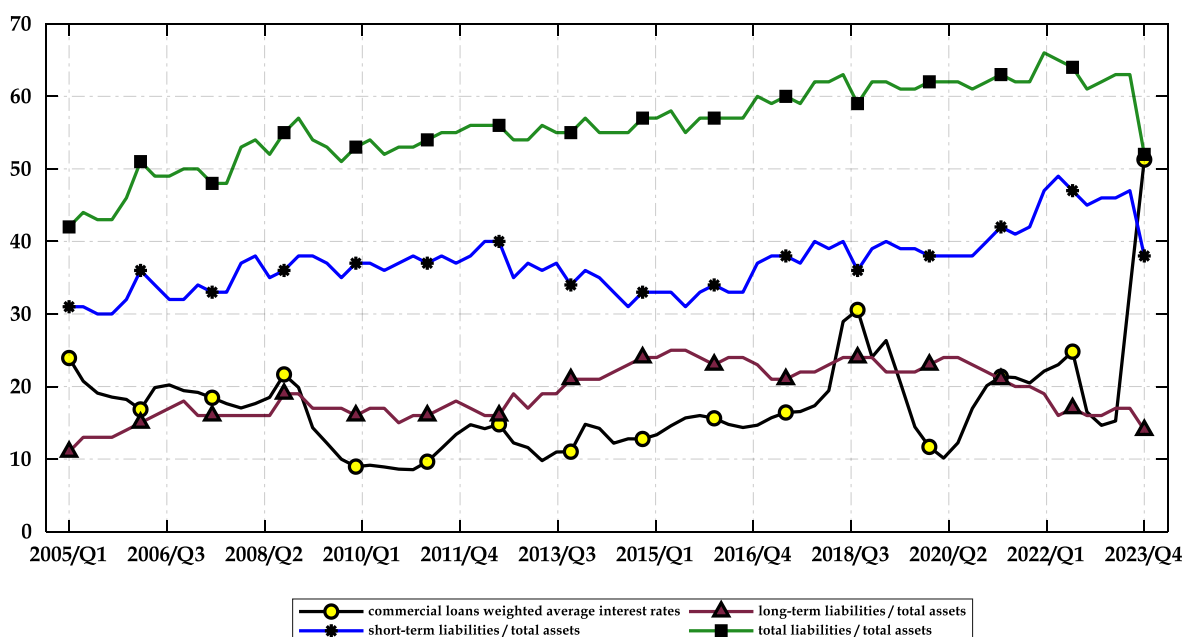


Fig. 1. Capital structure & interest rate trends in borsa istanbul manufacturing sector (2005–2023).

lowest weighted average cost of capital (WACC) and highest firm value. Modigliani and Miller (1958) contend, with various assumptions and constraints, that, under ideal market conditions, a firm's capital structure does not influence its value. However, Modigliani and Miller (1963) show that including corporate taxes in the calculations could reduce WACC and increase firm value through the use of debt capital. Miller (1977) extends this idea by incorporating personal taxes and specific tax benefits, suggesting that the use of debt could potentially reduce WACC and increase firm value.

Amid intense debate about Modigliani's and Miller's theories, Myers (1977) introduces the static and dynamic trade-off theories. Specifically, the static version determines the optimal capital structure by weighing the tax shield benefits of borrowing at low leverage against the disadvantages, such as increased financial distress and expected bankruptcy costs at high leverage. In contrast, the dynamic approach assumes that companies can only change their capital structure if the benefits exceed the costs at various leverage degrees. Jensen and Meckling (1976) and Jensen (1986) develop the conflict-of-interest theory, which states there is a conflict of interest between managers and shareholders. According to this theory, managers allocate cash flows to their own projects, while shareholders view debt as a solution, as it restricts managers' ability to use free cash flows for their own interests. Thus, the theory states that debt reduces the cost of capital, disciplines managers, and sets the optimal cost of capital by minimizing bankruptcy costs and the conflict of interest between owners and managers, ensuring that managers make rational financing decisions.

Akerlof (1978), Rothschild and Stiglitz (1978), and Spence (1978) describe information asymmetry between managers and investors as a manifestation of similar conflicts of interest between managers, shareholders, and creditors. Building on this idea, Ross (1977) argues that corporate managers conceal some financing decisions from investors, thereby creating information asymmetry. In response, managers signal to investors the expectation of positive future cash flows and increases in firm value when they opt for debt financing in their investments, and evidence suggests that investors view companies that increase their leverage more favourably. Consequently, hierarchy theory, which follows on from information asymmetry theory, implies that companies adopt a distinct financing approach. The theory, initially proposed by Donaldson (1961), suggests that companies rely primarily on internal resources rather than external capital without explicitly discussing this hierarchy. Myers (1984) and Myers and Majluf (1984) extend this approach and propose a financing hierarchy starting with internal resources. In essence, the theory states that firms meet their financing needs through retained earnings (internal resources), debt financing, and new capital issuance. Notably, it denies the existence of an optimal capital structure and argues that this method can maximize firm value due to the lower cost of internal resources compared to external resources.

As Modigliani and Miller's theories have evolved, several modern theories have emerged, offering both critique and revision. For example, the Brusov-Filatova-Orekhova (hereafter BFO) BFO-1 approach, which analyses the financial conditions of firms at various ages, contradicts Modigliani and Miller's assumption that firms exist forever (Brusov et al., 2011). The new models suggest that changes in debt and equity components increase financial risks, and argue against the existence of an optimal capital structure (Brusov et al., 2013). A model incorporating macroeconomic measures suggests that inflation can increase the cost of equity capital and reduce firm value (Brusov et al., 2014). Developed for companies that have ceased operations, the BFO-2 approach expands on this idea by separately assessing the company's age and duration of operations (Brusov et al., 2018). Finally, BFO-3 offers a new approach based on a rating method for non-financial companies and long-term projects (Brusov et al., 2018, 2021; Brusov & Filatova, 2023).

2.2. Literature review and hypothesis development

Recent studies examine the relationship between the cost of capital, firm performance, and firm value through three main approaches: the irrelevance hypothesis, positive correlations, and negative correlations, which reflect the complexity of such dynamics. The irrelevance hypothesis suggests no significant relationship between capital structure and firm performance, as seen in El-Sayed Eba (2009) for Egyptian firms and Phillips and Sipahioglu (2004) for UK hotel companies, both of which find no measurable impact of leverage on performance metrics.

The second strand of literature indicates that leverage can enhance the value of a firm under specific conditions. For instance, Jiraporn and Liu (2008) argue that governance structures, such as staggered boards, influence leverage decisions to protect firm value, while Khan et al. (2021) document the role of increased debt in enhancing value in specific industries. Similarly, Ramli et al. (2019) highlight regional differences in leverage effects on performance, with positive impacts observed in Malaysian but not Indonesian firms. Çam and Özer (2022) investigate how country-level governance factors influence firms' capital structure and investment financing decisions, finding that stronger governance leads to decreased leverage, increased debt maturity, and greater reliance on long-term debt and equity issuances for financing capital expenditures. Bui et al. (2023) find mixed results for Vietnamese firms, where general debt ratios positively impact performance, but long-term debt exerts a negative effect.

The third strand of literature focuses on a negative correlation, emphasizing managerial self-interest and pecking order theory. Friend and Lang (1988) and Moh'd et al. (1998) argue that managers reduce leverage to mitigate personal risk, while Booth et al. (2001) and Chakraborty (2010) support the pecking order theory, showing that profitable firms prefer internal financing to avoid the cost of external debt. Similarly, Chen (2004) finds that Chinese firms with high profitability rely on internal funds, avoiding leverage. Collectively, these studies reveal diverse capital structure effects shaped by market conditions, governance structures, and firm-specific factors. Huang and Song (2006) analyse data from over 1200 Chinese listed companies (1994–2003) to examine capital structure dynamics, finding that leverage negatively impacts firm performance, larger firms and those with more fixed assets have higher debt ratios, profitability and growth opportunities correlate with lower debt ratios, and state or institutional ownership has minimal influence. Similarly, Oino and Ukaegbu (2015) conduct an analysis of capital structure on Nigerian non-financial firms, and identify that trade-off and pecking order theories support profitability and asset structure deterring leverage, while firm size and non-debt tax shield positively affect leverage characteristics, with relatively speedy adjustments on the part of firms towards the target capital structure. Vo and Ellis (2017) assess firms on the Ho Chi Minh Stock Exchange (2007–2013) and note that increased financial leverage decreases shareholder value. Doorasamy (2021) examines the East African context, finding that leverage generally decreases firm value, though owner-managed firms can use debt effectively to enhance value. The literature underlines the main determinants in the cost of capital-firm value relationship.

Previous studies positively relate tax shield benefits, low borrowing costs, managerial control, firm size and returns from short-term borrowing, while negative associations are variously made between managerial interests, profitability, institutional and financial constraints, cost of debt, ownership structure, and inefficient utilization of debt. This paper posits that the relationship between cost of capital and firm value is nonlinear but rather complex and requires further investigation. Based on this, we propose the following hypotheses.

H1. The relationship between capital structure and firm value is non-monotonic (concave); positive for low levels of liability and negative for high levels.

H2. There is a significant bidirectional causal relationship between

capital structure and firm value.

3. Methodology

3.1. Data

This study uses data from manufacturing firms listed on Borsa Istanbul (BIST). For reasons of data availability, our dataset includes 94 firms with annual data over 19 years, from 2005 to 2023, giving a total of 1786 observations. As a matter of fact, there are currently 242 manufacturing firms listed on the BIST according to the public disclosure platform (PDP). Among these, we prioritize firms that provide full data from 2005 to 2023. As such, firms with missing values or outliers in all variables, primarily Tobin's Q and market-to-book ratio, during the relevant period are excluded. This implementation provides consistency in the relationship between the cost of capital and firm value that this study seeks to uncover. Thus, given the reliability of the data, a balanced panel dataset with 94 manufacturing firms is constructed, considering all time series and cross-sectional dimensions together. The data are provided by the PDP (KAP) and the Finnet database system. The MMQR, half-panel jackknife estimation, and JKS non-causality tests are performed with the STATA 17 version, and the LA-VAR non-causality test is applied with the Gauss 16 Light version.

3.2. Model specifications

The primary aim of this study is to reveal the nonlinear relationship between cost of capital and firm value, particularly under the influence of the financial crisis and COVID-19 pandemic. We estimate the following regression model to assess how the cost of capital affects firm value:

$$FV_{it} = \beta_0 + \beta_1 (LEV_{it}) + \beta_2 (LEV_{it})^2 + \beta_3 (FIXED_{it}) + \beta_4 (GROWTH_{it}) + \beta_5 (SIZE_{it}) + \beta_6 (NCFLOW_{it}) + \beta_7 (Crises_t) + \beta_8 (Covid - 19_t) + \mu_{it} + \varepsilon_{it} \quad (1)$$

In model-1, we measure the dependent variable, firm value (FV) using two proxies: TOBINQ and MARKET. We calculate TOBINQ as the sum of the market value of equity and total liabilities over the book value of assets (Chung & Pruitt, 1994; Karaca, 2023; Martínez-Sola et al., 2013), and MARKET represents the market-to-book ratio, a commonly used measure of firm value (Karaca, 2023; Martínez-Sola et al., 2013). Three distinct proxies represent the primary independent variable, leverage (LEV): short-term liabilities to equity (STLEQ), long-term liabilities to equity (LTEQ), and total liabilities to equity (TLEQ). The model also incorporates the squares of these variables to capture the nonlinear relationship between the cost of capital and firm value (Bui et al., 2023). To confirm the first hypothesis, we expect the coefficient of B1 to be positive, since we think low levels of LEV have a positive effect on firm value. At the same time, we expect the coefficient of B2 to be negative as we conclude that high levels of LEV have a negative impact on firm value according to the current hypothesis. Thus, this study reveals whether there is a nonlinear relationship between short-term, long-term, and total debt in the capital structure of both TOBINQ and MARKET.

The model incorporates several control variables to account for other factors that may influence firm value: FIXED, the ratio of fixed assets to the book value of assets (Naseer et al., 2024); GROWTH, annual sales growth; SIZE, calculated as the natural logarithm of net sales; and NCFLOW, the ratio of net income plus depreciation and amortization to sales (Karaca, 2023; Martínez-Sola et al., 2013; Naseer et al., 2024). To account for external economic shocks, the model also includes the effects of the financial crisis and COVID-19. The dummy variable CRISIS is set equal to 1 for the 2008 and 2009 financial crisis and 0 for all other years (Karaca, 2023), while the dummy variable COVID19 is set to 1 for 2020, 2021, and 2022 and 0 for all other years (Bose et al., 2022). In the

model, i represents each firm, while t is the time effect, ε_{it} denotes the residuals, and μ_{it} accounts for unobservable heterogeneity.

3.3. Cross-sectional dependence and slope homogeneity

The Borsa Istanbul manufacturing firms likely exhibit heterogeneity and CSD due to their adherence to the BST100 index, the influence of supply chain dependencies, macroeconomic shocks, interconnections in financial markets, credit and financing conditions, external trade and global linkages, investor sentiment, and market expectations on their economic activities. CSD among Borsa Istanbul manufacturing firms is analysed using the LM test developed by Breusch and Pagan (1980), along with Pesaran (2021) CD_{LM} and CD tests, and the LM_{adj} test proposed by Pesaran et al. (2008). Slope homogeneity is assessed through the $\Delta \sim$ and $\Delta \sim_{adj}$ tests introduced by Pesaran and Yamagata (2008).

3.4. Panel unit root tests

We use the Pesaran (2007) CADF and CIPS panel unit root test, which takes into account heterogeneity and CSD. The test formulates the null and alternative hypotheses as:

$$H_0 = \beta_i = 0 \text{ (Series non-stationary)}$$

$$H_a = \beta_i < 0 \text{ (Series stationary)}$$

The CADF regression model can be expressed in its simplified form as:

$$\Delta Y_{it} = \alpha_i + \rho_i^* Y_{it-1} + d_0 \bar{Y}_{t-1} + d_1 \bar{Y}_t + \varepsilon_{it} \quad (2)$$

We present the expanded model, which includes the lagged first differences, as:

$$\Delta Y_{it} = \alpha_i + \rho_i^* Y_{it-1} + d_0 \bar{Y}_{t-1} + \sum_{j=0}^p d_{j+1} \Delta \bar{Y}_{t-j} + \sum_{k=1}^p c_k \Delta Y_{i,t-k} + \varepsilon_{it} \quad (3)$$

The CADF test is applicable in both the scenario where T exceeds N and where N exceeds T . The stationarity test results for each unit are determined by comparing the calculated test statistics with the critical values provided in the Pesaran (2007) CADF table. We reject the null hypothesis if the CADF critical value exceeds the CADF statistic, indicating that only the unit series is stationary. The CIPS test yields the stationarity test result for the entire panel. The CIPS test statistic is calculated by computing the arithmetic mean of the CADF test statistics:

$$CIPS = \frac{1}{N} \sum_{i=1}^N CADF_i \quad (4)$$

3.5. Method of moments quantile regression (MMQR) estimator

Identifying the optimal cost of capital requires an estimator that accounts for both heterogeneous panels and panels with CSD. The estimated fixed effect panel regression results usually portray the average effects of capital structure on firm value. However, it must be acknowledged that such effects can differ throughout a firm's value distribution spectrum. To account for such heterogeneous effects, the quantile regression model of Koenker and Bassett (1978), which has gained currency over time, is a potent tool because it can capture the effect of independent variables (IDV - capital structure and control variables) at various points along the conditional distribution of the dependent variable (firm value). The quantile regression estimations are quite robust in cases of outliers or non-normally distributed data. We use a panel quantile regression method that includes fixed effects, the MMQR, newly suggested by Machado and Santos Silva (2019), with bootstrap replications.

Unobserved heterogeneity is a key aspect of estimation of models for panel data. The fixed effects panel quantile regression is most widely

applied as it can cater for this type of variation. Machado and Santos Silva (2019) assert that one strong advantage of the MMQR approach is that it enables the determination of how independent variables affect the entire conditional distribution of the dependent variable, not just the conditional mean. This methodology is more extensive than that of, for instance, Koenker (2004) and Canay (2011), who take into account just the conditional mean responses. Consequently, the MMQR approach can investigate individual heterogeneity along the whole distribution and opens the possibility of endogenous variables within the model.

Using the dataset $\{(FV_{it}, IDV_{it})'\}$ that spans n entities, each observed over t periods (where $i = 1, \dots, n$ and $t = 1, \dots, T$), we demonstrate the estimation of the conditional quantiles $Q_y(\tau|IDV)$ for a model characterized by location and scale in the following manner:

$$FV_{it} = \alpha_{it} + IDV_{it}\beta + (\delta_{it} + Z_{it}\gamma) u_{it} \quad (5)$$

In the specified model, the probability $\Pr\{\delta_{it} + Z_{it}\gamma\} > 0$ is 1, with $(\alpha\beta\delta\gamma)$ representing the parameters estimated. The individual fixed effects for each entity i are denoted by $(\alpha_i\delta_i)$, for $i = 1, \dots, n$. For a given i , IDV_{it} is assumed to be strictly exogenous, identically distributed across time, and independent across entities. The error terms u_{it} are considered identically distributed across both individuals and time periods, orthogonal to IDV_{it} and normalized to fulfil the moment conditions described by Machado and Santos Silva (2019). Additionally, Z represents a vector of components from IDV that have undergone differentiable transformations, with each component l specified accordingly:

$$Z_l = Z_l(IDV), l = 1, \dots, k \quad (6)$$

Equation Z_l can be expressed in the following manner:

$$Q_y(\tau|IDV_{it}) = (\alpha_i + \delta_i q(\tau)) + IDV_{it}\beta + Z_{it}\gamma q(\tau) \quad (7)$$

In this formulation, IDV_{it}^T represents a vector of independent variables (IDV - capital structure and control variables), while $Q_y(\tau|IDV_{it})$ denotes the conditional quantile distribution of the dependent variable (firm value) FV_{it} , which depends on the independent variables' positions. It should be noted that $\alpha_i(\tau)$ defined as $\alpha_i + \delta_i q(\tau)$ serves as the scalar coefficient reflecting the fixed effect for individual i at quantile $-\tau$, where $q(\tau)$ is the τ -th sample quantile.

3.6. Robustness checks

3.6.1. Half-panel jackknife estimator

We use the recently developed JKS non-Granger causality test, introduced by Juodis et al. (2021) in the robustness analysis, specifically for panels with heterogeneity and CSD, to ensure robust findings. This test incorporates the half-panel jackknife (HPJ) method, applying a Wald-type statistic to correct for bias, and offers the following equation for calculating the test statistic:

$$\widehat{W}_{HPJ} = NT\beta'(\widehat{J}^{-1}\widehat{V}\widehat{J}^{-1})^{-1}\beta \rightarrow \chi^2(P) \quad (8)$$

The originality of the JKS non-Granger causality test lies in its enhanced size and power properties, achieved by employing a pooled estimator with a $\sqrt{NT}$ convergence rate. These features are very important for empirical studies that test causality in both univariate and multivariate frameworks because they allow for various nuisance parameters and take into account CSD and cross-sectional heteroscedasticity (Juodis et al., 2021; Xiao et al., 2023). We propose the following methodology for the construction of the models:

$$y_{it} = \pi_{0,i} + \sum_{k=1}^K \delta_{p,i} y_{i,t-k} + \sum_{q=1}^Q \varphi_{q,i} x_{i,t-k} + \varepsilon_{it} \quad (9)$$

The parameters in the model are defined for country $i = 1, \dots, N$ ($=94$) and years $t = 1, \dots, T$ ($=19$). In this framework, $x_{i,t}$ is treated as a scalar, while $y_{i,t}$ accounts for heterogeneous autoregressive effects, and $\varphi_{p,i}$ represents the heterogeneous Granger causality effects. Juodis et al.

(2021) assume that $y_{i,t}$ follows an autoregressive distributed lag process under the null hypothesis (H_0), where $\varphi_{p,i}$ remains constant across all i and q . This allows for the use of a pooled estimator $\varphi_{p,i}$. To mitigate the bias introduced by the pooled estimator, the test algorithm incorporates the HPJ estimator developed by Dhaene and Jochmans (2015). We compute the variance of the HPJ estimator using bootstrapping, drawing bootstrap samples across cross-sectional units when CSD is present. We correct the resulting estimates for bias and use them to produce Wald statistics for testing Granger non-causality. Rejecting the null hypothesis (H_0) indicates that the alternative hypothesis, $H_0 = \varphi_{p,i} \neq 0$ for some i and q , is statistically significant.

3.6.2. Panel causality testing under heterogeneity and cross-sectional dependence

The existence of a relationship between the optimal cost of capital and firm value raises the question of whether there is a causal link between them. While the JKS non-Granger causality test (Juodis et al., 2021) reveals causality for heterogeneous panels with CSD, the presence of a causal relationship is verified by the LA-VAR test (Emirmahmutoglu & Kose, 2011), based on the bootstrap technique. Fisher's meta-analysis, building on the Toda-Yamamoto (TY) causality test, introduces the lag augmented VAR (LA-VAR) method, which incorporates the level VAR model with additional $dmax$ lags to test for Granger causality in heterogeneous mixed panels. The level VAR model in such panels is specified with $k_i + dmax_i$ lags as:

$$x_{i,t} = \mu_{i,t}^x + \sum_{j=1}^{k_i+dmax} A_{11,ij} x_{i,t-j} + \sum_{j=1}^{k_i+dmax} A_{12,ij} y_{i,t-j} + \mu_{i,t}^y \quad (10)$$

$$y_{i,t} = \mu_{i,t}^y + \sum_{j=1}^{k_i+dmax} A_{21,ij} x_{i,t-j} + \sum_{j=1}^{k_i+dmax} A_{22,ij} y_{i,t-j} + \mu_{i,t}^x \quad (11)$$

In this context, i ($i = 1, \dots, N$) represents firm cross-sectional units, while t ($t = 1, \dots, T$) denotes time series observations. $\mu_{i,t}^x$ and $\mu_{i,t}^y$ refer to vectors of fixed effects, while $\mu_{i,t}^x, \mu_{i,t}^y$ represent column vectors of error terms. The test assumes that the lag structure k_i is known and can vary across cross-sectional units. For each i unit, $dmax_i$ denotes the maximum order of integration in the model.

This test uses the bootstrap technique, and begins by identifying the maximum order of integration, denoted as $dmax$, for the variables in the system for each cross-sectional unit, which is achieved using the augmented Dickey-Fuller (ADF) unit root test.

We select the appropriate lag order, k_i , based on information criteria such as AIC or SB, and estimate the Breusch and Pagan (1980) LM test using the OLS method. We then re-estimate the LM test under the null hypothesis of non-causality, using $dmax$ and k_i , and obtain the residuals for each firm as follows:

$$\widehat{u}_{i,t}^y = y_{i,t} - \widehat{u}_{i,t}^y + \sum_{j=1}^{k_i+dmax} \widehat{A}_{21,j} x_{i,t-j} + \sum_{j=1}^{k_i+dmax} \widehat{A}_{22,j} y_{i,t-j} \quad (12)$$

The subsequent step involves centring the residuals as shown in the equation:

$$\widetilde{u}_{i,t} = \widehat{u}_{i,t} - (T - k - l - 2)^{-1} \sum_{t=k+l+2}^T \widehat{u}_{i,t} \quad (13)$$

The test develops a matrix $[\widetilde{\mu}_{it}]_{N \times T}$ from these residuals. At each step, random full columns are selected from the matrix with replacement to preserve the cross-covariance structure of the errors. The bootstrap residuals are denoted as $\widetilde{\mu}_{i,t}^*$, where $(t = 1, \dots, T)$.

Next, a bootstrap sample of y is produced under the null hypothesis:

$$y_{i,t}^* = \hat{\mu}_i^y + \sum_{j=1}^{k_i+dmax} \hat{A}_{21,ij} x_{i,t-j} + \sum_{j=1}^{k_i+dmax} \hat{A}_{22,ij} y_{i,t-j}^* + u_{i,t}^* \quad (14)$$

Here, $\hat{\mu}_i^y$, $\hat{A}_{12,ij}$, and $\hat{A}_{22,ij}$ are estimates derived from last step. For each firm, Wald statistics are computed to test the non-causality null hypothesis by replacing $y_{i,t}^*$ with $y_{i,t}^*$ and estimating the LM test model without applying any parameter constraints. The Fisher test statistic, λ , is calculated using the firm p -values (p_i) corresponding to the Wald statistic for the i cross-sectional unit, as follows:

$$\lambda = -2 \sum_{i=1}^N \ln(p_i) \quad i = 1, \dots, N \quad (15)$$

Finally, the bootstrap empirical distribution of the Fisher test statistics is constructed by repeating steps 3 to 5 a total of 10,000 replications, and the bootstrap critical values are obtained by selecting the appropriate percentiles from these distributions. Simulation studies by Emirmahmutoglu and Kose (2011) demonstrate that the LA-VAR approach performs well for all values of t and n , regardless of whether cross-sectional independence or dependence exists.

4. Empirical results

The study presents the descriptive statistics, correlation matrix, unit root test results, baseline empirical results, robustness analyses, and causality test results in this order.

4.1. Descriptive statistics

Table 1 shows the descriptive statistics. The two dependent variables of the study, TOBINQ and MARKET, have mean values of 1.327 and 1.749, respectively. We can infer that firms in the BIST manufacturing sector are financially viable for investment based on the Chung and Pruitt (1994) approach, which suggests that values above 1 indicate value creation in the industry. On the other hand, examining the key components of the study related to capital structure (STL/EQ, LTL/EQ, TL/EQ), the average ratios of short-term liabilities, long-term liabilities, and total liabilities to equity are 0.958, 0.377, and 1.304, respectively. These figures suggest that BIST manufacturing firms follow a risky asset financing policy and operate with a high leverage ratio. Such risky financing is considered an important factor influencing firm value. Among the control variables, the ratio of fixed asset investments to total assets (FIXED) is around 35%, sales growth (GROWTH) is approximately 26%, the natural logarithm of firm size (SIZE) is 20.05, and cash flows (NCFLOW) are around 9.3%. Finally, according to the Jarque-Bera test statistics, the data do not follow a normal distribution, indicating the need for robust econometric analyses. Moreover, in regression-based models, high correlations among independent variables may produce misleading outcomes (Lavery et al., 2019) (see

Table 1
Descriptive statistics.

Variables	N	Mean	SD	Median	p1	p10	Jarque-Bera	Probability
MARKET	1786	1.749	1.159	1.430	0.300	0.610	895.2128	0.000
TOBINQ	1786	1.327	0.573	1.180	0.540	0.780	1269.03	0.000
STL/EQ	1786	0.958	0.818	0.670	0.060	0.170	547.4547	0.000
LTL/EQ	1786	0.377	0.478	0.190	0.010	0.040	5413.487	0.000
TL/EQ	1786	1.304	1.088	0.930	0.080	0.260	586.8303	0.000
FIXED	1786	0.350	0.170	0.330	0.020	0.140	46.11774	0.000
GROWTH	1786	0.264	0.402	0.160	−0.360	−0.090	2001.769	0.000
SIZE	1786	20.052	1.902	19.830	15.690	17.900	45.12878	0.000
NCFLOW	1786	0.093	0.151	0.090	−0.360	−0.020	119599.6	0.000

Note: (MARKET), market value of the firm/book value of the firm. (TOBINQ), market value of equity and total liabilities/book value of assets. (STL/EQ), ratio of short-term liabilities to total equity. (LTL/EQ), ratio of long-term liabilities to total equity. (TL/EQ), ratio of short- and long-term liabilities to total equity. (FIXED), ratio of fixed assets of the firm to total assets. (GROWTH), growth in sales of each firm. (SIZE), natural logarithm of total net sales. (NCFLOW), net profit plus depreciation/total sales.

Table 2).

In the first step of the analysis, CSD and firm-specific heterogeneity are examined, with the results presented in Table 3. The hypothesis stating the absence of CSD among firms is rejected, indicating that all variables exhibit CSD. This implies that a shock occurring in one firm is felt and propagated to other firms within the panel. Furthermore, the homogeneity tests conducted for Model 1, Model 2, and Model 3 reveal that the firms are heterogeneous, meaning that each firm experiences its own unique shocks and fluctuations. These initial findings guide the application process of the unit root tests planned for the subsequent phases of the analysis.

Granger (2003) asserts that the choice of econometric test is critical, since it depends on whether all series are stationary. Analyses carried out on non-stationary series may yield biased results, leading to spurious regression outputs. At the second stage of the analysis, we examine the presence of unit roots in all variables using the Fisher-type ADF, IPS, and CIPS tests and present the results in Table 4. According to the Fisher-type ADF test results, all series are statistically significant at least at the 10% level, indicating that they are stationary. This test is suitable for heterogeneous panels. The IPS test supports this result and confirms that all series are stationary. Being first- and second-generation unit root tests, these two tests may be weak where there is CSD among firms. However, the cross-sectional IPS (CIPS) test, which is a third-generation unit root test, gives strong and consistent results when firms are dependent on each other across time periods. The results show that the growth and size variables are significant at the 10% level, while the other variables are significant at the 1% level. This indicates that all series are stationary at a significance level of at least 10%, or $I(0)$. These findings are critical for selecting the appropriate estimator in the analysis process, and emphasize the importance of choosing tests that align with results.

4.2. Baseline estimation results

This section examines the nonlinear inverted U-shaped relationship between capital structure decisions and firm value in the manufacturing sector of BIST. Firm value is measured using two proxies: MARKET and TOBINQ, while capital structure is represented by three proxies: short-term liabilities, long-term liabilities, and total liabilities. The findings are presented in Table 5, Tables 6, and Table 7, respectively.

Table 5 shows an inverted U-shaped relationship between STL/EQ and MARKET in all quantiles. This implies that BIST manufacturing firms benefit from financial leverage both at low and high values of MARKET. However, this study reveals that short-term borrowing is not infinite, and the market variable starts to decline after a certain point (peak). As a result, the average vertex points of the quadratic equations based on STL/EQ and MARKET are calculated as 3.50 for all quantiles. Hence, it is recommended that BIST manufacturing firms' short-term liabilities should not exceed 3.50 times their equity. After this point, each increase in short-term liability may have a negative impact on firm

Table 2
Correlation matrix.

Variables	MARKET	TOBINQ	STL/EQ	LTL/EQ	TL/EQ	FIXED	GROWTH	SIZE	NCFLOW
MARKET	1.000								
TOBINQ	0.956***	1.000							
STL/EQ	0.217***	0.081***	1.000						
LTL/EQ	0.148***	0.024	0.563***	1.000					
TL/EQ	0.211***	0.07***	0.954***	0.736***	1.000				
FIXED	−0.177***	−0.165***	−0.226***	0.159***	−0.149***	1.000			
GROWTH	0.243***	0.232***	0.174***	0.060***	0.153***	−0.123***	1.000		
SIZE	0.232***	0.185***	0.297***	0.283***	0.306***	−0.144***	0.342***	1.000	
NCFLOW	0.178***	0.241***	−0.432***	−0.213***	−0.399***	−0.054***	0.214***	0.152***	1.000

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. (MARKET), market value of the firm/book value of the firm. (TOBINQ), market value of equity and total liabilities/book value of assets. (STL/EQ), ratio of short-term liabilities to total equity. (LTL/EQ), ratio of long-term liabilities to total equity. (TL/EQ), ratio of short- and long-term liabilities to total equity. (FIXED), ratio of fixed assets of the firm to total assets. (GROWTH), growth in sales of each firm. (SIZE), natural logarithm of total net sales. (NCFLOW), net profit plus depreciation/total sales. As the variables in the dataset do not exhibit a normal distribution, the Spearman rank-order criterion is preferred for the correlation analysis.

Table 3
Cross-sectional dependence and slope homogeneity.

	LM	CD _{LM}	CD	LM _{adj}
<i>Cross—Sectional Dependence</i>				
MARKET	6910.327***	27.159***	−1.633**	22.416***
TOBINQ	6965.995***	27.754***	−2.154**	27.979***
STL/EQ	7928.837***	38.052***	−2.041**	63.214***
LTL/EQ	8258.548***	41.579***	−2.632***	71.618***
TL/EQ	8429.766***	43.410***	−2.275***	83.111***
FIXED	9118.247***	50.773***	−0.443	61.691***
GROWTH	5990.309***	17.319***	−1.741**	8.908***
SIZE	9885.056***	58.975***	−1.810**	44.613***
NCFLOW	7084.516***	29.022***	−1.616**	26.950***
<i>Homogeneity</i>				
	Delta ($\hat{\Delta}$)	Delta adjusted ($\hat{\Delta}_{adj}$)		
Model 1	1.597	[0.055]*	1.980	[0.024]**
Model 2	2.756	[0.003]***	3.419	[0.000]***
Model 3	1.795	[0.036]**	2.227	[0.013]***

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. (MARKET), market value of the firm/book value of the firm. (TOBINQ), market value of equity and total liabilities/book value of assets. (STL/EQ), ratio of short-term liabilities to total equity. (LTL/EQ), ratio of long-term liabilities to total equity. (TL/EQ), ratio of short- and long-term liabilities to total equity. (FIXED), ratio of fixed assets of the firm to total assets. (GROWTH), growth in sales of each firm. (SIZE), natural logarithm of total net sales. (NCFLOW), net profit plus depreciation/total sales. LM (Lagrange multiplier test), CD_{LM} (cross-sectional dependence LM), CD (cross-sectional dependence test), and LM_{adj} (adjusted LM test) are statistical tests used to detect CSD in panel data, with LM being effective for large cross-sections, CD_{LM} suitable for panels with a large time dimension, CD working well for both small and large samples, and LM_{adj} providing improved performance in large samples. Homogeneity tests are conducted for Model 1, Model 2, and Model 3, with firm value as the dependent variable in each model. In these models, short-term liabilities, long-term liabilities, and total liabilities, respectively, are included along with control variables.

value. BIST manufacturing firms can incorporate optimal capital structures into their financial planning by taking this peak point into account in terms of the market. An inverted U-shaped relationship between short-term liabilities and firm value is also found for TOBINQ. However, this relationship emerges only in the Q10 and Q20 quantiles. In other words, short-term liabilities increase firm value during periods of low firm value but decline after the peak of 2.49. For TOBINQ, although the coefficient is negative in the medium and high quantiles, it is not significant, and the concave relationship disappears. Considering both proxies of firm value, firms' short-term borrowing levels should, on average, not exceed 3 times their equity.

Considering the control variables, the effect of FIXED on MARKET and TOBINQ is negative at low quantiles (Q10–Q50). This suggests that

firms with low firm value experience liquidity and flexibility constraints. Moreover, these results suggest that firms with high firm value overcome liquidity constraints through internal financing. Therefore, the significant effect of fixed asset investments on firm value disappears in periods of high firm value. These results are consistent with Naseer et al. (2024), who suggest that the effect of fixed assets on firm value is negative. GROWTH has an insignificant effect on MARKET in all quantiles, suggesting that investors do not consider growth rates as a sufficient indicator of firm valuation in the short run. However, growth rates have a positive and significant effect on TOBINQ in medium and high quantiles (Q50–Q90), suggesting that investors' expectations of sales growth are consistent with their long-run expectations. In addition, investors take into account the growth in sales by taking into account the cost of replacing assets. The study reveals that firms take advantage of growth opportunities in the middle and high quantiles. SIZE has a positive and significant effect on MARKET and TOBINQ at medium and high quantiles (Q50–Q90). NCFOW has a positive and significant effect on MARKET in all quantiles and on TOBINQ in medium and high quantiles (Q50–Q90). In contrast, Naseer et al. (2024) find that cash flows negatively affect firm value in developed economies. This study supports the view of Ni et al. (2019), that investors in developing countries take cash flows into account and positive cash flows have an impact on firm value. CRISIS has a negative and significant effect on MARKET and TOBINQ in all quantiles (Q10–Q90), indicating that the 2008–2009 financial crisis caused economic fluctuations in the manufacturing sector. This is consistent with the study of Karaca (2023). Finally, COVID19 has a positive and significant impact on MARKET and TOBINQ in all quantiles, suggests a strong positive effect of the COVID-19 pandemic on the BIST manufacturing industry, in a developing country, although there are arguments that the pandemic had a negative effect on the value of international firms (Bose et al., 2022).

Table 6 shows the impact of long-term liabilities on firm value. The results show an inverted U-shaped relationship between LTL/EQ and MARKET in all quantiles. These results are similar to those of the relationship between STL/EQ and firm value, showing the impact of short-term liabilities (see Table 3). For the MARKET proxy, long-term debt increases firm value during periods of low market capitalization. However, after a certain point (peak at 1.84), firm value decreases when borrowing continues. The findings suggest that, for the MARKET proxy, the point at which firms stop borrowing in the long run should be 1.84 times the average equity. For the TOBINQ proxy, the nonlinear relationship between long-term liabilities and firm value emerges only in quantiles Q10 and Q20. The peak in terms of firm value calculated with TOBINQ is 1.50 on average. This implies that firms should not exceed 1.50 times their equity on average. Considering both proxies of firm value, firms' short-term borrowing levels should not exceed 1.67 ((1.84 + 1.50)/2) times their equity.

The control variables GROWTH and NCFLOW show some differences

Table 4

Unit root test results.

Variable/Method	Fisher-Type ADF				Im, Pesaran Shin (IPS)		Cross - Sectional IPS (CIPS)
	P	Z	L*	Pm	W-t-bar		CIPS*
MARKET	285.96***	−3.85***	−4.27***	5.05***	−8.54***		−2.59***
TOBINQ	227.40**	−2.23**	−2.05**	2.03**	−6.68***		−2.47***
STL/EQ	334.73***	−5.62***	−6.14***	7.57***	−8.05***		−2.71***
LTL/EQ	216.56*	−2.56***	−2.67***	1.47*	−4.43***		−2.92***
TL/EQ	256.10***	−3.43***	−3.51***	3.51***	−5.13***		−2.43***
FIXED	255.96***	−2.92***	−3.13***	3.50***	−4.24***		−2.00*
GROWTH	952.46***	−19.82***	−25.74***	39.42***	−24.61***		−4.15***
SIZE	294.69***	−3.75***	−4.28***	5.50***	−4.55***		−2.05*
NCFLOW	350.99***	−6.79***	−6.83***	8.41***	−12.06***		−2.95***

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. (MARKET), market value of the firm/book value of the firm. (TOBINQ), market value of equity and total liabilities/book value of assets. (STL/EQ), ratio of short-term liabilities to total equity. (LTL/EQ), ratio of long-term liabilities to total equity. (TL/EQ), ratio of short- and long-term liabilities to total equity. (FIXED), ratio of fixed assets of the firm to total assets. (GROWTH), growth in sales of each firm. (SIZE), natural logarithm of total net sales. (NCFLOW), net profit plus depreciation/total sales. In the Fisher-type ADF and IPS unit-root tests, P , Z , L^* , and P_m , respectively, represent the inverse chi-squared, inverse normal, inverse logit t, and modified inverse chi-squared values. For the ADF test, an appropriate lag length of 1 is selected due to the annual nature of the dataset. For the IPS test, a lag of 1 is deemed suitable according to the Newey–West criterion. The W - t -bar test statistic is selected based on the Akaike information criterion (AIC). Critical values for the CIPS test, considering both firm and time dimensions for each panel, are sourced from Pesaran (2007) and are identified as −2.30 for the 1% level, −2.16 for the 5% level, and −2.08 for the 10% level.

Table 5

MMQR results for short-term debt and firm value.

Panel A: MARKET									
	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
STL/EQ	0.454*** (0.094)	0.463*** (0.083)	0.472*** (0.079)	0.481*** (0.077)	0.489*** (0.081)	0.499*** (0.091)	0.511*** (0.108)	0.524*** (0.131)	0.545*** (0.169)
STL/EQ ²	−0.061** (0.030)	−0.064** (0.027)	−0.066*** (0.025)	−0.068*** (0.024)	−0.070*** (0.024)	−0.072*** (0.026)	−0.075*** (0.030)	−0.078** (0.036)	−0.082* (0.046)
FIXED	−0.746*** (0.243)	−0.645*** (0.215)	−0.544*** (0.203)	−0.450** (0.195)	−0.355* (0.193)	−0.246 (0.205)	−0.110 (0.232)	0.035 (0.270)	0.267 (0.334)
GROWTH	0.050 (0.073)	0.057 (0.072)	0.063 (0.073)	0.069 (0.074)	0.075 (0.077)	0.082 (0.083)	0.091 (0.091)	0.100 (0.103)	0.115 (0.119)
SIZE	−0.006 (0.029)	0.009 (0.027)	0.025 (0.026)	0.041 (0.026)	0.056** (0.027)	0.074** (0.030)	0.096*** (0.034)	0.119*** (0.039)	0.157*** (0.047)
NCFLOW	0.298* (0.163)	0.319** (0.158)	0.339** (0.159)	0.358** (0.163)	0.377** (0.170)	0.399** (0.185)	0.426** (0.206)	0.456** (0.233)	0.503* (0.280)
CRISIS	−0.561*** (0.072)	−0.534*** (0.065)	−0.506*** (0.061)	−0.480*** (0.059)	−0.454*** (0.057)	−0.424*** (0.059)	−0.387*** (0.065)	−0.347*** (0.076)	−0.283*** (0.093)
COVID19	0.467*** (0.081)	0.550*** (0.078)	0.634*** (0.077)	0.711*** (0.077)	0.790*** (0.081)	0.880*** (0.091)	0.991*** (0.101)	1.112*** (0.114)	1.304*** (0.135)
Panel B: TOBINQ									
	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
STL/EQ	0.168*** (0.055)	0.123** (0.051)	0.087* (0.049)	0.050 (0.049)	0.011 (0.051)	−0.035 (0.056)	−0.082 (0.063)	−0.139* (0.073)	−0.236*** (0.090)
STL/EQ ²	−0.036*** (0.013)	−0.028** (0.012)	−0.020* (0.012)	−0.013 (0.012)	−0.005 (0.013)	0.003 (0.014)	0.012 (0.016)	0.023 (0.018)	0.043* (0.023)
FIXED	−0.424*** (0.123)	−0.376*** (0.115)	−0.338*** (0.112)	−0.298*** (0.113)	−0.256** (0.119)	−0.206 (0.130)	−0.156 (0.147)	−0.096 (0.170)	0.006 (0.210)
GROWTH	0.017 (0.039)	0.031 (0.036)	0.042 (0.036)	0.054 (0.037)	0.067* (0.039)	0.081* (0.044)	0.096* (0.051)	0.114* (0.060)	0.144* (0.075)
SIZE	0.002 (0.016)	0.009 (0.015)	0.015 (0.014)	0.021 (0.014)	0.027* (0.015)	0.035** (0.017)	0.043** (0.019)	0.052** (0.022)	0.067** (0.027)
NCFLOW	0.117 (0.142)	0.150 (0.130)	0.177 (0.125)	0.205* (0.124)	0.234* (0.127)	0.269** (0.137)	0.304** (0.152)	0.346** (0.175)	0.418** (0.216)
CRISIS	−0.328*** (0.041)	−0.307*** (0.038)	−0.291*** (0.035)	−0.274*** (0.034)	−0.255*** (0.034)	−0.234*** (0.034)	−0.212*** (0.036)	−0.186*** (0.041)	−0.141*** (0.049)
COVID19	0.213*** (0.036)	0.250*** (0.034)	0.279*** (0.034)	0.309*** (0.035)	0.341*** (0.037)	0.380*** (0.042)	0.418*** (0.049)	0.464*** (0.057)	0.543*** (0.070)

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. This table gives MMQR-based estimates for the relationship between short-term debt (STL/EQ) and firm value. The quadratic term (STL/EQ²) captures the nonlinear effect. (MARKET), market value of the firm/book value of the firm. (TOBINQ), market value of equity and total liabilities/book value of assets. (STL/EQ), ratio of short-term liabilities to total equity. (FIXED), ratio of fixed assets of the firm to total assets. (GROWTH), growth in sales of each firm. (SIZE), natural logarithm of total net sales. (NCFLOW), net profit plus depreciation/total sales. The vertex points of the quadratic equations for STL/EQ and MARKET are: Q10: 3.72, Q20: 3.62, Q30: 3.58, Q40: 3.54, Q50: 3.49, Q60: 3.47, Q70: 3.41, Q80: 3.36, and Q90: 3.32, with an average vertex point of 3.50 across all quantiles. For LTL/EQ in relation to TOBINQ, the vertex points are: Q10: 2.33, Q20: 2.20, Q30: 2.18, Q80: 3.02, and Q90: 2.74, with an average of 2.49. We include dummy variables for the 2008 global financial crisis (CRISIS) and the pandemic (COVID19). CRISIS takes the value of 1 for the years 2008 and 2009 and 0 otherwise, capturing the impact of the financial turmoil on firm value. COVID19 is set to 1 for the years 2020–2022 and 0 otherwise, reflecting the economic and financial disruption caused by the pandemic. The results are determined based on 5000 bootstrap simulations.

Table 6
MMQR results for long-term debt and firm value.

Panel A: MARKET									
	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
LTL/EQ	0.598*** (0.122)	0.631*** (0.114)	0.662*** (0.115)	0.688*** (0.123)	0.720*** (0.140)	0.755*** (0.168)	0.798*** (0.202)	0.846*** (0.246)	0.910*** (0.304)
LTL/EQ ²	−0.147*** (0.052)	−0.161*** (0.047)	−0.173*** (0.047)	−0.184*** (0.050)	−0.197*** (0.057)	−0.211*** (0.068)	−0.228*** (0.084)	−0.247*** (0.103)	−0.273*** (0.128)
FIXED	−1.209*** (0.208)	−1.082*** (0.203)	−0.963*** (0.201)	−0.865*** (0.205)	−0.742*** (0.217)	−0.608*** (0.231)	−0.443* (0.250)	−2.589 (0.276)	−0.013 (0.318)
GROWTH	0.093 (0.083)	0.106 (0.075)	0.118* (0.071)	0.128* (0.070)	0.140** (0.072)	0.154** (0.078)	0.170* (0.089)	0.189* (0.105)	0.213* (0.129)
SIZE	0.006 (0.030)	0.022 (0.028)	0.037 (0.027)	0.049* (0.027)	0.064** (0.029)	0.081** (0.033)	0.102*** (0.039)	0.125*** (0.046)	0.155*** (0.057)
NCFLOW	0.095 (0.193)	0.110 (0.181)	0.124 (0.175)	0.135 (0.175)	0.149 (0.180)	0.165 (0.196)	0.184 (0.219)	0.205 (0.253)	0.234 (0.302)
CRISIS	−0.534*** (0.071)	−0.502*** (0.065)	−0.473*** (0.063)	−0.449*** (0.063)	−0.418*** (0.063)	−0.385*** (0.066)	−0.344*** (0.075)	−0.298*** (0.086)	−0.237*** (0.105)
COVID19	0.488*** (0.085)	0.575*** (0.085)	0.656*** (0.086)	0.723*** (0.090)	0.807*** (0.098)	0.898*** (0.108)	1.011*** (0.121)	1.137*** (0.137)	1.305*** (0.161)
Panel B: TOBINQ									
	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
LTL/EQ	0.165*** (0.063)	0.125** (0.058)	0.096* (0.055)	0.066 (0.054)	0.032 (0.055)	−0.005 (0.058)	−0.045 (0.065)	−0.093 (0.075)	−0.172* (0.092)
LTL/EQ ²	−0.056** (0.025)	−0.043* (0.023)	−0.033 (0.022)	−0.023 (0.021)	−0.012 (0.021)	−0.000 (0.023)	0.012 (0.025)	0.028 (0.028)	0.053 (0.035)
FIXED	−0.508*** (0.114)	−0.433*** (0.107)	−0.378*** (0.105)	−0.321*** (0.107)	−0.256** (0.114)	−0.185 (0.126)	−0.109 (0.144)	−0.018 (0.169)	0.130 (0.210)
GROWTH	0.032 (0.040)	0.043 (0.037)	0.051 (0.036)	0.060 (0.037)	0.069* (0.040)	0.080* (0.045)	0.091* (0.052)	0.104* (0.061)	0.126* (0.076)
SIZE	0.006 (0.016)	0.012 (0.015)	0.016 (0.014)	0.021 (0.015)	0.026* (0.015)	0.032* (0.017)	0.038** (0.019)	0.046** (0.022)	0.058** (0.027)
NCFLOW	0.050 (0.137)	0.108 (0.129)	0.149 (0.121)	0.193 (0.119)	0.242** (0.123)	0.296** (0.132)	0.354** (0.147)	0.424** (0.170)	0.537*** (0.210)
CRISIS	−0.321*** (0.042)	−0.301*** (0.038)	−0.286*** (0.034)	−0.270*** (0.035)	−0.253*** (0.034)	0.234*** (0.035)	−0.213*** (0.037)	−0.189*** (0.041)	−0.148*** (0.050)
COVID19	0.217*** (0.036)	0.253*** (0.034)	0.280*** (0.034)	0.307*** (0.035)	0.339*** (0.037)	0.373*** (0.042)	0.410*** (0.049)	0.454*** (0.057)	0.526*** (0.071)

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. This table gives MMQR-based estimates for the relationship between long-term debt (LTL/EQ) and firm value. The quadratic term (LTL/EQ²) captures the nonlinear effect. (MARKET), market value of the firm/book value of the firm. (TOBINQ), market value of equity and total liabilities/book value of assets. (LTL/EQ), ratio of long-term liabilities to total equity. (FIXED), ratio of fixed assets of the firm to total assets. (GROWTH), growth in sales of each firm. (SIZE), natural logarithm of total net sales. (NCFLOW), net profit plus depreciation/total sales. The vertex points of the quadratic equations for LTL/EQ and MARKET are: Q10: 2.03, Q20: 1.96, Q30: 1.91, Q40: 1.87, Q50: 1.83, Q60: 1.79, Q70: 1.75, Q80: 1.71, and Q90: 1.67, with an average vertex point of 1.84 across all quantiles. For LTL/EQ, in relation to TOBINQ, the vertex points are: Q10: 1.47, Q20: 1.45, Q30: 1.45, and Q90: 1.62, with an average of 1.50. We include dummy variables for the 2008 global financial crisis (CRISIS) and the pandemic (COVID19). CRISIS takes the value of 1 for the years 2008 and 2009 and 0 otherwise, capturing the impact of the financial turmoil on firm value. COVID19 is set to 1 for the years 2020–2022 and 0 otherwise, reflecting the economic and financial disruption caused by the pandemic. The results are determined based on 5000 bootstrap simulations.

in Tables 5 and 6. In Table 5, GROWTH is shown to have a statistically significant relationship with TOBINQ with a positive coefficient at high quantiles, while it is statistically insignificant for MARKET. In contrast, in Table 6, GROWTH is shown to have a statistically significant and positive coefficient for both MARKET and TOBINQ at high quantiles. These findings suggest that, in the short run, sales growth is driven by internal factors rather than external factors. Similarly, NCFLOW has a statistically significant effect on MARKET and TOBINQ with a positive coefficient at high quantiles (Table 5) but a statistically insignificant effect on MARKET (Table 6). NCFLOW has a statistically significant effect with a positive coefficient on TOBINQ at high quantiles, suggesting that cash flows are more closely linked to a firm's intrinsic valuation than its market capitalization. This implies that firm's value can be increased by allocating cash flows to long-term strategic and productive projects.

Table 7 shows that, similar to the results for short-term and long-term liabilities, the relationship between LTL/EQ and MARKET and TOBINQ is an inverted U shape in all quantiles (Q10–Q90). Initially, as firms increase their long-term liabilities, firm value increases. However, after a certain level of debt (vertex point), firm value decreases. The peak points in terms of total debt and MARKET and TOBINQ are 4.09 and 3.17, respectively. According to this calculation, the ratio of firms'

long-term liabilities to equity should be 3.63 on average. These results indicate that BIST manufacturing firms can determine their optimal capital structure based on the peak points determined by this study to maximize firm value. On the other hand, the control variables show other effects on firm value. Firstly, FIXED negatively affects firm value in low and medium quantiles (Q10–Q50) given the optimal capital structure of firms. Secondly, GROWTH positively affects firm value in medium and high quantiles (Q50–Q90). Thirdly, SIZE positively affects firm value at medium and high quantiles (Q50–Q90). Fourthly, NCFLOW positively affects firm value at medium and high quantiles (Q40–Q90). Finally, the financial crisis has a negative effect on firm value, while the COVID-19 pandemic has a positive effect.

The results of this study partially support the view that there is a positive relationship between capital structure and firm value (Bui et al., 2023; Durand, 1952; Jiraporn & Liu, 2008; Khan et al., 2021; Miller, 1977; Ramli et al., 2019; Ross, 1977). The study argues that this approach holds validity during periods of low and medium firm value. Moreover, in periods of low firm value, firms tend to increase their value by increasing their debt, according to the tax-saving effect advocated by Miller (1977) and the information asymmetry and signalling theory proposed by Ross (1977). On the other hand, the findings confirm the view that if firms continue to borrow beyond a certain point (in all

Table 7
MMQR results for total debt and firm value.

Panel A: MARKET									
	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
TL/EQ	0.328*** (0.082)	0.346*** (0.072)	0.362*** (0.067)	0.376*** (0.064)	0.393*** (0.064)	0.411*** (0.071)	0.434*** (0.084)	0.460*** (0.102)	0.495*** (0.130)
TL/EQ ²	−0.035** (0.017)	−0.038*** (0.015)	−0.042*** (0.014)	−0.045*** (0.013)	−0.048*** (0.013)	−0.052*** (0.015)	−0.057*** (0.017)	−0.062*** (0.021)	−0.070*** (0.027)
FIXED	−0.877*** (0.195)	−0.762*** (0.180)	−0.659*** (0.175)	−0.570*** (0.178)	−0.458*** (0.186)	−0.343* (0.209)	−0.194 (0.243)	−0.029 (0.286)	0.196 (0.354)
GROWTH	0.070 (0.071)	0.078 (0.063)	0.085 (0.059)	0.092 (0.057)	0.099* (0.057)	0.107* (0.061)	0.118* (0.069)	0.129 (0.081)	0.145 (0.101)
SIZE	−0.007 (0.028)	0.009 (0.026)	0.024 (0.025)	0.037 (0.025)	0.053** (0.026)	0.069*** (0.028)	0.091*** (0.032)	0.115*** (0.038)	0.147*** (0.047)
NCFLOW	0.274 (0.184)	0.291* (0.164)	0.307** (0.154)	0.321** (0.151)	0.338** (0.155)	0.356** (0.170)	0.379* (0.198)	0.405* (0.238)	0.439 (0.302)
CRISIS	−0.543*** (0.068)	−0.514*** (0.064)	−0.489*** (0.062)	−0.466*** (0.063)	−0.438*** (0.065)	−0.409*** (0.071)	−0.371*** (0.079)	−0.330*** (0.092)	−0.273*** (0.112)
COVID19	0.469*** (0.079)	0.558*** (0.077)	0.637*** (0.077)	0.706*** (0.078)	0.793*** (0.081)	0.882*** (0.093)	0.997*** (0.103)	1.124*** (0.115)	1.299*** (0.139)
Panel B: TOBINQ									
	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
TL/EQ	0.135*** (0.043)	0.099*** (0.039)	0.073* (0.038)	0.045 (0.038)	0.014 (0.039)	−0.020 (0.043)	−0.057 (0.048)	−0.099* (0.056)	−0.174*** (0.069)
TL/EQ ²	−0.022*** (0.008)	−0.016** (0.007)	−0.012* (0.007)	−0.088 (0.007)	−0.003 (0.007)	0.001 (0.008)	0.007 (0.009)	0.013 (0.010)	0.025* (0.013)
FIXED	−0.447*** (0.120)	−0.388*** (0.111)	−0.346*** (0.108)	−0.302*** (0.109)	−0.252** (0.115)	−0.195 (0.128)	−0.136 (0.146)	−0.069 (0.171)	0.050 (0.213)
GROWTH	0.024 (0.038)	0.037 (0.035)	0.046 (0.035)	0.056 (0.036)	0.067* (0.039)	0.080* (0.044)	0.093* (0.051)	0.108* (0.060)	0.134* (0.075)
SIZE	0.000 (0.016)	0.008 (0.014)	0.014 (0.014)	0.020 (0.014)	0.027* (0.015)	0.035** (0.017)	0.042** (0.019)	0.052** (0.022)	0.068** (0.028)
NCFLOW	0.111 (0.144)	0.151 (0.133)	0.179 (0.127)	0.208* (0.125)	0.242* (0.128)	0.280** (0.137)	0.319** (0.152)	0.364** (0.175)	0.444** (0.216)
CRISIS	−0.324*** (0.042)	−0.303*** (0.038)	−0.288*** (0.036)	−0.272*** (0.035)	−0.255*** (0.034)	−0.234*** (0.035)	−0.213*** (0.037)	−0.189*** (0.041)	−0.147*** (0.050)
COVID19	0.209*** (0.037)	0.249*** (0.035)	0.277*** (0.034)	0.306*** (0.036)	0.340*** (0.038)	0.378*** (0.043)	0.417*** (0.050)	0.462*** (0.058)	0.542*** (0.072)

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. This table gives MMQR-based estimates for the relationship between total debt (TL/EQ) and firm value. The quadratic term (TL/EQ²) captures the nonlinear effect. (MARKET), market value of the firm/book value of the firm. (TOBINQ), market value of equity and total liabilities/book value of assets. (TL/EQ), ratio of short- and long-term liabilities to total equity. (FIXED), ratio of fixed assets of the firm to total assets. (GROWTH), growth in sales of each firm. (SIZE), natural logarithm of total net sales. (NCFLOW), net profit plus depreciation/total sales. The vertex points of the quadratic equations for TL/EQ and MARKET are: Q10: 4.69, Q20: 4.55, Q30: 4.31, Q40: 4.18, Q50: 4.09, Q60: 3.95, Q70: 3.81, Q80: 3.71, and Q90: 3.54, with an average vertex point of 4.09 across all quantiles. For TL/EQ in relation to TOBINQ, the vertex points are: Q10: 3.07, Q20: 3.09, Q30: 3.04, and Q90: 3.48, with an average of 3.17. We include dummy variables for the 2008 global financial crisis (CRISIS) and the pandemic (COVID19). CRISIS takes the value of 1 for the years 2008 and 2009 and 0 otherwise, capturing the impact of the financial turmoil on firm value. COVID19 is set to 1 for the years 2020–2022 and 0 otherwise, reflecting the economic and financial disruption caused by the pandemic. The results are determined based on 5000 bootstrap simulations.

quantiles of firm value), the value of firms decreases (Booth et al., 2001; Brusov et al., 2014; Chakraborty, 2010; Chen, 2004; Doorasamy, 2021; Friend & Lang, 1988; Huang & Song, 2006; Jensen, 1986; Jensen & Meckling, 1976; Oino & Ukaegbu, 2015; Vo & Ellis, 2017). Therefore, this study offers a crucial recommendation for firms, to cease borrowing when their value reaches a maximum level.

4.3. The results of robustness checks

To check robustness, we apply the test of Juodis et al. (2021), known as the JKS non-Granger causality test, using the half-panel jackknife method with a Wald-type statistic. We choose this essentially for its strong power over heterogeneity and CSD in panel data and the soundness of the results. The original contribution of the JKS non-Granger causality test relies on its effective dealing with bias through a pooled estimator with a $\sqrt{NT}$ convergence rate. This not only gives better performance but enriches some size and power properties, making it highly attractive for empirical studies in which the complexities of panel data are involved. Given this advantage, the JKS non-Granger causality test is particularly suited for studies of capital structure and firm value, as it considers firm heterogeneity and CSD with an accuracy which is crucial for robust statistical inferences and reliable

evidence.

Table 8 confirms the inverted U-shaped relationship between firms' short-term (STL/EQ) and long-term (LTL/EQ) liabilities and total liabilities (TL/EQ) on firm value (MARKET and TOBINQ) and reveals that the relationship in question is dynamic. While the lagged value of debt initially has a positive effect on firm value, it has a negative effect after a certain point. These results show that the lagged value of debt provides firms with financial flexibility and resources for growth. However, this positive effect reverses as financial risks increase as debt increases. At the same time, these results support the results of the panel bootstrap quantile regression method. Examined in terms of control variables, the GROWTH and CRISIS variables are different from the panel quantile regression results. This difference stems from a dynamic structure and managerial structure. In other words, the lagged values of sales growth (the value one year ago) have a negative effect on firm value. These results show that the agency and conflict of interest theories (Jensen, 1986, 1988) are valid for BIST manufacturing firms. Growth in sales means that firms benefit from growth opportunities and increase cash flows. However, the fact that managers direct cash flows to low-yield projects instead of distributing dividends to shareholders in line with their own interests makes the growth process unsustainable and has a negative effect on firm value in the long term. At this point, BIST

Table 8

Dynamic effects of capital structure on firm value: half-panel jackknife estimation.

	Panel A: MARKET			Panel B: TOBINQ		
STL/EQ_{t-1}	1.229***			0.349***		
	–0.145			–0.056		
STL/EQ_{t-1}^2	–0.251***			–0.075***		
	–0.036			–0.015		
LTL/EQ_{t-1}		1.314***			0.464***	
		–0.135			–0.066	
LTL/EQ_{t-1}^2		–0.310***			–0.149***	
		–0.056			–0.027	
TL/EQ_{t-1}			0.767***			0.226***
			–0.086			–0.042
TL/EQ_{t-1}^2			–0.094***			–0.033***
			–0.017			–0.009
$FIXED_{t-1}$	–0.848***	–1.424***	–0.997***	–0.396***	–0.579***	–0.442***
	–0.293	–0.228	–0.226	–0.115	–0.113	–0.114
$GROWTH_{t-1}$	–0.782***	–0.658***	–0.722***	–0.336***	–0.294***	–0.320***
	–0.098	–0.071	–0.07	–0.034	–0.035	–0.034
$SIZE_{t-1}$	0.371***	0.399***	0.346***	0.186***	0.190***	0.183***
	–0.058	–0.043	–0.044	–0.021	–0.021	–0.022
$NCFLOW_{t-1}$	0.36	–0.012	0.298	0.214**	0.097	0.184**
	–0.244	–0.185	–0.191	–0.095	–0.09	–0.094
$CRISIS_{t-1}$	0.464***	0.534***	0.484***	0.324***	0.345***	0.330***
	–0.062	–0.064	–0.064	–0.032	–0.032	–0.032
$COVID\ 19_{t-1}$	0.116	0.134	0.142*	0.103**	0.107***	0.107***
	–0.094	–0.084	–0.084	–0.041	–0.041	–0.041
HPJ wald test	401.52***	515.55***	507.02***	416.92***	425.32***	410.00***
P – value	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
BIC tests	–2205.67	–2114.03	–2232.66	–4308.55	–4220.27	–4352.89
Maxlags	(1)	(1)	(1)	(1)	(1)	(1)

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. This table gives the estimated dynamic and nonlinear effects of capital structure on firm value using the half-panel jackknife estimator, controlling for CSD. All independent variables are included with their one-period lag to account for potential endogeneity, persistence effects, and dynamic adjustments in capital structure decisions. STL/EQ_{t-1} represents the one-period lagged ratio of short-term liabilities to total equity, while LTL/EQ_{t-1} denotes the one-period lagged ratio of long-term liabilities to total equity. TL/EQ_{t-1} captures the total leverage effect by considering both short-term and long-term liabilities relative to total equity. The quadratic terms, STL/EQ_{t-1}^2 , LTL/EQ_{t-1}^2 , and TL/EQ_{t-1}^2 , capture the nonlinear effects of leverage on firm value, reflecting the inverted U-shaped relationship between capital structure and firm performance. $FIXED_{t-1}$ captures the lagged effect of the ratio of fixed assets to total assets, while $GROWTH_{t-1}$ represents the previous period's sales growth. $SIZE_{t-1}$ is the lagged natural logarithm of total net sales. $NCFLOW_{t-1}$ denotes the lagged ratio of net profit plus depreciation to total sales. We include dummy variables for the 2008 global financial crisis ($CRISIS_{t-1}$) and the COVID-19 pandemic ($COVID\ 19_{t-1}$). With a lag of 1, the Bayesian information criterion (BIC) value is determined to be –4352.8916. The results are determined based on 5000 bootstrap simulations.

manufacturing firms should take precautions against managerial problems that limit growth opportunities. On the other hand, the positive effects of financial crises shown by the robustness results indicate that BIST manufacturing firms are sensitive to crises. Firms develop strong policies against shocks and make moves to increase firm value. Finally, the robustness results show that the COVID-19 pandemic increases the value of BIST manufacturing firms both in current periods and in dynamic processes.

In the second stage of the robustness analysis, we examine the causality relationships between the variables, using the LA-VAR and JKS non-Granger causality panel causality tests. We prefer these methods for several reasons. Firstly, these tests can be used even when all series are stationary at level $I(0)$. Secondly, they take into account unobserved heterogeneity across firms. Thirdly, they take into account horizontal CSD across firms. Finally, the LA-VAR test provides panel causality results with bootstrap simulations and the JKS test is a new test that derives results under heterogeneity and CSD. Table 9, the panel causality results, reveals a unidirectional causality from STL/EQ , LTL/EQ , and TL/EQ to firm value. However, there is no strong causality from firm value to STL/EQ , LTL/EQ , and TL/EQ . There is a strong bidirectional causality relationship between the control variables $FIXED$ and $SIZE$ and firm value. On the other hand, while there is a weak causality relationship from $GROWTH$ and $NCFLOW$ to firm value, there is a strong causality relationship from firm value to $GROWTH$ and $NCFLOW$.

5. Conclusion and policy implication

The aim of this study is to reveal the nonlinear relationship between capital structure and firm value using annual data from 2005 to 2023 of 94 manufacturing firms listed on Borsa Istanbul (BIST). We measure firm value using two proxies, MARKET and TOBINQ, and the capital structure using three proxies: short-term and long-term liabilities, and total liabilities. We employ the Method of Moments Quantile Regression (MMQR) strengthened with bootstrap simulations for the nonlinear relationship between capital structure and firm value. To add robustness to the study, we firstly use the newly developed half-panel jackknife (HPJ) estimator to reveal the dynamic effects of the nonlinear relationship between capital structure and firm value, then the newly developed JKS non-Granger causality test, which takes into account heterogeneity and cross-sectional dependency in the causal relationships between capital structure and firm value. Finally, we test the consistency of the results using the LA-VAR panel causality test augmented with bootstrap simulations.

Based on the results, we find a nonlinear inverted U-shaped relationship between the cost of capital and firm value. In periods of low firm value, we find that firm value increases as firms' short-term and long-term liabilities and total liabilities increase. This supports the net income approach (Durand, 1952) and the debt and taxes theory (Miller, 1977), which suggest that firms increase their firm value through borrowing due to the tax shield effect. Additionally, we confirm Jensen and Meckling (1976) and Jensen's (1986) conflict of interest theory, as well as Ross's (1977) information asymmetry and signalling theory,

Table 9

Panel causality test results with CSD.

Panel A: MARKET			EK (2011) Test			JKS (2021) Test	
Null Hypothesis:			LA-VAR Test Stat.	Asymp. <i>p</i> - value	Bootstrap <i>p</i> - value	HPJ Wald Test Stat.	Bootstrap <i>p</i> - value
STL/EQ	⇒	MARKET	493.336	0.000***	0.016**	28.311	0.000***
MARKET	⇒	STL/EQ	1884.062	0.000***	0.000***	0.474	0.491
LTL/EQ	⇒	MARKET	447.636	0.000***	0.052**	30.891	0.000***
MARKET	⇒	LTL/EQ	877.140	0.000***	0.000***	1.742	0.186
TL/EQ	⇒	MARKET	792.809	0.000***	0.005***	49.833	0.000***
MARKET	⇒	TL/EQ	1482.692	0.000***	0.001***	0.388	0.533
FIXED	⇒	MARKET	483.218	0.000***	0.103*	10.905	0.001***
MARKET	⇒	FIXED	248.387	0.002***	0.959	21.745	0.000***
GROWTH	⇒	MARKET	563.076	0.000***	0.069*	1.268	0.260
MARKET	⇒	GROWTH	348.602	0.000***	0.585	107.439	0.000***
SIZE	⇒	MARKET	613.539	0.000***	0.372	51.514	0.000***
MARKET	⇒	SIZE	362.178	0.000***	0.959	43.725	0.000***
NCFLOW	⇒	MARKET	332.933	0.000***	0.245	0.039	0.843
MARKET	⇒	NCFLOW	341.346	0.000***	0.562	11.921	0.001***
Panel B: TOBINQ			LA-VAR Test Stat.			HPJ Wald Test Stat.	
Null Hypothesis:			LA-VAR Test Stat.	Asymp. <i>p</i> - value	Bootstrap <i>p</i> - value	HPJ Wald Test Stat.	Bootstrap <i>p</i> - value
STL/EQ	⇒	TOBINQ	442.438	0.000***	0.069*	15.938	0.000***
TOBINQ	⇒	STL/EQ	394.487	0.000***	0.239	0.663	0.415
LTL/EQ	⇒	TOBINQ	572.872	0.000***	0.000***	10.640	0.001***
TOBINQ	⇒	LTL/EQ	485.662	0.000***	0.004***	0.128	0.719
TL/EQ	⇒	TOBINQ	1671.499	0.000***	0.000***	17.469	0.000***
TOBINQ	⇒	TL/EQ	386.732	0.000***	0.183	0.102	0.748
FIXED	⇒	TOBINQ	297.403	0.000***	0.948	11.868	0.000***
TOBINQ	⇒	FIXED	382.046	0.000***	0.189	11.506	0.000***
GROWTH	⇒	TOBINQ	676.206	0.000***	0.072*	0.015	0.899
TOBINQ	⇒	GROWTH	324.916	0.000***	0.589	43.342	0.000***
SIZE	⇒	TOBINQ	381.338	0.000***	0.076*	55.919	0.000***
TOBINQ	⇒	SIZE	432.483	0.000***	0.274	29.870	0.000***
NCFLOW	⇒	TOBINQ	322.979	0.000***	0.197	0.137	0.710
TOBINQ	⇒	NCFLOW	357.218	0.000***	0.364	10.171	0.001***

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. This table presents the estimated causal relationship between independent variables and firm value, controlling for CSD. (MARKET), market value of the firm/book value of the firm. (TOBINQ), market value of equity and total liabilities/book value of assets. (STL/EQ), ratio of short-term liabilities to total equity. (LTL/EQ), ratio of long-term liabilities to total equity. (TL/EQ), ratio of short- and long-term liabilities to total equity. (FIXED), ratio of fixed assets of the firm to total assets. (GROWTH), growth in sales of each firm. (SIZE), natural logarithm of total net sales. (NCFLOW), net profit plus depreciation/total sales. The EK-FK test statistic represents the Fisher-type test statistic from the panel causality test developed by [Emir-mahmutoglu and Kose \(2011\)](#) for heterogeneous and cross-sectional mixed panels. The maximum lag length is determined according to the Schwarz information criterion (SIC). The all results are determined based on 5000 bootstrap simulations.

aligning with the views put forward in parallel ([Bui et al., 2023](#); [Jiraporn & Liu, 2008](#); [Khan et al., 2021](#); [Ramli et al., 2019](#)). However, we differ from these studies by showing that the positive relationship between the level of debt and firm value is valid in periods when firm value is low. At the same time, we argue that the total level of borrowing is not infinite in either the short or long run as firm value reaches a maximum at a certain level of borrowing, and declines after this level. We support [Solomon's \(1955\)](#) traditional theory and more recent studies ([Booth et al., 2001](#); [Chakraborty, 2010](#); [Chen, 2004](#); [Doorasamy, 2021](#); [Friend & Lang, 1988](#); [Huang & Song, 2006](#); [Oino & Ukaegbu, 2015](#); [Vo & Ellis, 2017](#)), which state that there is a point at which firm value starts to decline due to excessive borrowing. Moreover, we confirm the BFO-2 theory of BFO (2014), which explains that the negative impact of macroeconomic conditions such as inflation on firm value is valid at the point where BIST manufacturing firms exceed the optimal capital structure threshold. At this point, we provide new evidence of how far borrowing should continue for the optimal capital structure that maximizes firm value for BIST manufacturing firms. In the optimal capital structure model, we find that fixed asset investments have a negative impact on firm value in the low and medium quantiles. It observed that, while sales growth has no effect on firm value in the short run in all quantiles, investors take it into account in the long run, but it is reflected in firm value in a weak form in high quantiles. On the other hand, there are signals that sales-based firm size may increase firm value in periods of high firm

value. Moreover, it appears that firms' cash flows have no effect on firm value in the short run but have a positive effect in the long run and in high quantiles of firm value. Finally, a negative effect of financial crises on the value of BIST manufacturing firms is identified. However, we observe that the COVID-19 pandemic has a positive effect on firm value, and investors increase their investments in manufacturing firms during the pandemic.

In the robustness analyses, we confirm the inverted U-shaped relationship between capital structure and firm value. Moreover, we examine the effect of firm borrowing levels on firm value in a dynamic approach, and find that borrowing decisions taken by firms in the previous year do not change the capital structure-firm value relationship, which remains inverted U-shaped. However, when the dynamic structure of the model is analysed, we find a change in the effect of growth in sales on firm value. Previously, in models established for different capital structures, it has been found that growth in sales is reflected positively in firm value, albeit in a weak form. However, in the robustness study, we find a negative relationship in the dynamic structure between sales growth in the previous year and firm value. We find evidence of the existence of the agency and conflict of interest theory effect ([Jensen, 1986, 1988](#)) in BIST manufacturing firms, which suggests that firms may want to take advantage of growth opportunities but managers invest in low-return projects instead of distributing dividends to shareholders in their own interest, and there is a conflict of interest

between managers and shareholders. Other than these issues, there are no significant differences in the relationships between fixed asset investment, firm size, cash flows, and firm value. To enhance the originality of the study, we conduct panel causality analyses, both of which show a strong unidirectional causality from short-term and long-term borrowing and total borrowing to firm value. However, we find that firm value has no causal effect on borrowing.

Based on the findings of this research, we put forward several policy recommendations regarding optimal capital structure. Firstly, firms should develop policies regarding their borrowing strategies in line with the peak point calculated in this study for optimal short- and medium-term borrowing and total borrowing that maximizes firm value. In doing so, firms must develop policies on where to stop borrowing in the short and long run at the point where firm value is maximized. Secondly, we find that firms' fixed asset investments are not sufficiently reflected in firm value. Therefore, asset diversification and focusing on more liquid assets, especially during periods of low firm value, may eliminate liquidity risk for the firm. Thirdly, policymakers need to incentivize firms with tax benefits and long-term productive projects in order to prevent managers from trying to block borrowing strategies and take advantage of growth opportunities for their own benefit. Thus, conflicts of interest between firm managers and shareholders can be avoided. Finally, given that BIST manufacturing firms exhibit aggressive borrowing policies, they should control short-term borrowing during financial crisis periods, but be bold in their long-term borrowing strategies without postponing long-term projects due to their ability to take quick measures against financial crises. Contrary to expectations, the positive impact of the COVID-19 pandemic on the BIST manufacturing industry reveals that firms should accelerate their investments during

pandemic periods.

There are several limitations to this study. Firstly, there are currently 242 BIST firms. Due to missing values, outliers, and a lack of full data from 2005 to 2023, many firms are excluded from the initial dataset, leaving 94 firms analysed. This sample shows consistent results for the relationship between cost of capital and firm value for BIST manufacturing firms. Secondly, the study is conducted on the BIST manufacturing industry, which is an emerging market, and non-manufacturing sectors and other developing countries are excluded from the sample. Thirdly, in this study, nonlinear modelling is introduced through the second-order equation. Future studies should adapt this model, firstly, to other stock exchanges in developing countries and other sectors, and then to developed countries, examining the differences and consistencies in optimal capital structures. Moreover, since this study reveals a nonlinear relationship through a second-order equation, future studies could employ cubic terms, interaction terms, panel threshold regressions (PTRs), or spline regression extensions to test the nonlinearity of the results. In addition to the model established, the impact of debt on firm value could be revealed using capital structure indicators based not on equity but on total assets.

CRedit authorship contribution statement

Cengizhan Karaca: Software, Methodology, Formal analysis, Data curation, Conceptualization, review & editing. **Walid Mensi:** Writing – review & editing, Validation, Supervision, Conceptualization. **Eray Gemici:** Resources, Supervision, Validation, Writing – original draft, Investigation, review & editing.

Appendix

Table A1
List of Sample Firms

ADEL	BRISA	DURDO	HEKTS	LUKSK	SILVR
AFYON	BRSAN	DYOB	IHEVA	MNDRS	SKTAS
AKCNS	BTCIM	EGEEN	IZMDC	MNDTR	SNPAM
AKSA	BUCIM	EGGUB	KAPLM	NUHCM	TATGD
ALCAR	BURCE	EGPRO	KARSN	OTKAR	TOASO
ALKA	CELHA	EGSER	KARTN	OYAKC	TTRAK
ALKIM	CEMTS	ERBOS	KLMSN	PARSN	TUKAS
ARCLK	CIMSA	EREGL	KNFRT	PENG	TUPRS
ARSAN	CMBTN	ERSU	KONYA	PETKM	ULKER
ASUZU	CMEN	FRIGO	KORDS	PETUN	USAK
ATEKS	DERIM	FROTO	KRDMA	PINSU	VESBE
AYGAZ	DESA	GENTS	KRDMB	PNSUT	VESTL
BAGFS	DEVA	GEREL	KRDMD	PRKAB	YATAS
BAKAB	DITAS	GOLTS	KRSTL	SARKY	YUNSA
BANVT	DMSAS	GOODY	KRTEK	SASA	
BOSSA	DOGUB	GUBRF	KUTPO	SELGD	

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