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Essays on Debt Maturity Structure, Investment and Complementarities in Financial Decisions

Cognome / Surname Rispoli Nome / Name Marco

Matricola / Registration number 839408

Tutore / Tutor: Prof. Luca Stanca

Supervisor: Prof. Enzo Dia

Coordinatore / Coordinator: Prof. Matteo Manera

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Ph.D. candidate: Marco Rispoli

Supervisor: Prof. Enzo Dia

Introduction

This dissertation aims to build a theoretical and empirical framework to test for complementarities between debt maturity choices and to study the effect of debt maturity heterogeneity on firms' financing and investment choices. Most existing capital structure models assume that firms optimally choose their financial policy using a single debt type, excluding any possible advantage of a more complex financing profile. However, borrowing diversity can affect a firm's investment if economies of scope reduce financial costs. In the presence of convex debt costs, business firms choose an optimal composition of debt sources to minimize the costs of external finance, efficiently exploiting any cost-complementarities.

The first chapter introduces a model that allows testing for cost-complementarities between short-and long-term debt while controlling for investment opportunities. The empirical results reveal that firms do not benefit from complementarities between short- and long-term debt independently of the investment scale. Differently, the negative and statistically significant coefficients on both financing sources support the existence of financial cost convexities once controlling for investment opportunities. Hence, when firms choose the optimal issuance of short-and long-term debt, they trade off the different interest rate costs with debt-maturity-specific convexities.

The second chapter investigates strategic complementarities between short-and long-term debt. In particular, by allowing firms to issue both short-and long-term debt, I study whether combining the two financing sources is profit-enhancing compared to single-debt-type strategies. The results of the empirical analysis suggest that for most manufacturing sectors, shorter and longer maturities are not strategic complements. However, they are strategic complements in some specific sectors.

Finally, in the third chapter, we develop and estimate a theoretical model in which investment policy and debt issuance are endogenous variables and firms issue costly short- and long-term debt to finance their capital expenditure. This strategy does not assume the existence of explicit debt targets; instead, it allows for the recovery of contingent debt targets from firms' investment and financing decisions. The analysis revealed that contingent debt target ratios vary across firms with different financial characteristics, sizes and credit ratings.

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Contents

Chapter 1

Investment, Debt Maturity and Complementarities

Author: Marco Rispoli

Abstract
I model a firm with a composite debt structure featuring interaction terms between short-and long-term debt. Debt costs are convex, but cost complementarities can reduce the overall cost of external finance, and induce higher investment rates. To test the theory, I nest the proposed specification in a Q-theoretic framework, testing the restrictions of the model using data on a large sample of US public firms. Irrespective of the investment scale and financial characteristics, firms do not benefit from cost complementarities between short-and long-term debt. Therefore, when choosing between short-and long-term debt, firms trade off fixed costs with debt-maturity-specific convexities.

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1.1 Introduction

The wider availability of financing instruments increases the importance of optimally combining them. For this reason, debt heterogeneity is a relevant topic in corporate debt management. In principle, in fact, companies with a heterogeneous debt structure may benefit from positive spillovers between financing sources. Hence, borrowing diversity can affect a firm's investment if economies of scope reduce financial costs. In the presence of convex debt costs, business firms choose an optimal composition of debt sources to minimize the costs of external finance efficiently exploiting any cost-complementarities.

This paper proposes a model involving convex industrial adjustment costs and convex costs on external finance due to capital market imperfections and interaction terms between different debt sources. Hence, in this environment the Modigliani-Miller theorem does not hold, and financing variables alter the relationship between investment rate and Tobin's Q.

I use conditional quantile regression techniques and panel fixed-effects to estimate these terms on a large panel of US firms' data obtained from Compustat, spanning the period from 1975 to 2019. To take into account endogeneity concerns I use an instrumental variable approach combined with fixed-effects. The model specification generates interaction terms between Q and external finance and a set of restrictions that can be empirically tested to evaluate the significance of financial-cost complementarities while controlling for investment opportunities. When the sum of the interaction terms is positive and statistically significant, it is possible to conclude that firms benefit from complementarities between short-term and long-term debt.

The empirical results reveal that firms do not benefit from complementarities between short-and long-term debt independently of the investment scale. The negative and statistically significant coefficients on both financing sources support the existence of consistent financial cost convexities once controlling for investment opportunities. Moreover, the conditional quantile regressions show that short-term debt convexities are larger than long-term debt ones for lower investment scales. At the same time, the degree of convexity is not statistically different for larger investment scales. Hence, debt-specific convexities are crucial for debt maturity choices when the investment scale is small, while instead the total amount of debt and the economies of scale related to fixed costs are more critical for larger investment scales. Finally, the econometric analysis confirms the results obtained for the overall sample when subsetting the sample based on firm-financial conditions. Irrespective of the EBITDA-to-debt ratio level, firms cannot reap benefits from complementarities between financing sources. Hence, when firms choose the optimal issuance of short-term and long-term debt, they trade off the different interest rate costs with the financial convexities associated with the two financing sources.

The remainder of the paper is organized as follows. Section 2.2 introduces the relevant literature. Section 1.3 explains the theoretical model, beginning with the specification of financial costs and then a standard Q-theoretic framework nesting financial costs and the optimal investment equation. Section 1.4 describes the dataset and the empirical model, and Section 1.5 presents the empirical results for the whole sample, the quantile regression, and the sub-sample regressions. Section 1.6 presents the robustness checks, and Section 1.7 concludes.

1.2 Literature Review

The original formalization of the link between market valuation and the optimal investment level, the so-called Tobin's Q, was introduced by James Tobin (1969). Despite its theoretical power, the practical use was limited because marginal q is an unobservable object. Hayashi (1982) initially stated the conditions for marginal and average Tobin's Q to coincide: this is the case under perfect competition with constant returns to scale both in the production function and the installation cost of capital. The result has two implications: Q becomes a sufficient statistic in the presence of convex adjustment costs without financial constraints, and the investment model can therefore be estimated by directly calculating the average Q. Some authors questioned the robustness of Tobin's Q as a sufficient statistic. Fazzari and Petersen (1988) provided empirical evidence for the significance of cash flows and attributed the results to financial constraints. Several studies, however, have challenged this interpretation: Gomes (2001) introduced a structural model with financial frictions, simulated the data, and demonstrated that positive coefficients attached to cash flows survive when removing financial frictions. Similarly, Abel and Eberly (2011) found that cash flow and Tobin's Q have positive coefficients in a framework with no financial frictions. Finally, Abel (2018) provides evidence that even when marginal and average Q coincide, the cash-flows coefficient is subject to measurement error due to omitted variables. I contribute to this literature by considering debt sources along with cash flow as determinants of the investment rate and debt market imperfections as the main responsible of financial friction.

Most existing capital structure models assume that firms optimally choose their financial policy using a single debt type, excluding any possible advantage of a more complex financing profile. Moreover, given the relevance of the debt market, as highlighted by Bolton and Scharfstein (1996), it is more important to focus on debt rather than the choice of debt over equity. A diversified debt structure can be a relevant tool for managers to increase financial flexibility. A survey by Graham and Harvey (2001) confirms that financial flexibility is a first-order consideration for corporate managers. Recently, Rauh and Sufi (2010) highlight the first-order importance of debt heterogeneity in capital structure choices and its beneficial impact on investment. On the same line, Tengulov (2019) show that borrowing diversity positively affects the response of firms to credit supply shocks. In particular, a higher debt heterogeneity reduces external financing costs and positively affects debt issuance volumes. Finally, Jungherr and Schott (2021) state that the choice debt maturity, short-term and long-term debt, is critical in models with investment and financing policies.

Concerning debt maturity, Choi et al. (2018) show that US non-financial firms might benefit from adopting a dispersed maturity structure. When optimally choosing debt maturity, firms trade-off the lower fixed costs associated with shorter maturities with the reduction in roll over risk associated with longer maturities. As recently shown by Chen et al. (2021), an increase in long-term debt can reduce the refinancing risk and the ex-ante cost of financial distress, thus decreasing the marginal cost of short-term debt. However, neither the issuance of only short-term nor the issuance of only long-term debt can avoid the negative effect of rollover risk on investment. Therefore, firms can obtain additional benefits by combining short-term and long-term debt. For example, Diamond (1991) underlines that the simultaneous use of short- and long-term debt allows obtaining the information benefit of short-term debt without incurring rollover risk. Houston and Venkataraman (1994) show that a mix of short- and long-term debt may increase financial flexibility, thereby reducing the cost of external finance.

To properly formalize the additional flexibility guaranteed by a heterogeneous debt structure, I follow Yan (2006), which uses a cost function to analyze the complementarities between debt and leasing. On the same line, Stenbacka and Tombak (2002) identify conditions for complementarities between debt and equity, analyzing their impact on the investment rate. In the presence of complementarities, due to the positive spillovers between financing sources, the authors find that firms can further expand their investments. I contribute to the literature by testing the existence of potential complementarities arising from a diversified maturity structure. In particular, I show that potential cost complementarities can manifest as a positive effect of the sum of short-term and long-term debt-to-capital ratios on investment. Moreover, differently from Stenbacka and Tombak (2002) and Yan (2006), I nest a financial cost specification in a Q-theoretic framework, which allows us to incorporate investment opportunities in the test for complementarities. Crucially, investment opportunities are an important determinant for adopting a dispersed maturity structure, as recently shown by Choi et al. (2021). By using the optimal investment condition, which relates investment with debt sources, it is possible to obtain information on convexities and spillovers that affect debt choices in equilibrium.

1.3 Theoretical framework

1.3.1 Financial costs and cost complementarities

Following Yan (2006), I propose a specific formalization of the financial cost function based on the industrial organization theory.[1] Panzar and Willig (1981) show that economies of scope arise whenever costs are sub-additive: when this is the case, combining two or more product lines in a single firm is less costly than producing each of them separately. When applied to a general financial cost function $C(S, L)$ where S indicates the current stock of short-term debt and L of long-term debt, this property requires that:

$$C(S, L) \leq C(S) + C(L). \tag{1.1}$$

Furthermore, equation (1.2) states the standard properties of the cost function:

$$C_s = \frac{\partial C}{\partial s} > 0; \quad C_l = \frac{\partial C}{\partial l} > 0; \quad C_{sS} = \frac{\partial C}{\partial s \partial S} > 0; \quad C_{lL} = \frac{\partial C}{\partial l \partial L} > 0, \tag{1.2}$$

where s and l represent new issuance of short- and long-term debt, respectively. The positive first derivative means that increasing short-term or long-term debt issuance is costly because of transaction costs and interest rates. The positive sign of the second derivative captures the increase in the risk premium due to higher leverage. As clarified by Fazzari and Petersen (1988), the increasing marginal cost of debt is associated with financial distress costs, capturing firms' difficulties in meeting their principal and interest payments. For instance, in the case of short-term debt, the convexity parameter well captures the rollover risk, that is to say, the difficulties in rolling over debt at shorter maturities. Furthermore, following the analysis of Nehring and Puppe (2004), cost functions can satisfy a more stringent property than sub-additivity, i.e. the sub-modularity property that relates to the sign of the cross-partial derivative of the cost function. If applied to long-and short-term debt, the property requires that any marginal increase in the quantity of short-term debt outstanding in the firm's debt structure reduces the marginal cost of long-term debt and vice versa. Hence, to properly test for cost complementarities, I formalize financial costs allowing for cross-partial derivatives. For instance, I define the total cost function as:

$$C(S, L, K) = r_S S + r_L L, \tag{1.3}$$

where K is the gross capital stock, $S = S_0 + s$ is the current stock of short-term debt, $L = L_0 + l$ is the current stock of long-term debt, S_0 and L_0 indicate the existing stock of debt at time $t-1$, while s and l represent new issuance in period t. The corresponding

[1] Miravete and Pernías (2010) and Kretschmer et al. (2012) use multiplicative interaction terms between variables to formalize and estimate strategic complementarities.

cost functions for the two sources, taking into consideration the external finance specifications proposed by Billett and Garfinkel (2004) and Hennessy et al. (2007), are the following:

$$r_S = k_1 + \frac{\delta_1}{2}\frac{S}{K} + \theta_1 \frac{L}{K} \tag{1.4}$$

$$r_L = k_2 + \frac{\delta_2}{2}\frac{L}{K} + \theta_2 \frac{S}{K}. \tag{1.5}$$

The first part is the sum of transaction fees and interest rate costs specific to each financing source (k_1 and k_2). The second part measures the risk premium, which captures the convexity of external finance, and the third part is the spillover generated by the other source of debt financing. By substituting the expressions for the cost of the two sources in equation (1.3), I obtain:

$$C(S, L, K) = k_1 S + k_2 L + \frac{\delta_1}{2}\frac{S^2}{K} + \frac{\delta_2}{2}\frac{L^2}{K} + (\theta_1 + \theta_2)\frac{SL}{K}, \tag{1.6}$$

where S, L are the stock of short-and long-term debt, K is the gross capital stock,[2] $\delta_1 > 0$ and $\delta_2 > 0$ are the parameters controlling for the effect of the stock of debt on risk-premia, and θ_1, θ_2 govern the spillovers between the two financing sources. Consequently, I obtain the following first partial derivatives concerning the variables indicating the issuance of the two financing sources:

$$\begin{aligned} C_s &= \frac{\partial C}{\partial s} = \frac{\partial C}{\partial S} = k_1 + \delta_1 \frac{S}{K} + (\theta_1 + \theta_2)\frac{L}{K} \\ C_l &= \frac{\partial C}{\partial l} = \frac{\partial C}{\partial L} = k_2 + \delta_2 \frac{L}{K} + (\theta_1 + \theta_2)\frac{S}{K}, \end{aligned} \tag{1.7}$$

where the impact of the issuance of each financing source depends on the existing stock of both short-and long-term debt. The second-order and cross-partial derivatives are given by:

$$C_{sS} = \frac{\partial C}{\partial s \partial S} = \frac{\delta_1}{K}; \quad C_{lL} = \frac{\partial C}{\partial l \partial L} = \frac{\delta_2}{K} \tag{1.8}$$

$$C_{sL} = \frac{\partial C}{\partial s \partial L} = \frac{\theta_1 + \theta_2}{K}; \quad C_{lS} = \frac{\partial C}{\partial l \partial S} = \frac{\theta_1 + \theta_2}{K}. \tag{1.9}$$

Consistently with the general property of cost functions, the second partial derivatives are positive and capture the increase in risk-premium associated with higher leverage ($\delta_1, \delta_2 > 0$). Moreover, in line with the analysis by Yan (2006), the cross partial derivatives are equal. Economies of scope, as demonstrated by Nehring and Puppe (2004),

[2] The book value of capital is normally the main collateral guarantee specified in the covenants of most corporate bonds or loan contracts.

arise whenever the cross-partial derivatives have a negative sign, that is to say when the sum (θ_1 + θ_2) has a negative sign. Therefore, long-term debt issuance decreases the marginal cost of short-term debt, and short-term debt issuance decreases the marginal cost of long-term debt. When this happens, firms can reduce the refinancing risk and the ex-ante financial distress associated with an increase in leverage by using a diversified debt maturity structure.[3]

1.3.2 Investment model with external finance

When financial frictions are relevant, the Modigliani-Miller theorem does not hold, and the first-order optimality conditions that provide an optimal investment equation change accordingly. Bolton et al. (2011) find that the general expression in the presence of financial frictions is given by:

$$\text{marginal cost of investing} = \frac{\text{marginal q}}{\text{marginal cost of financing}}.$$

Firms invest up to the point where the shadow value of installed capital is equal to the marginal cost of investment, including now the cost of funds: marginal benefits must therefore also cover the marginal increase in the cost of external finance. Hence, with costly external finance, the general formulation of the optimal condition proposed by Hennessy et al. (2007) is given by:

$$\frac{q}{C_E(E,K)} = 1 + G_I(I,K), \tag{1.10}$$

where $C_E(E,K)$ stands for the financial costs associated with external finance, $G_I(I,K)$ are the convex adjustment costs on capital, K denotes the capital stock, and I aggregate investment rate.

I propose a model based on the framework by Hennessy et al. (2007) featuring debt maturity heterogeneity and the possibility of cost complementarities. The model is continuous, investors are risk-neutral, and cash flows are discounted at the risk-free rate of $r > 0$. The firm's operating profits are given by:

$$F(K,\epsilon) - G(I,K), \tag{1.11}$$

where ϵ is an exogenous variable capturing innovations in prices and productivity. F is a production function strictly increasing in both arguments and homogeneous of degree

[3] Choi et al. (2018) underlines that, in choosing debt maturities, firms prefer a more dispersed maturity structure that allows a smooth refinancing profile.

one in K. $G(I, K)$ is the adjustment cost function on investment and can be specified as:

$$G(I_t, K_t) = \frac{1}{2}\delta_I K_t \left[\frac{I_t}{K_t} - \alpha\right]^2, \tag{1.12}$$

which, as standard in the literature, is strictly convex and homogeneous of degree one in the arguments. The external finance cost function,[4] taking into account that firms have access both to short-term and long-term debt, is given by:

$$C(S, L, K) = k_1 S + k_2 L + \frac{\delta_1}{2}\frac{S^2}{K} + \frac{\delta_2}{2}\frac{L^2}{K} + (\theta_1 + \theta_2)\frac{SL}{K}, \tag{1.13}$$

The vector (K_t, ϵ_t) contains all the relevant information, and at each point in time, the manager chooses the optimal investment and financial policy I_t,s_t,l_t to minimize the external finance costs $C(S_t, L_t, K_t)$, and the optimal time to default indicated by T. The value function of the problem is given by:

$$V(K_t, \epsilon_t) = \max_{\mathrm{I}_{t+\tau}, \mathrm{s}_{t+\tau}, \mathrm{l}_{t+\tau}, T} E_t\left[-\int_0^{T-t} e^{-r\tau}\left[C(S_{t+\tau}, L_{t+\tau}, K_{t+\tau})\right]d\tau\right] \tag{1.14}$$

$$\text{s.t.} \quad dK_t = (\mathrm{I}_t - \delta K_t)dt \tag{1.15}$$

$$s_t + l_t = \mathrm{I}_t + G(I_t, K_t) - F(K_t, \epsilon_t) \tag{1.16}$$

$$d\epsilon_t = \mu(\epsilon_t)dt + \sigma(\epsilon_t)dW_t, \tag{1.17}$$

where s_t and l_t indicate new issuances of short- and long-term debt respectively.[5] The last term in the budget constraint, represented by equation (1.16), captures the sources of funds (operating profits) alternative to the sum of short- and long-term debt. The solution of equation (1.14) is obtained by using the Bellman equation:[6]

$$\begin{aligned} rV = \max_{I,s,l} \quad & (I - \delta K)V_K - C[S, L, K] + \mu(\epsilon)V_\epsilon + \frac{1}{2}\sigma^2(\epsilon)V_{\epsilon\epsilon} \\ & + \lambda[s + l - I - G(I, K) + F(K, \epsilon)]. \end{aligned} \tag{1.18}$$

The first-order conditions with respect to debt issuances are:

$$\lambda = k_1 + \delta_1\frac{S}{K} + (\theta_1 + \theta_2)\frac{L}{K} \tag{1.19}$$

$$\lambda = k_2 + \delta_2\frac{L}{K} + (\theta_1 + \theta_2)\frac{S}{K}, \tag{1.20}$$

[4]The function is homogeneous of degree one, decreasing and convex in K and increasing and convex in S and L. See the Appendix for the derivations.

[5]In line with Billett and Garfinkel (2004), I assume that the constraint is binding and firms need external finance for their investments, so that firms issue both kinds of debt in equilibrium.

[6]For a simple derivation of the HJB equation from discrete time Bellman equation, see https://benjaminmoll.com/wp-content/uploads/2019/07/Lecture4_ECO521_web.pdf.

which combined gives rise to:

$$k_1 + \delta_1 \frac{S}{K} + (\theta_1 + \theta_2)\frac{L}{K} = k_2 + \delta_2 \frac{L}{K} + (\theta_1 + \theta_2)\frac{S}{K}. \tag{1.21}$$

In equilibrium firms equate the marginal cost of the two financing sources, which is expressed as the sum of fixed costs (k_1, k_2), financial convexities capturing roll over risk and risk-premium effects (δ_1, δ_2) and possible financial cost spillovers (θ_1, θ_2). In the case in which short-term and long-term debt are complement, the sign of $(\theta_1 + \theta_2)$ is negative and therefore the marginal cost associated to the two financing sources is reduced. By solving the maximization problem with respect to investment, it is possible to test for spillover effects and differences in convexities. Therefore, the optimal investment equation in the second step of optimization is used to recover information concerning the optimal choice between short-term and long-term debt in equilibrium. The budget constraint is inserted directly in the financial cost function $C(S_t, L_t, K_t)$. Moreover, by using the fact that $S = S_0 + s$ and $L = L_0 + l$, I can write the Bellman equation in the following way:

$$\begin{aligned} rV = \max_{I,s,l} \quad & (I - \delta K)V_K - C[I + G(I,K) - F(K,\epsilon) - l + S_0, L, K] + \\ & - C[S, I + G(I,K) - F(K,\epsilon) - s + L_0, K] + \mu(\epsilon)V_\epsilon + \frac{1}{2}\sigma^2(\epsilon)V_{\epsilon\epsilon}. \end{aligned} \tag{1.22}$$

The optimal condition concerning investment rate allows us to derive a testable implication linking investment rate to debt sources. The optimal condition with respect to investment is:

$$V_K = q = C_s * [1 + G_I(I^*, K)] + C_l * [1 + G_I(I^*, K)], \tag{1.23}$$

where $C_s = \frac{\partial C}{\partial s}$ and $C_l = \frac{\partial C}{\partial l}$ are the first derivatives of the financial cost function with respect to the issuance of short- and long-term debt, as reported in equations (1.7). To understand this condition, let us start with the first equality. V_K is the marginal increase in the value of the firms which arises from an additional unit of capital; thus, by definition, it corresponds to Tobin's q.[7] The second equality states that the optimal investment policy requires firms to invest up to the point in which the marginal value of investing covers the adjustment costs on investment and the costs of external finance. The equation can be rewritten as:

$$q = (C_s + C_l)[1 + G_I(I^*, K)] \implies G_I(I^*, K) = \frac{q}{C_s + C_l} - 1, \tag{1.24}$$

which is the optimality condition in the presence of financial costs. By taking into account the formalization of financial costs introduced before, the sum of the $C_s + C_l$ is

[7] For a detailed explanation, see Dixit and Pindyck (1994) pp. 386.

given by:[8]

$$C_s + C_l = k + \delta_1 \frac{S}{K} + \delta_2 \frac{L}{K} + (\theta_1 + \theta_2)\frac{S}{K} + (\theta_1 + \theta_2)\frac{L}{K} \tag{1.25}$$

with $k = k_1 + k_2 > 0$, given that these terms refer to the sum of transaction and interest rate costs[9]. The other terms, multiplied by the ratio-to-capital of the financing sources, are of a small order of magnitude since they are products of decimals. By defining $x = [\delta_1 + \theta_1 + \theta_2]\frac{S}{K} + [\delta_2 + \theta_1 + \theta_2]\frac{L}{K}$ and using the first derivative of 1.12, I can use a first-order Taylor approximation of equation 1.24:

$$\delta_I \left[\frac{I}{K} - \alpha\right] = \frac{q}{[k+x]} - 1 \approx q\left[\frac{k-x}{k^2}\right] - 1 = q\left[\frac{1}{k} - \frac{x}{k^2}\right] - 1, \tag{1.26}$$

where to obtain the approximation I multiplied numerator and denominator for $k - x$. This boils down to:

$$\delta_I \left[\frac{I}{K} - \alpha\right] = q\left[\frac{1}{k} - \frac{\delta_1 + \theta_1 + \theta_2}{k^2}\frac{S}{K} - \frac{\delta_2 + \theta_1 + \theta_2}{k^2}\frac{L}{K}\right] - 1, \tag{1.27}$$

Starting from equation (1.27), I obtain the final expression for optimal investment, which contains interaction terms between Tobin's q and external finance:

$$\frac{I}{K} = \left(\alpha - \frac{1}{\delta_I}\right) + \frac{1}{k\delta_I}q - \left(\frac{\delta_1 + \theta_1 + \theta_2}{k^2\delta_I}\right)\left(q * \frac{S}{K}\right) - \left(\frac{\delta_2 + \theta_1 + \theta_2}{k^2\delta_I}\right)\left(q * \frac{L}{K}\right). \tag{1.28}$$

The equations above show that the interaction terms coefficients are composed of two terms: the parameters multiplying the risk-premium and the parameters capturing financial cost spillovers. Based on the sign of these terms, it is possible to test the existence of cost complementarities between short-term and long-term debt, conditioning on investment opportunities.

1.4 Data and empirical model

1.4.1 Data and sample selection

To construct the dataset for this analysis, I used the annual Compustat database for the period from 1975 to 2019. The whole sample construction includes all firms except regulated utilities (SIC Codes 4900-4999), financial firms (6000-6999), and other

[8] I assume that $k + \delta_1 \frac{S}{K} + \delta_2 \frac{L}{K} > (\theta_1 + \theta_2)(\frac{S}{K} + \frac{L}{K})$, which guarantees that the sum of the first order derivatives is always positive.

[9] Gomes (2001) assumed a common transaction costs of 3%

firms (9000+). Following the analysis by Andrei et al. (2019), I remove firms with a negative book value of assets or sales and firms with less than $5 million in physical capital. I measure the market value of equity as prcc_ f multiplied by csho. I define the numerator of Tobin's q as the market value of equity plus book value of total debt minus current assets and its denominator as gross PP&E. Physical investment is defined as capital expenditure divided by lagged PP&E and also the stocks of short-term and long-term debt are normalized by the gross PP&E. Cash flow is measured as income before extraordinary items plus depreciation divided by gross PP&E and equity issuance as the difference between sales and purchases of common and preferred stock, divided by gross PP&E. Furthermore, all firm-level accounting ratios are winsorized at the 1% level to remove outliers. I show a complete definition of the variables in the Appendix 1.8. Table (1.1) shows the summary statistics:

Table 1.1: Descriptive statistics

Variable	Obs	Mean	Std Dev	Median
Investment	189978	0.17	0.21	0.11
Total investment	178829	0.20	0.18	0.15
Tobin's Q	183265	3.56	7.97	1.02
Total Tobin's Q	183536	1.1	1.74	0.6
Market-to-book	184568	1.76	1.41	1.31
Short term debt	213051	0.15	0.32	0.04
Long term debt	212824	0.56	1.04	0.25
Cash flow	210097	0.06	0.69	0.13
Equity issuance	196531	0.14	0.64	0.00

Note: The table displays descriptives for the core variables used in the empirical analysis.

1.4.2 Empirical model and parameter's restrictions

To test the relevance of cost complementarities, I need to focus on the sum of two estimated coefficients. When the sum of the financial cost spillovers ($\theta_1 + \theta_2$) is higher than the sum of individual risk-premiums factor loadings ($\delta_1 + \delta_2$), the sum of the interaction terms between Q and external finances can positively affect the investment rate. In line with Yan (2006), cost complementarities between short-term debt and long-term debt are symmetric, and it is impossible to estimate the specific effect of one financing source on the other. As standard in the literature, I use predetermined variables by taking the first-order lag of Tobin's Q and the interaction terms.[10] The econometric model I use in

[10] Hennessy et al. (2007) state that including lagged values make them predetermined and so less subject to endogeneity concerns. Similarly, Campello and Hackbarth (2012) use the interaction between Q and tangibility lagged one time period to address endogeneity concerns. I use a similar approach given that the test proposed by Wooldridge (2010), and used recently by Grieser and Hadlock (2019), confirms that the covariates are not strictly exogenous. The results of the test are available upon request.

the rest of the empirical analysis is:

$$\frac{I_t}{K_{t-1}} = \beta_0 + \beta_1 Q_{i,t-1} + \beta_2 \left(Qx\frac{S}{K}\right)_{i,t-1} + \beta_3 \left(Qx\frac{L}{K}\right)_{i,t-1} + \mu_i + \tau_t + \epsilon_{i,t}, \quad (1.29)$$

where firms (μ_i) and time (τ_t) fixed effects are included in the regression. The former accounts for individual unobservable heterogeneity, and the latter control for time effects common across companies. The relationship between the parameters of the theoretical model and the empirical specification is the following:

$$\beta_1 = \frac{1}{k\delta_I}, \qquad \beta_2 = -\frac{\delta_1 + \theta_1 + \theta_2}{k^2\delta_I}, \qquad \beta_3 = -\frac{\delta_2 + \theta_1 + \theta_2}{k^2\delta_I}. \quad (1.30)$$

It is possible to identify the parameter restrictions allowing to test for complementarities by investigating the sum of the following coefficients:

$$\beta_2 + \beta_3 = -\frac{\delta_1 + \delta_2 + 2(\theta_1 + \theta_2)}{k^2\delta_I}. \quad (1.31)$$

Table (1.2) reports the conditions under which it is possible to assert the existence of cost complementarities between short-term and long-term debt and differences between convexity parameters (δ_1, δ_2):[11]

Table 1.2: Interpretation of the coefficients' sign

Condition on the coefficients	Condition on the parameters	Interpretation
$\beta_2 + \beta_3 > 0$	$\theta_1 + \theta_2 < 0$	Cost complementarities
$\frac{\beta_2}{\beta_1} = \frac{\beta_3}{\beta_1}$	$\frac{\delta_1}{k} = \frac{\delta_2}{k}$	Convexities are equal

To analyze how cost complementarities vary across different investment scales, I then use a conditional quantile regression approach, which allows studying the effect of external finance across the different quantiles of the conditional distribution. The conditional quantile regression specification is given by:

$$\frac{I_t}{K_{t-1}} = \beta_{0\tau} + \beta_{1\tau} Q_{i,t-1} + \beta_{2\tau} \left(Qx\frac{S}{K}\right)_{i,t-1} + \beta_{3\tau} \left(Qx\frac{L}{K}\right)_{i,t-1} + \tau_t + \epsilon_{i,t}, \quad (1.32)$$

[11] Yan (2006) identifies a similar set of restrictions, analyzing the substitution or complementarity between leasing and debt in a purely financial model that does not allow conditioning on investment opportunities. Other studies instead analyze the investment-q regression with interaction terms: see Hennessy et al. (2007) for the case of debt overhang and costly external equity, and Campello and Hackbarth (2012) for the interaction between tangibility and Q.

where τ_t control for time effects and $\beta_{1\tau}, \beta_{2\tau}, \beta_{3\tau}$ are the vector of regressor coefficients which are estimated for the quantiles, $\tau = 0.10, 0.25, 0.5, 0.75, 0.9$. To properly control for heteroskedasticity and autocorrelation within firms, I perform a quantile regression with firm-level clustered standard errors as proposed by Machado and Silva (2005) and Parente and Silva (2016).

1.5 Empirical results

1.5.1 Results for the whole sample

Table 1.3: Panel regressions with different fixed effects

	Investment rate	Investment rate	Investment rate
Q	0.0127***	0.0121***	0.0113***
	(0.000251)	(0.000239)	(0.000238)
Q x short term debt	-0.00119***	-0.00108***	-0.000967***
	(0.000304)	(0.000291)	(0.000282)
Q x long term debt	-0.000637***	-0.000461***	-0.000346***
	(0.0000713)	(0.0000674)	(0.0000645)
Firm FE	Yes	Yes	Yes
Year dummies	No	Yes	No
Sector-Year FE	No	No	Yes
Observations	161819	161819	160144
Adjusted R2	0.365	0.411	0.434
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0013***	-0.0015***	-0.0018***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.044*	-0.051**	-0.055**

Note: The table displays panel regressions with different fixed effects. SE clustered at the firm level are in parenthesis. * = significant at 10%, ** = at 5% and *** = at 1%.

Table (1.3) shows the results of firm-year panel regressions with fixed effects alone, or associated with year dummies or year-industry dummies. As expected, Tobin's Q coefficient is always statistically significant and positively associated with the investment rate across the three specifications.[12] The final part of the Table reports the results of the linear Wald test for the sum between estimated coefficients. The negative coefficient for short-and long-term debt implies that an additional increase in debt levels raises the risk premium offsetting any spillover effect. Therefore, the full sample results do not support the existence of cost-complementarities between short-term and long-term debt. Furthermore, the results suggest that the convexities on short-and long-term debt are statistically different from each other. In particular, short-term debt convexities are

[12] Although Tobin's Q can be subject to measurement error, the need to estimate the interaction between Q and financing sources makes the new error-in-variables methodologies developed by Erickson et al. (2014) for linear models inapplicable in this context.

higher than long-term debt ones, highlighting the importance of roll over risk for the optimal financial policy.

To analyze to what extent the investment scale matters for complementarities and convexities, I study how the interaction term's coefficients vary along with the conditional distribution of the investment rate. Table (1.4) displays the results of the pooled quantile regression:

Table 1.4: Pooled conditional quantile regression

	Investment rate	Investment rate	Investment rate	Investment rate	Investment rate
	0.10	$\tau = 0.25$	$\tau = 0.5$	$\tau = 0.75$	$\tau = 0.9$
Q	0.00299***	0.00527***	0.00934***	0.0167***	0.0234***
	(0.000108)	(0.000148)	(0.000224)	(0.000340)	(0.000469)
Q x short term debt	-0.000829***	-0.00117***	-0.00126***	-0.00126***	-0.000635
	(0.000281)	(0.000192)	(0.000271)	(0.000471)	(0.000963)
Q x long term debt	-0.000182***	-0.000351***	-0.000691***	-0.00133***	-0.00176***
	(0.0000284)	(0.0000390)	(0.0000519)	(0.000139)	(0.000150)
Observations	162151	162151	162151	162151	162151
Firm FE	No	No	No	No	No
Year dummies	Yes	Yes	Yes	Yes	Yes
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0010***	-0.0015***	-0.0020***	-0.0026***	-0.0024***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.216**	-0.154***	-0.061*	0.004	0.048

Note: The table displays CQR for quantiles (0.10,0.25,0.50,0.75,0.90). Year dummies are included but not reported in the table. Firm-level clustered standard errors are in parentheses. * = significant at 10%, ** = at 5% and *** = at 1%.

The intra-cluster correlation test proposed by Parente and Silva (2016) always rejects the null hypothesis of no intra-cluster correlation, where clusters correspond to firms. Through a conditional quantile regression approach, it is possible to isolate the effect of investment scale from the level of investment opportunities. The results of the last column of Table (1.4) refer to the effect of interaction terms on investment when for each level of investment opportunities, from low to high, only the firm-year observations with the largest investment scale are taken into account. The bottom part of the Table displays the test for spillovers and the equality between convexities. The effects of financing sources interacting with investment opportunities are negative across all conditional quantiles of the investment distribution. Therefore, independently of their investment scale, firms face substantial convexity in financial costs, with more adverse effects for greater investment scales. Concerning convexities, lower conditional quantiles of the investment distribution show that increasing short-term debt accelerates costs faster than long-term debt. Therefore, financial convexities are critical for the equilibrium debt choices for smaller investment scales. For the higher-investment quantiles there is no statistically significant difference between short-and long-term debt convexities, indicating that only the total level of debt matters, in connection with potential economies of scale in the presence of fixed costs (proxied by k in the model).

1.5.2 Complementarities and firm's financial characteristics

This section explores the link between cost complementarities and firms' financial characteristics by employing a metric commonly used by rating agencies, namely the EBITDA-to-debt ratio, an indicator of the firm's financial soundness.[13] For firms in worse financial conditions, as underlined by Yan (2006), both the impact of financial spillovers (θ_1,θ_2 in the notation) and the marginal risk-premium parameters (δ_1,δ_2 in the notation), are expected to increase. However, in the case of firms under severe financial distress, the negative effect on risk-premia can consistently outsize that of the spillover effects, especially the roll over risk associated to shorter maturities. Table (1.5) displays the descriptive statistics for the four quarters of EBITDA-to-debt ratio based on the yearly distribution.[14]

Table 1.5: Summary statistics across EBITDA-to-debt and cash-flow volatility quarters

Bins	Variable	Observations	Mean	Minimum	Maximum	Standard deviation	Median
(q_1)	Ebitda/Debt	47,666	13	0.46	233.7	39	2.00
(q_2)	Ebitda/Debt	47,667	0.59	0.21	1.2	0.18	0.57
(q_3)	Ebitda/Debt	47,658	0.26	-0.15	0.57	0.10	0.25
(q_4)	Ebitda/Debt	47,667	-3.9	-84	0.31	14	-0.096
Total	Ebitda/Debt	190,667	2.5	-84	233.7	21	0.38

Note: The table displays descriptives for the EBITDA-to-debt ratio across four quarters based on their yearly distribution; q_1 includes firms with EBITDA-to-debt higher than the third quartile, q_2 between the second and the third quartile included, q_3 between the first and the second quartile included and q_4 lower or equal to the first quartile.

[13] Gebauer et al. (2018) suggest combining the stock of debt with debt's service capacity, which the authors measure as the EBIDTA-to-debt ratio, to measure debt overhang correctly.

[14] Results are robust when using the pooled distribution of the metrics.

Table 1.6: Panel regressions across EBITDA-to-debt

	EBITDA-to-debt ratio (q_1)	EBITDA-to-debt ratio (q_2)	EBITDA-to-debt ratio (q_3)	EBITDA-to-debt ratio (q_4)
	Investment rate	Investment rate	Investment rate	Investment rate
Q	0.0107***	0.0167***	0.0176***	0.0130***
	(0.000297)	(0.000859)	(0.00115)	(0.000461)
Q x short term debt	-0.00108**	-0.00142***	-0.000307	-0.00151***
	(0.000447)	(0.000528)	(0.000656)	(0.000518)
Q x long term debt	-0.000457*	-0.00127***	-0.00113***	-0.000398***
	(0.000245)	(0.000156)	(0.000192)	(0.000122)
Observations	55791	36386	32161	29554
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R2	0.488	0.470	0.405	0.376
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0015***	-0.0026***	-0.014**	-0.0019***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.059	-0.0090	0.047	-0.085**

Note: The table displays the results of panel fixed effect regressions for four quarters of the yearly distribution of the EBITDA-to-debt ratio and cash-flow volatility; q_1 includes firms with EBITDA-to-debt higher than the third quartile, q_2 between the second and the third quartile included, q_3 between the first and the second quartile included and q_4 lower or equal to the first quartile. Cluster-robust standard errors at the firm level are in parentheses. * = significant at 10%, ** = at 5% and *** = at 1%.

Table (1.6) displays the regression results for the different quarters of the yearly distribution of the EBITDA-to-debt ratio. The sub-sample separation does not show any clear pattern concerning the existence of complementarities. Differently, irrespective of the level of the financial ratio, firms face substantial convexities in raising external finance, either short-or long-term debt. Hence, firms cannot reap any benefits from complementarities between financing sources. Moreover, short-and long-term debt convexities do not differ for levels of the EBITDA-to-debt ratio higher than the first quartile. In the case of firms belonging to the lowest-ratio quantile, however, short-term debt convexities are substantially higher than long-term debt ones, highlighting the financial dstress costs associated with shorter maturities.

1.6 Robustness checks

1.6.1 Endogeneity

Consistently with Hennessy et al. (2007), in the empirical analysis, I used Tobin's Q and its interaction terms at the beginning of the year. Measuring the investment rate during the year implies that the explanatory variables may be considered predetermined, even if not strictly exogenous. More importantly, as the authors clarify, any endogeneity bias in the interaction terms likely generates an upward bias in the coefficients. This bias can arise because, in case of an unexpected positive shock, firms will increase both the investment rate and debt, generating a positive correlation between the two. For instance, in line with Elsas et al. (2013), investment can be financed by debt, equity, cash-flows and other financing sources, where the last one is of minor relevance. Therefore, the endogeneity bias is strictly related to the omitted variable bias. As a result, short-and long-term debt coefficients can erroneously capture the effect of other financing sources on the investment rate.

Control for cash flows and equity

Following the pecking order theory, firms should use cash flows as the marginal source to finance investment. Moreover, starting from Fazzari and Petersen (1988), cash flows have been considered an essential determinant of the investment rate and a proxy for financial constraints. Concerning equity, Klein and Zur (2011) find significant interactions between the cost of equity and the cost of debt. Therefore, omitting these financing sources from the empirical model can lead to a misidentification problem and a wrong interpretation of the estimated coefficients. For this reason, along with the variable derived from the theoretical model, I introduce cash flows and equity issuance as additional covariates lagged by one time period, consistently with the principal text analysis.

Table 1.7: Pooled conditional quantile regression with cash flows

	Investment rate	Investment rate	Investment rate	Investment rate	Investment rate
	0.10	τ = 0.25	τ = 0.5	τ = 0.75	τ = 0.9
Q	0.00253***	0.00421***	0.00726***	0.0117***	0.0163***
	(0.000116)	(0.000232)	(0.000203)	(0.000269)	(0.000577)
Q x short term debt	-0.000698*	-0.000994***	-0.00111***	-0.00109***	-0.00119
	(0.000392)	(0.000224)	(0.000328)	(0.000266)	(0.00169)
Q x long term debt	-0.000198***	-0.000337***	-0.000564***	-0.000790***	-0.00111***
	(0.0000468)	(0.0000497)	(0.0000450)	(0.0000797)	(0.000258)
Cash flow	0.0258***	0.0332***	0.0355***	0.0336***	0.0330***
	(0.000855)	(0.00102)	(0.00108)	(0.00126)	(0.00158)
Equity issuance	0.0144***	0.0262***	0.0529***	0.115***	0.205***
	(0.000840)	(0.00126)	(0.00223)	(0.00277)	(0.00645)
Observations	150791	150791	150791	150791	150791
Year dummies	Yes	Yes	Yes	Yes	Yes
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0009**	-0.0013***	0.0017***	-0.0019***	-0.0023***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.1979	-0.156***	-0.075	-0.026	-0.0046

Note: The table displays CQR for quantiles (0.25,0.50,0.75,0.90). Year dummies are included but not reported in the table. Firm-level clustered standard errors are in parentheses. * = significant at 10%, ** = at 5% and *** = at 1%.

Table 1.8: Panel regressions across EBITDA-to-debt

	EBITDA-to-debt ratio (q_1)	EBITDA-to-debt ratio (q_2)	EBITDA-to-debt ratio (q_3)	EBITDA-to-debt ratio (q_4)
	Investment rate	Investment rate	Investment rate	Investment rate
Q	0.00825***	0.0124***	0.0132***	0.0103***
	(0.000326)	(0.000949)	(0.00121)	(0.000578)
Q x short term debt	-0.00107**	-0.000661	0.000350	-0.00193***
	(0.000429)	(0.000699)	(0.000777)	(0.000603)
Q x long term debt	-0.000266	-0.00115***	-0.000896***	-0.000216
	(0.000262)	(0.000182)	(0.000202)	(0.000153)
Cash_flow	0.0243***	0.0552***	0.0375***	0.0212***
	(0.00288)	(0.00628)	(0.00526)	(0.00304)
Equity issuance	0.0467***	0.0500***	0.0470***	0.0472***
	(0.00278)	(0.00602)	(0.00594)	(0.00358)
Observations	55791	36386	32161	29554
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adjusted R2	0.488	0.470	0.405	0.376
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0013**	-0.0018**	-0.0005	-0.0021***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.097*	0.040	0.094	-0.167***

Note: The table displays the results of panel fixed effect regressions for four quarters of the yearly distribution of the EBITDA-to-debt ratio and cash-flow volatility; q_1 includes firms with EBITDA-to-debt higher than the third quartile, q_2 between the second and the third quartile included, q_3 between the first and the second quartile included and q_4 lower or equal to the first quartile. * = significant at 10%, ** = at 5% and *** = at 1%.

The sub-sample regressions confirm the results of the principal text analysis, in particular the fact that firms with the highest conditional investment scale face higher financial convexities than firms with minor investment scales. Moreover, the results of the sub-sample division based on firms' financial characteristics show that firms with a very low average EBITDA-to-debt ratio face the highest financial convexities and short-term debt convexities are consistently higher than long-term debt ones.

Instrumental variable approach

The theoretical model can be easily extended to include the dividend policy. In particular, to include key factors in a tractable manner, I can rewrite the budget constraint in the following way:

$$s_t + l_t = \mathrm{I}_t + G(I_t, K_t) - \beta F(K_t, \epsilon_t), \tag{1.33}$$

where to capture the dividend policy, I assumed that a fixed share $1 - \beta$ of the operating profits is distributed to shareholders. This assumption is consistent with the findings of Brav et al. (2005) showing that the dividend policy is conservative and that managers take the current level of dividend payments as given. The model variation does not alter the results and supports the choice of instrumental variables in a way consistent with the model specification. The payout policy, as indicated by Brav et al. (2005), is altered in response to the availability of investment opportunities, which in the model are proxied by Tobin's Q. However, dividends choices are secondary to the investment decisions, and therefore they are presumably uncorrelated with the current investment rate. Similarly, while the current value of the Tobin's Q and interactions terms are likely endogenous, past values computed at the industry levels should not directly explain current investment decisions. Therefore, the instrumental variable strategy is based on these two pillars. First, I use a dummy variable for the dividend policy that takes a value of one if firms have positive dividends and zero otherwise. Secondly, I use the yearly industry averages of the Q and the interaction terms as additional instruments. The two-stage least square regressions with fixed effects include the following two steps:

$$X_{i,t-1} = \beta_0 + \beta_1 Ind\_Q_{i,t-1} + \beta_1 Ind\_\frac{QxS}{K}_{i,t-1} + \beta_2 Ind\_\frac{QxL}{K}_{i,t-1} + \beta_3 D\_Div_{t-1} + \\ + \mu_i + \tau_t + \epsilon_{i,t}, \tag{1.34}$$

where $X_{i,t-1} = Q_{i,t-1}, \frac{QxS}{K}_{i,t-1}, \frac{QxL}{K}_{i,t-1}$. The second step use the Tobin's Q and the interactions with debt-to-capital ratios estimated in the first regression step:

$$\frac{I_{i,t}}{K_{i,t-1}} = \beta_0 + \beta_1 \hat{Q}_{i,t-1} + \beta_2 \frac{Q\hat{x}S}{K}_{i,t-1} + \beta_3 \frac{Q\hat{x}L}{K}_{i,t-1} + \mu_i + \tau_t + \epsilon_{i,t}, \tag{1.35}$$

Table (3.12) displays the results of these two regression steps.

Table 1.9: Instrumental variable regression with fixed effects

	First stage IV-FE regression		
	$Q_{i,t-1}$	$\frac{QxS}{K}_{i,t-1}$	$\frac{QxL}{K}_{i,t-1}$
$Ind\_Q_{i,t-1}$	0.8259***	0.0076	0.052
	(0.026)	(0.014)	(0.0647)
$Ind\_\frac{QxS}{K}_{i,t-1}$	-0.028	0.8461***	-0.161
	(0.044)	(0.076)	(0.229)
$Ind\_\frac{QxL}{K}_{i,t-1}$	-0.0316***	-0.0127*	0.798***
	(0.0128)	(0.0065)	(0.080)
$Dummy\_Div_{t-1}$	0.296***	0.0479	0.351
	(0.069)	(0.056)	(0.268)
Observations	161410	161410	161410
SW F $statistic^a$	554.78 (16.85)	92.33 (16.85)	112.47 (16.85)
		Second stage IV-FE regression	
		Investments	
Q_{t-1}		0.0152***	
		(0.0006)	
$\left(Qx\frac{S}{K}\right)_{i,t-1}$		-0.0007	
		(0.0010)	
$\left(Qx\frac{L}{K}\right)_{i,t-1}$		-0.0012***	
		(0.0002)	
Observations		161410	
Sargan-Hansen $test^b$		1.059 (0.3033)	
KP Wald rk F^c		45.52(10.27)	
$\hat{\beta}_2 + \hat{\beta}_3$		-0.0019*	
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$		0.036	

Note: The table displays instrumental-variable with firm and year fixed effects for fixed asset investments. Clustered standard errors at the firm level are in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. *(a)* Sanderson-Windmeijer F statistic, Stock-Yogo critical values at 5 % maximum relative bias in parenthesis, *(b)* Hansen J-statistic. P-values in parenthesis and *(c)* Kleibergen-Paap rk Wald F statistic, Stock-Yogo critical values at 10% maximal IV size in the parenthesis.

The instrumental variable regression confirms the results of the full sample concerning the negative effect of the interaction terms and the fact that firms cannot benefit from complementarities. Differently, convexities associated to short-term and long-term debt are not statistically different from each other.

1.6.2 Measurement error in Tobin's Q

Although Tobin's Q can be subject to measurement error, the need to estimate the interaction between Q and financing sources makes the new error-in-variables methodologies developed by Erickson et al. (2014) for linear models inapplicable in this context. Therefore, to improve the estimates' accuracy, I follow the suggestion by Erickson and

Whited (2006) to reduce bias. In particular, as stated by the authors, an appropriate valuation and inclusion of the intangible assets in the numerator of Tobin's Q can consistently alleviate the measurement problem in this context. For this reason, I rerun the various steps using Total Tobin's Q, recently introduced by Peters and Taylor (2017). Furthermore, Erickson and Whited (2006) found that the market-to-book ratio measure of Tobin's Q, widely used in the corporate finance literature, is an especially poor proxy for investment opportunities and in this context is not consistent with the theoretical model, which scales all the variables by the capital stock. As shown below, when the market-to-book ratio is used as a proxy for investment opportunities, the empirical analysis erroneously supports the existence of complementarities between short-term and long-term debt. Moreover, under the model assumptions, the measure of Q used in the main text is the appropriate one. Below, I show the results of the empirical analysis when intangibles are included in the definition of investments, capital and Tobin's Q, following the definitions adopted by Peters and Taylor (2017).

Table 1.10: Total Tobin's Q: panel regressions

	Investment rate	Investment rate	Investment rate
Total Q	0.0522***	0.0490***	0.0451***
	(0.000774)	(0.000744)	(0.000743)
Total Q x short term debt	-0.00505	-0.00827**	-0.00653*
	(0.00390)	(0.00373)	(0.00360)
Total Q x long term debt	-0.00543***	-0.00458***	-0.00389***
	(0.00139)	(0.00131)	(0.00129)
Firm FE	Yes	Yes	Yes
Year dummies	No	Yes	No
Sector-Year FE	No	No	Yes
Observations	161500	161500	159935
Adjusted R2	0.501	0.549	0.568
$\hat{\beta}_2 + \hat{\beta}_3$	-0.010**	-0.013***	-0.010***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	0.007	-0.075	-0.059

Note: The table displays panel regressions with different fixed effects. SE clustered at the firm level are in parenthesis. * = significant at 10%, ** = at 5% and *** = at 1%.

Table 1.11: Total Tobin's Q: Pooled conditional quantile regression

	Investment rate	Investment rate	Investment rate	Investment rate	Investment rate
	0.10	τ = 0.25	τ = 0.5	τ = 0.75	τ = 0.9
Total Q	0.0216***	0.0318***	0.0472***	0.0699***	0.0885***
	(0.000930)	(0.000736)	(0.000858)	(0.00123)	(0.00152)
Total Q x short term debt	-0.0221***	-0.0141***	-0.00996*	0.00208	0.0120
	(0.00532)	(0.00356)	(0.00524)	(0.0158)	(0.0123)
Total Q x long term debt	-0.0189***	-0.0235***	-0.0270***	-0.0251***	-0.00787***
	(0.00172)	(0.00119)	(0.00138)	(0.00235)	(0.00159)
N	163114	163114	163114	163114	163114
Firm FE	No	No	No	No	No
Year dummies	Yes	Yes	Yes	Yes	Yes
$\hat{\beta}_2 + \hat{\beta}_3$	-0.041***	-0.038***	-0.037***	-0.023	0.004
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.149	0.298**	0.361***	0.389	0.225

Note: The table displays CQR for quantiles (0.25,0.50,0.75,0.90). Year dummies are included but not reported in the table. Firm-level clustered standard errors are in parentheses. * = significant at 10%, ** = at 5% and *** = at 1%.

Table 1.12: Panel regressions across EBITDA-to-debt

	EBITDA-to-debt ratio (q_1)	EBITDA-to-debt ratio (q_2)	EBITDA-to-debt ratio (q_3)	EBITDA-to-debt ratio (q_4)
	Investment rate	Investment rate	Investment rate	Investment rate
Total Q	0.0405***	0.0586***	0.0710***	0.0594***
	(0.000877)	(0.00248)	(0.00346)	(0.00158)
Total Q x short term debt	0.00147	-0.0276***	-0.0159**	-0.0272***
	(0.00685)	(0.00870)	(0.00756)	(0.00644)
Total Q x long term debt	-0.00486*	-0.0182***	-0.0222***	-0.00318
	(0.00249)	(0.00364)	(0.00282)	(0.00262)
Observations	54311	35742	33643	30030
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adjusted R2	0.640	0.588	0.529	0.503
$\hat{\beta}_2 + \hat{\beta}_3$	-0.003	-0.046***	-0.038***	-0.0304***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	0.156	-0.160	0.089	-0.405***

Note: The table displays the results of panel fixed effect regressions for four quarters of the yearly distribution of the EBITDA-to-debt ratio; q_1 includes firms with EBITDA-to-debt higher than the third quartile, q_2 between the second and the third quartile included, q_3 between the first and the second quartile included and q_4 lower or equal to the first quartile. * = significant at 10%, ** = at 5% and *** = at 1%.

The results obtained using Total Tobin's Q, which appropriately includes intangible assets, confirm the principal text analysis, implying that measurement bias is not the main driver of the results. In particular, in all regression results, the existence of complementarities between short-term and long-term debt is rejected. The conditional quantile regression approach results confirm the relevance of total debt for larger investment scales. In contrast, long-term debt convexities are higher than short-term debt ones for minor investment scales. The result is the opposite of the one obtained for physical investment, which aligns with the difficulty of using intangible assets as collateral for obtaining longer maturities. Additionally, the results concerning the EBITDA-to-debt ratio confirm the principal text analysis, showing that short-term debt convexities are substantially higher for firms under severe financial distress (low or negative ratio value). Below, I show the results for the case where the Market-to-book ratio is a proxy for investment opportunities.

Table 1.13: Market-to-book ratio: Pooled conditional quantile regression

	Investment rate	Investment rate	Investment rate	Investment rate	Investment rate
	0.10	τ = 0.25	τ = 0.5	τ = 0.75	τ = 0.9
MTB	0.00788***	0.0185***	0.0376***	0.0729***	0.126***
	(0.000529)	(0.000630)	(0.000914)	(0.00135)	(0.00131)
MTB x short term debt	-0.00686***	-0.00862***	-0.00467***	0.00557*	0.0230***
	(0.000556)	(0.000847)	(0.00128)	(0.00304)	(0.00406)
MTB x long term debt	0.000939***	0.00195***	0.00309***	0.00497***	0.00536***
	(0.000308)	(0.000375)	(0.000615)	(0.000737)	(0.00134)
N	161014	161014	161014	161014	161014
Year dummies	Yes	Yes	Yes	Yes	Yes
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0059***	-0.0067***	0.0016	0.011***	0.0284***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.990***	-0.572***	-0.206***	0.0083	0.140***

Note: The table displays CQR for quantiles (0.25,0.50,0.75,0.90). Year dummies are included but not reported in the table. Firm-level clustered standard errors are in parentheses. * = significant at 10%, ** = at 5% and *** = at 1%.

Table 1.14: Market-to-book ratio: Panel regressions across EBITDA-to-debt

	EBITDA-to-debt ratio (q_1)	EBITDA-to-debt ratio (q_2)	EBITDA-to-debt ratio (q_3)	EBITDA-to-debt ratio (q_4)
	Investment rate	Investment rate	Investment rate	Investment rate
MTB	0.0499***	0.0633***	0.0734***	0.0491***
	(0.00142)	(0.00314)	(0.00455)	(0.00225)
MTB x short term debt	-0.00276	-0.00186	0.0104**	-0.00987***
	(0.00288)	(0.00346)	(0.00433)	(0.00246)
MTB x long term debt	0.000244	0.000757	0.00306**	0.00169*
	(0.00140)	(0.00117)	(0.00134)	(0.000979)
Observations	54395	35424	31912	29533
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adjusted R2	0.466	0.474	0.417	0.337
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0025	-0.0011	0.013***	-0.0082***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.060	-0.0413	0.10*	-0.236***

Note: The table displays the results of panel fixed effect regressions for four quarters of the yearly distribution of the EBITDA-to-debt ratio; q_1 includes firms with EBITDA-to-debt higher than the third quartile, q_2 between the second and the third quartile included, q_3 between the first and the second quartile included and q_4 lower or equal to the first quartile. * = significant at 10%, ** = at 5% and *** = at 1%.

The results consistently change when the market-to-book ratio is used. The measure supports the existence of complementarities for large investment scales and firms with a low EBITDA-to-debt. Consistently with the principal text analysis, the empirical analysis confirm that short-term debt convexities are larger than long-term debt ones for minor investment scales and substantially higher for firms with the lowest EBITDA-to-debt ratio.

1.6.3 Model misspecification

A potential source of model misspecification can arise from the inconsistency between the definition of the interaction terms coming from the model and the correspondent one in the econometric framework. As highlighted by Nelder (1977), the neglect of marginality in a model with interaction terms can consistently bias the interpretation of the coefficients. Therefore, besides the interaction terms derived from the optimal investment model, I also specify an econometric model where the debt variables in levels are included:

$$\frac{I_t}{K_{t-1}} = \beta_0 + \beta_1 Q_{i,t-1} + \beta_2 \left(Qx\frac{S}{K}\right)_{i,t-1} + \beta_3 \left(Qx\frac{L}{K}\right)_{i,t-1} + \beta_4 \frac{S}{K}_{i,t-1} + \beta_5 \frac{L}{K}_{i,t-1} + \mu_i + \tau_t + \epsilon_{i,t}. \tag{1.36}$$

Table 1.15: Panel regressions

	Investment rate	Investment rate	Investment rate
Q	0.0127***	0.0122***	0.0114***
	(0.000252)	(0.000240)	(0.000239)
Q x short term debt	-0.00102***	-0.000665**	-0.000592*
	(0.000337)	(0.000324)	(0.000313)
Q x long term debt	-0.000680***	-0.000664***	-0.000510***
	(0.0000859)	(0.0000812)	(0.0000782)
short term debt	-0.00551	-0.0123***	-0.0113***
	(0.00336)	(0.00310)	(0.00310)
long term debt	0.00165	0.00800***	0.00659***
	(0.00169)	(0.00155)	(0.00155)
Firm FE	Yes	Yes	Yes
Year dummies	No	Yes	No
Sector-Year FE	No	No	Yes
Observations	161819	161819	160144
Adjusted R2	0.365	0.411	0.434
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0017***	-0.00133***	-0.0011***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.026	-0.0001	-0.072

Note: The table displays panel regressions with different fixed effects. SE clustered at the firm level are in parenthesis. * = significant at 10%, ** = at 5% and *** = at 1%.

Table 1.16: Pooled conditional quantile regression

	Investment rate	Investment rate	Investment rate	Investment rate	Investment rate
	0.10	τ = 0.25	τ = 0.5	τ = 0.75	τ = 0.9
Q	0.00297***	0.00526***	0.00931***	0.0168***	0.0235***
	(0.000101)	(0.000140)	(0.000240)	(0.000428)	(0.000557)
Q x short term debt	-0.000297*	-0.000621**	-0.000974***	-0.00176**	-0.00211***
	(0.000173)	(0.000271)	(0.000234)	(0.000713)	(0.000478)
Q x long term debt	-0.000394***	-0.000561***	-0.000813***	-0.00128***	-0.00145***
	(0.0000318)	(0.0000518)	(0.0000587)	(0.0000794)	(0.000163)
short term debt	-0.0103***	-0.0113***	-0.00501***	0.0110***	0.0300***
	(0.000825)	(0.00115)	(0.00163)	(0.00410)	(0.00664)
long term debt	0.00607***	0.00552***	0.00332***	-0.00167*	-0.00921***
	(0.000507)	(0.000608)	(0.000742)	(0.000947)	(0.00273)
N	163539	163539	163539	163539	163539
Year dummies	Yes	Yes	Yes	Yes	Yes
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0007***	-0.0012***	-0.0018***	-0.0030***	-0.0036***
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	0.0325	-0.2247***	-0.017	-0.029	-0.028

Note: The table displays CQR for quantiles (0.25,0.50,0.75,0.90). Year dummies are included but not reported in the table. Firm-level clustered standard errors are in parentheses. * = significant at 10%, ** = at 5% and *** = at 1%.

Table 1.17: Panel regressions across EBITDA-to-debt

	EBITDA-to-debt ratio (q_1)	EBITDA-to-debt ratio (q_2)	EBITDA-to-debt ratio (q_3)	EBITDA-to-debt ratio (q_4)
	Investment rate	Investment rate	Investment rate	Investment rate
Q	0.0107***	0.0168***	0.0183***	0.0131***
	(0.000297)	(0.000859)	(0.00115)	(0.000466)
Q x short term debt	-0.00129**	-0.00135**	-0.000466	-0.000720
	(0.000519)	(0.000627)	(0.000713)	(0.000552)
Q x long term debt	-0.000635*	-0.00143***	-0.00150***	-0.000709***
	(0.000324)	(0.000178)	(0.000215)	(0.000144)
short term debt	0.00834	-0.000492	0.0105*	-0.0233***
	(0.00782)	(0.00727)	(0.00622)	(0.00520)
long term debt	0.00756	0.00705**	0.0136***	0.0133***
	(0.00520)	(0.00325)	(0.00265)	(0.00332)
Observations	55790	36385	32161	29554
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adjusted R2	0.488	0.470	0.406	0.377
$\hat{\beta}_2 + \hat{\beta}_3$	-0.0019***	-0.0028***	-0.0020***	-0.0014**
$\frac{\hat{\beta}_2}{\hat{\beta}_1} - \frac{\hat{\beta}_3}{\hat{\beta}_1}$	-0.062	0.005	0.056	-0.0009

Note: The table displays the results of panel fixed effect regressions for four quarters of the yearly distribution of the EBITDA-to-debt ratio; q_1 includes firms with EBITDA-to-debt higher than the third quartile, q_2 between the second and the third quartile included, q_3 between the first and the second quartile included and q_4 lower or equal to the first quartile. * = significant at 10%, ** = at 5% and *** = at 1%.

When the model is enlarged to take into account the level of debt-to-capital ratios, all the results concerning the dominant role of financial convexities and the non existence of complementarities, are confirmed. Differently, across all specifications there is no statistically significant difference between short-term and long-term debt convexities.

1.6.4 Quantile regression with fixed-effects

To properly assess the existence of cost complementarities, I rely on two methods that nest individual fixed effects in a quantile regression framework. As the first approach, I use the two-step estimation proposed by Canay (2011), which considers fixed effects as additive location shifts. Secondly, I show results for the estimation approach recently proposed by Machado and Santos Silva (2019). Despite being based on a more restrictive location-scale model, individual fixed effects can change across quartiles in terms of location and scale.

Table 1.18: Quantile regression with FE

	Canay two-step estimator				
	Investment rate	Investment rate	Investment rate	Investment rate	Investment rate
	$\tau = 0.10$	$\tau = 0.25$	$\tau = 0.5$	$\tau = 0.75$	$\tau = 0.9$
Q	0.0076***	0.0087***	0.011***	0.015***	0.021***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0017)
Q x short term debt	-0.011***	-0.0012***	-0.0009***	-0.0012***	-0.0013***
	(0.00024)	(0.0011)	(0.0002)	(0.0003)	(0.0024)
Q x long term debt	-0.0002***	-0.0002***	-0.0004***	-0.0008***	-0.0012***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0007)
N	163539	163539	163539	163539	163539
Firm FE	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
	MM-QR-FE approach				
	$\tau = 0.10$	$\tau = 0.25$	$\tau = 0.5$	$\tau = 0.75$	$\tau = 0.9$
Q	-0.00001	0.004***	0.011***	0.022***	0.035***
	(0.0009)	(0.0002)	(0.0002)	(0.00028)	(0.0004)
Q x short term debt	-0.001***	-0.0010***	-0.0011***	-0.0011***	-0.0012**
	(0.0002)	(0.0002)	(0.00027)	(0.00037)	(0.0006)
Q x long term debt	0.00015***	-0.0001	-0.00038***	-0.00097***	-0.0016***
	(0.00006)	(0.0001)	(0.00007)	(0.00008)	(0.0001)
N	163539	163539	163539	163539	163539
Firm FE	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes

Note: The table displays conditional quantile regression with fixed-effects computed with two different methodologies: Canay two-step approach and Quantile via moments approach. Year dummies are included in the estimation. Estimation is done for quantiles (0.10,0.25,0.50,0.75,0.90). Clustered standard errors are in parentheses. Bootstrap replications (500). * = significant at 10%, ** = at 5% and *** = at 1%.

Table (1.18) shows that the pattern concerning cost complementarities across the distribution is confirmed. The fact that the results are pretty robust across all the different methods means that firm-level idiosyncratic factors do not play a significant role in the conclusions regarding cost complementarities.

1.7 Conclusions

This study provided empirical evidence about cost complementarities between short-and long-term debt, building on a theoretical model that embedded a financial cost specification in a Q-theoretic framework. The optimal investment equation, by generating interaction terms between Tobin's Q and debt sources, allowed testing for the existence of complementarities while controlling for investment opportunities. The results from conditional quantile regressions suggested that irrespective of the investment scale, firms face substantial financial cost convexities and cannot reap benefits from accessing a broader range of alternative sources of finance. Furthermore, lower conditional quantiles of the investment distribution show that increasing short-term debt implies higher cost of financial distress than long-term debt. Therefore, financial convexities are critical for the equilibrium debt choices for smaller investment scales. However, for larger scales, there is no statistically significant difference between short-and long-term debt convexities, meaning that fixed costs and economies of scale related to total debt are the most important determinant of financial choices.

Additionally, I related the existence of cost complementarities to firm-specific financial conditions. The analysis of firms across time-varying quartiles of the EBITDA-to-debt ratio, confirmed the empirical results obtained for the overall sample: firms do not benefit from complementarities between short-and long-term debt. Moreover, firms with the lowest EBITDA-to-debt ratio, often under severe financial distress, exhibit short-term debt convexities substantially higher than long-term debt ones. In addition, results are robust to other sources of financing, like cash flow and equity, that can generate an omitted variable problem and bias the coefficients in the presence of an unexpected positive shock on investment. Therefore in equilibrium, firms choose short-term and long-term debt issuance based on the specific interest rate costs and their financial convexities, whose dominant role over possible spillover effects is robust across all the different analyses. Finally, the empirical analysis reveals that the results heavily depend on the definition of Tobin's Q and the inclusion or not of intangible assets. When intangible assets are considered, the conditional quantile regression approach reveals that long-term debt convexities are higher than short-term debt ones. The measure confirms the results of the principal text regressions concerning the fact that firms cannot reap benefits from complementarities. Finally, when the Market-to-book ratio is used, which is not model-consistent and subject to higher measurement error, the results erroneously hinge in favour of the existence of complementarities.

This study came with some limitations. For instance, the model analyzed financial choices considering risk-premium and possible spillover effects and abstracted from alternative explanations of debt maturity choices and heterogeneity, such as hold-up, agency issues and coordination problems in case of multiple investors. Nevertheless, the results indicate that firms do not benefit from cost-complementarities between short-term and long-term debt once controlling for investment opportunities. Moreover, in equilibrium, firms choose short-and long-term debt issuance based on the specific interest rate costs and their financial convexities. In future research, it might be interesting to test the existence of complementarities between specific financing sources (loans, bonds and commercial papers) and to access more detailed information on the actual investment opportunity of the firms instead of relying on the standard proxy. Obtaining access to detailed company data is a promising area that can deliver better and more realistic results which are robust to measurement errors.

1.8 Appendix

1.8.1 Definitions of the variables

Table 1.19: Definitions of the variables

Variables	Description	Definition	Source
Tobin's Q	Defined as market value of equity plus book value of debt minus current assets scaled by gross PP&E, in line with Hennessy et al. (2007) and Peters and Taylor (2017)	$\frac{MVE+DLC+DLTT-ACT}{PPEGT}$	Compustat
Total Tobin's Q	Modified Tobin's Q that includes intangible assets proposed by Peters and Taylor (2017).	q_tot	Compustat
MTB	Market-to-book ratio, defined as total assets plus the market value of common stock less the sum of book value of common equity and balance sheet deferred taxes scaled by total assets. Same definition used by Choi et al. (2018)	$\frac{AT-CEQ-TXDITC+MVE}{AT}$	Compustat
Investment rate	Capital expenditures divided by lagged gross PP&E, in line with Peters and Taylor (2017) and Andrei et al. (2019).	$\frac{CAPX}{PPEGT_{t-1}}$	Compustat
Total Investment rate	Defined as is capital expenditures plus R&D expense plus 30% of selling, general, and administrative expense, scaled by lagged gross PP&E plus intangible capital; XSGA is computed following Peters and Taylor (2017).	$\frac{CAPX+XRD+0.30*XSGA}{PPEGT_{t-1}+K\_INT_{t-1}}$	Compustat
Short-term debt	Short-term debt stock divided by gross PP&E	$\frac{DLC}{PPEGT}$	Compustat
Long-term debt	Long-term debt stock divided by gross PP&E	$\frac{DLTT}{PPEGT}$	Compustat
Cash-flow	Income before extraordinary items plus depreciation, divided by gross PP&E. Same definition adopted by Hennessy et al. (2007)	$\frac{IBC+DP}{PPEGT}$	Compustat
Equity issuance	Difference between sales and purchases of Common and Preferred Stock, divided by gross PP&E. Same definition adopted by Hennessy et al. (2007) and Elsas et al. (2013).	$\frac{SSTK-PRSTKC}{PPEGT}$	Compustat
EBITDA-to-debt	Earnings before interest, taxes, depreciation and amortization before interests over total debt. This is the measure of debt-overhang used by Gebauer et al. (2018).	$\frac{EBITDA}{DLTT+DLC}$	Compustat
Dummy Dividend	Defined as a dummy variable that takes value one if the dividends for common stocks divided by gross PP&E are positive and zero otherwise	Dummy Dividend is equal to one if $\frac{DVC}{PPEGT} > 0$ and zero if $\frac{DVC}{PPEGT} = 0$	Compustat

1.8.2 Assumptions of the investment model

Proof of theoretical assumptions

Based on the framework of Hennessy et al. (2007), the following characteristics must be verified:

a) The gross profit function $F(K, \epsilon)$ is C^2, strictly increasing in both arguments and homogeneous of degree one in K.

b) The function $G(I, K)$ is twice differentiable, strictly convex and homogeneous of degree one in the arguments.

c) The cost function $C(S, L, K)$ is twice differentiable, strictly increasing and convex in S and L, decreasing and convex in K and homogeneous of degree one in the arguments.

Consistently with the analysis presented in the main text, I report the specification of the financial cost function:

$$C(S, L, K) = k_1 S + k_2 L + \frac{\delta_1}{2}\frac{S^2}{K} + \frac{\delta_2}{2}\frac{L^2}{K} + (\theta_1 + \theta_2)\frac{SL}{K}. \tag{1.37}$$

This function satisfies the three properties stated above.

a) Homogeneity of degree one: $C(\omega S, \omega L, \omega K) =$

$$= k_1 \omega S + \frac{\delta_1}{2}\omega^2 \frac{S^2}{\omega K} + \theta_1 \omega^2 \frac{SL}{\omega K} + k_2 \omega L + \tag{1.38}$$
$$\frac{\delta_2}{2}\omega^2 \frac{L^2}{\omega K} + \theta_2 \omega^2 \frac{SL}{\omega K} \tag{1.39}$$
$$= \omega[k_1 S + \frac{\delta_1}{2}\frac{S^2}{K} + \theta_1 \frac{SL}{K} + k_2 L + \tag{1.40}$$
$$\frac{\delta_2}{2}\frac{L^2}{K} + \theta_2 \frac{SL}{K}] \tag{1.41}$$
$$= \omega C(S, L, K). \tag{1.42}$$

b) The function is decreasing and convex in K:

$$\frac{\partial C(S, L, K)}{\partial K} = -[k_1 S + \frac{\delta_1}{2}S^2 + \theta_1 SL + k_2 L + \frac{\delta_2}{2}L^2 + \theta_2 SL]\frac{1}{K^2} < 0, \tag{1.43}$$

and

$$\frac{\partial^2 C(S, L, K)}{\partial K^2} = 2[k_1 S + \frac{\delta_1}{2}S^2 + \theta_1 SL + k_2 L + \frac{\delta_2}{2}L^2 + \theta_2 SL]\frac{1}{K^3} > 0. \tag{1.44}$$

c) The function is increasing and convex in S and L:

$$\begin{aligned}\frac{\partial C}{\partial s} &= k_1 + \delta_1 \frac{S}{K} + (\theta_1 + \theta_2)\frac{L}{K} > 0,\\ \frac{\partial C}{\partial l} &= k_2 + \delta_2 \frac{L}{K} + (\theta_1 + \theta_2)\frac{S}{K} > 0,\end{aligned} \tag{1.45}$$

by combining the two expressions and using the fact that $k = k_1 + k_2$, I obtain the total marginal cost:

$$C_s + C_l = k + (\delta_1 + \theta_1 + \theta_2)\frac{S}{K} + (\delta_2 + \theta_1 + \theta_2)\frac{L}{K} > 0, \tag{1.46}$$

which has a positive sign due to the assumption $k + (\delta_1 + \delta_2)(\frac{S+L}{K}) > (\theta_1 + \theta_2)(\frac{S+L}{K})$. The second and cross partial derivatives are given by:

$$C_{sS} = \frac{\partial C}{\partial s \partial S} = \frac{\delta_1}{K} > 0 \tag{1.47}$$

$$C_{lL} = \frac{\partial C}{\partial l \partial L} = \frac{\delta_2}{K} > 0 \tag{1.48}$$

$$C_{sL} = \frac{\partial C}{\partial s \partial L} = \frac{\theta_1 + \theta_2}{K} \tag{1.49}$$

$$C_{lS} = \frac{\partial C}{\partial l \partial S} = \frac{\theta_1 + \theta_2}{K}, \tag{1.50}$$

where C_{sL} and C_{lS} are equal but their sign is not known or assumed a priori.

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Chapter 2

Debt Maturity and Strategic Complementarities

Author: Marco Rispoli

Abstract
In this paper, I investigate financial decisions from a strategic point of view. In particular, by allowing firms to issue both short-and long-term debt, I study whether combining the two financing sources is profit-enhancing compared to single-debt-type strategies. To test for strategic complementarities across all U.S. manufacturing sectors, I use a flexible profit function allowing interaction terms between short-and long-term debt while controlling for interactions between asset-and liability-side choices. The structural model results are robust to unobserved heterogeneity and a wide arrange of initial values. When the data support the model with complementarities, I find that some specific industries only benefit from strategic complementarities between short-and long-term debt.

JEL classification: G31, G32, C35, L60.

Keywords: Strategic complementarities; Debt maturity; Financial strategy; Firm profitability.

2.1 Introduction

When changing their capital structure, firms try to increase returns by reducing the cost of external finance. Hence, the design of an optimal capital structure, which appropriately considers the management of asset liquidity and refinancing risks, should exploit any complementarity between asset-and liability-side strategic choices and between different financial sources. A possible channel to reduce financial cost convexities is a diversified debt maturity structure, because firms can decrease the overall convexity of their financial liabilities and positively affect profitability by issuing an optimal combination of short-and long-term debt. In this article I will test whether short-and long-term debt are strategic complements, meaning that using the two financial sources together delivers higher profits than single-debt-type strategies. In order to account for the complementarity between asset-and liability-side strategic choices, the model controls for the impact of debt sources on profitability when used to increase the investment in fixed assets. Moreover, I explore the role of specific characteristics of the assets of different industries, such as different degrees of depreciation or asset tangibility and redeployability, may influence the potential benefits from debt finance and hence the relevance of strategic complementarities, which, therefore, must be investigated within specific industrial sectors.

Testing complementarities is not an easy task. Among the main problem in the literature, unobserved heterogeneity can bias the results. Firms, but not the econometrician, may be aware of the exogenous variables affecting the returns from adopting each strategy. Therefore, an appropriate methodology should isolate the impact of complementarities from that of unobserved heterogeneity. This paper uses a flexible profit function approach, previously used in the literature concerning innovation strategies, to test for the existence of strategic complementarities between short-and long-term debt while controlling for relevant complementarities between asset-and liability-side choices. By using a strategic approach, firms select a particular combination of strategies only when combining the two is better than adopting one single strategy. From an empirical point of view, the paper contributes to the literature by analyzing the impact of leverage on firm performance considering strategic aspects and allowing for the possible reductions of financial cost convexities obtainable from a diversified maturity structure. The results suggest that, for models supporting complementarities, the significance of strategic complementarities between short-and long-term debt is industry specific. Among the sectors where firms can increase their profits by issuing short-and long-term debt together, the most relevant are Chemicals, Machinery, Instruments and Transportation.

The remainder of the paper is organized as follows. Section (2.2) introduces the relevant literature. Section (2.3) makes a recap of the methodology developed by Miravete and Pernias (2006) and Miravete and Pernías (2010) that I applied to the case of financial choices. Then, section (2.4) describes the dataset and presents the empirical results focusing on the sectors supporting the model with complementarities. Finally, section (2.5) concludes, and Section (2.6) shows the definition of the sectors used and the robustness checks based on the sensitivity analysis.

2.2 Literature Review

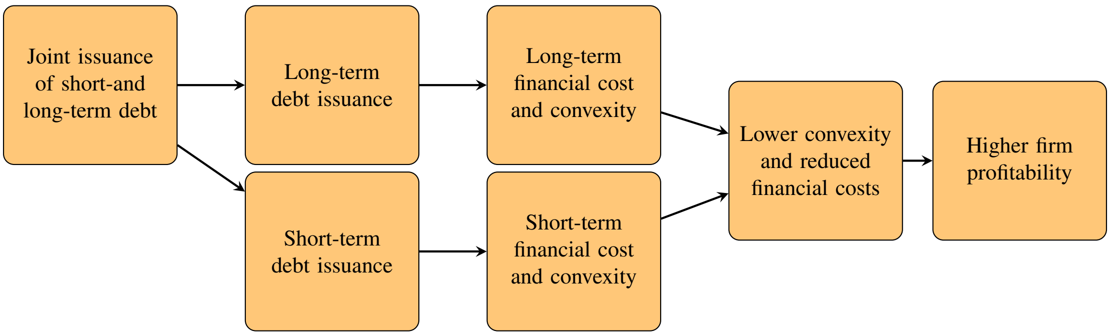
This article focuses on the complementarities between financial decisions and their consequences on firm profitability. As highlighted by Barton and Gordon (1988), capital structure and corporate strategy are firmly connected, and financial decisions are channels to increase firm profitability. Moreover, from a strategic point of view, firms must design capital structure policies consistent with the business strategy to increase firm profitability, as stated by Kochhar (1997). Among the empirical papers that connect the use of debt with firm performance, Berger and Bonaccorsi di Patti (2006) use a non-parametric approach to construct a profit efficiency frontier and find that higher leverage is associated with an increase in profit efficiency, in line with the agency cost model proposed by Jensen and Meckling (1976). By following a similar approach, Margaritis and Psillaki (2010) construct industry efficient frontier and find out that the effect of leverage on efficiency is positive and significant for all leverage levels. While all these papers analyze the effect of leverage on firm profitability and performance, little space is given to the importance of debt heterogeneity as a channel to increase firm efficiency and profitability.

When changing their capital structure, firms try to strategically preserve future profitability by reducing the cost of external finance. Therefore, an optimal capital structure design should appropriately consider the management of refinancing risks and financial convexities. As a significant channel to reduce financial costs, firms can decrease financial convexities and refinancing risk by using a diversified debt maturity structure. Recently, Choi et al. (2018) analyzed U.S. firms' debt maturity choices and found that only a diversified maturity structure can reduce the inefficiencies generated by rollover risk. Furthermore, Houston and Venkataraman (1994) showed that allowing firms to issue short-and long-term debt together can increase financial flexibility and provide different results than single-debt type structures.[1] Moreover, from an optimal contractual design point of view, Berglöf and von Thadden (1994) showed that a capital structure with multiple investors specializing in short-and long-term debt is superior to a structure with only one type of debt. It is possible to formalize further the connection between debt maturity heterogeneity, financial costs and firm profitability by taking into account

[1] Houston and Venkataraman (1994), pp. 189 state: "When multiple debt contracts can be issued simultaneously, the characteristics inherited by this mixture could be related to the liquidation or continuation of assets in a very different manner than their relationship to short or long-term debt in isolation. This is because the mix provides the firm with additional flexibility not available with pure contracts."

the model introduced by Billett and Garfinkel (2004). Firstly the authors show that a lower financial cost convexity positively impacts firm profitability and, secondly, that when firms raise finance from two debt sources, they can reduce the convexity of financial costs. For this reason, firms issuing both short-and long-term debt can reduce financial costs and increase firm profitability. In order to test this hypothesis, the model compares the profits associated with the simultaneous issuance of debt sources with the profits obtained using either short-term or long-term debt; whenever the former performance is higher than the latter, short-and long-term debt are strategic complements. In the empirical section, I show the conditions for testing strategic complementarities, as proposed by Miravete and Pernías (2010), applied to the context of financial choices. Figure (2.1) summarizes the channels leading to complementarities between short-and long-term debt based on the framework proposed by Billett and Garfinkel (2004).

Figure 2.1: **Debt maturity Complementarities.**



Among other channels firms have to reduce the refinancing risk, they can adopt maturity-matching strategies. Myers (1977) is the first to emphasize the interdependence between asset and debt maturity as a tool to reduce risk and protect investors. For instance, by synchronizing the inflows of assets with the outflows of debt repayments, maturity-matching strategies can decrease refinancing risk. Hart and Moore (1994) propose a model that explains the features of debt contracts based on the characteristics of a firm's assets. Concerning the empirical evidence supporting maturity matching, Ozkan (2000) analyzes the determinants of debt maturity in a sample of UK firms and find that firms match asset and liabilities maturity. Furthermore, by analyzing the determinants of debt issues for U.S. firms, Julio et al. (2007) confirm that long-term debt issues are more likely to be used to finance investment in fixed assets. The relationship between investment needs, financial strategy and firm performance is particularly relevant from a strategic point of view, as highlighted by Miller and Bromiley (1990). Therefore, when analyzing the impact of leverage on a firm's performance, it is critical to consider the connection between financial choices and investment needs. The flexible profit function used in the model directly controls for interaction terms between debt sources and investment in fixed assets, taking into account the different maturities of debt issuances.

From a strategic point of view, the knowledge of complementarities allows making explicit and transparent the existence of an optimal combination of strategies, as emphasized by Roberts (2007). Although several studies find that firms can increase their efficiency through complementarities, it is not easy to empirically test for them.[2] Among the main problem in this literature, as recently emphasized by Masschelein and Moers (2020), unobserved heterogeneity can bias the results. Firms, but not the econometrician, may be aware of the exogenous variables affecting the return to adopt each strategy. In the literature on strategic complementarities, correlation and performance tests are the two main methods used to test their existence empirically. The former, originally introduced by Arora and Gambardella (1990), does not require any performance metrics and has its roots in the industrial organization literature. The latter introduces a return function that tests complementarities based on a particular performance measure.[3] Although the test proposed by Arora and Gambardella (1990) is intuitive and straightforward, Miravete and Pernías (2010) underline that it is impossible to apply the methodology to zero-one strategies. Moreover, the method does not consider the role of unobserved heterogeneity in estimating strategic complementarities. Therefore, I follow the empirical model developed by Miravete and Pernias (2006), which appropriately controls for unobserved heterogeneity.

2.3 Empirical methodology

To test for strategic complementarities in financial choices, I follow the approach by Miravete and Pernias (2006) that define the following profit function for a firm i in the presence of possible complementarities between strategies:

$$\pi_i(x_{1i}, x_{2i}) = (\omega_1 + \epsilon_{1i})x_{1i} + (\omega_2 + \epsilon_{2i})x_{2i} + \theta_{12}x_{1i}x_{2i}, \tag{2.1}$$

where ω captures the observable effect of the strategy, and ϵ captures the unobserved characteristics as viewed from the econometrician. The additional term, which captures the interaction between x_1 and x_2, controls for the presence or not of complementarities. A positive coefficient θ means that adopting the strategy x_1 increases the return of strategy x_2 and vice versa. In line with the authors, the profit function for financial

[2]For a complete review of complementarities in the management literature, see Ennen and Richter (2010)

[3]Considering two discrete strategies x_{i1} and x_{i2} and a return function V, the test statistic for complementarities using performance metrics is $C_p = V(1,1) - V(0,0) \geq V(1,0) - V(0,0) + V(0,1) - V(0,0)$. For a complete overview of strategic complementarities, see the first chapter of Gibbons and Roberts (2012) pp 11.

choices is :

$$\pi(x_{si}, x_{li}, x_{ai}) = \omega_\pi + \epsilon_{\pi i} + (\omega_s + \epsilon_{si})x_{si} + (\omega_l + \epsilon_{li})x_{li} + (\omega_a + \epsilon_{ai})x_{ai} + \\ \theta_{sl}x_{si}x_{li} + \theta_{sa}x_{si}x_{ai} + \theta_{la}x_{li}x_{ai} - \left(\frac{\delta_a}{2}\right)x_{ai}^2, \tag{2.2}$$

where s and l stand for short-and long-term debt issuance and a for investments in capital expenditure. The profit function is quadratic in the scale of the investment in fixed assets x_{ai}, meaning that it is costly to adjust its scale, and allows for the presence of interactions between all the choice variables; in particular, ω captures the direct impact of the strategies on profits and the sign of θ controls for possible strategic complementarities. Furthermore, by normalizing the scale of investment in fixed assets by subtracting the median value, ω_π refers to medium-sized firms which do not rely on external finance. In the setting proposed, I use two dichotomous financing strategies, a dummy variable for issuing short-term debt and one for issuing long-term debt and a continuous strategic variable regarding the choice of the scale of investments. From expression (2.2), the optimal scale of investment in the assets as a function of the financing strategy profiles is:

$$I_a^* = \delta_a^{-1}(\omega_a + \epsilon_{ai} + \theta_{sa}x_{si}x_{ai} + \theta_{la}x_{li}x_{ai}). \tag{2.3}$$

where, as stated by Kretschmer et al. (2012), the sufficient condition for profit maximization is given by $\delta_a > 0$. Substituting the optimal scale, I obtain the following:

$$\pi^* = k_{\pi i} + \epsilon_{\pi i} + (k_{si} + \epsilon_{si})x_{si} + (k_{li} + \epsilon_{li})x_{li} + \theta x_{si}x_{li}, \tag{2.4}$$

The parameter θ is the result of the sum of θ_{sl}, controlling for complementarities between debt maturity profiles, and $\theta_{sa}\theta_{la}$ which stands for the product of the complementarities between assets' scale and each debt source divided by the adjustment cost.

2.3.1 Financial strategy profile

From equation (2.4), it is possible to associate profits with each strategic financial profile:

$$\pi^*(1,1) = k_{\pi i} + k_{si} + k_{li} + \theta + \epsilon_{\pi i} + \epsilon_{si} + \epsilon_{li} \tag{2.5}$$

$$\pi^*(1,0) = k_{\pi i} + k_{si} + \epsilon_{si} + \epsilon_{\pi i} \tag{2.6}$$

$$\pi^*(0,1) = k_{\pi i} + k_{li} + \epsilon_{li} + \epsilon_{\pi i} \tag{2.7}$$

$$\pi^*(0,0) = k_{\pi i} + \epsilon_{\pi i}. \tag{2.8}$$

A firm decides to issue both short-term debt and long-term debt when:

$$\pi^*(1,1) > \pi^*(1,0) \tag{2.9}$$

$$\pi^*(1,1) > \pi^*(0,1) \tag{2.10}$$

$$\pi^*(1,1) > \pi^*(0,0). \tag{2.11}$$

Kretschmer et al. (2012) and Miravete and Pernías (2010) identify these regions' shapes for the case in which the strategies are complements or substitutes. For the construction of the final likelihood, it is assumed that the joint density of the error terms $(\epsilon_{\pi i}, \epsilon_{ai}, \epsilon_{si}, \epsilon_{li})$ follows a normal distribution with zero mean and standard deviations $(\sigma_{\pi}, \sigma_s, \sigma_l, \sigma_a)$, which will be the starting values for the maximization of the likelihood. The final log-likelihood for each firm, whose complete details are described in Kretschmer et al. (2012), is obtained by multiplying the conditional probability of a given financing profile and the joint density of the distribution of the scale of assets and profits. To estimate the parameters of interest, indicated by Θ, I maximize the sum :

$$\sum_{i=1}^{N} lnL_i = L(\Theta|x_a, \pi, x_s, x_l), \tag{2.12}$$

obtained by summing each firm's contribution to the log-likelihood function. In order to estimate the model, I exploit the cross-sectional variation of firm-year observations in each industry without considering the time dynamics of the panel structure. To appropriately consider the within-firm correlation, firm-level clustered standard errors are used. The estimation allows investigating the sign and significance of (θ_{sl}, θ_{sa}, θ_{la}), which controls for strategic complementarities between variables.[4]

For each estimation, I use the LIkelihood ratio test to select the best model among these four: Model (I) is the base model which does not allow for correlations between the unobserved returns (all $\rho = 0$) and complementarities (all $\theta = 0$); Model (II) allows for the existence of complementarities ($\theta \neq 0$), Model (III) allows for the existence of correlations between error terms ($\rho \neq 0$) and Model (IV) allows for both the presence of complementarities ($\theta \neq 0$) and correlations ($\rho \neq 0$). When the model are non-nested, as in the case of the model (II) and model (III), I use the test proposed by Vuong (1989).

2.4 Econometric results

2.4.1 Dataset

I test the structural model using yearly data from Compustat for industries classified with SIC two-digit codes spanning from 1985 to 2015. In line with Andrei et al. (2019), I exclude firm-year observations with a negative value of total assets and sales and gross capital values lower than five million. Finally, I winsorize the data at 1% to remove the extreme outliers, in line with the financial literature. I use investment in long-term assets (capital expenditure) as a scale variable. For the definition of the debt issuance

[4] I implement the methodology using the R environment, and the package and functions made publicly available by Kretschmer et al. (2012).

variables, I follow Elsas et al. (2013). Furthermore, I use Tobin's Q and cash flows as additional control variables that can affect the return of each strategy. Concerning the use of Tobin's Q, Choi et al. (2021) show that firms with higher investment opportunities have a smoothed maturity profile and tend to issue debt with different maturities. For what concerns cash flows, under the pecking order hypothesis, firms should issue debt when internal cash flows are not large enough to finance investment projects. Therefore internal financing can reduce the impact of debt choices on firm profitability acting as a substitute. Moreover, as shown by Houston and Venkataraman (1994), cash flows can affect the share of long-term debt in the choice of the optimal debt maturity mix.[5] The table below shows the definition of the variables:

Table 2.1: Definition of the variables

Variables	Description	Definition	Source
Accounting profits	It is defined as Net annual income as a proportion of total book assets. Differently from Elsas et al. (2013), it is also net of extraordinary items.	$\frac{NI}{AT}$	Compustat
Investment rate	It is defined as Capex divided by Total Assets, as done by Elsas et al. (2013). The variable is computed in a logarithm scale, where adding one allows zero values to be included.	$log(1 + \frac{Capex}{AT})$	Compustat
Long-term debt net issuance	It is defined as a dummy variable which takes the value of 1 when the net issuance of long-term debt is positive and zero otherwise. Long-term debt issuance is computed following Elsas et al. (2013).	$\frac{DLTIS-DLTR}{AT}$	Compustat
Short-term debt net issuance	It is defined as a dummy variable which takes the value of 1 when the net change of short-term debt is positive and zero otherwise. Short-term debt issuance is computed following Elsas et al. (2013).	$\frac{DLCCH}{AT}$	Compustat
MTB	Market-to-book ratio, defined as total assets plus the market value of common stock less the sum of book value of common equity and balance sheet deferred taxes scaled by total assets. Computed following Choi et al. (2018).	$\frac{AT-CEQ-TXDITC+MVE}{AT}$	Compustat
Cash-flow	Income before extraordinary items plus depreciation, divided by total assets. The numerator is computed following Andrei et al. (2019).	$\frac{IBC+DP}{AT}$	Compustat

[5]For the sake of space, I show just the parameters of interest. Results related to constant returns and control variables are available upon request.

2.4.2 Are interaction terms robust to unobserved heterogeneity?

From a methodological point of view, in this framework it is crucial to control for unobserved heterogeneity. As recommended recently by Masschelein and Moers (2020), unobserved factors may influence the interdependence between strategic variables, erroneously supporting complementarities. In order to run the maximum likelihood model, I need to set initial values for the standard deviations of unobservable returns $(\sigma_\pi, \sigma_a, \sigma_s, \sigma_l)$. As a starting point, following the plug-in approach, I fix the value of standard deviations at their sample values for profits, capital expenditure, short-and long-term debt issuance. Concerning the adjustment cost parameter on expenditure in fixed assets, I follow Cooper and Haltiwanger (2006) that estimated an adjustment cost of capital equal to 0.05 for U.S. manufacturing firms. Moreover, as highlighted by Kretschmer et al. (2012), the non-linearity of the model requires testing for the robustness of the results. Therefore, I use a comprehensive combination of the initial values for $(\delta_a, \sigma_s, \sigma_l)$ to see how the model results change.[6] Finally, to further mitigate unobserved heterogeneity, as suggested by Gibbons and Roberts (2012), I focus the analysis on homogeneous industry sub-populations of firms. This procedure allows removing as many unobserved variations as possible *ex-ante*. Table (2.2) shows the results for U.S. manufacturing sectors illustrating in particular whether they support the model with complementarities for most initial values used in the sensitivity analysis.

[6] Kretschmer et al. (2012) at pp 17 in note 28 state the following: "We checked for the robustness of our estimates by using a wide array of initial values. This is the standard procedure to check for identification and uniqueness in the estimation of nonlinear models."

Table 2.2: U.S. manufacturing and complementarities

Sectors	Model convergence
Textile	No Support for strategic complementarities
Printing	Support for strategic complementarities
Apparel	Support for strategic complementarities
Furniture	Support for strategic complementarities
Paper	Support for strategic complementarities
Wood	Support for strategic complementarities
Chemical	Support for strategic complementarities
Petroleum	Support for strategic complementarities
Plastic	Support for strategic complementarities
Primary Metal	Support for strategic complementarities
Fabricated Metal	Support for strategic complementarities
Machinery	Support for strategic complementarities
Electronics	Support for strategic complementarities
Transportation	Support for strategic complementarities
Instruments	Support for strategic complementarities

Note: The table displays the results for a wide arrange of initial values and the most supported model.

The conclusions concerning the convergence of the model are based on a wide arrange of initial values. When the model does not support strategic complementarities, it means that for the majority of the combinations of initial values either the model with complementarities does not converge, or the Likelihood ratio test and the Vuong test select the model without complementarities as the best model (that corresponding either to the baseline Model (I) or Model (III)).

2.4.3 A focus on sectors supporting strategic complementarities

This section illustrates in detail the results for some specific manufacturing sectors that support the existence of strategic complementarities.[7]. The focus on particular manufacturing sectors is in line with other studies. Indeed, Margaritis and Psillaki (2010) test the impact of leverage on firm performance in four manufacturing sectors in France. The results support the existence of statistically significant strategic complementarities for the following sectors: Chemicals, Machinery, Transportation and Instruments. For each sector, I display tables showing the shares of short-and long-term debt, average ratios of capital expenditure and profits to total assets for each combination of short-and long-

[7] In the appendix, results are shown for all the sectors supporting complementarities

term debt issuance, and the Kendall correlation index between the variables. Furthermore, I show a table including the result of the estimates for sample standard deviations as initial values and the adjustment cost for expenditure on fixed assets equal to 0.05. Given the non-linearity nature of the model, I present robustness checks by analyzing the behaviour of the model for $N = 150$ different initial values of the parameters obtained as a combination of ($\delta_a = 0.03, 0.04, 0.05, 0.06, 0.07, 0.08$, $\sigma_s = 0.4, 0.5, 0.6, 0.7, 0.8$, $\sigma_l = 0.4, 0.5, 0.6, 0.7, 0.8$, $\bar{\sigma_a}$ and $\bar{\sigma_\pi}$ fixed at the respective sample values). Below I provide a sketch of the algorithm that I used to perform the sensitivity analysis:

Algorithm 1 Sensitivity analysis

Input: $(\delta_{a,1}, \sigma_{s,1}, \sigma_{l,1}, \bar{\sigma_a}, \bar{\sigma_\pi}) \dots (\delta_{a,N}, \sigma_{s,N}, \sigma_{l,N}, \bar{\sigma_a}, \bar{\sigma_\pi})$
Output: $Best - model$ (Estimated parameters of the best model)

function SENSITIVITY($\delta_a[\,], \sigma_s[\,], \sigma_l[\,]$,$\bar{\sigma_a}$ = sample sd,$\bar{\sigma_\pi}$ = sample sd)
    for $k \leftarrow 1$ to N **do**
        Run base model.
        Run model with only complementarities.
        Run model with only unobserved heterogeneity.
        Run model with complementarities and unobserved heterogeneity.
        Select only the models that converge.
        Compare the models with LR test or Vuong test at 5% significance.
    end for
    return $Best - model$
end function
Keep the combinations where the model converge most of the time.
Construct histograms for the parameters and their p-values.

Chemical Sector

Table 2.3: Descriptive statistics and Kendall correlation index

Variables	No debt issuance	Only Short-term debt	Only Long-term debt	Joint issuance
Debt issuance (%)	53%	19%	17%	12%
Capex to total assets	0.04	0.05	0.06	0.07
Profits to total assets	-0.15	-0.07	-0.07	-0.02
Kendall correlation index				
(Short,Capex)	(Short,Profits)	(Long,Capex)	(Long,Profits)	(Short,Long)
0.150(0.000)	0.103(0.000)	0.175(0.000)	0.073(0.000)	0.142(0.000)

Note: The table displays descriptives for debt issuances, average capital expenditures and average profits normalized by total assets. Furthermore, it displays the Kendal correlation index along with the p-value in parenthesis.

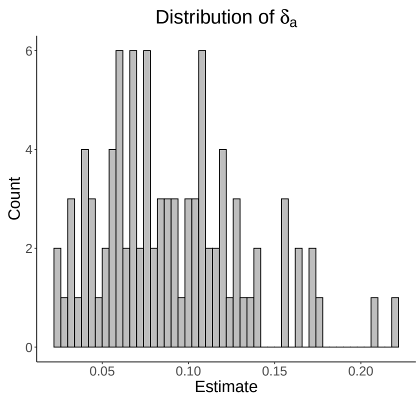
Table 2.4: ML estimation: Chemical industry

Parameters	(I)	(II)	(III)	(IV)
δ_a	0.052**	0.068***	0.464***	(-)
	(0.023)	(0.027)	(0.1163)	(-)
θ_{sl}		0.0001***		(-)
		(0.00001)		(-)
θ_{sa}		0.0004***		(-)
		(0.00013)		(-)
θ_{la}		0.0009***		(-)
		(0.00001)		(-)
ρ_{sl}			0.208***	(-)
			(0.040)	(-)
ρ_{sa}			0.168***	(-)
			(0.0225)	(-)
ρ_{la}			0.275***	(-)
			(0.039)	(-)
Obs	5100	5100	5100	(-)
Ln L	10021	10858	9777	(-)
LR vs model I	-	1674.03(0.000)	-488.83(1.00)	(-)
Vuong test variance II vs III	-	4.184(0.000)	-	(-)
Vuong test model fit II vs III	-	7.403(0.000)	-	(-)

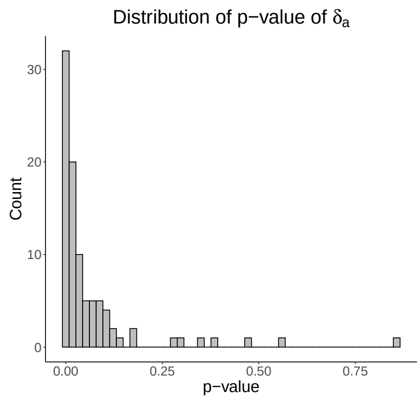
Initial values: δ_a = 0.05. Initial sample values: $\bar{\sigma_s}$ = 0.46, $\bar{\sigma_l}$ = 0.45, $\bar{\sigma_a}$ = 0.048, $\bar{\sigma_\pi}$ = 0.33
When the model does not converge given the initial values, the symbol (-) is used.
Clustered Standard errors in parentheses. LR is Likelihood ratio test and Vuong test for non-nested models.
Estimates of direct returns (ω), sd (σ) and controls are available upon request.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table (2.4) shows that Model (II), when I use sample values as starting parameters and δ_a = 0.05, is selected as the best model. The parameter δ_a is positive and statistically significant in line with our *a priori*. Likewise, all the parameters controlling for the interaction terms are positive and statistically significant. In particular, θ_{sl} is positive and statistically significant, hence for chemical firms the choice regarding the issuance of short-and long-term debt are strategic complements. The table also displays the estimate of the parameters and the p-values for a wide arrange of initial values:

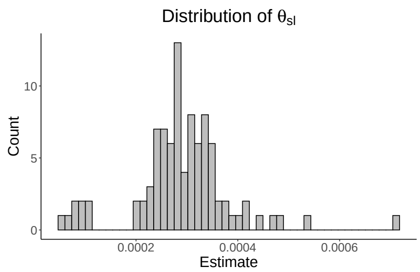
Figure 2.2: Chemical industry: δ_a and θ_{sl} distribution



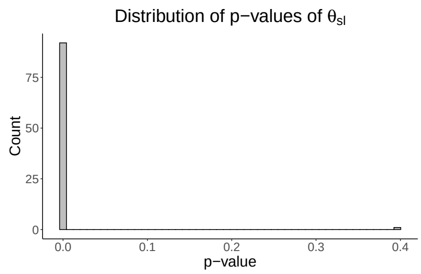
(a) Distribution δ_a



(b) P-values δ_a

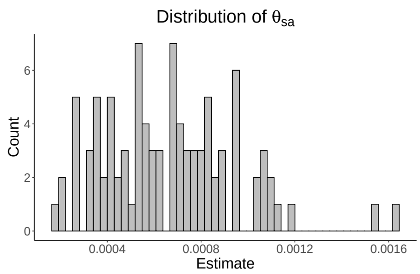


(c) Distribution θ_{sl}

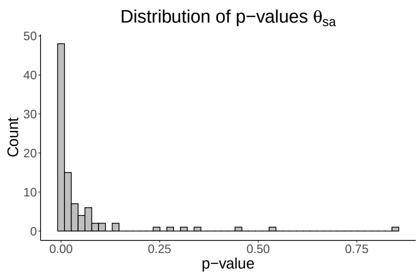


(d) P-values θ_{sl}

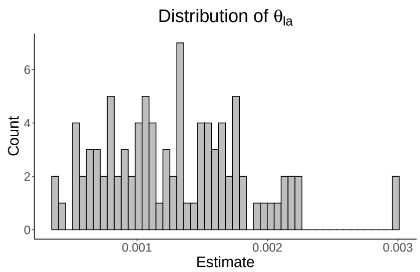
Figure 2.3: Chemical industry: θ_{sa} and θ_{la} distribution



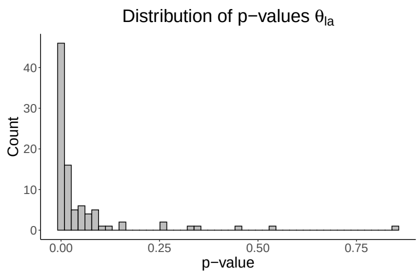
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



(c) Distribution θ_{la}



(d) P-values θ_{la}

The sensitivity analysis reveals that for the majority of the combinations the profit function is super modular in the strategic choices. In particular, θ_{sl} is positive and statistically significant, pointing to the existence of strategic complementarities between short-and long-term debt. Hence, issuing both kinds of debt increases profits more than single-debt-type strategies.

Machinery sector

Table 2.5: Descriptive statistics and Kendall correlation index

Variables	No debt issuance	Only Short-term debt	Only Long-term debt	Joint issuance
Debt issuance (%)	51%	23%	14%	11%
Capex to total assets	0.04	0.05	0.05	0.06
Profits to total assets	-0.02	-0.03	-0.02	-0.02

Kendall correlation index

(Short,Capex)	(Short,Profits)	(Long,Capex)	(Long,Profits)	(Short,Long)
0.081(0.000)	-0.016(0.152)	0.106(0.000)	-0.024(0.032)	0.123(0.000)

Note: The table displays descriptives for debt issuances, average capital expenditures, and average profits. Furthermore, it displays the Kendal correlation index along with the p-value in parenthesis.

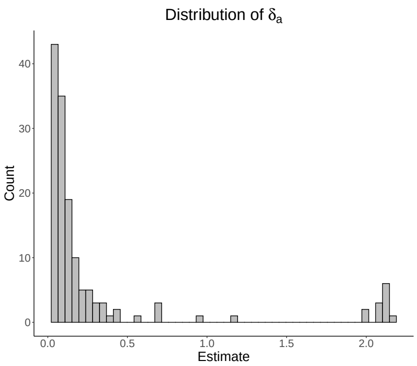
Table 2.6: ML estimation: Machinery

Parameters	(I)	(II)	(III)	(IV)
δ_a	0.059**	0.097**	(-)	2.074***
	(0.024)	(0.038)	(-)	(0.618)
θ_{sl}		0.006***		-0.0018
		(0.0001)		(-)
θ_{sa}		0.0007***		0.0012
		(0.0003)		(-)
θ_{la}		0.0011**		0.013
		(0.0005)		(-)
ρ_{sl}			(-)	0.5712
			(-)	(-)
ρ_{sa}			(-)	0.1211
			(-)	(-)
ρ_{la}			(-)	0.0446
			(-)	(-)
Obs	5088	5088	5088	5088
Ln L	10941	11047	(-)	11149
LR I vs model IV	415(0.000)	205(0.000)	(-)	(-)

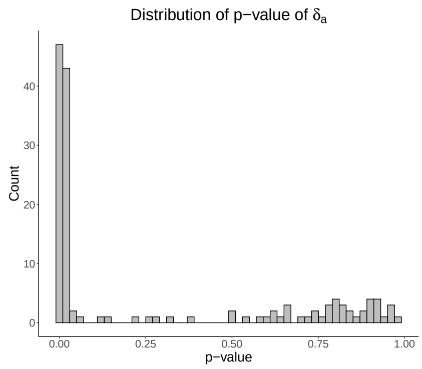
Initial values: δ_a = 0.05. Initial sample values: $\bar{\sigma_s}$ = 0.48,$\bar{\sigma_l}$ = 0.44, $\bar{\sigma_a}$ = 0.04, $\bar{\sigma_\pi}$ = 0.21.
When the model does not converge given the initial values, the symbol (-) is used.
Clustered Standard errors in parentheses. LR stands for Likelihood ratio test.
Estimates of direct returns (ω), sd (σ) and controls are available upon request.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table (2.6) shows that, when using sample values as starting parameters, Model (IV) is selected as the best one. The parameter δ_a is positive and significant in line with our *a priori*. The parameters θ_{sl} is negative and not statistically significant. Furthermore, the parameter θ_{la} and θ_{sa}, controlling for complementarities between debt and asset choices, are not statistically significant. However, in order to inspect the robustness of the results, I use a sensitivity analysis starting from a wide range of initial values. Fig. (2.4) and (2.5) below displays the results:

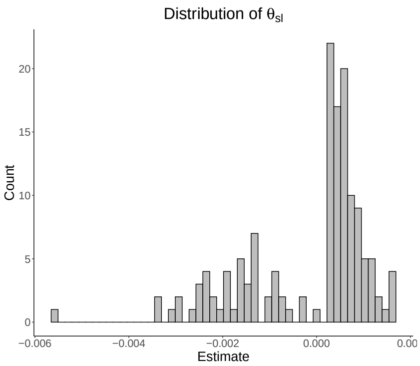
Figure 2.4: Machinery industry: δ_a and θ_{sl} distribution



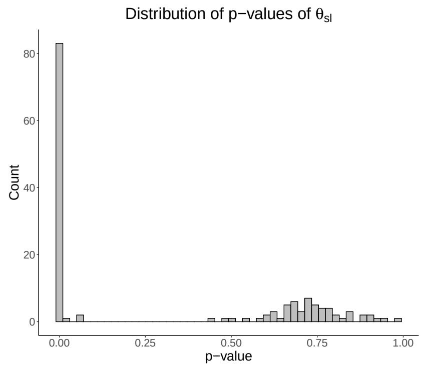
(a) Distribution δ_a



(b) P-values δ_a

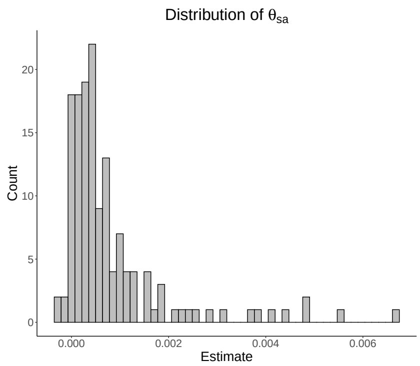


(c) Distribution θ_{sl}

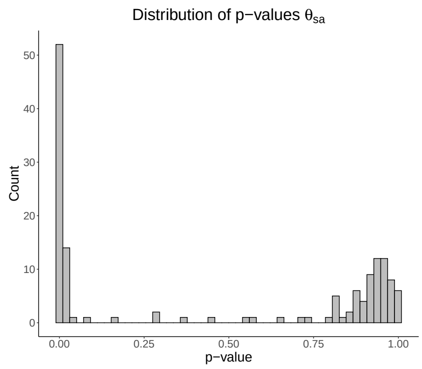


(d) P-values θ_{sl}

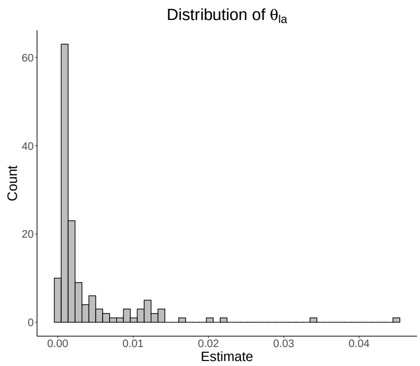
Figure 2.5: Machinery industry: θ_{sa} and θ_{la} distribution



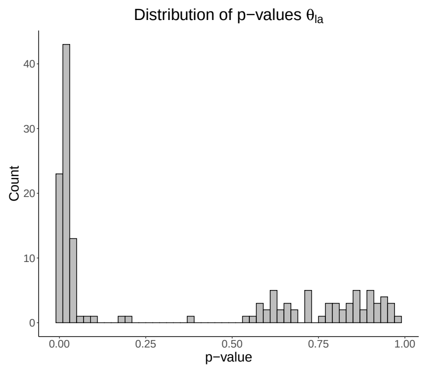
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



(c) Distribution θ_{la}



(d) P-values θ_{la}

The sensitivity analysis reveals that the parameter δ_a is positive and statistically significant for the majority of the initial values used. Furthermore, the majority of the estimates show that θ_{sl} is positive and statistically significant, hence firms belonging to the Machinery sector can benefit from complementarities between short-and long-term debt. Likewise, all the parameters controlling for the interaction terms between debt issuance and investment in fixed assets are positive and statistically significant.

Electronics Sector

Table 2.7: Descriptive statistics and Kendall correlation index

Variables	No debt issuance	Only Short-term debt	Only Long-term debt	Joint issuance
Debt issuance (%)	57%	19.4%	13.4%	10.2%
Capex to total assets	0.05	0.06	0.08	0.08
Profits to total assets	-0.02	-0.09	-0.04	-0.03
		Kendall correlation index		
(Short,Capex)	(Short,Profits)	(Long,Capex)	(Long,Profits)	(Short,Long)
0.110(0.000)	-0.075(0.000)	0.193(0.000)	-0.032(0.002)	0.168(0.000)

Note: The table displays descriptives for debt issuances, average capital expenditures to total assets, and average profits to total assets. Furthermore, it displays the Kendal correlation index along with the p-value in parenthesis.

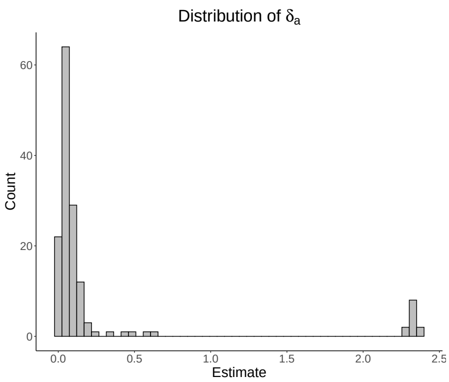
Table 2.8: ML estimation: Electronics

Parameters	(I)	(II)	(III)	(IV)
δ_a	0.023***	0.066***	(-)	0.027
	(0.0049)	(0.014)	(-)	(0.41)
θ_{sl}		0.0004***		-0.0006
		(0.00004)		(0.0025)
θ_{sa}		0.0006***		0.0001
		(0.0001)		(0.0021)
θ_{la}		0.0016***		0.0006
		(0.0003)		(0.01)
ρ_{sl}			(-)	0.4147
			(-)	(0.603)
ρ_{sa}			(-)	0.088
			(-)	(0.409)
ρ_{la}			(-)	0.0587
			(-)	(0.255)
Obs	6155	6155	(-)	6155
Ln L	11417	11715	(-)	11845
LR vs model IV	856.23(0.00)	(-)	261.24(0.00)	-

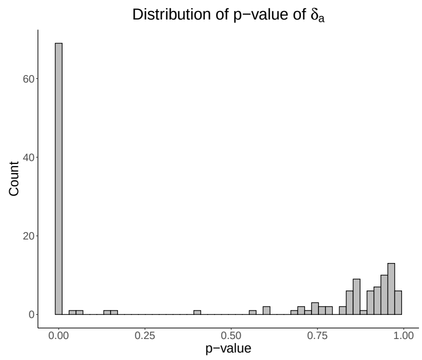
Initial values: $\delta_a = 0.05$. Initial sample values: $\bar{\sigma_s} = 0.46, \bar{\sigma_l} = 0.42$, $\bar{\sigma_a} = 0.051$, $\bar{\sigma_\pi} = 0.24$.
Clustered Standard errors in parentheses. LR stands for Likelihood ratio test.
When the model does not converge given the initial values, the symbol (-) is used.
Estimates of direct returns (ω), sd (σ) and controls are available upon request.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table (2.8) shows the results of the four models for the electronics industry, and that, when I use sample values as starting parameters and $\delta_a = 0.05$, Model (IV) is selected as the best model. The results suggest that all the interaction terms are not statistically significant. Fig. (2.6) and (2.7) below display the results of the sensitivity analysis for the Electronics sector:

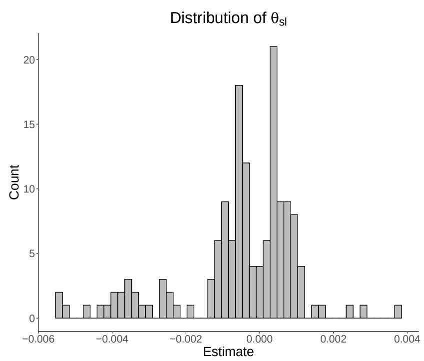
Figure 2.6: Electronics industry: δ_a and θ_{sl} distribution



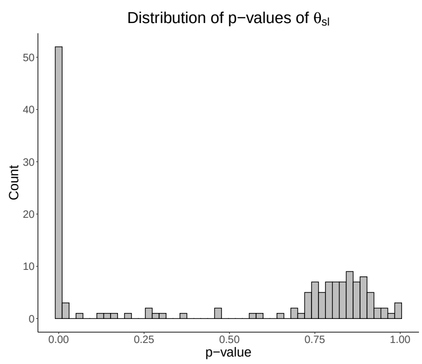
(a) Distribution δ_a



(b) P-values δ_a

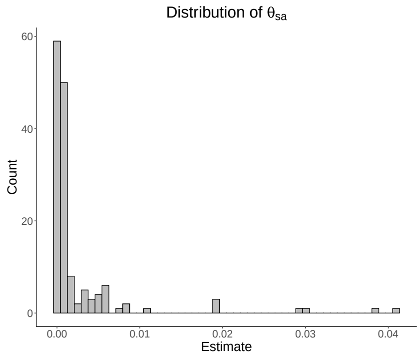


(c) Distribution θ_{sl}

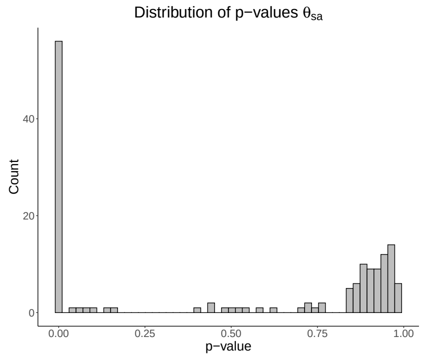


(d) P-values θ_{sl}

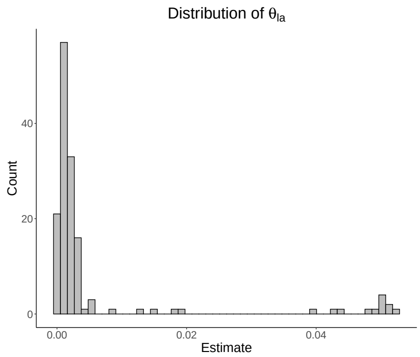
Figure 2.7: Electronics industry: θ_{sa} and θ_{la} distribution



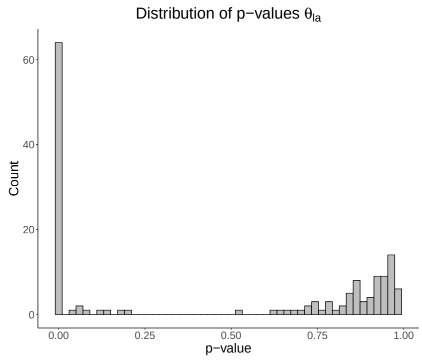
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



(c) Distribution θ_{la}



(d) P-values θ_{la}

The sensitivity analysis reveals that the parameter δ_a is positive and statistically significant in line with our a priori for the majority of the initial values used. Furthermore, the majority of the estimates show that θ_{sl} is negative and not statistically significant, hence firms belonging to the Electronics sector cannot benefit from complementarities between short-and long-term debt. For instance, as showed in (2.6), only for a small range of initial values $(\delta_a, \sigma_s, \sigma_l)$, θ_{sl} is positive and statistically significant.

Transportation Sector

Table 2.9: Descriptive statistics and Kendall correlation index

Variables	No debt issuance	Only Short-term debt	Only Long-term debt	Joint issuance
Debt issuance (%)	41%	23%	20%	16%
Capex to total assets	0.05	0.05	0.06	0.07
Profits to total assets	0.05	0.003	0.02	0.02
		Kendall correlation index		
(Short,Capex)	(Short,Profits)	(Long,Capex)	(Long,Profits)	(Short,Long)
0.083(0.000)	-0.098(0.000)	0.161(0.000)	-0.090(0.000)	0.090(0.000)

Note: The table displays descriptives for debt issuances, average capital expenditures to total assets, and average profits to total assets. Furthermore, it displays the Kendal correlation index along with the p-value in parenthesis.

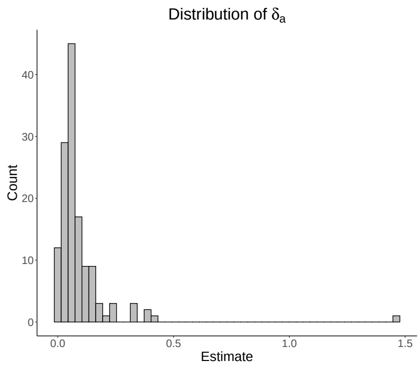
Table 2.10: ML estimation: Transportation

Parameters	(I)	(II)	(III)	(IV)
δ_a	0.0311	0.0328	(-)	(-)
	(0.072)	(0.0208)	(-)	(-)
θ_{sl}		0.00003**		(-)
		(0.00001)		(-)
θ_{sa}		0.0002*		(-)
		(0.00009)		(-)
θ_{la}		0.0005*		(-)
		(0.00028)		(-)
ρ_{sl}			(-)	(-)
			(-)	(-)
ρ_{sa}			(-)	(-)
			(-)	(-)
ρ_{la}			(-)	(-)
			(-)	(-)
Obs	1948	1948	1948	1948
Ln L	4709.5	4766.5	(-)	(-)
LR I vs model II	(-)	114(0.000)	(-)	(-)

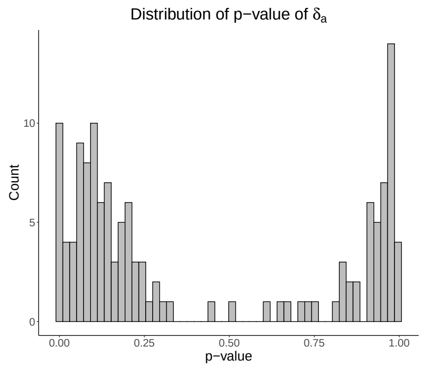
Initial values: δ_a = 0.05. Initial sample values: $\bar{\sigma_s}$ = 0.49,$\bar{\sigma_l}$ = 0.48, $\bar{\sigma_a}$ = 0.038, $\bar{\sigma_\pi}$ = 0.1061.
(-) The model does not converge given these initial values.
Clustered Standard errors in parentheses. LR stands for Likelihood ratio test.
Estimates of direct returns (ω), sd (σ) and controls are available upon request.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table (2.10) shows that, when using sample values as starting parameters and $\delta_a = 0.05$, Model (II) is selected as the best one. The parameter δ_a is positive, but not statistically significant. The parameter θ_{sl} is positive and statistically significant, meaning that firms belonging to the Transportation industry benefit from strategic complementarities between short-and long-term debt. Furthermore, the parameter θ_{la} and θ_{sa}, controlling for the interaction terms between debt issuance and investment in fixed assets, are both positive and statistically significant, albeit at 10% level only. Fig. (2.8) and (2.9) below display the results of the sensitivity analysis:

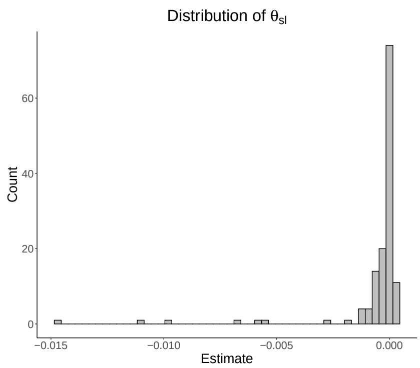
Figure 2.8: Transportation industry: δ_a and θ_{sl} distribution



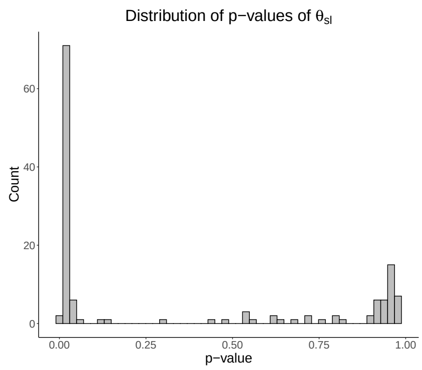
(a) Distribution δ_a



(b) P-values δ_a

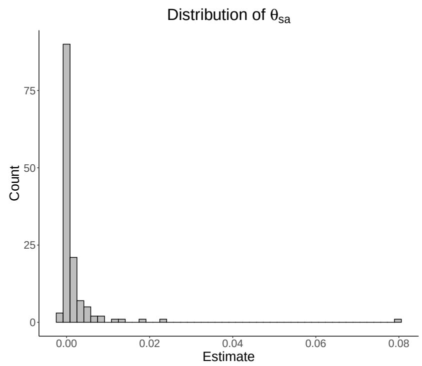


(c) Distribution θ_{sl}

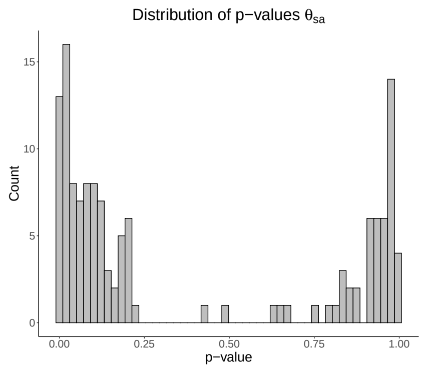


(d) P-values θ_{sl}

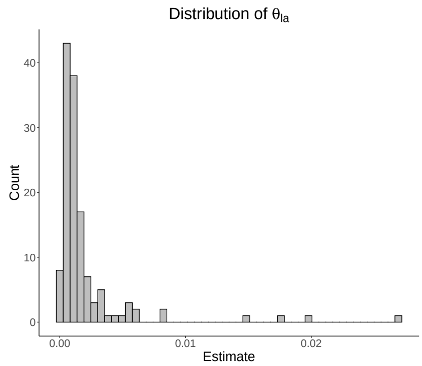
Figure 2.9: Transportation industry: θ_{sa} and θ_{la} distribution



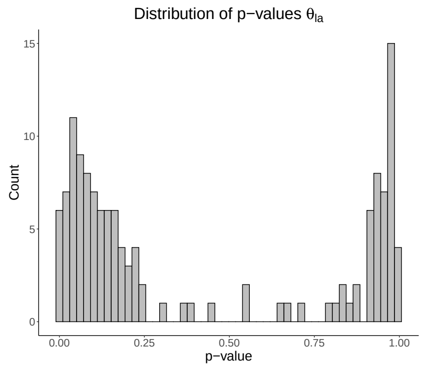
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



(c) Distribution θ_{la}



(d) P-values θ_{la}

The sensitivity analysis confirms the results obtained using sample standard deviations as starting values. For the majority of starting values, the parameter δ_a is positive but not statistically significant, as the parameters θ_{sa} and θ_{la} that are positive but not statistically significant for a wide range of initial values. Differently, θ_{sl} is positive and statistically significant for the majority of the initial parameters. Hence, the evidence hinges in favour of strategic complementarities between short-and long-term debt.

Instruments Sector

Table 2.11: Descriptive statistics and Kendall correlation index

Variables	No debt issuance	Only Short-term debt	Only Long-term debt	Joint issuance
Debt issuance (%)	56%	21%	13%	10%
Capex to total assets	0.04	0.05	0.05	0.06
Profits to total assets	-0.03	-0.042	-0.004	-0.021
		Kendall correlation index		
(Short,Capex)	(Short,Profits)	(Long,Capex)	(Long,Profits)	(Short,Long)
0.110(0.000)	-0.048(0.000)	0.105(0.000)	-0.003(0.795)	0.132(0.000)

Note: The table displays descriptives for debt issuances, average capital expenditures to total assets, and average profits to total assets. Furthermore, it displays the Kendal correlation index along with the p-value in parenthesis.

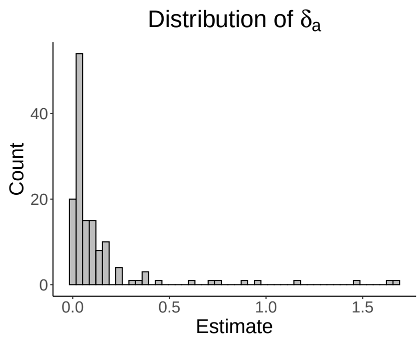
Table 2.12: ML estimation: Instruments

Parameters	(I)	(II)	(III)	(IV)
δ_a	0.010***	0.0087***	(-)	(-)
	(0.0029)	(0.0019)	(-)	(-)
θ_{sl}		0.0002***		(-)
		(0.00003)		(-)
θ_{sa}		0.00008***		(-)
		(0.00002)		(-)
θ_{la}		0.00012***		(-)
		(0.00003)		(-)
ρ_{sl}			(-)	(-)
			(-)	(-)
ρ_{sa}			(-)	(-)
			(-)	(-)
ρ_{la}			(-)	(-)
			(-)	(-)
Obs	4203	4203	4203	4203
Ln L	9586	9699	(-)	(-)
LR I vs model II	(-)	225(0.000)	(-)	(-)

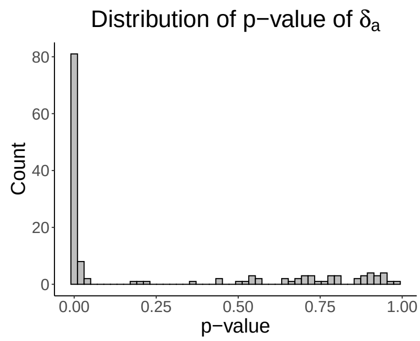
Initial values: δ_a = 0.05. Initial sample values: $\bar{\sigma_s}$ = 0.46,$\bar{\sigma_l}$ = 0.42, $\bar{\sigma_a}$ = 0.040, $\bar{\sigma_\pi}$ = 0.23.
(-) The model does not converge given these initial values.
Clustered Standard errors in parentheses. LR stands for Likelihood ratio test.
Estimates of direct returns (ω), sd (σ) and controls are available upon request.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table (2.12) shows that, when using sample values as starting parameters and $\delta_a = 0.05$, Model (II) is selected as the best one. The parameter δ_a is positive and statistically significant. The parameter θ_{sl} is positive and statistically significant, meaning that firms belonging to the Instruments industry benefit from strategic complementarities between short-and long-term debt. Furthermore, the parameter θ_{la} and θ_{sa}, controlling for the interaction terms between debt issuance and investment in fixed assets, are both positive and statistically significant. Fig. (2.10) and (2.11) below display the results of the sensitivity analysis:

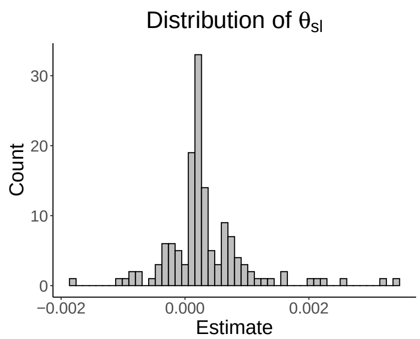
Figure 2.10: Instruments industry: δ_a and θ_{sl} distribution



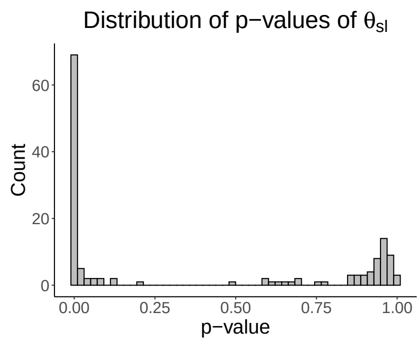
(a) Distribution δ_a



(b) P-values δ_a

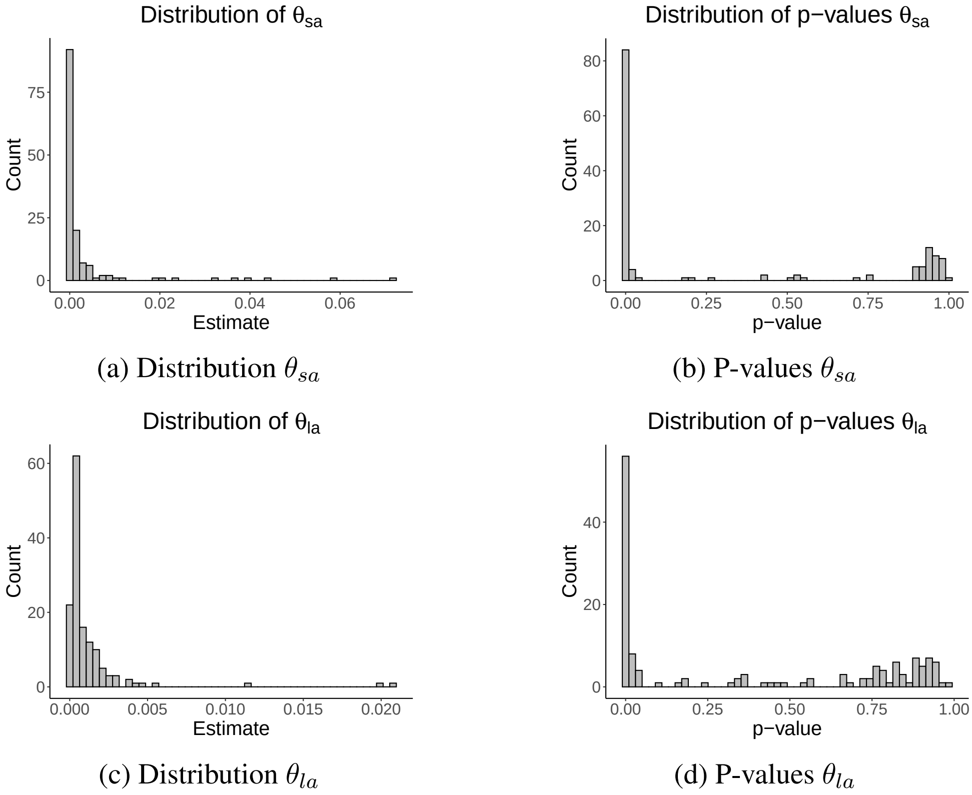


(c) Distribution θ_{sl}



(d) P-values θ_{sl}

Figure 2.11: Instruments industry: θ_{sa} and θ_{la} distribution



(a) Distribution θ_{sa} (b) P-values θ_{sa}

(c) Distribution θ_{la} (d) P-values θ_{la}

The sensitivity analysis confirms the results obtained using sample standard deviations as starting values. For the majority of starting values, the parameter δ_a is positive and statistically significant, as the parameters θ_{sa} and θ_{la}. Moreover, θ_{sl} is positive and statistically significant for the majority of the initial parameters. Therefore, the evidence hinges in favour of strategic complementarities between short-and long-term debt.

2.5 Conclusions

The paper analyzed the existence of strategic complementarities between short-and long-term debt, controlling for complementarities between investment in fixed assets and debt-maturity choices. A diversified maturity structure can generate efficiencies, and by reducing the financial cost convexities can positively affect firms' profits. To test this hypothesis, I used a flexible profit function approach, previously used in the innovation strategy literature, allowing interaction terms between firm strategic choices. Given the importance of unobserved heterogeneity, the model specification disentangles the effect of complementarities on profitability.

By applying the model to all U.S. manufacturing sectors, I found consistent heterogeneity regarding the support for the model with additional interaction terms and the existence of complementarities. Most sectors supporting complementarities do not exhibit significant complementarity in debt maturity. Among them, firms in the Chemicals, Machinery, Transportation and Instruments sectors can benefit from strategic complementarities between short-and long-term debt. For these firms having a diversified issuance maturity structure can therefore lead to a reduction of the overall financial cost convexities and an increase in profitability that is higher than the one obtainable with single-debt-type strategies (using either short-or long-term debt only). Given the non-linearity of the model, I applied a wide range of initial values. I found that the main conclusions are supported, even if the variability among the estimates is consistent. Therefore, the analysis reveals that complementarities are strongly industry-specific, and their magnitude depends on the initial values.

The findings suggest some avenues for future research. Firstly, it might be interesting to investigate the existence of complementarities between specific financial sources, apart from the maturity dimension. Secondly, it might be interesting to consider the time dimension of the panel dataset and study the dynamic evolution of complementarities and their different behaviour during economic expansion and recession phases.

2.6 Appendix

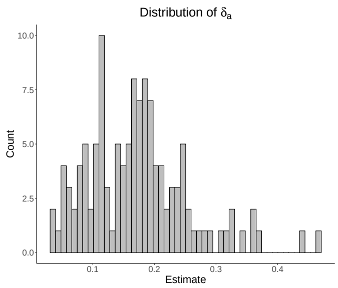
2.6.1 Manufacturing industry sectors included in the analysis

I classify sectors based on the 2-digit SIC code: Textile (22); Apparel (23); Wood (24); Furniture (25); Paper (26); Printing (27); Chemical (28); Petroleum (29); Plastic (30); Primary Metal (33); Fabricated Metal (34); Machinery (35); Electronics equipment (36); Transportation equipment (37); Instruments (38).

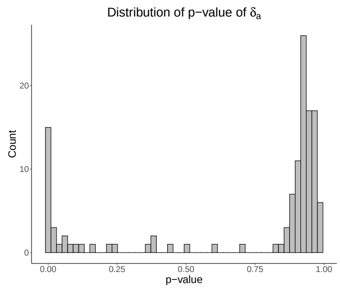
2.6.2 Robustness check: sensitivity analysis

Sensitivity analysis: Apparel sector

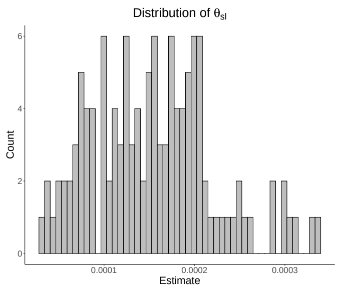
Figure 2.12: Apparel industry: δ_a and θ_{sl} distribution



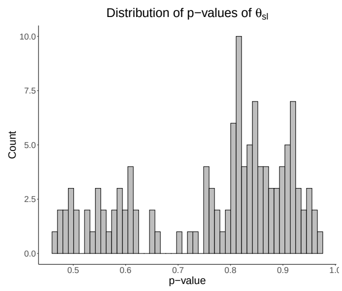
(a) Distribution δ_a



(b) P-values δ_a

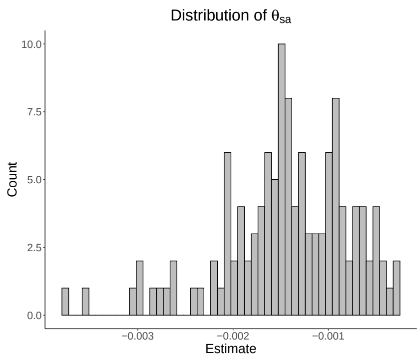


(c) Distribution θ_{sl}

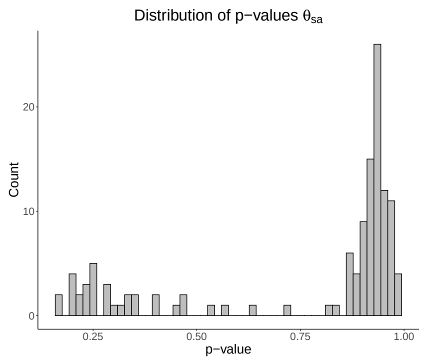


(d) P-values θ_{sl}

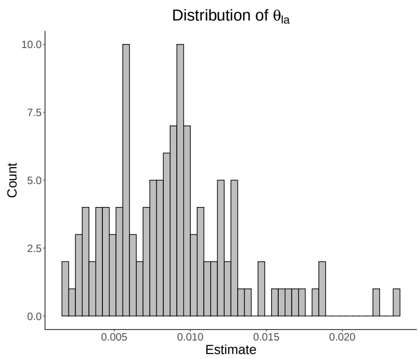
Figure 2.13: Apparel industry: θ_{sa} and θ_{la} distribution



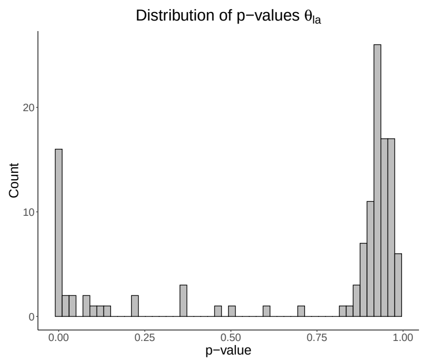
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



(c) Distribution θ_{la}

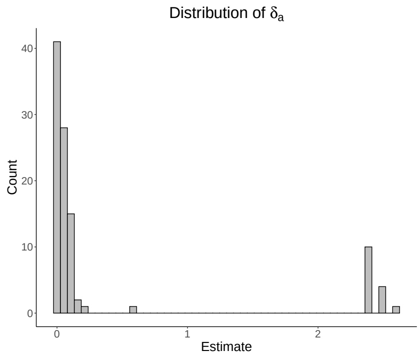


(d) P-values θ_{la}

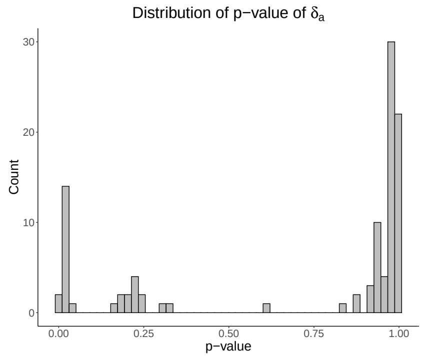
The sensitivity analysis shows that δ_a is positive but not statistically significant for the majority of the initial values. The same is true for θ_{sl}, therefore the analysis does not support the existence of strategic complementarities between the issuance of short-and long-term debt.

Sensitivity analysis: Wood sector

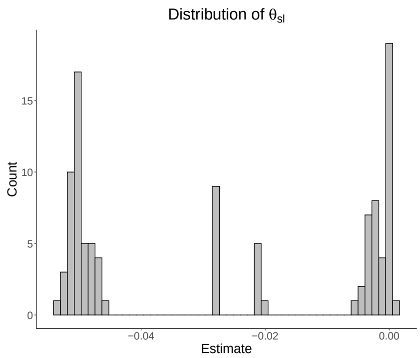
Figure 2.14: Wood industry: δ_a and θ_{sl} distribution



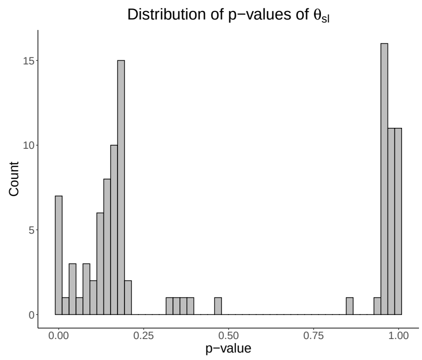
(a) Distribution δ_a



(b) P-values δ_a

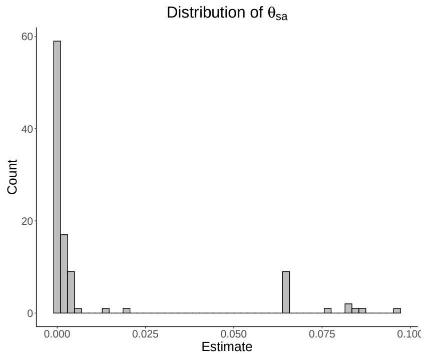


(c) Distribution θ_{sl}

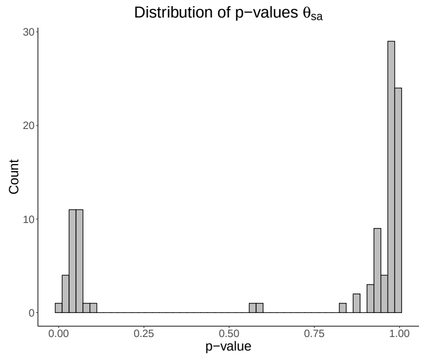


(d) P-values θ_{sl}

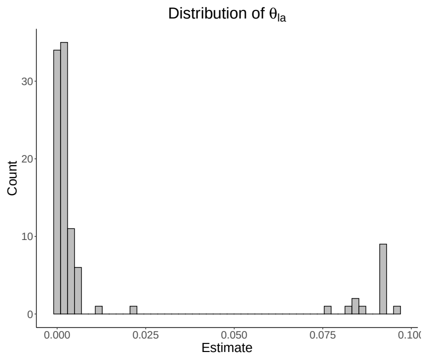
Figure 2.15: Wood industry: θ_{sa} and θ_{la} distribution



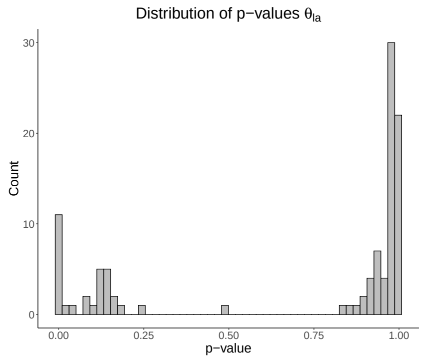
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



(c) Distribution θ_{la}

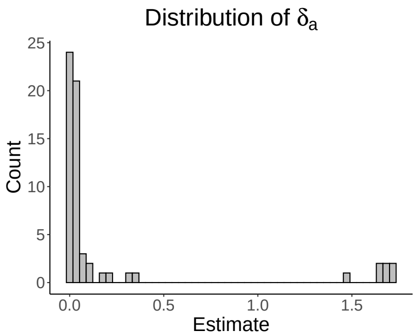


(d) P-values θ_{la}

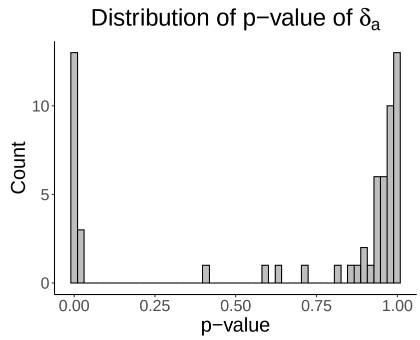
The sensitivity analysis shows that δ_a is positive but not statistically significant for the majority of the initial values. The same is true for θ_{sl}, therefore the analysis does not support the existence of strategic complementarities between the issuance of short-and long-term debt.

Sensitivity analysis: Petroleum sector

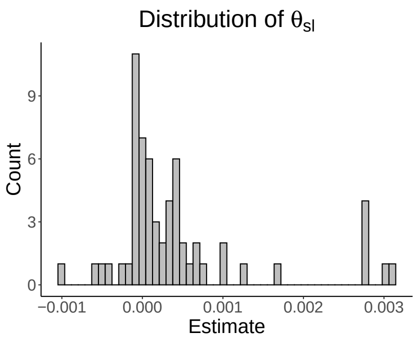
Figure 2.16: Petroleum industry: δ_a and θ_{sl} distribution



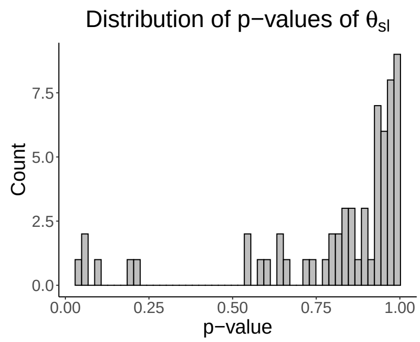
(a) Distribution δ_a



(b) P-values δ_a

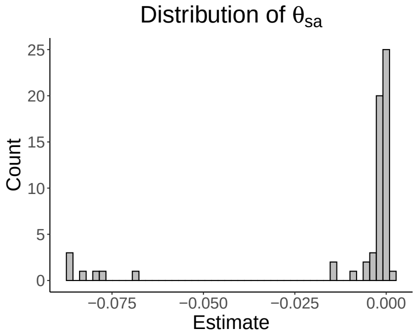


(c) Distribution θ_{sl}

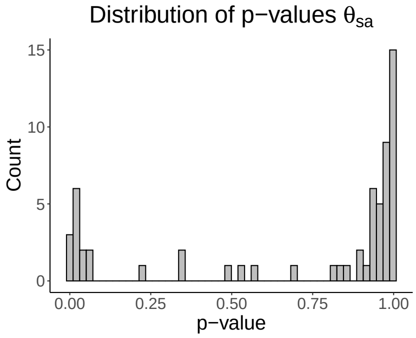


(d) P-values θ_{sl}

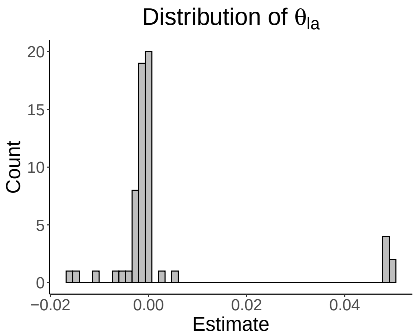
Figure 2.17: Petroleum industry: θ_{sa} and θ_{la} distribution



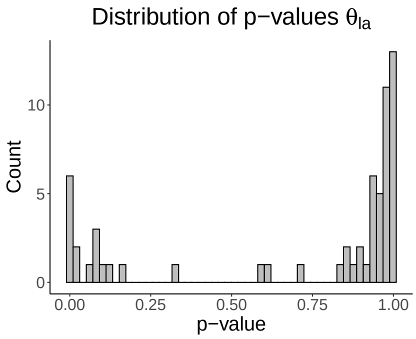
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



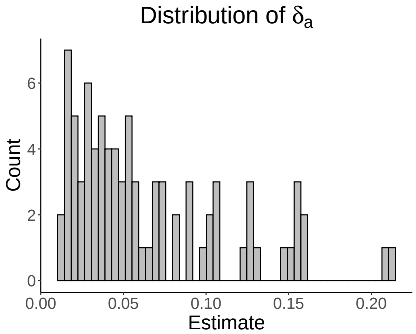
(c) Distribution θ_{la}



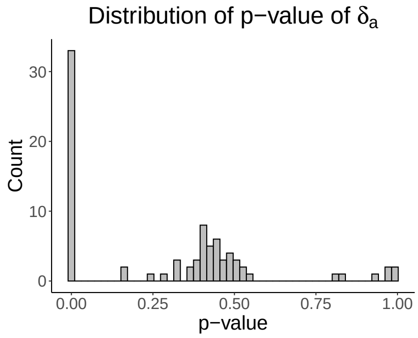
(d) P-values θ_{la}

Sensitivity analysis: Fabricated metal sector

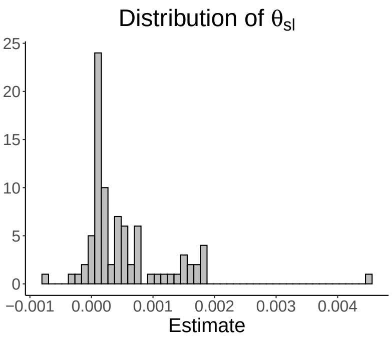
Figure 2.18: Fabricated metal industry: δ_a and θ_{sl} distribution



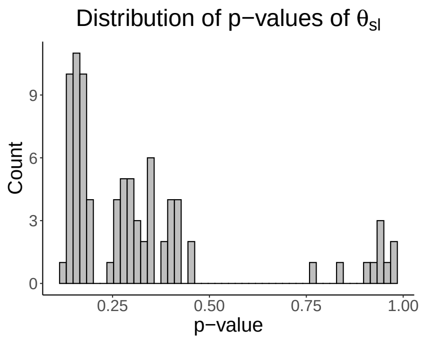
(a) Distribution δ_a



(b) P-values δ_a

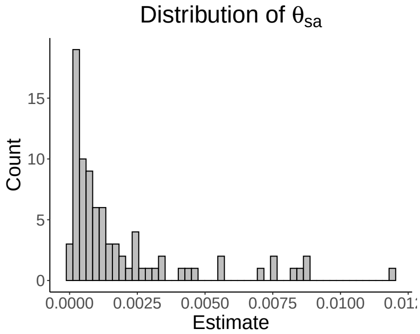


(c) Distribution θ_{sl}

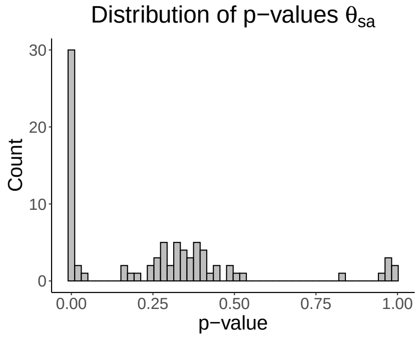


(d) P-values θ_{sl}

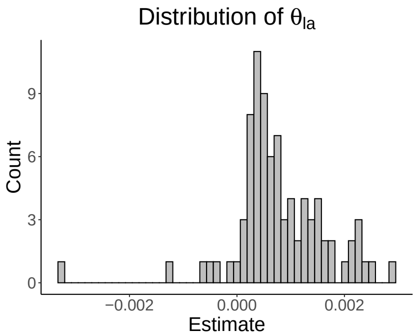
Figure 2.19: Fabricated industry: θ_{sa} and θ_{la} distribution



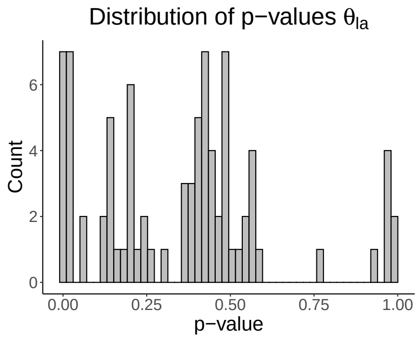
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



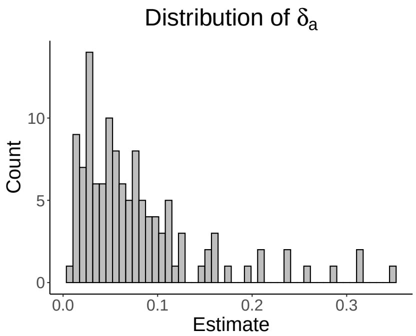
(c) Distribution θ_{la}



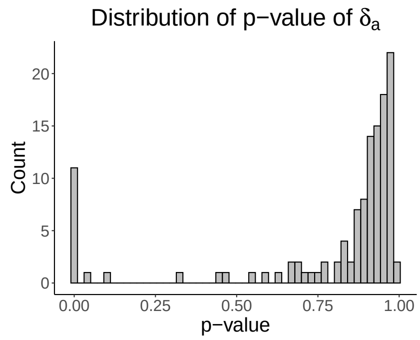
(d) P-values θ_{la}

Sensitivity analysis: Plastic sector

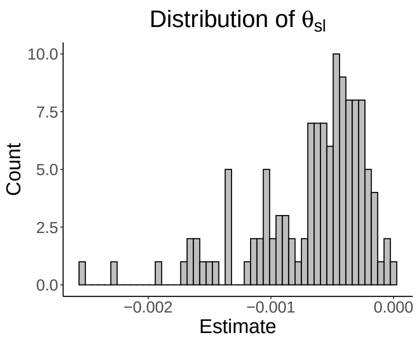
Figure 2.20: Plastic industry: δ_a and θ_{sl} distribution



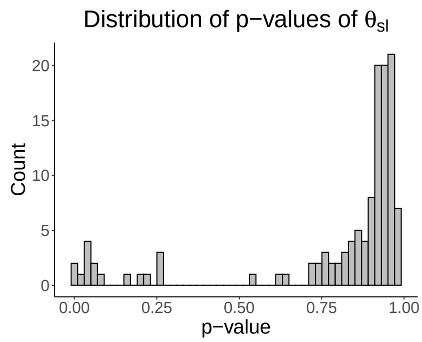
(a) Distribution δ_a



(b) P-values δ_a

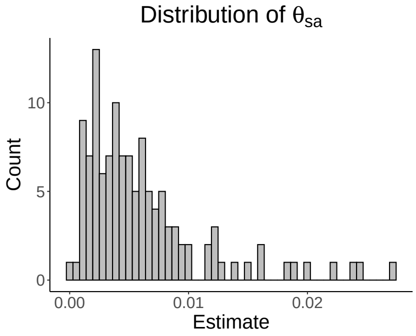


(c) Distribution θ_{sl}

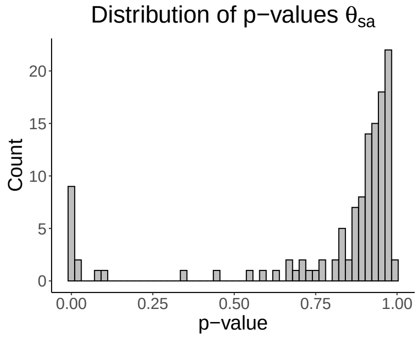


(d) P-values θ_{sl}

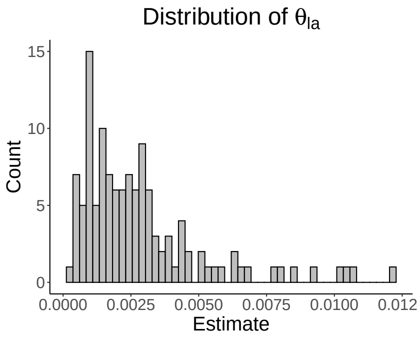
Figure 2.21: Plastic industry: θ_{sa} and θ_{la} distribution



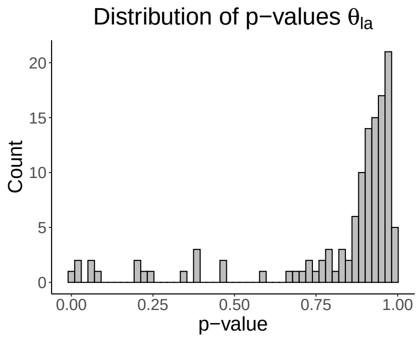
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



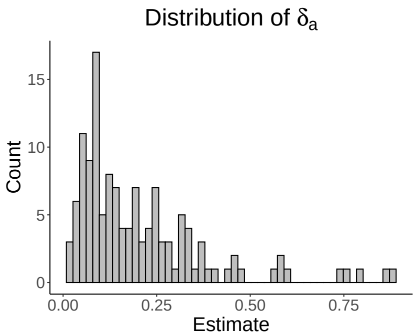
(c) Distribution θ_{la}



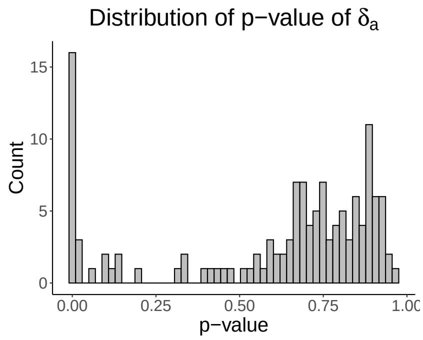
(d) P-values θ_{la}

Sensitivity analysis: Primary sector

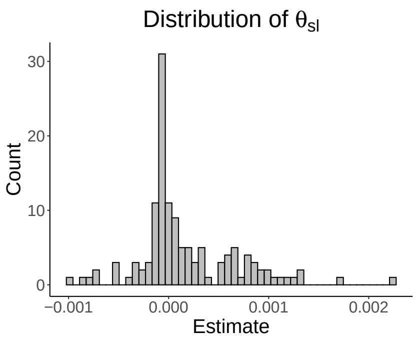
Figure 2.22: Primary industry: δ_a and θ_{sl} distribution



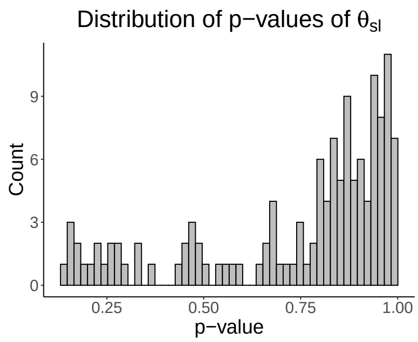
(a) Distribution δ_a



(b) P-values δ_a

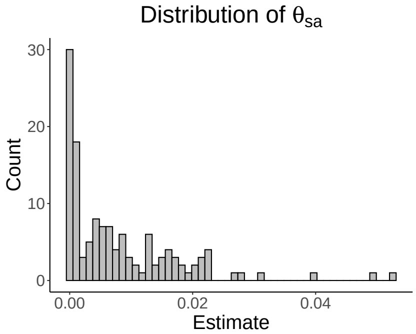


(c) Distribution θ_{sl}

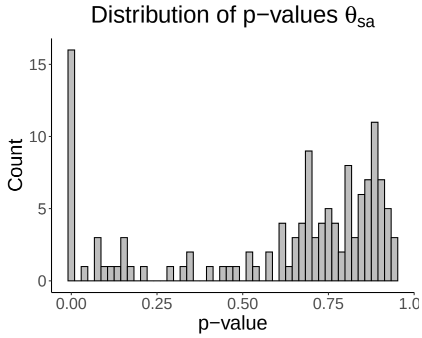


(d) P-values θ_{sl}

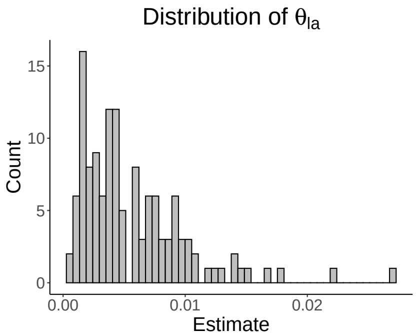
Figure 2.23: Primary industry: θ_{sa} and θ_{la} distribution



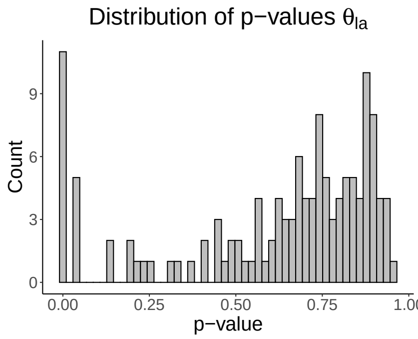
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



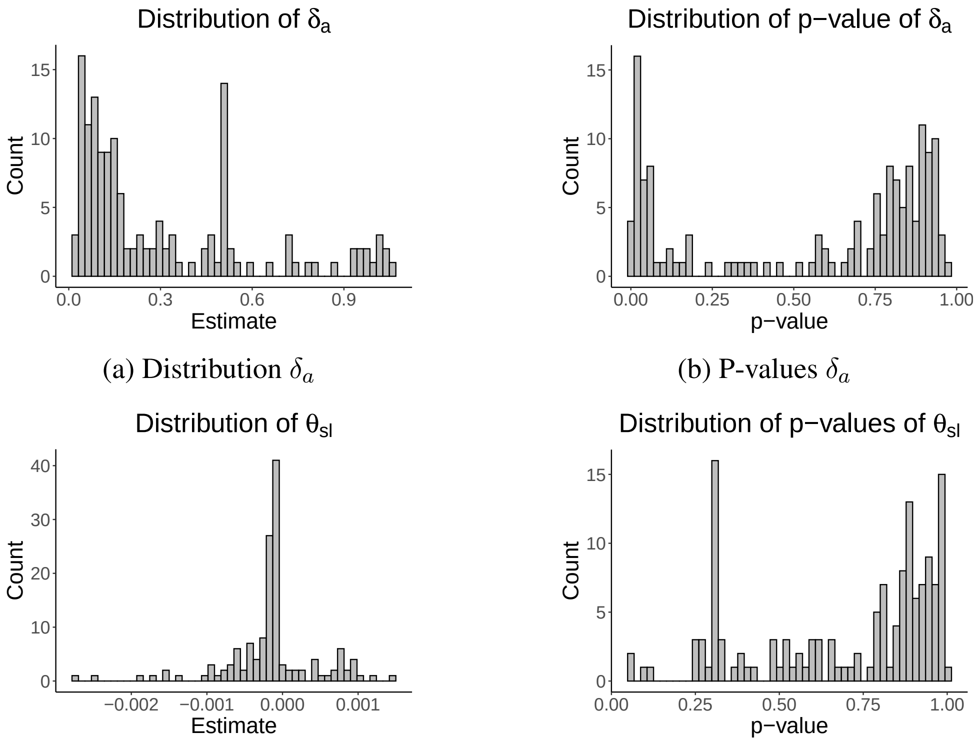
(c) Distribution θ_{la}



(d) P-values θ_{la}

Sensitivity analysis: Paper sector

Figure 2.24: Paper industry: δ_a and θ_{sl} distribution



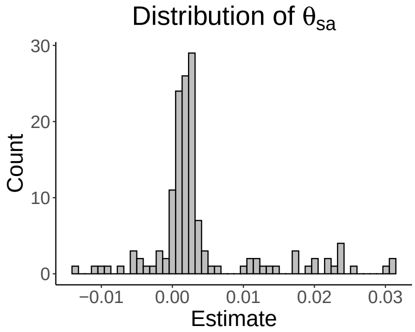
(a) Distribution δ_a

(b) P-values δ_a

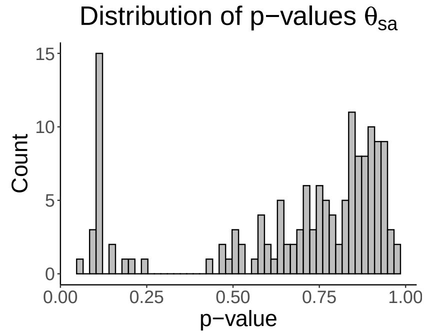
(c) Distribution θ_{sl}

(d) P-values θ_{sl}

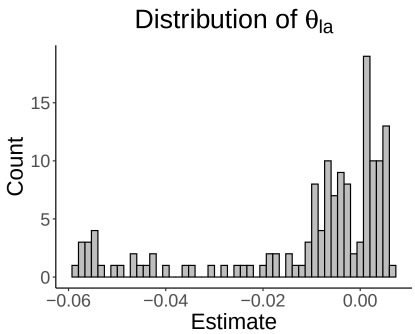
Figure 2.25: Paper industry: θ_{sa} and θ_{la} distribution



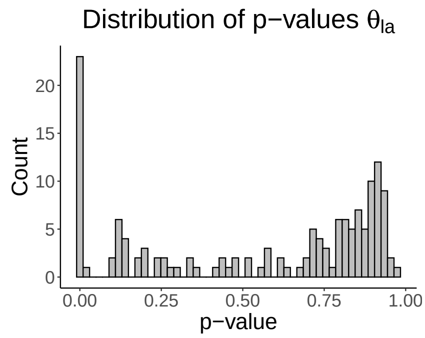
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



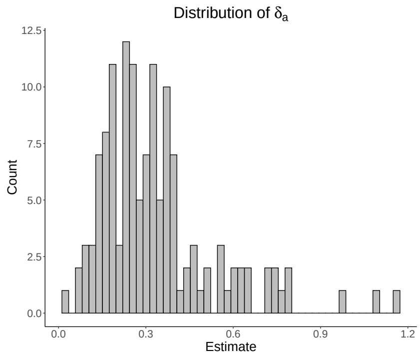
(c) Distribution θ_{la}



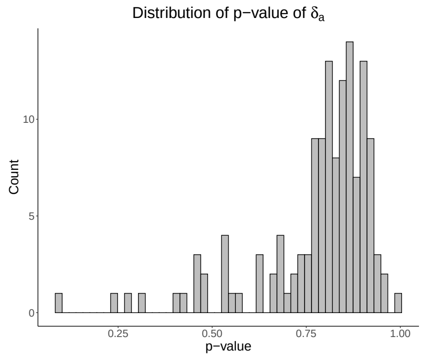
(d) P-values θ_{la}

Sensitivity analysis: Furniture sector

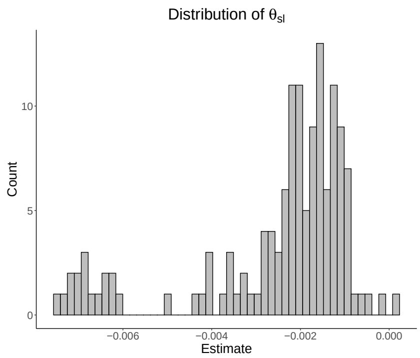
Figure 2.26: Furniture industry: δ_a and θ_{sl} distribution



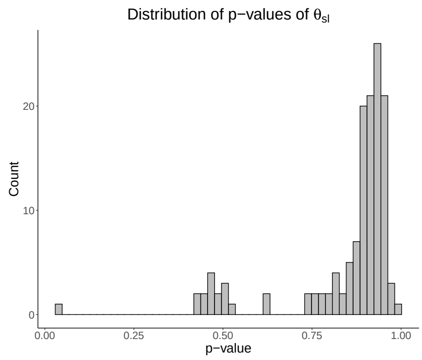
(a) Distribution δ_a



(b) P-values δ_a

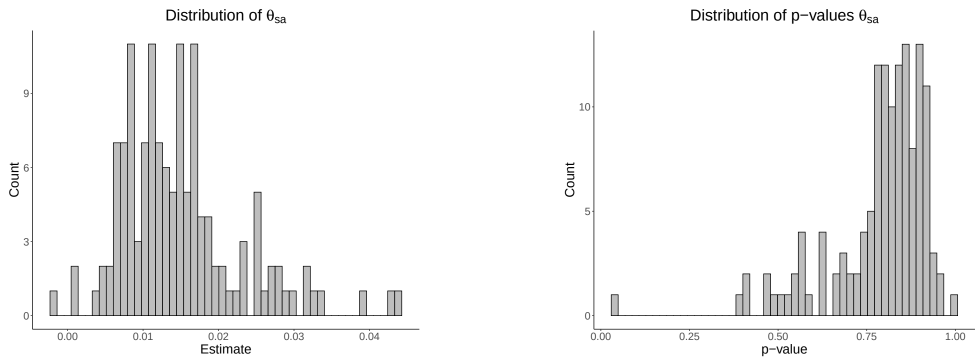


(c) Distribution θ_{sl}

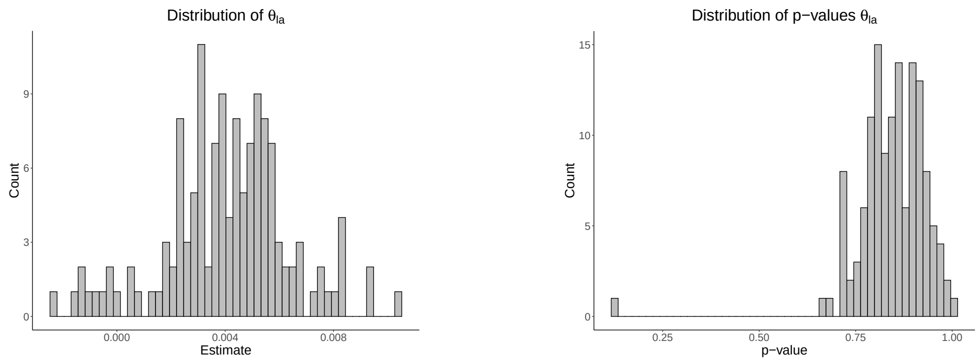


(d) P-values θ_{sl}

Figure 2.27: Furniture industry: θ_{sa} and θ_{la} distribution



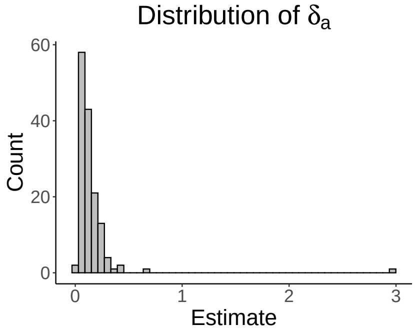
(a) Distribution θ_{sa} (b) P-values θ_{sa}



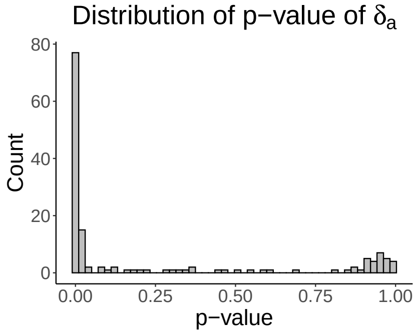
(c) Distribution θ_{la} (d) P-values θ_{la}

Sensitivity analysis: Printing sector

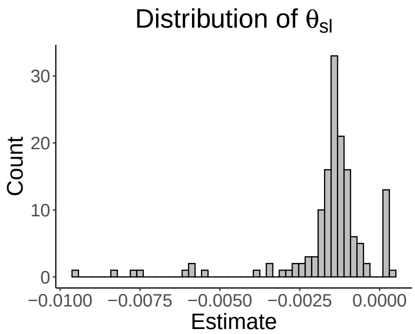
Figure 2.28: Printing industry: δ_a and θ_{sl} distribution



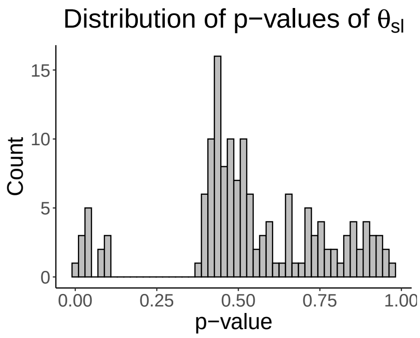
(a) Distribution δ_a



(b) P-values δ_a

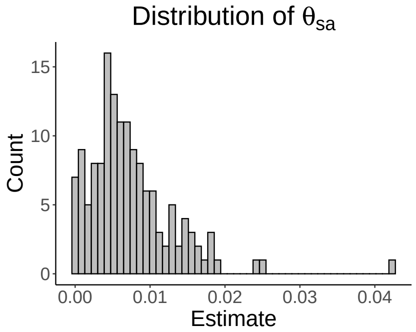


(c) Distribution θ_{sl}

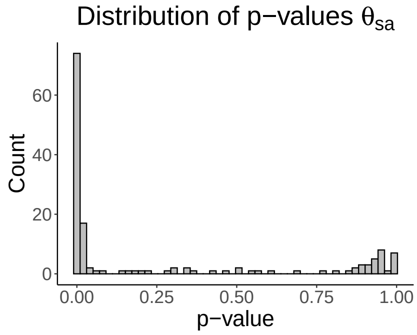


(d) P-values θ_{sl}

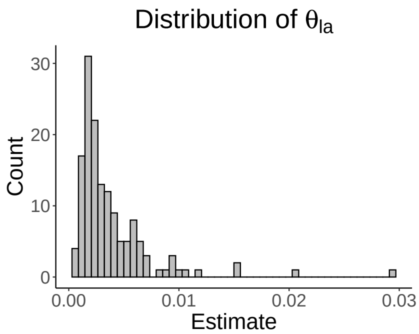
Figure 2.29: Printing industry: θ_{sa} and θ_{la} distribution



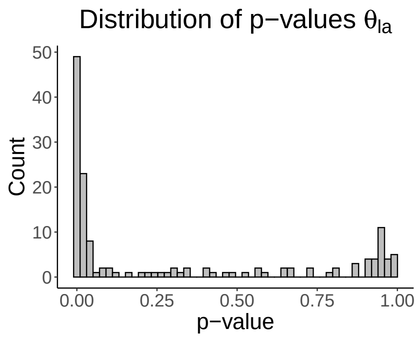
(a) Distribution θ_{sa}



(b) P-values θ_{sa}



(c) Distribution θ_{la}



(d) P-values θ_{la}

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Chapter 3

Contingent Debt Targets and Debt Maturity

Authors: Enzo Dia and Marco Rispoli

Abstract
We analyse industrial firms' financial policies by modelling investment and debt issuances as endogenous variables. In our setup, firms issue costly short-and long-term debt to cover their capital expenditure. This strategy does not assume the existence of explicit debt targets but allows the recovery of *contingent* debt targets from firms' investment and financing decisions. The empirical analysis reveals sizeable cross-sectional variation: contingent debt targets vary with financial conditions, firm size, and investment opportunities. Furthermore, we find that the magnitude of the contingent debt target ratio is sensitive to the investment type.

JEL classification: G14,G31, G32.
Keywords: Implicit Debt Targets; Debt Maturity; Financial Cost; Maturity-matching.

3.1 Literature Review

Following the seminal work of Myers (1977), a vast body of literature on corporate finance has analysed the relevance of leverage targets, estimated the speed of adjustment toward these targets, and studied the determinants of debt levels. The most recent examples, such as Frank and Shen (2019), use a simple two-factor model composed of the market-to-book ratio and asset size to calculate leverage targets from firm-level regressions, finding that this simple model of leverage can explain several dimensions of corporate financing decisions. Although Yin and Ritter (2020) find evidence consistent with the existence of permanent debt targets, the authors suggest that the speed of adjustment toward the target leverage is rather low. In addition, Korteweg et al. (2022) find that leverage dynamics are not entirely under the firms' direct control and, consequently, proactive leverage adjustments are less frequent and adjustment costs higher and more heterogeneous across different classes of firms than previously thought. Similarly, DeAngelo and Roll (2016) and DeAngelo et al. (2017) provide evidence that leverage dynamics are unstable and difficult to rationalise within the standard models used in the literature. They argue that while the existence of an optimal leverage target, grounded in trade-off theory, might be appealing and consistent from a theoretical perspective, the resulting dynamics can be at odds with the actual financial policies adopted by firms and their managers. More recently, DeAngelo (2022) further develops these views by proposing a concept of debt target different from the one based on the standard trade-off theory. Managers' knowledge is imperfect, and investment requires subjective evaluations of the best opportunities. Hence, firms desire to be ideally positioned to address any funding needs when new investment opportunities arise and maximising the option value of borrowing requires a low, when not zero, level of debt. However, when attractive new opportunities arise, they exercise the option to borrow and move temporarily to a higher but transitory target.

In a similar vein, DeAngelo et al. (2011) propose an alternative model in which the investment policy is endogenously determined because firms use debt as a short-term instrument to meet their investment needs, and leverage targets are strictly related to investment opportunities. Furthermore, DeAngelo (2021) highlights the need for a theoretical approach consistent with the evidence that business firms tailor the use of debt to match changes in the composition of their asset portfolios, emphasising the interdependence between asset and liability decisions. In line with this view, Korteweg et al. (2022) find that firms adjust their capital structure following the need to finance capital expenditure, working capital, and inventories. Finally, Bargeron et al. (2018) find that the investment spike driven by the demand associated with World War I has been largely financed with debt, despite strong fiscal incentives favouring equity finance. They conclude that this evidence supports models that stress the importance of the interdependence of firms' financing decisions with the evolution of their investment opportunities.

We contribute to the extant literature by developing and estimating a theoretical model in which investment policy and debt issuance are endogenous variables and firms issue costly short-and long-term debt to finance their capital expenditure. This strategy does not assume the existence of explicit debt targets; instead, it allows for the recovery of *contingent* debt targets from firms' investment and financing decisions. These targets are transitory and contingent on the current investment opportunities, reverting to zero when new investment opportunities are absent. Specifically, the model nests a cost function for external finance into Tobin's Q model with financial frictions. Hence, the model includes both quadratic industrial adjustment costs and costs in external finance because of capital market imperfections.

Our financial cost function exhibits debt maturity heterogeneity between short-and long-term debt and is composed of linear and non-linear terms that capture transaction costs and possible non-linearities. Depending on the estimated sign of the parameters, the non-linear terms capture either convexities causing diseconomies of scale (our baseline hypothesis), or concavities involving economies of scale. Our specification allows the retrieval of contingent debt targets from the estimated parameters of investment equations, which depend on two critical determinants: investment opportunities and the non-linear parameter of the cost function. In our empirical analysis, we recover the correspondent estimated values from reduced-form estimates of the model based on a large panel of U.S. firms followed over the years 1975 to 2019. We then analyse how these contingent targets change in different subperiods and vary as a function of the risk profile, the size of business firms and the type of investment. In addition, we calculate contingent targets specific to each financing source, in line with the findings of Bontempi et al. (2020) that short-and long-term debt follow different dynamics.

We find that debt targets are always significantly different from zero, except for working capital, which firms finance exclusively with long-term debt. In addition, the relative shares of the two classes of debt are broadly similar in the case of fixed asset investments, while inventories are mainly financed with long-term debt. Short-term debt complements internally generated funds and only low-risk firms use them. Long-term debt targets are larger for firms with a lower capability to generate cash but only if these flows are stable and predictable. Riskier firms cannot adopt this strategy because the market imposes a tighter constraint. Firms of different sizes have positive contingent long-term debt targets, but the amount of this target decreases with firm size. Therefore, smaller firms have larger debt targets on average because they face better investment opportunities. However, firms in the smallest quarter of our classification face substantial barriers to accessing external finance and have a negative contingent short-term debt target involving a positive cash balance to generate a liquidity buffer. We find evidence that non-investment-grade firms have consistently higher contingent debt target ratios than investment-grade firms, mainly because the former benefit from better investment opportunities. Finally, debt targets vary substantially over time, following variations in investment opportunities, confirming the hypothesis that contingent debt targets are only temporary. Somewhat surprisingly, short-term debt targets are positive only during periods of reduced investment opportunities.

The remainder of this paper is organised as follows. Section 3.2 describes the financial cost function and its rationale. Section 3.3 nests the financial specification in a standard Q-theoretic framework and derives the optimal investment equation. Section 3.4 discusses the basic estimates of the model, illustrating the contingent debt targets retrieved for different classes of firms and investment types. Section 3.5 presents the robustness checks, and Section 3.6 concludes the paper.

3.2 Financial costs and financial frictions

The introduction of financing frictions in an otherwise standard Q-theoretic framework departs from the Modigliani–Miller frictionless world, altering first-order optimality conditions. As discussed by Bolton et al. (2011), the general formulation of the investment-Q relationship in the presence of financial frictions becomes:

$$\text{marginal cost of investing} = \text{marginal q} - \text{marginal cost of financing.}$$

In this case, firms invest up to the point where the shadow value of installed capital is equal to the marginal cost of investment, considering the costs of funds; hence, the marginal benefit must also cover the marginal increase in the cost of external finance. By considering costly external finance, the general formulation of the optimal condition is given by:

$$q - C_E(E, K) = 1 + G_I(I, K) \implies q = 1 + C_E(E, K) + G_I(I, K),$$

where $C_E(E, K)$ and $G_I(I, K)$ are the adjustment costs on finance and the convex adjustment costs on capital, respectively.

3.2.1 Financial cost specification

The financial cost specification that we adopt is given by:

$$C(s_t, l_t, S_t, L_t, K_{t-1}) = \gamma_1 s_t + \gamma_2 l_t + \frac{1}{2}\delta_1 \frac{S_t^2}{K_{t-1}} + \frac{1}{2}\delta_2 \frac{L_t^2}{K_{t-1}}, \tag{3.1}$$

where s_t and l_t indicate the new issuance of short-and long-term debt, respectively, and S_t and L_t are the current corresponding stocks of outstanding debt, which can be expressed as the sum of the new issuance and the stock inherited from the previous period, $S_t = s_t + S_{t-1}$ and $L_t = l_t + L_{t-1}$. Although firms can control new issuances only, the existing stock of debt matters because debt choices are strongly dependent on past funding decisions, as discussed by Admati et al. (2018). The linear parameters γ_1 and γ_2 control for transaction costs, while δ_1 and δ_2 are loading parameters that capture the convexity or concavity of financial costs. As in Gomes (2001), transaction costs are expected to be positive ($\gamma_1 > 0$ and $\gamma_2 > 0$) and depend on the total amount of new issuances. δ_1 and δ_2 capture any non-linearity in financial costs and the existence of optimal debt targets requires their signs to be significant and negative, while positive signs are associated with negative debt targets, denoting cash holdings in line with with DeAngelo et al. (2011).

Optimal Contingent Debt Targets

To obtain contingent debt targets, we compute the derivatives of the cost function concerning the issuance of short-and long-term debt:

$$\frac{\partial C(s_t, l_t, S_t, L_t, K_{t-1})}{\partial s_t} = \gamma_1 + \delta_1 \frac{S_t}{K_{t-1}} = 0, \tag{3.2}$$

$$\frac{\partial C(s_t, l_t, S_t, L_t, K_{t-1})}{\partial l_t} = \gamma_2 + \delta_2 \frac{L_t}{K_{t-1}} = 0, \tag{3.3}$$

which give rise to the following optimal contingent debt targets:

$$\left(\frac{S_t}{K_{t-1}}\right)^* = -\frac{\gamma_1}{\delta_1}; \quad \left(\frac{L_t}{K_{t-1}}\right)^* = -\frac{\gamma_2}{\delta_2}. \tag{3.4}$$

$-\frac{\gamma_1}{\delta_1}$ and $-\frac{\gamma_2}{\delta_2}$ are contingent targets for short-and long-term debt respectively, and their sign is not restricted *a priori*. When γ_1 and γ_2 are positive, as is normally the case, firms have positive contingent targets for either short-or long-term debt when, respectively, δ_1 or δ_2 have a negative sign.

3.3 Investment model with financial frictions

Firms can use either internal funds by retaining earnings or external funds to finance their investments.[1] We split total external finance into short-and long-term debt, as

[1] Given that the focus of the analysis is on debt, we abstract from equity financing.

follows:

$$EF_t = \theta s_t + (1-\theta)l_t; \tag{3.5}$$

firms must satisfy the following use of fund constraints over time:

$$P_t^I I_t = EF_t + \alpha NCF_t, \tag{3.6}$$

where $NCF_t = P_t^Y F(K_t, N_t) - w_t N_t$ is the cash flow, α is the (fixed) share of cash flows that are not distributed, I_t is real investment, K_t is the stock of capital, N_t is labour, w_t is the nominal cost of labour, and P_t^Y and P_t^I indicate the prices of output and investment, respectively. After renaming the variables, $s_t = \frac{s_t}{P_t^I}$,$l_t = \frac{l_t}{P_t^I}$, $W_t = \frac{w_t}{P_t^I}$, and $R_t = \frac{P_t^Y}{P_t^I}$, the final expression in real terms is given by:

$$\begin{aligned} I_t &= EF_t + \alpha CF_t = EF_t + \alpha[R_t F(K_t, N_t) - W_t N_t] \\ &= \theta s_t + (1-\theta)l_t + \alpha[R_t F(K_t, N_t) - W_t N_t]. \end{aligned}$$

As is the standard in the literature, we also introduce convex adjustment costs on investment, specified as:

$$G(I_t, K_{t-1}) = \frac{1}{2}\delta_I K_{t-1}\left[\frac{I_t}{K_{t-1}} - \alpha\right]^2. \tag{3.7}$$

The complete Lagrangian function of the model is:

$$\begin{aligned} \mathcal{L} = \sum_{t=0}^{\infty} \beta^{t+j}[P_t^Y(F(K_t, N_t) - C(s_t, l_t, S_t, L_t, K_{t-1}) - G(I_t, K_{t-1})) - P_t^I I_t] \\ - \lambda_t[K_t - K_{t-1}(1-\delta) - I_t] - \mu_t[I_t - \theta s_t - (1-\theta)l_t - \alpha(R_t F(K_t, N_t) - W_t N_t)]. \end{aligned} \tag{3.8}$$

The first-order conditions concerning the two financing sources are given by:

$$\frac{\partial \mathcal{L}}{\partial s_{t+j}} = \beta^{t+j}\left[\theta\mu_{t+j} - P_{t+j}^Y\left(\gamma_1 + \delta_1\frac{S_{t+j}}{K_{t+j-1}}\right)\right] = 0, \tag{3.9}$$

and

$$\frac{\partial \mathcal{L}}{\partial l_{t+j}} = \beta^{t+j}\left[(1-\theta)\mu_{t+j} - P_{t+j}^Y\left(\gamma_2 + \delta_2\frac{L_{t+j}}{K_{t+j-1}}\right)\right] = 0. \tag{3.10}$$

Combining the two first-order conditions helps obtain a better understanding of the optimality conditions, as presented below:

$$\mu_{t+j} = \theta\mu_{t+j} + (1-\theta)\mu_{t+j} = P_{t+j}^Y\left(\gamma_1 + \gamma_2 + \delta_1\frac{S_{t+j}}{K_{t+j-1}} + \delta_2\frac{L_{t+j}}{K_{t+j-1}}\right). \tag{3.11}$$

Equation (3.11) states that the shadow value of the external finance constraint is equal to the total marginal external finance cost, which comprises transaction costs and non-linearities. The model is closed by deriving the optimal condition concerning the investment rate, which is the other control variable, as follows:

$$\frac{\partial \mathcal{L}}{\partial I_{t+j}} = \beta^{t+j}[-P^I_{t+j} - P^Y_{t+j}G(I_{t+j})' + \lambda_{t+j} - \mu_{t+j}] = 0. \tag{3.12}$$

Given the investment adjustment cost specification, we can write the optimal condition for investment as follows:

$$\lambda_{t+j} = \mu_{t+j} + P^I_{t+j} + P^Y_{t+j}\delta_I \frac{I_{t+j}}{K_{t+j-1}} - P^Y_{t+j}\delta_I \alpha, \tag{3.13}$$

which, given the definition $q = \frac{\lambda_{t+j} - P^I_{t+j}}{P^Y_{t+j}}$ for Tobin's Q, can be rewritten as:

$$q_{t+j} = \frac{\mu_{t+j}}{P^Y_{t+j}} + \delta_I \frac{I_{t+j}}{K_{t+j-1}} - \alpha\delta_I. \tag{3.14}$$

By combining the optimal conditions for external finance and investment, we obtain the optimal equation linking investment to Tobin's Q and the two external finance sources:[2]

$$\frac{I_{t+j}}{K_{t+j-1}} = \left(\alpha - \frac{\gamma_1 + \gamma_2}{\delta_I}\right) + \frac{1}{\delta_I} q_{t+j} - \frac{\delta_1}{\delta_I}\frac{S_{t+j}}{K_{t+j-1}} - \frac{\delta_2}{\delta_I}\frac{L_{t+j}}{K_{t+j-1}}. \tag{3.15}$$

3.3.1 Estimation approach

To estimate the contingent debt target ratios, we use yearly data from Compustat, spanning the 1975–2019 period. In line with the corporate finance literature, we exclude utilities and firms in the financial and public services industries, all firm-year observations with a negative value of total assets, and sales and gross capital value lower than five million. Finally, we winsorise the data at 0.5% to remove extreme outliers.[3]

As discussed by Strebulaev and Whited (2013), empirical analyses of capital structure theories are troublesome when proxy variables subject to measurement errors are used. In light of the well-known measurement issues associated with Tobin's Q, we adopt an estimation method that allows for a more precise estimate in the presence of measurement errors, the error-in-variable model estimated through the cumulant regression proposed by Erickson et al. (2014). The method[4] uses higher-order cumulants of the joint distribution of observable variables to obtain estimates free from measurement bias. To

[2] Our analysis follows Casalin and Dia (2014) and Casalin and Dia (2013).
[3] Erickson et al. (2014) adopt the same threshold for winsorization.
[4] For further information concerning how to implement the method, read Erickson et al. (2017).

take into account both firm heterogeneity and common factors across years, we demean the variables at the firm-level and by year, a procedure that allows comparing our estimation results with those of standard fixed-effect models.[5] Following Erickson et al. (2014), we use a multiple-regressor version of the classical errors-in-variables model:

$$\frac{I_{i,t}}{K_{i,t-1}} = \beta_1 q_{i,t-1} + \beta_2 \frac{S_{i,t-1}}{K_{i,t-2}} + \beta_3 \frac{L_{i,t-1}}{K_{i,t-2}} + u_i \tag{3.16}$$

$$Q_{i,t-1} = q_{i,t-1} + \epsilon_i, \tag{3.17}$$

where the first equation is a linear regression model containing within-transformed regressors assumed to be measured without error, $\frac{S_{i,t-1}}{K_{i,t-2}}$ and $\frac{L_{i,t-1}}{K_{i,t-2}}$, and a within-transformed regressor that is imperfectly measured, $q_{i,t-1}$. The estimation procedure is based on a two-step plug-in approach wherein the second-step sample cumulants estimate the coefficients of the within-transformed variables. Unlike classic econometrics, which builds on normality assumptions, the cumulant estimator requires mismeasured variables to be skewed, as in the case of Q. A drawback of this procedure is that it does not provide an optimal order of cumulants; therefore, a data analyst must choose this. To select the appropriate order of cumulants, we select the one that provides a higher and significant ρ^2, which is the estimated R^2 of the regression, and a higher and statistically significant τ^2, which indicates the quality of measurement for the proxy for Tobin's Q. We discuss the results for our chosen order; however, the appendix shows that the empirical results for several orders of cumulants provide broadly similar results. We also run traditional Q-regressions as a robustness test.

The estimation allows the reconstruction of the contingent debt target ratios when assuming that the γ_1 and γ_2 values are time-invariant. To obtain our numerical results, following Gomes (2001), we initially set $\gamma_1 = \gamma_2 = 0.028 \approx 0.03$, which corresponds to a common transaction cost of 3%; however, we test for a range of alternative values. In particular, we use two alternative values for the γs obtained from the time-mean value of short-and long-term debt in our sample.[6]

We summarise the relationship between the estimated coefficients and the model's pa-

[5] Given the unbalanced nature of the panel we use, we adopt an iterative procedure for demeaning the variables.

[6] For the former, we use the average of the treasury bill rate with a maturity less than one year (4.7%) and for the latter the average of the treasury bill rate with a maturity greater than one year (5.9%) during the 1975–2019 period. This choice is coherent with the definitions of short-and long-term debt provided by COMPUSTAT.

rameters in the following equations:

$$\hat{\delta}_1 = -\frac{\hat{\beta}_2}{\hat{\beta}_1} \tag{3.18}$$

$$\hat{\delta}_2 = -\frac{\hat{\beta}_3}{\hat{\beta}_1}, \tag{3.19}$$

where δ_1 and δ_2 are increasing functions of the short-and long-term debt coefficients ($\hat{\beta}_2$ and $\hat{\beta}_3$) and a decreasing function of the coefficient on Tobin's Q ($\hat{\beta}_1$). Hence, the corresponding contingent debt target ratios, $\frac{\hat{S}}{\hat{K}} = -\frac{\gamma_1}{\hat{\delta}_1}$ and $\frac{\hat{L}}{\hat{K}} = -\frac{\gamma_2}{\hat{\delta}_2}$, are decreasing functions of the estimated coefficient of short- and long-term debt, and positive functions of the estimated investment opportunities.

3.4 Test results

3.4.1 Contingent debt targets: full sample and subperiods

The first column of Table (3.1) displays the results of a third-order cumulant regression for investment in fixed assets and the corresponding results for the contingent short-and long-term debt targets. We find that debt targets are always significantly differ from zero and that the relative shares of the two classes of debt are broadly similar. The results for the full sample, however, can potentially blur different underlying dynamics that would make debt targets temporary, rather than structural. To test the hypothesis that debt targets are temporary we split the sample in three subperiods. Although the estimated parameter for long-term debt remains fairly stable, the estimates of the parameters for short-term debt and Tobin's Q vary substantially among the subsamples.[7] Tobin's Q, in particular, is smaller in the 1990-2007 subsample, and the resulting debt targets for long-term debt become much smaller. Somewhat surprisingly, however, short-term debt targets become larger, and they become significant, while they are non-significant in the earlier or later subsamples.

[7]The estimation results are displayed in the remaining columns of Table (3.1), while the estimated contingent debt targets are displayed in the lower rows of the table.

Table 3.1: Contingent debt targets: full sample and subperiods

	Fixed assets			
	Full sample	1975-1989	1990-2007	2008-2019
Q_{t-1}	0.163***	0.2283***	0.1499***	0.231***
	(0.0071)	(0.0384)	(0.0067)	(0.0389)
$short-term_{t-1}$	0.0139***	0.01153	0.0195***	0.0093
	(0.0032)	(0.0070)	(0.0039)	(0.0066)
$long-term_{t-1}$	0.0172***	0.0185***	0.018***	0.0177***
	(0.0013)	(0.0033)	(0.0016)	(0.0029)
Observations	153661	35310	73080	41846
τ^2	0.276**	0.267**	0.318**	0164**
ρ^2	0.251**	0.189**	0.276**	0.336*
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Full sample	0.3518***	0.2843***	0.5512***	0.5591***
1975-1989	(-)	0.3702***	(-)	0.7281***
1990-2007	0.2306***	0.2498***	0.3613***	0.4913***
2008-2019	(-)	0.3915***	(-)	0.7700***

Note: The table displays linear third-order cumulant regressions with firm fixed effects and year dummies. Standard errors are in parentheses under the parameter estimates. The dependent variable is the investments in fixed assets. ρ^2 is the R2. $\tau^2 \in (0, 1)$ is the index of the measurement quality of the proxy. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

3.4.2 Contingent debt targets: firm's financial conditions

While the complete sample analysis provides information about the significance and magnitude of debt targets, it does not provide any information concerning the cross-sectional variations in the targets based on different financial characteristics. Therefore, we estimate the model for different quartiles of the pooled distribution of cash flows and cash flow volatility, which provides widely used metrics to assess corporate debt risk over the business cycle. Tables (3.2) and (3.3) show the results of the estimations and contingent debt targets obtained by classifying firms based on the quartiles of cash flows and cash flow volatility distribution. For example, firms belonging to q_1 have cash flows higher than the third quartile and cash flow volatility lower than the first quartile.

The pattern emerging for fixed asset investments indicates that debt targets differ substantially among firms. Firms with high cash flows and low cash flow volatility have positive and significant contingent short-term debt target ratios. However, as financial conditions deteriorate, the targets become insignificant, suggesting that these firms may find potential difficulties in accessing debt markets.

The long-term debt targets become larger as cash flows decline, but the targets drop substantially beyond a critical value for firms with low or negative cash flows. The same targets decline non-monotonically as cash flow volatility increases. Hence, long-term debt can offset the reduced capability to generate financial flows internally, but only if cash flows are stable and predictable.

The emerging picture is that short-term debt complements internally generated funds

Table 3.2: Cash flows quartiles and contingent debt targets

	Fixed assets			
	Cash flows (q_1)	Cash flows (q_2)	Cash flows (q_3)	Cash flows (q_4)
Q_{t-1}	0.115***	0.133***	0.202***	0.148***
	(0.00547)	(0.0071)	(0.0131)	(0.00646)
$short-term_{t-1}$	0.021***	0.0341***	0.00104	-0.00123
	(0.0040)	(0.00752)	(0.0078)	(0.00512)
$long-term_{t-1}$	0.0144***	0.0131***	0.0211***	0.0168***
	(0.0015)	(0.00245)	(0.0034)	(0.00218)
Observations	38056	40004	38698	36011
τ^2	0.342**	0.424**	0.326**	0259**
ρ^2	0.222**	0.179**	0.201**	0.218**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
CF(1)	0.1643***	0.2396***	0.2574***	0.4712***
CF(2)	0.1170***	0.3046***	0.1833***	0.5990***
CF(3)	(-)	0.2872***	(-)	0.5648***
CF(4)	(-)	0.2643***	(-)	0.5198***

Note: The table displays linear sixth-order cumulant regressions with firm fixed effects and year dummies for fixed assets. Standard errors are in parentheses under the parameter estimates. q_1 includes firms with cash flows higher than the third quartile, q_2 between the second and the third quartile included, q_3 between the first and the second quartile included and q_4 lower or equal to the first quartile. ρ^2 is the R2. $\tau^2 \in (0,1)$ is the index of the measurement quality of the proxy. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

Table 3.3: Cash-flow volatility quartiles and contingent debt targets

	Fixed assets			
	Cash-flow vol (q_1)	Cash-flow vol (q_2)	Cash-flow vol (q_3)	Cash-flow vol (q_4)
Q_{t-1}	0.100***	0.170***	0.109***	0.142***
	(0.0118)	(0.0104)	(0.0056)	(0.00565)
$short-term_{t-1}$	0.0279***	0.033***	0.020***	-0.00697
	(0.0065)	(0.0059)	(0.00445)	(0.0061)
$long-term_{t-1}$	0.011***	0.0156***	0.0141***	0.0191***
	(0.00355)	(0.0023)	(0.00197)	(0.0021)
Observations	36039	39895	40002	37616
τ^2	0.552*	0.294**	0.464**	0.279**
ρ^2	0.104**	0.256**	0.174**	0.235**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
VOL(1)	0.1075***	0.2727***	0.1685***	0.5364***
VOL(2)	0.1532***	0.3269***	0.2399***	0.6429***
VOL(3)	0.1595***	0.2319***	0.2499***	0.4561***
VOL(4)	(-)	0.2230***	(-)	0.4386***

Note: The table displays linear sixth-order cumulant regressions with firm fixed effects and year dummies for fixed assets across the pooled distribution of cash-flow volatility. Standard errors are in parentheses under the parameter estimates. q_1 includes firms with cash-flow volatility lower or equal to the first quartile, q_2 between the first and the second quartile included, q_3 between the second and the third quartile included and q_4 higher than the third quartile. ρ^2 is the R2. $\tau^2 \in (0,1)$ is the index of the measurement quality of the proxy. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

and is used only by solid, low-risk firms. Long-term debt targets are more significant for firms with a lower capability to generate cash but only if these flows are stable and predictable. The riskier ones cannot adopt this strategy because the market imposes a much tighter constraint; hence, their financial structure may be inefficient, as suggested by Chernenko et al. (2019).

3.4.3 Firm size and credit rating

Information costs generate substantial fixed costs, and the issuance of instruments such as corporate bonds or commercial papers requires multiples of hundreds of millions of dollars that are accessible only to the largest firms. Conversely, banks may obtain economies of scale by monitoring large firms rather than many small firms, rendering long-term debt more expensive for small firms, even when provided by banks.[8] Hence, in this section, we test whether firms of different sizes differ in their strategic choices of debt targets. In light of the evidence on market segmentation for large buyers of long-term debt instruments such as insurance companies, we also test whether owning an investment-grade rating is associated with higher contingent debt targets.

Dang et al. (2018) provide a comprehensive review on the measurement of firm size, indicating that corporate finance results are sensitive to different proxies for the firm size. Based on their classification, we use the following proxies for firm size:

a) Asset size, measured as the logarithm of total assets. This variable is a proxy for the total amount of resources used in the firm.

b) Sale size, measured as the logarithm of total sales. This measure is affected by the degree of product market competition.

c) Market valuation size, measured as the logarithm of market valuation, captures growth opportunities and equity market conditions.

d) Employment size, measured as the full-time equivalent number of employees.

In Tables (3.4) and (3.5), we display the results of the different regressions and estimates of the contingent debt targets, where we classify firms based on the quartiles of the pooled distribution of firm size. For example, firms belonging to q_1, have a size value lower or equal than those in the first quartile and are among the smallest firms.

[8] Campello and Hackbarth (2012) argue that small firms are typically young, and therefore, more likely to face capital market frictions.

Table 3.4: Size quartiles and contingent debt targets: total assets and sales

	Fixed assets			
	Total assets (q_1)	Total assets (q_2)	Total assets (q_3)	Total assets (q_4)
Q_{t-1}	0.158***	0.150***	0.126***	0.109***
	(0.0113)	(0.00667)	(0.00475)	(0.0058)
$short-term_{t-1}$	-0.0156*	0.0158***	0.0193***	0.0165***
	(0.00799)	(0.00473)	(0.0056)	(0.00498)
$long-term_{t-1}$	0.0053	0.0143***	0.0136***	0.0195***
	(0.00659)	(0.00259)	(0.00164)	(0.00167)
Observations	31188	38577	41037	42859
τ^2	0.138**	0.351**	0.461**	0.427**
ρ^2	0.181**	0.213**	0.203**	0.229**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Asset(1)	-0.3038*	(-)	-0.4760*	(-)
Asset(2)	0.2848***	0.3147***	0.4462***	0.6189***
Asset(3)	0.1959***	0.2779***	0.3068***	0.5466***
Asset(4)	0.1982***	0.1677***	0.3105***	0.3298***
	Fixed assets			
	Total sales (q_1)	Total sales (q_2)	Total sales (q_3)	Total sales (q_4)
Q_{t-1}	0.180***	0.139***	0.126***	0.093***
	(0.0108)	(0.0066)	(0.00462)	(0.0063)
$short-term_{t-1}$	-0.0165*	0.0132***	0.020***	0.0186***
	(0.00938)	(0.00455)	(0.00519)	(0.0046)
$long-term_{t-1}$	0.0184***	0.0177***	0.0154***	0.0141***
	(0.00495)	(0.0024)	(0.0016)	(0.00156)
Observations	30537	37792	40328	41595
τ^2	0.170**	0.401**	0.478**	0.414**
ρ^2	0.194**	0.208**	0.239**	0.205**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Sales(1)	-0.3273*	0.2935***	-0.5127*	0.5772***
Sales(2)	0.3159***	0.2356***	0.4949***	0.4633***
Sales(3)	0.1853***	0.2455***	0.2903***	0.4827***
Sales(4)	0.1505***	0.1985***	0.2358***	0.3904***

Note: The table displays linear sixth-order cumulant regressions with firm fixed effects, year dummies across the pooled distribution of the logarithm of total assets and sales. Standard errors are in parentheses under the parameter estimates. q_1 includes firms with a value of the size's proxy lower or equal to the first quartile, q_2 between the first and the second quartile included, q_3 between the second and the third quartile included and q_4 higher than the third quartile. ρ^2 is the R2. $\tau^2 \in (0, 1)$ is the index of the measurement quality of the proxy. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

Table 3.5: Size quartiles and contingent debt targets: mve and employment

	Fixed assets			
	Market value (q_1)	Market value (q_2)	Market value (q_3)	Market value (q_4)
Q_{t-1}	0.188***	0.222***	0.188***	0.133***
	(0.0194)	(0.0167)	(0.0095)	(0.0049)
$short-term_{t-1}$	-0.0093**	0.0272***	0.0219***	0.0187**
	(0.0046)	(0.00613)	(0.0063)	(0.0069)
$long-term_{t-1}$	0.015***	0.010***	0.0177***	0.0199***
	(0.00246)	(0.00255)	(0.0023)	(0.0020)
Observations	34529	36894	39310	42010
τ^2	0.180**	0.188**	0.269**	0.330**
ρ^2	0.169**	0.237**	0.285**	0.336**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
MVE(1)	-0.6065*	0.3760***	-0.9501*	0.7395***
MVE(2)	0.2449***	0.6680***	0.3836***	1.3137***
MVE(3)	0.2575***	0.3186***	0.4035***	0.6267***
MVE(4)	0.2134**	0.2005***	0.3343**	0.3943***
	Fixed assets			
	Employment (q_1)	Employment (q_2)	Employment (q_3)	Employment (q_4)
Q_{t-1}	0.156***	0.126***	0.127***	0.060***
	(0.010)	(0.0048)	(0.0053)	(0.0058)
$short-term_{t-1}$	0.0020	0.011**	0.0183***	0.0149**
	(0.0080)	(0.00457)	(0.0056)	(0.0057)
$long-term_{t-1}$	0.0163***	0.0159***	0.0158***	0.0136***
	(0.00365)	(0.0019)	(0.00167)	(0.0017)
Observations	32234	35619	37559	38242
τ^2	0.202**	0.435**	0.476**	0.687*
ρ^2	0.191**	0.212**	0.218**	0.134**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Employment(1)	(-)	0.2871***	(-)	0.5647***
Employment(2)	0.3405**	0.2377***	0.534**	0.4675***
Employment(3)	0.2082***	0.2411***	0.3262***	0.4742***
Employment(4)	0.1210**	0.1326***	0.1896**	0.2607***

Note: The table displays linear sixth-order and fifth-order cumulant regressions with firm fixed effects, year dummies across the pooled distribution of the logarithm of market value and employment. Standard errors are in parentheses under the parameter estimates. q_1 includes firms with a value of the size's proxy lower or equal to the first quartile, q_2 between the first and the second quartile included, q_3 between the second and the third quartile included and q_4 higher than the third quartile. ρ^2 is the R2. $\tau^2 \in (0, 1)$ is the index of the measurement quality of the proxy. * = significant at 10%, ** = at 5% and *** = at 1%.(-) corresponds to the absence of statistically significant debt targets.

The most critical result is that small firms, independent of their classification, exhibit a negative and barely significant contingent short-term debt target, which means that small firms face substantial barriers to accessing external finance and may need to target a positive cash balance to generate a liquidity buffer. However, firms of all sizes have a positive and significant contingent long-term debt target ratio, and the size of this target non-monotonically declines with firm size. A plausible explanation for this result is that, on average, small firms have better investment opportunities, as indicated by the larger estimated parameter for Tobin's Q in all the regressions. A declining pattern also emerges for short-term debt targets for quartiles beyond the first, indicating that firms use both classes of debt to finance investment.

Finally, in Table (3.6), we display the results for partitioning firms with an investment-grade rating from their high-yield counterparts. We find that speculative-grade firms have larger debt targets than investment-grade firms; long-term debt targets are always significant for both firms, while short-term targets are not significant. This result can be understood by observing that non-investment-grade companies have far better investment opportunities, measured by Q, than their counterparts; higher expected investment returns can support larger contingent debt target ratios.

Table 3.6: Credit rating: Speculative vs Investment grades

	Fixed assets	
	Speculative	Investment grade
Q_{t-1}	0.144***	0.0755***
	(0.0103)	(0.0114)
$short-term_{t-1}$	0.0118*	0.0041
	(0.0069)	(0.0065)
$long-term_{t-1}$	0.0216***	0.0144***
	(0.0019)	(0.0031)
Firm FE	Yes	Yes
Year FE	Yes	Yes
Observations	15186	14554
τ^2	0.435**	0.390*
ρ^2	0.195**	0.223**

	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Speculative grade	0.3661*	0.200***	0.5736*	0.3933***
Investment grade	(-)	0.1573***	(-)	0.3093***

Note: The table displays linear third-order cumulant regressions with firm fixed effects, year dummie. Standard errors are in parentheses under the parameter estimates. ρ^2 is the R2. $\tau^2 \in (0,1)$ is the index of the measurement quality of the proxy. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets

3.4.4 Contingent debt targets and asset type

The empirical results from Korteweg et al. (2022) suggest that business firms adjusts their capital capital structure not to only in response to fixed assets investment, but also to manage expected and unexpected changes in working capital and inventories. In this section we replicate our analysis for these alternative assets, by substituting capital expenditure with inventory and working capital expenditure as the main dependent variable.

Table 3.7: Results for whole sample

	Inventory investments	Working capital investments
Q_{t-1}	0.349***	1.332***
	(0.0416)	(0.0788)
$short - term_{t-1}$	0.170***	-0.0009
	(0.0165)	(0.0411)
$long - term_{t-1}$	0.0598***	0.100***
	(0.00636)	(0.0159)
Observations	153949	152056
τ^2	0.088**	0.177**
ρ^2	0.097**	0.237**

Contingent debt targets

	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Inventories	0.0616***	0.1751***	0.0965***	0.3443***
Working capital	(-)	0.3996***	(-)	0.7859***

Note: The table displays linear third-order cumulant regressions with firm and year fixed effects. Standard errors are in parentheses under the parameter estimates. The dependent variables are inventories and working capital. ρ^2 is the R2. $\tau^2 \in (0,1)$ is the index of the measurement quality of the proxy. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

We find that debt targets are always significantly differ from zero, except for short-term debt when related to working capital. Furthermore, we find that inventories are mainly financed with long-term debt, even if short-term debt targets are significant. Industrial firms, instead, finance working capital investments with long-term debt only.

We analyse the contingent targets associated with inventory investment. Short-term debt is a substitute for cash flows because the contingent short-term debt target ratios are higher for firms with lower cash flows. The target, however, becomes smaller in the case of firms with the lowest cash flow availability, because investment opportunities are fewer for firms with very low or negative cash flows. Simultaneously, firms with higher cash flow volatility have both higher short-term and long-term debt targets, in contrast to the case of fixed asset investments. As the volatility of cash flows increases, a combination of short-term and long-term debt targets can guarantee additional financial flexibility for firms.

Finally, in the case of working capital investments, only firms with high cash flow availability exhibit positive and statistically significant short-term target ratios. Hence, short-term debt cannot substitute for internal funds to finance working capital. As the level

Table 3.8: Cash flows quartiles and contingent debt targets

	Inventories			
	Cash flows (q_1)	Cash flows (q_2)	Cash flows (q_3)	Cash flows (q_4)
Q_{t-1}	0.454***	0.514***	-0.057	0.167***
	(0.164)	(0.190)	(0.149)	(0.0464)
$short-term_{t-1}$	0.232***	0.227***	0.211***	0.0843***
	(0.0291)	(0.0314)	(0.0342)	(0.0169)
$long-term_{t-1}$	0.0698***	0.0711***	0.0596***	0.0428***
	(0.0125)	(0.0120)	(0.0163)	(0.00611)
Observations	38043	40030	38595	36006
τ^2	0.077**	0.051**	-0.452	0.106**
ρ^2	0.104**	0.110**	0.035**	0.052**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
CF(1)	0.0587***	0.1951***	0.0920***	0.3838***
CF(2)	0.0679***	0.2169***	0.1064***	0.4265***
CF(3)	(-)	(-)	(-)	(-)
CF(4)	0.0594**	0.1171***	0.0931***	0.2302***
	Working capital			
	Cash flows (q_1)	Cash flows (q_2)	Cash flows (q_3)	Cash flows (q_4)
Q_{t-1}	1.47***	1.236***	1.075***	1.292***
	(0.0659)	(0.076)	(0.0178)	(0.0532)
$short-term_{t-1}$	0.216***	-0.145***	-0.118**	-0.170***
	(0.0640)	(0.0458)	(0.0575)	(0.0541)
$long-term_{t-1}$	0.122***	0.104***	0.0699***	0.0804***
	(0.0219)	(0.0204)	(0.0210)	(0.0259)
Observations	37452	39563	38030	35822
τ^2	0.187**	0.111**	0.137**	0.163**
ρ^2	0.245**	0.256**	0.215**	0.199**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short(γ_1 = 4.7%)	Long (γ_2 = 5.9%)
CF(1)	0.2042***	0.3615***	0.3199***	0.7109***
CF(2)	-0.2557***	0.3565***	-0.4006***	0.7012***
CF(3)	-0.2733*	0.4614***	-0.4282*	0.9074***
CF(4)	-0.2280***	0.4821***	-0.3572**	0.9481***

Note: The table displays linear sixth-order cumulant regressions with firm fixed effects and year dummies for working capital and third-order cumulant regressions for inventories across the pooled distribution of cash flows. Standard errors are in parentheses under the parameter estimates. q_1 includes firms with cash flows higher than the third quartile, q_2 between the second and the third quartile included, q_3 between the first and the second quartile included and q_4 lower or equal to the first quartile. ρ^2 is the R2. $\tau^2 \in (0,1)$ is the index of the measurement quality of the proxy. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

Table 3.9: Cash-flow volatility quartiles and contingent debt targets

	Inventories			
	Cash-flow vol (q_1)	Cash-flow vol (q_2)	Cash-flow vol (q_3)	Cash-flow vol (q_4)
Q_{t-1}	0.506	0.354***	0.405***	0.361***
	(0.365)	(0.110)	(0.0836)	(0.0596)
$short-term_{t-1}$	0.258***	0.299***	0.186***	0.0586***
	(0.0449)	(0.0450)	(0.0310)	(0.0214)
$long-term_{t-1}$	0.0491***	0.0757***	0.0760***	0.0443***
	(0.0182)	(0.0138)	(0.0157)	(0.00759)
Observations	36247	39992	39991	37598
τ^2	0.078**	0.105**	0.105**	0.064**
ρ^2	0.079**	0.109**	0.132**	0.109**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
VOL(1)	(-)	(-)	(-)	(-)
VOL(2)	0.0355***	0.1403***	0.0556***	0.2759***
VOL(3)	0.0653***	0.1599***	0.1023***	0.3144***
VOL(4)	0.1848***	0.2445***	0.2895***	0.4808***
	Working capital			
	Cash-flow vol (q_1)	Cash-flow vol (q_2)	Cash-flow vol (q_3)	Cash-flow vol (q_4)
Q_{t-1}	0.771***	1.333***	1.278***	1.361***
	(0.068)	(0.0977)	(0.0694)	(0.0481)
$short-term_{t-1}$	0.569	0.070	0.0979	-0.146*
	(0.0749)	(0.0697)	(0.0793)	(0.0766)
$long-term_{t-1}$	0.146***	0.0878***	0.0510*	0.120***
	(0.0422)	(0.0283)	(0.0271)	(0.0267)
Observations	35385	39334	39530	37710
τ^2	0.309**	0.162**	0.187**	0.176**
ρ^2	0.126**	0.221**	0.242**	0.245**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short(γ_1 = 4.7%)	Long (γ_2 = 5.9%)
VOL(1)	(-)	0.1584***	(-)	0.3116***
VOL(2)	(-)	0.4555***	(-)	0.8958***
VOL(3)	(-)	0.7518*	(-)	1.4785*
VOL(4)	-0.2816*	0.3403***	-0.4412*	0.6692***

Note: The table displays linear sixth-order cumulant regressions with firm fixed effects and year dummies for working capital and third-order cumulant regressions for inventories across the pooled distribution of cash-flow volatility. Standard errors are in parentheses under the parameter estimates. q_1 includes firms with cash-flow volatility lower or equal to the first quartile, q_2 between the first and the second quartile included, q_3 between the second and the third quartile included and q_4 higher than the third quartile. ρ^2 is the R2. $\tau^2 \in (0, 1)$ is the index of the measurement quality of the proxy. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

of cash flow decreases, the contingent short-term debt target ratios become negative and statistically significant, implying that firms belonging to these classes need to target a positive cash balance. Similarly, firms with the highest cash flow volatility display a short-term debt target with a negative sign and require a cash buffer to face the considerable uncertainty associated with the volatility of operating profits. These regressions reveal that the lack of significance of short-term debt targets for working capital results from the radically different behaviour of different classes of firms. While the less risky firms with considerable cash flows have positive, large, and highly significant contingent debt targets, their riskier counterparts hold equally large and significantly negative contingent targets. These results align with recent findings from Denis and McKeon (2021) that "firms exhibiting persistent negative net cash flows (NCFs) play an empirically important role in the surge in average cash balances over recent decades."[9] By contrast, the contingent long-term debt targets are always positive and statistically significant, and they follow a clear pattern across the cash flow distribution: firms with the lowest cash flows have the largest long-term debt targets. The contingent long-term debt target reaches the maximum for firms with cash flow volatility between the median and the third quartile, again suggesting that firms with the most volatile cash flows need moderate debt targets.

3.5 Robustness checks

3.5.1 An alternative proxy for Tobin's Q

Even if the cumulant estimation can deal with measurement error in Tobin's Q, finding the best proxy for investment opportunities is still an issue. Therefore, to test for the robustness of the results, we take into account recent development in the literature by Peters and Taylor (2017), and we rerun all the cumulant regressions by using Total Tobin's Q. This definition also includes the intangible assets, whose share is becoming more and more critical for the US economy. The regression results, available upon request, strongly support the sign and significance obtained using the standard measure of Tobin's Q used in the corporate finance literature. Moreover, in line with Peters and Taylor (2017), the measure is a better proxy for investment opportunities than the market-to-book ratio.

3.5.2 Controls for heteroskedasticity: clustered standard errors

One drawback of the cumulant estimation procedure is that it does not allow control for heteroskedasticity. To account for the within-firm correlation typical of firm-level studies, we run a panel fixed effects analysis with standard errors clustered at the firm

[9] Denis and McKeon (2021) pp. 293.

level. From the optimal investment specification of Equation (3.15), by adding firm and year fixed effects and the error term, we obtain the following empirical specification:

$$\frac{I_{i,t}}{K_{i,t-1}} = \beta_0 + \beta_1 Q_{i,t-1} + \beta_2 \frac{S_{i,t-1}}{K_{i,t-2}} + \beta_3 \frac{L_{i,t-1}}{K_{i,t-2}} + \mu_i + \tau_t + \epsilon_{i,t}, \tag{3.20}$$

where firms (μ_i) and time (τ_t) fixed effects are included in the regression. The former accounts for individual unobservable heterogeneity, and the latter control for time effects common across companies. Moreover, the independent financial variables are lagged by one period to reduce endogeneity concerns.

Table 3.10: Results for whole sample

	Fixed asset investments	Fixed asset investments	Fixed asset investments
Q_{t-1}	0.0457*** (0.00122)	0.0441*** (0.00118)	0.0386*** (0.00119)
$short - term_{t-1}$	0.0135*** (0.00275)	0.00776*** (0.00264)	0.00633** (0.00276)
$long - term_{t-1}$	0.0127*** (0.00108)	0.0142*** (0.00103)	0.0126*** (0.000992)
Firm FE	Yes	Yes	Yes
Year FE	No	Yes	No
Industry-Year FE	No	No	Yes
Observations	151947	151947	150222
R2	0.379	0.416	0.491

Contingent debt targets

	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Firm FE	0.102***	0.108**	0.159***	0.212**
Firm-Year FE	0.170***	0.093***	0.267***	0.183***
Firm Industry-Year FE	0.183**	0.092***	0.287**	0.181***

Note: The table displays panel regressions with year and firm fixed effects and cluster-robust standard errors at the firm level.* = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

Table (3.10) displays the results of the fixed effect regression for the whole sample of firms, and the corresponding contingent debt target ratios for the case of fixed asset investments.[10] The results suggest that both short-and long-term debt targets are always positive and stable across the different specifications. Moreover, the fact that the coefficients are always statistically significant is reassuring because the results are robust when we use heteroskedasticity robust standard errors. However, as expected, the results differ from those obtained from cumulant regressions. The main reason for this downward discrepancy is the correction for the measurement error of the Q coefficient in the cumulant regressions, which makes its magnitude more than three times larger than that of the fixed effect regressions (0.163 vs. 0.0441)[11]. Suppose we compute the contingent debt target ratios by using the short-and long-term debt coefficients obtained from the model with both firm and year fixed effects (0.0077 and 0.0142, respectively),

[10] Results are robust to the inclusion of cash flows as an additional regressor.

[11] The downward bias in the estimation of the Tobin's Q is in line with Erickson et al. (2014) and LI et al. (2020)

but the investment opportunity set corrected for measurement error. In this case, we would obtain similar results for contingent long-term debt targets, while the contingent short-term debt target would be considerably higher.

3.5.3 Instrumental variable approach

Another potential issue that could affect our analysis is the endogeneity of debt and investment that might induce reverse causality, which can bias the estimated coefficients of short-and long-term debt. Although our methodology is relatively standard in the literature, we use an instrumental variable approach as a robustness test to compare the magnitude of the coefficients and assess any potential bias. To find suitable instruments, we rely on the maturity-matching principle, which states that industrial firms aim to match the maturity of their debt liabilities with that of assets, as suggested by Hart and Moore (1994), Stohs and Mauer (1996), and Aivazian et al. (2005). As we have two endogenous variables, we need to find three instruments. The first instrument we choose is the 4-digit SIC industry-year average of the ratio of long-term assets over total assets. The measure is slightly different from the asset tangibility proxy proposed by Giambona and Schwienbacher (2007), because it includes all long-term assets and not only tangible assets at the numerator. We expect the ratio to be correlated with debt maturity choices, in light of the maturity-matching principle, but not directly with the actual investment choices at the firm-level. The other two instruments we use are lagged values of short- and long-term debt-to-capital ratios, measured at the firm level, given the evidence of a strong autocorrelation in leverage choice measures highlighted by Admati et al. (2018). We can directly test for endogeneity in the presence of heteroskedasticity using the two-stage approach proposed by Wooldridge (2010), which requires estimating the following regressions:

$$
\begin{aligned}
\frac{L_{i,t-1}}{K_{i,t-2}} &= \beta_0 + \beta_1 Ind\_long\_asset_t + \beta_2 \frac{L_{i,t-2}}{K_{i,t-3}} + \beta_3 \frac{S_{i,t-2}}{K_{i,t-3}} + \\
&\quad + \beta_4 Q_{t-1} + \mu_i + \tau_t + v_{si,t} \\
\frac{S_{i,t-1}}{K_{i,t-2}} &= \beta_0 + \beta_1 Ind\_long\_asset_t + \beta_2 \frac{L_{i,t-2}}{K_{i,t-3}} + \beta_3 \frac{S_{i,t-2}}{K_{i,t-3}} + \\
&\quad + \beta_4 Q_{t-1} + \mu_i + \tau_t + v_{li,t},
\end{aligned}
\tag{3.21}
$$

calculate the fitted values of the residuals, and introduce these values in the investment regression.[12]

$$\frac{I_{i,t}}{K_{i,t-1}} = \beta_0 + \beta_1 Q_{i,t-1} + \beta_2 \frac{S_{i,t-1}}{K_{i,t-2}} + \beta_3 \frac{L_{i,t-1}}{K_{i,t-2}} + \rho_1 \widehat{v_{si,t}} + \\ + \rho_2 \widehat{v_{li,t}} + \mu_i + \tau_t + \epsilon_{i,t}. \quad (3.22)$$

Testing for endogeneity simply requires a Wald test for the joint significance of the ρ_1 and ρ_2 coefficients:

Table 3.11: Test for endogeneity

	$Long-term_{t-1}$	$Short-term_{t-1}$	Fixed asset Investments
Q_{t-1}	-0.021*** (0.0043)	-0.00227*** (0.00105)	0.0383*** (0.00114)
$short-term_{t-1}$			0.030*** (0.009)
$long-term_{t-1}$			0.00879*** (0.00213)
$Ind\_long\_asset_t$	0.297*** (0.067)	-0.0192 (0.0186)	
$Short-term_{t-2}$	0.045* (0.025)	0.3033*** (0.013)	
$Long-term_{t-2}$	0.454*** (0.013)	0.0192*** (0.0026)	
$\widehat{v_{si,t}}$			-0.0279*** (0.009)
$\widehat{v_{li,t}}$			0.0055*** (0.002)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	139110	139110	139110
R2	0.581	0.686	0.405
F	152.5	329.5	249.0
Wald test			6.81(0.001)

Note: The table displays the regressions to perform the two-step approach to test for endogeneity. Wald test is an F-test for the joint significance of ρ_1 and ρ_2. Cluster-robust standard errors at the firm level are in parentheses. * = significant at 10%, ** = at 5% and *** = at 1%.

Table (3.11) shows that we cannot reject the hypothesis of the absence of endogeneity. In particular, we can observe the direction of the bias we commit by using ordinary least squares: we estimate a downward biased coefficient for short-term debt and an upward biased coefficient for long-term debt. Consistent with the earlier analysis, we use an instrumental variable approach with fixed effects and firm-level clustered standard errors. Furthermore, we adopt a two-stage least squares regression with the following two stages:

[12]Although in principle the use of fitted values causes measurement error in the computation of standard errors, we adopt procedures, developed following Dumont(2005) that are robust.

$$
\begin{aligned}
\frac{L_{i,t-1}}{K_{i,t-2}} &= \beta_0 + \beta_1 Ind\_long\_asset_t + \beta_2 \frac{L_{i,t-2}}{K_{i,t-3}} + \beta_3 \frac{S_{i,t-2}}{K_{i,t-3}} + \\
&\quad + \beta_4 Q_{t-1} + \mu_i + \tau_t + \epsilon_{i,t} \\
\frac{S_{i,t-1}}{K_{i,t-2}} &= \beta_0 + \beta_1 Ind\_long\_asset_t + \beta_2 \frac{L_{i,t-2}}{K_{i,t-3}} + \beta_3 \frac{S_{i,t-2}}{K_{i,t-3}} + \\
&\quad + \beta_4 Q_{t-1} + \mu_i + \tau_t + \epsilon_{i,t}
\end{aligned} \tag{3.23}
$$

$$
\frac{I_{i,t}}{K_{i,t-1}} = \beta_0 + \beta_1 Q_{i,t-1} + \beta_2 \widehat{\frac{S_{i,t-1}}{K_{i,t-2}}} + \beta_3 \widehat{\frac{L_{i,t-1}}{K_{i,t-2}}} + \mu_i + \tau_t + \epsilon_{i,t}, \tag{3.24}
$$

where $\frac{S_{i,t-1}}{K_{i,t-2}}$ and $\frac{L_{i,t-1}}{K_{i,t-2}}$ are the debt-to-capital ratios estimated in the first regression. Table (3.12) displays the results of these two regression steps.

Table 3.12: Instrumental variable regression with fixed effects

	First stage IV-FE regression	
	$Long - term_{t-1}$	$Short - term_{t-1}$
$Ind\_long\_asset_t$	0.299*** (0.067)	-0.0190 (0.0186)
$Long - term_{t-2}$	0.454*** (0.013)	0.0192*** (0.0026)
$Short - term_{t-2}$	0.0478* (0.025)	0.303*** (0.0132)
Q_{t-1}	-0.021*** (0.0043)	-0.00227** (0.00105)
Observations	139110	139110
SW F $statistic^a$	612.50 (13.91)	263.43 (13.91)
	Second stage IV-FE regression	
	Fixed asset Investments	
Q_{t-1}	0.0383*** (0.00114)	
$Long - term_{t-1}$	0.00879*** (0.00215)	
$Short - term_{t-1}$	0.030*** (0.009)	
Observations	139110	
Sargan-Hansen $test^b$	0.202 (0.653)	
KP Wald rk F^c	180.24 (13.43)	
	Contingent debt targets	
	(γ = 3%)	(γ_1 = 4.7%, γ_2 = 5.9%)
Short	0.038***	0.06***
Long	0.131***	0.2045***

Note: The table displays instrumental-variable with firm and year fixed effects for fixed asset investments. Clustered standard errors at the firm level are in parentheses. * $p < .10$, ** $p < .05$, *** $p < .01$. *(a)* Sanderson-Windmeijer F statistic, Stock-Yogo critical values at 5 % maximum relative bias in parenthesis, *(b)* Hansen J-statistic. P-values in parenthesis and *(c)* Kleibergen-Paap rk Wald F statistic, Stock-Yogo critical values at 10% maximal IV size in the parenthesis.

The results show that the industry long-term asset share is statistically significant and positively associated with long-term debt while not significant but negatively associated with short-term debt, as expected. Furthermore, the lagged values of both the short-and long-term debt-to-capital ratios are statistically significant for both financing sources. The Sanderson-Windmeijer and Kleibergen-Paap Wald F statistics show that we reject the null hypothesis of weakly identified instruments. Moreover, we find that the instruments we use, that is, the two times lagged value of the short-and long-term debt-to-capital ratios and the contemporaneous industry long-term asset share, are not correlated with the error process as the Hansen test fails to reject the null at standard significance levels. Both coefficients of the financing sources in the second-stage regression are positive and statistically significant, in line with the results in the main text. The coefficient on long-term debt is smaller than the one obtained from OLS regressions, because we are restricting the variation in long-term debt to match the more limited variability of long-term assets. In contrast, the correlation between capital expenditure and short-term debt investment is now higher. Table (3.12) shows that the values of recovered contingent debt targets for short-and long-term debt are positive and statistically significant. The former is substantially lower than the corresponding values from the ordinary least squares estimates displayed in the second column of Table (3.10), whereas the latter is higher than the ordinary least squares estimates. Furthermore, in the case of long-term debt, the potential bias from the ordinary least squares estimates is far smaller than that in the short-term case.

3.6 Conclusions

This study provided a simple theoretical model to explain debt heterogeneity with a financial cost specification. We can reconstruct contingent debt target ratios for short- and long-term debt by nesting the financial specification in an otherwise standard Q-theoretic framework. Our empirical estimates were robust to measurement errors, and we found that contingent long-term debt target ratios followed a decreasing pattern across the cash flow volatility distribution. Firms with lower cash flow volatility had larger contingent long-term debt targets than their high-volatility counterparts. Furthermore, firms belonging to the highest cash flow volatility quarter of our classification faced substantial difficulties in accessing debt markets, as shown by the non-significant short-term debt targets and low long-term debt targets. By contrast, firms with large cash flows displayed positive and statistically significant short-and long-term debt targets, with long-term debt targets rising for lower cash flow quartiles but dropping substantially beyond a critical value for firms with low or negative cash flows. Finally, small firms had a cash target instead of a positive short-term debt target, and the magnitude of the contingent long-term debt target ratio decreased with size, declining substantially because a larger size is associated with worse investment opportunities.

To inspect the sensitivity of the targets to the type of investment, we estimated the contingent debt target ratios for investments in inventories and working capital. Analogous to fixed asset investments, working capital is primarily financed by long-term debt. On the contrary, we found evidence of a substitution and flexibility channel in inventories: firms with low cash flows and high cash flow volatility had large contingent short-and long-term debt targets.

3.7 Appendix

3.7.1 Definitions of the variables and descriptive statistics

Table 3.13: Definitions of the variables

Variables	Description	Definition	Source
Tobin's Q	Market-to-book ratio, defined as total assets plus the market value of common stock less the sum of book value of common equity and balance sheet deferred taxes scaled by total assets. Same definition used by Choi et al. (2018).	$\frac{AT-CEQ-TXDITC+MVE}{AT}$	Compustat
Total Tobin's Q	Modified Tobin's Q that includes intangible assets proposed by Peters and Taylor (2017).	q_tot	Compustat
Investment rate	Capital expenditures divided by lagged gross PP&E, in line with Peters and Taylor (2017) and Andrei et al. (2019).	$\frac{CAPX}{PPEGT_{t-1}}$	Compustat
Short-term debt	Short-term debt stock divided by by lagged gross PP&E.	$\frac{DLC}{PPEGT_{t-1}}$	Compustat
Long-term debt	Long-term debt stock divided by by lagged gross PP&E.	$\frac{DLTT}{PPEGT_{t-1}}$	Compustat
Cash-flow	Income before extraordinary items plus depreciation, divided by gross PP&E. Same definition adopted by Andrei et al. (2019).	$\frac{IBC+DP}{PPEGT}$	Compustat
Cash flow volatility	Defined as the within-firm volatility of the sum of income before extraordinary items plus depreciation divided by total assets during the entire lifetime of the firm in Compustat. Same volatility calculation used by Andrei et al. (2019) for Tobin's Q.	$\sigma(\frac{IBC+DP}{AT})$	Compustat
Asset size	It is defined as the logarithm of total assets, following Dang et al. (2018).	$log(AT)$	Compustat
Sale size	It is defined as the logarithm of total sales, following Dang et al. (2018).	$log(SALE)$	Compustat
Market valuation size	It is defined as the logarithm of the market value of equity, which, following Dang et al. (2018), is computed as the product between prcc_f and csho.	$log(PRCC_F xCSHO)$	Compustat
Employment size	It is defined as the logarithm of total number of employees, following Dang et al. (2018).	$log(EMP)$	Compustat
Speculative firms	Following the definition of S&P, it is a Dummy variable that takes one if the S&P Domestic Long-Term Issuer Credit Rating is lower than BBB- and zero otherwise.	SPLTICRM	Compustat
Investment grade firms	Following the definition of S&P, it is a Dummy variable that takes one if the S&P Domestic Long-Term Issuer Credit Rating is higher or equal to BBB- and zero otherwise.	SPLTICRM	Compustat

Table 3.14: Descriptive statistics

Variable	Observations	Mean	Std. Dev.	Min	Max	Median
Mean pooled sample						
$\frac{S_{i,t}}{K_{i,t-1}}$	196063	0.17	0.41	0	3.57	0.04
$\frac{L_{i,t}}{K_{i,t-1}}$	195865	0.69	1.51	0	13.52	0.28
Mean within firms						
$\frac{S_{i,t}}{K_{i,t-1}}$	19174	0.23	.44	0	3.57	0.08
$\frac{L_{i,t}}{K_{i,t-1}}$	19173	0.85	1.65	0	13.52	0.36
Median within firms						
$\frac{S_{i,t}}{K_{i,t-1}}$	19174	0.19	.44	0	3.57	0.05
$\frac{L_{i,t}}{K_{i,t-1}}$	19173	0.75	1.65	0	13.52	0.29
Mean within year						
$\frac{S_{i,t}}{K_{i,t-1}}$	44	.17	0.02	0.14	0.23	0.16
$\frac{L_{i,t}}{K_{i,t-1}}$	44	.68	0.19	0.42	1.33	0.66
Median within year						
$\frac{S_{i,t}}{K_{i,t-1}}$	44	.04	0.02	0.01	0.06	0.04
$\frac{L_{i,t}}{K_{i,t-1}}$	44	.28	0.06	0.17	0.49	0.29

Note: The table displays sample statistics using the variation between and within firms of the debt target ratios. Mean, and Median within firms correspond to each firm's average and median values. Mean and Median within a year correspond to the average and median values of the debt ratios for each year (1975-2019).

3.7.2 Cumulant regressions: different orders

Table (3.15) shows that most results are coherent for the different orders of cumulants, and the estimated coefficients of both Q and the long-term debt variables remain very similar after the introduction of cash flows as controls. The contingent debt target ratios decrease when we introduce cash flows as an additional regressor because short-term debt is a close substitute for available cash flows.

Table 3.15: Fixed assets cumulant regressions with and without controls

	Fixed assets			
	Cumulant(3)	Cumulant(4)	Cumulant(5)	Cumulant(6)
Q_{t-1}	0.163***	0.143***	0.166***	0.146***
	(0.00710)	(0.00457)	(0.00465)	(0.00354)
$short-term_{t-1}$	0.0139***	0.0136***	0.0140***	0.0137***
	(0.00322)	(0.00305)	(0.00324)	(0.00307)
$long-term_{t-1}$	0.0172***	0.0165***	0.0173***	0.0166***
	(0.00132)	(0.00123)	(0.00132)	(0.00123)
Observations	153661	153661	153661	153661
τ^2	0.276**	0.316**	0.272**	0.310**
ρ^2	0.251**	0.220**	0.255**	0.224***
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
3th order	0.3518***	0.2843***	0.5512***	0.5591***
4th order	0.3154***	0.2600***	0.4942***	0.5113***
5th order	0.3557***	0.2879***	0.5573***	0.5661***
6th order	0.3197***	0.2639***	0.5009***	0.5189***
	Fixed assets			
	Cumulant(3)	Cumulant(4)	Cumulant(5)	Cumulant(6)
Q_{t-1}	0.163***	0.144***	0.165***	0.149***
	(0.00738)	(0.00474)	(0.00469)	(0.00380)
$short-term_{t-1}$	0.0143***	0.0142***	0.0143***	0.0142***
	(0.00320)	(0.00305)	(0.00322)	(0.00308)
$long-term_{t-1}$	0.0171***	0.0164***	0.0172***	0.0166***
	(0.00133)	(0.00124)	(0.00132)	(0.00125)
$cash-flow_{t-1}$	0.00795***	0.0110***	0.00762***	0.0103***
	(0.00242)	(0.00212)	(0.00229)	(0.00211)
Observations	152776	152776	152776	152776
τ^2	0.273**	0.308**	0.270**	0.299**
ρ^2	0.253**	0.226**	0.256**	0.233***
	contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
3th order	0.3420***	0.2860***	0.5357***	0.5624***
4th order	0.3042***	0.2634***	0.4766***	0.5180***
5th order	0.3462***	0.2878***	0.5423***	0.5660***
6th order	0.3148***	0.2693***	0.4932***	0.5296***

Note: The table displays linear order cumulant regressions with firm fixed effects and year dummies for the different orders of cumulants, from the third order in Column(1) to the sixth order in Column(4). ρ^2 is the R2. $\tau^2 \in (0, 1)$ is the index of the measurement quality of the proxy. Standard errors are in parentheses under the parameter estimates. * = significant at 10%, ** = at 5% and *** = at 1%.

Table 3.16: Inventories cumulant regressions with and without controls

	Inventories			
	Cumulant(3)	Cumulant(4)	Cumulant(5)	Cumulant(6)
Q_{t-1}	0.349***	0.0672***	0.0578***	-0.00396
	(0.0416)	(0.0213)	(0.0175)	(0.0129)
$short-term_{t-1}$	0.170***	0.166***	0.166***	0.165***
	(0.0165)	(0.0160)	(0.0160)	(0.0160)
$long-term_{t-1}$	0.0598***	0.0495***	0.0491***	0.0469***
	(0.00636)	(0.00606)	(0.00606)	(0.00609)
Observations	153949	153949	153949	153949
τ^2	0.088**	0.450	0.523	-7.615
ρ^2	0.097**	0.041***	0.040***	0.027***
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
3th order	0.0616***	0.1751***	0.0965****	0.3443***
4th order	0.0121***	0.0407***	0.0190***	0.0801***
5th order	0.0104***	0.0353***	0.0164***	0.0695***
6th order	(-)	(-)	(-)	(-)
	Inventories			
	Cumulant(3)	Cumulant(4)	Cumulant(5)	Cumulant(6)
Q_{t-1}	0.350***	0.0801***	0.0677***	-0.00656
	(0.0434)	(0.0225)	(0.0175)	(0.0130)
$short-term_{t-1}$	0.174***	0.172***	0.172***	0.171***
	(0.0166)	(0.0159)	(0.0159)	(0.0159)
$long-term_{t-1}$	0.0601***	0.0497***	0.0492***	0.0464***
	(0.00646)	(0.00605)	(0.00605)	(0.00607)
$cash-flow_{t-1}$	0.0402***	0.0840***	0.0860***	0.0981***
	(0.0096)	(0.00655)	(0.00640)	(0.00637)
Observations	153041	153041	153041	153041
τ^2	0.083**	0.335*	0.395	-3.984
ρ^2	0.105**	0.059***	0.056***	0.044***
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
3th order	0.0603***	0.1747***	0.0945***	0.3436***
4th order	0.0140***	0.0484***	0.0219***	0.0951***
5th order	0.0118***	0.0413***	0.0185***	0.0812***
6th order	(-)	(-)	(-)	(-)

Note: The table displays linear order cumulant regressions with firm fixed effects and year dummies for the different orders of cumulants, from the third order cumulant in Column(1) to the sixth order in Column(4). ρ^2 is the R2. $\tau^2 \in (0,1)$ is the index of the measurement quality of the proxy. Standard errors are in parentheses under the parameter estimates. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

Table (3.16) shows the cumulant estimations for the different orders of cumulants. Third-order cumulant results are preferred because they deliver a higher R^2 and statistically significant values for the quality of the proxy used for investment opportunities. Depending on the magnitude of the transaction costs, the contingent short-term debt target ranges from 6.03% to 9.45% and the contingent long-term debt target ranges from 17.47% to 34.36%. Compared with fixed asset investments, the short-term debt target is always lower than the long-term debt target, irrespective of the magnitude of the transaction cost used.

Table 3.17: Working capital cumulant regressions with and without controls

	Working capital			
	Cumulant(3)	Cumulant(4)	Cumulant(5)	Cumulant(6)
Q_{t-1}	1.332***	1.385***	1.296***	1.355***
	(0.0788)	(0.0438)	(0.0399)	(0.0399)
$short-term_{t-1}$	-0.009	-0.008	-0.0097	-0.0087
	(0.0411)	(0.0414)	(0.0409)	(0.0413)
$long-term_{t-1}$	0.100***	0.102***	0.0990***	0.101***
	(0.0159)	(0.0157)	(0.0155)	(0.0156)
Observations	152056	152056	152056	152056
τ^2	0.177**	0.171***	0.182**	0.174***
ρ^2	0.237**	0.246**	0.231**	0.241**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
3th order	(-)	0.3996***	(-)	0.7859***
4th order	(-)	0.4074***	(-)	0.8011***
5th order	(-)	0.3927***	(-)	0.7724***
6th order	(-)	0.4025***	(-)	0.7915***
	Working capital			
	Cumulant(3)	Cumulant(4)	Cumulant(5)	Cumulant(6)
Q_{t-1}	1.341***	1.403***	1.319***	1.340***
	(0.0801)	(0.0445)	(0.0406)	(0.0352)
$short-term_{t-1}$	-0.00301	-0.00275	-0.00310	-0.00302
	(0.0396)	(0.0401)	(0.0395)	(0.0396)
$long-term_{t-1}$	0.0997***	0.102***	0.0989***	0.0997***
	(0.0158)	(0.0155)	(0.0154)	(0.0154)
$cash-flow_{t-1}$	0.110***	0.0995***	0.114***	0.110***
	(0.0311)	(0.0300)	(0.0292)	(0.0289)
Observations	151210	151210	151210	151210
τ^2	0.173**	0.166***	0.176**	0.173***
ρ^2	0.246**	0.256**	0.242***	0.246**
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
3th order	(-)	0.4035***	(-)	0.7936***
4th order	(-)	0.4126***	(-)	0.8115***
5th order	(-)	0.4001***	(-)	0.7869***
6th order	(-)	0.4032***	(-)	0.7930***

Note: The table displays linear order cumulant regressions with firm fixed effects and year dummies for the different orders of cumulants, from the third order in Column(1) to the sixth order in Column(4). ρ^2 is the R2. $\tau^2 \in (0,1)$ is the index of the measurement quality of the proxy. Standard errors are in parentheses under the parameter estimates. * = significant at 10%, ** = at 5% and *** = at 1%.(-) corresponds to the absence of statistically significant debt targets. (-) corresponds to the absence of statistically significant debt targets.

Table (3.17) shows the results for the different orders of cumulants. The results are robust across all the different orders of cumulants in this case. The coefficient of short-term debt is always negative and not statistically significant, whereas the coefficient of long-term debt is always positive and statistically significant. Depending on the magnitude of the transaction cost, the min-max range of long-term debt targets is (40.01%,41.26%) or (78.69%,81.15%).

3.7.3 Panel fixed effects: financial characteristics

We analyse the cross-sectional variation in the contingent debt target ratios for different firms' financial characteristics by subsetting the whole sample into four quartiles based on the firms' distribution of cash flows and cash flow volatility.

Table 3.18: Cash flows quartiles

	Fixed assets			
	Cash flows (q_1)	Cash flows (q_2)	Cash flows (q_3)	Cash flows (q_4)
Q_{t-1}	0.0358***	0.0569***	0.0704***	0.0331***
	(0.00166)	(0.00303)	(0.00548)	(0.00187)
$short - term_{t-1}$	0.00737**	0.0218**	-0.00573	0.00143
	(0.00357)	(0.00899)	(0.00897)	(0.00464)
$long - term_{t-1}$	0.0111***	0.0164***	0.0192***	0.0166***
	(0.00143)	(0.00281)	(0.00463)	(0.00218)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	36095	37485	36160	33015
R2	0.504	0.546	0.481	0.458
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
CF(1)	0.146**	0.097***	0.219**	0.194***
CF(2)	0.078**	0.104***	0.117**	0.208***
CF(3)	(-)	0.110***	(-)	0.220***
CF(4)	(-)	0.060***	(-)	0.120***

Note: The table displays panel regressions with year and firm fixed effects and firm-level cluster-robust standard errors across the pooled distribution of cash flows. q_1 includes firms with cash flows higher than the third quartile, q_2 between the second and the third quartile included, q_3 between the first and the second quartile included and q_4 lower or equal to the first quartile. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets. (-) corresponds to the absence of statistically significant debt targets.

Table 3.19: Cash-flow volatility quartiles

	Fixed assets			
	Cash-flow vol (q_1)	Cash-flow vol (q_2)	Cash-flow vol (q_3)	Cash-flow vol (q_4)
Q_{t-1}	0.0572***	0.0495***	0.0484***	0.0372***
	(0.00362)	(0.00273)	(0.00227)	(0.00167)
$short - term_{t-1}$	0.0204***	0.0212***	0.0122***	-0.00351
	(0.00690)	(0.00500)	(0.00442)	(0.00480)
$long - term_{t-1}$	0.0128***	0.0119***	0.0127***	0.0163***
	(0.00375)	(0.00167)	(0.00174)	(0.00173)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	35471	39635	39673	37064
R2	0.512	0.466	0.417	0.363
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
VOL(1)	0.0841**	0.1341***	0.1262**	0.2681***
VOL(2)	0.070**	01248***	0.1051**	0.2496***
VOL(3)	0.1190**	0.1143***	01785**	0.2287***
VOL(4)	-	0.0685***	-	0.1369***

Note: The table displays panel regressions with year and firm fixed effects and firm-level cluster-robust standard errors across the pooled distribution of cash-flow volatility. q_1 includes firms with cash-flow volatility lower or equal to the first quartile, q_2 between the first and the second quartile included, q_3 between the second and the third quartile included and q_4 higher than the third quartile. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets. (-) corresponds to the absence of statistically significant debt targets.

Tables (3.18) and (3.19) summarise the results, and the pattern indicates that debt targets differ substantially among different classes: firms with high cash flows and low cash flow volatility have positive and significant contingent short-term debt target ratios. However, as financial conditions deteriorate, the targets become insignificant and negative, suggesting that these firms may need to hold a cash buffer to manage their cash flow volatility and the potential difficulties in accessing debt markets. Next, we perform robustness checks for the different proxies of firm size.

Table 3.20: Size quartiles and contingent debt targets: total assets and sales

	Fixed assets			
	Total assets (q_1)	Total assets (q_2)	Total assets (q_3)	Total assets (q_4)
Q_{t-1}	0.0191***	0.0488***	0.0574***	0.0461***
	(0.00153)	(0.00217)	(0.00247)	(0.00259)
$short-term_{t-1}$	-0.0248***	-0.00454	0.00592	0.00629
	(0.00635)	(0.00475)	(0.00507)	(0.00517)
$long-term_{t-1}$	-0.00668**	0.00439*	0.00517***	0.0172***
	(0.00311)	(0.00243)	(0.00162)	(0.00188)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	29704	36955	39932	42403
R2	0.406	0.496	0.522	0.531
F	58.84	169.0	181.3	116.8
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Asset(1)	-0.0231***	-0.0858**	-0.0347***	-0.1716**
Asset(2)	(-)	0.3335**	(-)	0.6670**
Asset(3)	(-)	0.3708***	(-)	0.7416***
Asset(4)	(-)	0.0804***	(-)	0.1608***
	Fixed assets			
	Total sales (q_1)	Total sales (q_2)	Total sales (q_3)	Total sales (q_4)
Q_{t-1}	0.0262***	0.0529***	0.0571***	0.0375***
	(0.00188)	(0.00260)	(0.00253)	(0.00215)
$short-term_{t-1}$	-0.0236***	0.00174	0.00850*	0.00990**
	(0.00812)	(0.00454)	(0.00465)	(0.00476)
$long-term_{t-1}$	0.0116***	0.00844***	0.00954***	0.0120***
	(0.00373)	(0.00217)	(0.00182)	(0.00157)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	29012	36234	39384	41238
R2	0.421	0.509	0.553	0.509
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Sales(1)	-0.0333***	0.0678**	-0.05***	0.1355**
Sales(2)	(-)	0.1880**	(-)	0.3761**
Sales(3)	0.2015*	0.1796**	0.3023*	0.3591**
Sales(4)	0.1136**	0.0938**	0.1705**	0.1875**

Note: The table displays panel regressions with year and firm fixed effects and firm-level cluster-robust standard errors across the pooled distribution of the logarithm of total assets and sales. q_1 includes firms with a value of the size's proxy lower or equal to the first quartile, q_2 between the first and the second quartile included, q_3 between the second and the third quartile included and q_4 higher than the third quartile.* = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets. (-) corresponds to the absence of statistically significant debt targets.

Table 3.21: Size quartiles and contingent debt targets: mve and employment

	Fixed assets			
	Market value (q_1)	Market value (q_2)	Market value (q_3)	Market value (q_4)
Q_{t-1}	0.0268***	0.0328***	0.0458***	0.0423***
	(0.00270)	(0.00222)	(0.00226)	(0.00198)
$short-term_{t-1}$	-0.00803**	0.0180***	0.0145**	0.00791
	(0.00345)	(0.00591)	(0.00588)	(0.00583)
$long-term_{t-1}$	0.0120***	0.00467**	0.00752***	0.0152***
	(0.00202)	(0.00230)	(0.00173)	(0.00183)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	32457	34690	37678	41253
R2	0.399	0.485	0.509	0.558
F	47.83	75.75	140.2	162.5
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
MVE(1)	-0.1001**	0.0670***	-0.1502**	0.1340***
MVE(2)	0.0547***	0.2107**	0.0820***	0.4214**
MVE(3)	0.0948**	0.1827***	01421**	0.3654***
MVE(4)	(-)	0.0835***	(-)	0.1670***
	Fixed assets			
	Employment (q_1)	Employment (q_2)	Employment (q_3)	Employment (q_4)
Q_{t-1}	0.0275***	0.0523***	0.0602***	0.0403***
	(0.00172)	(0.00231)	(0.00297)	(0.00232)
$short-term_{t-1}$	-0.00385	0.00428	0.00218	0.00408
	(0.00711)	(0.00426)	(0.00488)	(0.00617)
$long-term_{t-1}$	0.00945***	0.0109***	0.0119***	0.0133***
	(0.00322)	(0.00207)	(0.00152)	(0.00201)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	30871	34279	36693	37917
R2	0.419	0.485	0.543	0.504
	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Employment(1)	(-)	0.0873***	(-)	0.1746***
Employment(2)	(-)	0.1439***	(-)	0.2879***
Employment(3)	(-)	0.1518***	(-)	0.3035***
Employment(4)	(-)	0.0909***	(-)	0.1818***

Note: The table displays panel regressions with year and firm fixed effects and firm-level cluster-robust standard errors across the pooled distribution of the logarithm of market value and employment. q_1 includes firms with a value of the size's proxy lower or equal to the first quartile, q_2 between the first and the second quartile included, q_3 between the second and the third quartile included and q_4 higher than the third quartile. Panel regressions with year and firm fixed effects and cluster-robust standard errors at the firm level are in parentheses. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets. (-) corresponds to the absence of statistically significant debt targets.

Finally, we separate firms with investment-grade ratings from their high-yield counterparts.

Table 3.22: Credit rating: Investment vs speculative grades

	Fixed asset investments	Fixed asset investments
Q_{t-1}	0.0634***	0.0236***
	(0.00526)	(0.00188)
$short-term_{t-1}$	0.00979	0.00616
	(0.00637)	(0.00616)
$long-term_{t-1}$	0.0187***	0.00821**
	(0.00207)	(0.00368)
Firm FE	Yes	Yes
Year FE	Yes	Yes
Observations	14800	14436
R2	0.555	0.577

	Contingent debt targets			
	Short (γ = 3%)	Long (γ = 3%)	Short (γ_1 = 4.7%)	Long (γ_2 = 5.9%)
Speculative grade	(-)	0.1017***	(-)	0.2034***
Investment grade	(-)	0.0862***	(-)	0.1725***

Note: Panel regressions with year and firm fixed effects and cluster-robust standard errors at the firm level are in parentheses. * = significant at 10%, ** = at 5% and *** = at 1%. (-) corresponds to the absence of statistically significant debt targets.

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Chapter 4

Conclusions

While most existing capital structure models focus on choosing between debt and equity, only some studies focus on debt choices, despite firms using the debt market more often. Moreover, most models exclude any possible advantage from a heterogenous debt structure by focusing on a single debt type. However, the empirical evidence concerning U.S. firms shows that, at least for what concerns debt maturity profiles, firms have dispersed maturity structures.

Therefore, this dissertation aimed to build a theoretical and empirical framework to test for the existence of possible complementarities between shorter and longer maturities. When controlling for investment opportunities, I found that firms cannot reap any benefits from cost-complementarities between short-and long-term debt. Therefore in equilibrium, firms choose the issuance of short-and long-term debt based on the specific interest rate costs and their financial convexities, whose dominant role over possible spillover effects is robust across all the different analyses. Additionally, the analysis of firms across time-varying quartiles of the EBITDA-to-debt ratio confirmed the empirical results obtained for the overall sample: firms do not benefit from complementarities between short-and long-term debt. Moreover, firms with the lowest EBITDA-to-debt ratio, often under severe financial distress, exhibit short-term debt convexities substantially higher than long-term debt ones.

When firms optimally design their capital structure, they consider refinancing risks and financial convexities; therefore, a diversified maturity structure can be critical. To consider the possible reductions of financial cost convexities associated with a diversified maturity structure, I tested whether issuing short-and long-term debt delivers higher profits than single debt-type strategies. Using data on U.S. manufacturing sectors, I used a flexible profit function allowing for interactions between strategic choices and tested their sign and statistical significance. While most manufacturing sectors support the model with complementarities, only a few sectors, like Chemical, Machinery, Transportation and Instruments, can increase their profits by jointly issuing short-and long-term debt. Given the nonlinearity of the model, I applied a wide range of initial values. I found that the main conclusions are supported, even if the variability among the estimates is consistent. Therefore, the analysis reveals that complementarities are strongly industry-specific, and their magnitude depends on the initial values.

Finally, a new definition of contingent debt targets is applied to the specific debt maturity. A simple theoretical model explains debt maturity heterogeneity across different classes of firms with a financial cost specification. In the empirical application, we reconstructed contingent debt target ratios for short-and long-term debt by nesting the financial specification in an otherwise standard Q-theoretic framework. This strategy did not assume the existence of explicit debt targets; instead, it allows for the recovery of contingent debt targets from firms' investment and financing decisions. These targets are transitory and contingent on the current investment opportunities, reverting to zero when new opportunities are absent. Our estimates were robust to measurement error, and we found that contingent long-term debt target ratios followed a decreasing pattern across the cash flow volatility distribution. Furthermore, firms belonging to the highest cash flow volatility quarter of our classification faced substantial difficulties accessing debt markets, as shown by the non-significant short-term and low long-term debt targets. Finally, small firms had a cash target instead of a short-term debt target, and the magnitude of long-term debt targets decreased with size, declining substantially because a larger size is associated with worse investment opportunities.