Non-Linearity in the Determinants of Capital Structure: Evidence from UK Firms

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Abstract

We develop a model of the firm's maximization programme in which the firm's capital structure is a non linear function of a vector of costs including asymmetric information costs and is subject to a debt ceiling. Using conditional quantile regression methods, we test for the existence of such a non-linearity in a heterogeneous sample of UK firms and demonstrate that, by exploiting more fully the distribution of leverage, this technique yields new insights into the choice of leverage ratio. Not only is the estimated effect of the explanatory variables different at different quantiles of the distribution, we find evidence that the effect of a variable changes sign between low leveraged and high leveraged firms.

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1. Introduction

There is considerable evidence that in the United States and other industrialized countries firms' leverage is systematically related to a small number of variables. In data for the United States, Japan, Germany, France Italy, the United Kingdom, and Canada Rajan and Zingales (1995) find a significant relationship between firms' leverage and variables measuring firms' size, asset tangibility, profitability, and growth prospects. Those four variables had been shown to have been significant in numerous studies of US firms (Harris and Raviv, 1991) and Rajan and Zingales' estimates are particularly significant because they find that their relationship to leverage is broadly similar in each of the seven countries despite their institutional differences. Following Rajan and Zingales' findings similar relationships have been estimated in larger international samples (Wald, 1999, Booth, Aivazian, Demirguc-Kunt, and Maksimovic, 2001) giving further support to the belief that systematic correlations exist between leverage and Rajan and Zingales' four variables in a range of countries although national institutional features might have led us to expect otherwise.

Possible explanations for capital structure's relationship with firms' size, asset tangibility, profitability, and growth opportunities can be found in theories that explain firms' financing decisions by agency costs and other costs arising from asymmetric information, for those variables may act as proxy measure of such costs. For example, a high proportion of tangible to total assets might lead to a high leverage ratio because a high degree of asset tangibility, and hence collateralisable assets, reduces the agency cost of debt attributable to asset substitution (Jensen and Meckling, 1976).

However, the empirical regularities discovered by Rajan and Zingales do not offer direct support to such theoretical explanations. Variables that may be related to such costs might equally represent other explanatory factors; for example high asset tangibility might have an effect through reducing expected bankruptcy costs instead of reducing the agency costs of protecting against asset substitution. Additionally, the broad similarity of findings across countries with different institutional structures makes it difficult to relate the variables directly to agency and other asymmetric information costs, or, indeed, to other variables whose effect can be expected to reflect institutional differences. Those and other problems justify the conclusion that 'the theoretical underpinnings of the observed correlations are still largely unresolved'

(Rajan and Zingales, 1995, 1458). Moreover the replication of empirical findings similar to Rajan and Zingales in more recent studies does not diminish those problems of interpretation.

Rajan and Zingales suggest that further study of the relation between theoretical models and their empirical representation is necessary, as do Barclay and Smith (1999). One route is to investigate more fully the relation between the variables measured and the theoretical variables (agency costs and other asymmetric information costs) that they are thought to proxy. Another is to examine alternative theoretical models relating firms' capital structure to agency and other asymmetric information costs and estimate them using appropriate techniques. In this paper we take the second path. We develop a model of the firm's maximization programme in which the firm's capital structure is a non linear function of such costs and is subject to a debt ceiling. Using conditional quantile regression methods we test for the existence of such a non-linearity in a heterogeneous sample of UK firms.

Most existing knowledge of the relation between capital structure and its determinants is derived from linear regression models[1] and therefore rest on the maintained hypothesis that the true relation between firms' leverage and its determinants is linear. Since regression equations yield estimated coefficients at conditional means of the whole sample, they do not fully exploit the information at different moments of the distribution of the sample. Such information is particularly valuable if there is significant heterogeneity in firms' leverage ratios and if the true model of firms' capital structure choice is non linear, for then the effect of a variable on a firm's capital structure will differ significantly according to the firm's position in the leverage distribution. In this paper we use quantile regression techniques to estimate capital structure equations similar to those of Rajan and Zingales for one of the countries in their study. Our model includes variables similar to the four identified by Harris and Raviv and Rajan and Zingales, incorporating them in a framework that additionally takes account of the effect of tax shields. Using data for the United Kingdom we demonstrate that, by exploiting more fully the distribution of

[1] Rajan and Zingales derive maximum likelihood estimates of the coefficients of an equation linear in the variables (one of which, the variable for size, is logarithmic).

observations[2], the technique yields new insights into the choice of leverage ratio. Not only is the estimated effect of the explanatory variables different at different quantiles of the distribution, we find evidence that the effect of a variable changes sign between low leveraged and high leveraged firms.

Our finding that firms in different quantiles have different degrees of sensitivity to changes in the explanatory variables conforms to our non-linear model of the relation between asymmetric information costs and a firm's capital structure choice. Our finding of sign reversal is consistent with the existence of an upper constraint on debt in the non linear model. In the presence of non-linearities quantile regression provides more reliable estimates than linear regression models, for the latter assume that the impact of firm-specific variables on firm's capital structure is the same across firms with low and high leverage.

These results suggest that using quantile regression in the presence of non linearities does yield richer insights than hitherto available into the relation between capital structure and proxies for explanatory variables. Therefore it provides a new foundation for studying explanations of capital structure.

In Section 2 we set out a model of a firm's capital structure that incorporates non linearity and an upper constraint on debt. In Section 3 we outline the quantile regression method we use, and in Section 4 we discuss our data, the results of related studies, and the interpretation of variables represented by the data. In section 5 we summarize our regression results and contrast them with ordinary least squares estimates. Robust quantile regression results show that in our model the sensitivity of leverage to each variable, or the coefficient's statistical significance, changes between quantiles[3]. Most notably, the effect of size on leverage changes sign, becoming negative for the most highly leveraged quantiles. These results are consistent with the model of Section 2 with non linearities and an upper debt constraint. In Section 6 we conclude. By exploiting more fully the information in the whole sample we achieve estimates that shed new light on the relation between leverage and standard variables.

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[2] As Rajan and Zingales note (1995, 1449-1450) the distribution of firms by leverage in the UK was similar to that of the United States in 1991 and distinct from other countries in their study apart from Canada.

[3] The variable representing growth opportunities is not statistically significant at usual levels for any quantile.

2 A model of capital structure with non linearities

Consider the following objective function for the firm:

$$\max V_t = E_t\left\{\sum_{s=0}^{\infty} b_{t+s}\Pi_{t+s}\right\} \tag{1}$$

where b_{t+s} is the time-varying discount factor and Π_{t+s} are after-tax cash flows:

$$\Pi_t = (1-t_t)[p_t F(K_t, L_t) - w_t L_t - A(B_{t-1};\mathbf{x}_t)] + t_t(D_t + r_t B_{t-1}) + [B_t - (1+r_t)B_{t-1}] - p_t^k I_t \tag{2}$$

where t_t is the corporate tax rate, p_t is output price, K_t and L_t are the inputs of capital and labor services, w_t is the wage rate, B_t is the outstanding stock of debt, D_t is depreciation, r_t is the interest rate on debt, $p^k_t I_t$ is nominal investment, and $F(K_t, L_t)$ is the production function. The function $A(B_{t-1};\mathbf{x}_t)$ captures the costs of debt in terms of foregone revenue; these costs may be interpreted as agency or asymmetric information costs. The vector $\mathbf{x}_t$ includes a set of variables that proxy such costs of debt, such as firm's profitability and the tangibility of its assets.[4] We assume that $A_B > 0$ and $A_{BB} > 0$: that is, the marginal cost of debt is positive and increasing in the outstanding stock of debt. The tax shield from debt and depreciation is given by $t_t(D_t + r_t B_{t-1})$.

The maximization program for the firm is also subject to the accumulation equation for the capital stock and to an upper constraint on debt [5]:

$$K_{t+1} = (1-d)K_t + I_t \tag{3}$$

$$B_t \le H_t \tag{4}$$

where H_t is the upper limit on the stock of debt for the firm. The upper constraint on the level of the debt captures the notion that agency and asymmetric costs increase

[4] Jaramillo, Schiantarelli and Weiss (1996) provide an application of an agency cost function to the optimization program of the firm.

[5] We do not explicitly consider the non-negativity constraints on dividends and on new equity issues since these would not be relevant for our analysis.

steeply when the risk of bankruptcy is perceived to become significant[6]. The first-order condition for the stock of debt at time t is:

(5) $$b_{t+1}[1+(1-t_t)(r_{t+1}+A_B)]-b_t+m_t=0$$

where m_t is the Kuhn-Tucker multiplier on the upper constraint on debt. The complementary slackness condition gives:

(6) $$m_t\cdot(H_t-B_t)=0$$

In an interior solution the upper constraint on debt is not binding. Hence, $m_t = 0$ and the first-order condition becomes:

(7) $$b_{t+1}[1+(1-t_t)(r_{t+1}+A_B)]=b_t$$

The effect on debt of a change in a variable $x \in \mathbf{x}_t$ is given by:

(8) $$\frac{dB}{dx}=-\frac{A_{Bx}}{A_{BB}}$$

The effect is positive if and only if $A_{Bx} < 0$, that is, if the variable x_t decreases the marginal agency and asymmetric information cost of debt. In general, for the marginal effect of x_t on B_t to be constant we require that the ratio A_{Bx}/A_{BB} remain invariant to the level of debt or of the variable x_t. If this condition is not satisfied – for instance, if the marginal asymmetric information cost of debt is an increasing function of the stock of debt – then we could observe non-linearities in the determinants of capital structure.

When the upper constraint on debt is binding, the Kuhn-Tucker multiplier is positive: $m_t > 0$. The first-order condition (5) for a corner solution can thus be written as:

(9) $$m_t=b_t-b_{t+1}[1+(1-t_t)(r_{t+1}+A_B)]$$

From (9), the effect of a variable $x \in \mathbf{x}_t$ on B_t is given by (omitting the time index):

(10) $$\frac{dB}{dx}=-\frac{m_x+b_{t+1}(1-t_t)A_{Bx}}{m_B+b_{t+1}(1-t_t)A_{BB}}$$

[6] The upper constraint on debt can be regarded as a limit case where the firm faces an infinite cost of borrowing. The constraint could equivalently be expressed in terms of the leverage ratio, without any changes to the main results. The intuition underlying it is consistent with the finding of a non linearity in the effect of gearing on the external finance premium, Benito and Whitley 2003.

where m_x and m_B measure the sensitivity of the opportunity cost of the constraint on debt with respect to x_t and B_t. From (10), the marginal impact of a variable x_t on the stock of debt could exhibit non-linearities or even reversals of sign. The critical condition rests on the value of the marginal opportunity cost of the constraint, m_x, relative to the marginal asymmetric information cost of debt net of taxes. In particular, if $m_x + b_{t+1}(1-t_t)A_{Bx} = 0$ for levels of debt close to the upper bound, the two effects will cancel each other out. For instance, the availability of fixed assets that can be used as collateral is usually acknowledged to reduce the marginal cost of debt. However, this effect may cease to be valid for high values of debt, when collateral may prove insufficient to ensure that the firm is able to obtain borrowed funds.

3 Empirical Method

We test the implications of our model by using the conditional quantile regression estimator developed by Koenker and Basset (1978). Unlike the conditional mean regression estimators that concentrate only on the single central tendency measure, conditional quantile regression traces the entire distribution of leverage, conditional on a set of explanatory variables. An overview of the distribution of firms at different levels of financial leverage can be useful for our analysis since it allows us to estimate the slope parameters at different quantiles of the distribution. As our theoretical discussion suggests, the determinants of capital structure can be different depending on whether the upper constraint on the debt ratio is binding.

Let (y_i , x_i), $i=1,\ldots,n$, be a sample from some population where x_i is a (K´1) vector of regressors. Assuming that the qth quantile of the conditional distribution of y_i is linear in x_i, we can write the conditional quantile regression model as follows:

(11) $$y_i = x_i' b_q + u_{q\,i}$$

and

(12) $$Quant_q(y_i \mid x_i) \equiv \inf\{\, y : F_i(y \mid x) \geq q \,\} = x_i' b_q$$

and

(13) $$Quant_q(u_{q\,i} \mid x_i) = 0$$

where $Quant_q(y_i \mid x_i)$ denotes the qth conditional quantile of y_i, conditional on the regressor vector x_i, b_q is the unknown vector of parameters to be estimated for different values of q in (0,1), u_q is the error term which is assumed to have a continuously differentiable c.d.f., $F_{uq}(. \mid x)$, and a density function $f_{uq}(. \mid x)$, and $F_i(.|x)$ denotes the conditional distribution function. By varying the value of q from 0 to 1, we can trace the entire distribution of y, conditional on x.

The estimator for b_q is obtained from:

(14) $$\min \sum_{i}^{n} r_q(y_i - x_i' b_q)$$

Where $r_q(u)$ is the "check function" defined as

(15) $$r_q(u) = \begin{cases} qu & if \;\; u \geq 0 \\ (q-1)u & if \;\; u < 0 \end{cases}$$

The estimator does not have an explicit form, but the resulting minimization problem can be solved by linear programming techniques (Koenker and Basset, 1978).[7]

It is worth stressing that for each quantile all sample observations are used in the process of quantile fitting regression. Although each fit for each quantile is ultimately determined by p pair of sample points, where p is the number of parameters to be estimated, the selection of which p points depends on the entire number of observations in the sample (Koenker and Hallock, 2001). Thus, we use the entire sample as we vary the value of q from 0 to 1. Notice that this approach is different from segmenting the dependent variable into different subsets according to its unconditional distribution and then running least square regressions on each of these subsets, a method which is likely to yield inconsistent and biased estimates.

Two general approaches exist for the estimation of the covariance matrix of the regression parameter vector. The first derives the asymptotic standard error of the estimator while the second uses bootstrap methods to compute these standard errors and construct confidence intervals.[8] In this paper, we employ the design matrix

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[7] In this study, the minimisation problem is solved by the linear programming techniques suggested by Amstrong, Frome and Kung (1979).

[8] Although the literature is not definite as to the 'best' path to follow, this does not pose a serious problem. As noted by Koenker and Hallock (2001), the differences between competing methods of

bootstrap method to obtain estimates of the standard errors for the coefficients in quantile regression (Buchinsky, 1995, 1998). Based on a Monte Carlo study, Buchinsky (1995) recommends the use of this method as it performs well for relatively small samples and is robust to changes of the bootstrap sample size relative to the data sample size. More importantly, the design matrix bootstrap method is valid under many forms of heterogeneity.[9] In addition to the design matrix bootstrap method, we use the percentile method (Koenker and Hallock, 2001) which enables us to construct confidence intervals for each parameter in a_q.[10] Unlike the standard asymptotic confidence intervals, the bootstrap percentile intervals will not generally be symmetric around the underlying parameter estimate, which is highly useful when the true sampling distribution is not symmetric. It is important to note that these bootstrap procedures can be extended to deal with the joint distribution of various quantile regression estimators, allowing us to test for the equality of slope parameters across pairs of quantiles (Koenker and Hallock, 2001).

4 Data and Empirical Specification

A sample of publicly listed firms is identified from *Thomson Datastream* yielding observations over the eleven year period from 1988 to 1998. All the selected firms are listed on the London Stock Exchange. First, we exclude firms without a complete record for all years covering a set of accounting items – including total debt, net fixed assets, sales, and operating profits – that are required for the construction of variables to proxy the hypothesized determinants of capital structure. Second, we exclude from the sample all financial firms because the nature of their liabilities and capital structure are intrinsically different from those of non-financial firms. We finally exclude firms with fewer than three consecutive observations. This procedure yields a sample of 6416 firm observations.

Empirical evidence on the standard model from many countries suggests that size, asset tangibility, growth, profitability and non-debt tax shields are the main determinants of a firm's capital structure. Studies of the determinants of UK firms'

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inference for quantile regression are very small in practice and are more robust than other forms of inference in econometrics.

[9] The design bootstrap matrix performs very well (better than the other methods considered in Buchinsky's paper) even when the errors are homoskedastic.

[10] See Buchinsky (1998) for a detailed description of the percentile method.

capital structure have also found that variables representing agency and other costs arising from asymmetric information, as well as measures of tax shields, are significant explanatory variables for capital structure.[11] Using a panel of 390 UK companies for 1986-1996 and GMM estimation models Ozkan (2001) finds that firms' profitability, liquidity, and a proxy for growth opportunities have a negative effect on firms' capital leverage ratio, as does a measure of firms' non-debt tax shield. Panno (2003) finds that, for a sample of security issues by UK quoted companies 1992-1996, firms' leverage is related to size, profitability, liquidity, and the tax shield.[12]

Recent literature reporting measures of quoted UK non financial corporations' capital gearing has revealed a wide distribution of firms' leverage ratios and marked heterogeneity in their evolution. In 1998 the median ratio was 18 per cent compared with a ratio of 77 per cent for the top decile (90th percentile). Over the period 1974-1998 the distribution of firms by capital gearing widened markedly with the greatest divergence occurring from the end of the 1980s. Between 1990 and 1998, the capital gearing of highly geared companies, those in the 90th percentile of the distribution, rose from 58 per cent to 77 per cent while those in the 10th percentile fell from minus 30 per cent to minus 80 per cent[13] (Benito and Vlieghe, 2000).

The presence of such heterogeneity increases the value of using quantile regression to estimate the relation between firms' capital structure and its determinants for the method uses the information contained in the whole distribution, in contrast to OLS and other methods that estimate conditional means.

The potential existence of nonlinearities is suggested by the literature on the high borrowing costs of highly leveraged firms (DeAngelo and Masulis, 1980; Castanias, 1983; Gilson, 1997; Peyer and Shivdasani, 2001). For the highly leveraged firms may be reluctant to issue more debt because it raises the expected value of the costs of debt restructuring. Similarly, the closer the firm gets to bankruptcy, lenders will demand to be compensated more for the risk of default. Some lenders will also demand extra

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[11] Bennett and Donnelly 1993; Lasfer, 1995; Ozkan, 2001; Panno, 2003. Bunn and Young, 2003 estimate a basic model in which firms' desired capital structure is systematically related only to the tax shield properties of debt.

[12] Unlike empirical studies on US and international samples, and unlike the logit and probit estimates of Panno 2003 for the UK, Ozkan does not find significant evidence of a relationship between sales and capital structure. The sign on profitability in Panno's study is positive, unlike other studies.

[13] Measured in this case as the ratio of net debt to replacement cost of capital stock.

protection, such as restrictive covenants attached to their loans, which can prove very costly for highly leveraged firms. For such reasons, firm specific factors may exert a different impact on the capital structure choice of firms depending on their level of leverage. More directly, for the UK corporate sector, Benito and Whitley, 2003, find evidence that the external finance premium postulated by the 'pecking order hypothesis' has a non linear relation with firms' capital leverage, where changes in gearing only affect the rate at high levels of gearing.[14]

Firms' size, tangible assets, profitability and growth opportunities could be interpreted as proxies for agency costs and other costs arising from asymmetric information on the following grounds.

Bigger firms could have easier access to capital markets and borrow at more favourable interest rates, perhaps because they are more diversified in their investments and therefore have a lower risk of default than smaller firms (Ferri and Jones, 1979; Smith and Watts, 1992). This suggests a positive relationship between firm size and leverage.

Firms with large proportions of tangible assets are likely to face low costs of debt because the presence of collateralisable assets reduces the scope for asset substitution (Titman and Wessels, 1988; Harris and Raviv, 1991). In addition, tangible assets can serve as collateral against external loans (Scott, 1977). Furthermore, firms with higher liquidation value (e.g. with more tangible assets) will have higher debt since higher liquidation value makes it more likely that liquidation would be the best strategy (Harris and Raviv 1991). Thus, we expect asset tangibility to have a positive impact on the observed debt ratio by reducing the marginal agency cost of debt.

In contrast, growth opportunities represent non-collateralisable assets. Firms with a high proportion of non-collateralisable assets (such as growth opportunities or intangible assets) could find it more difficult to obtain credit because of the asset substitution effect (Bradley, Jarrell and Kim, 1984; Titman and Wessels, 1988). Furthermore, some studies have suggested that due to imperfect information regarding the behaviour of firms, those firms with low tangible assets may find it difficult to

[14] Benito and Whitley find such a non linearity in the estimates drawn from aggregate data not company level data.

raise funds via debt financing (Scott, 1977).[15] Either way, firms with important growth opportunities have a higher agency cost of debt.

The pecking order hypothesis suggests a negative relationship between profitability and leverage because firms prefer to rely first on internally generated funds for the financing of their investments. When such funds are not sufficient to finance their investment, firms will resort to debt rather than equity financing. This behavior can be explained by the high costs associated with issuing new equity in the presence of asymmetric information (Myers and Majluf, 1984; Myers, 1984). Hence, a firm's profitability through its effect on the amount of retained earnings is an important determinant of its capital structure. Other things being equal, firms with more retained earnings are less inclined to resort to external debt and hence will have lower debt in their capital structure.

Various theories examine the impact of taxes on the capital structure choice of firms. In a model that incorporates corporate taxes, personal taxes and non-debt tax shields such as depreciation allowances, De Angelo and Masulis (1980) show that tax deductions for depreciation act as a substitute for the tax benefits associated with higher debt. Thus, firms with large non-debt tax shields should include less debt in their capital structure.

We also include time dummies to control for factors that have the same effect for all firms within a quantile at a given point in time, but vary across time. These time-specific effects include macroeconomic variables such as the price level and risk-free competitive interest rates.

Based on the above discussion, we specify the following panel data model:

$$Quant_q(y_{it} \mid x_{it}) = a_o + a'_q\, x_{it} + g' z_t \qquad (15)$$

where y_{it} is the dependent variable at quantile θ. We use the ratio of net debt to capital as a measure of leverage. Data limitations confine us to measure debt only in book value. We use two indicators to measure a firm's size. These are the logarithm of total sales (SIZE1) and the logarithm of the total assets (SIZE2). We use two indicators to measure firm's profitability. These are the ratio of operating profits to

[15] Growth opportunities can be thought of as real options. Given the agency costs associated with these options, it is more difficult for a firm to borrow against them than against tangible fixed assets (Myers, 1977).

total assets (PROF1) and the earnings of a company before total interest expense, depreciation, amortization and provisions (EBITDA) divided by total assets (PROF2). Tangibility (TANG) is measured by the ratio of net fixed assets to total assets. To measure growth opportunities, we use the annual growth of the firm's total sales (GROWTH1) and annual growth of the firm's total assets (GROWTH2). The non-debt tax shield (DEP) is measured by the ratio of total depreciation to total assets.[16] A detailed description of these variables is provided in the data appendix. Table 1 presents the correlation matrix of these variables.

5. Empirical Results

Equation 15 is estimated for different values of q which allows us to examine the impact of explanatory variables at different points of the distribution of firms' leverage. Specifically, we estimate the coefficients at seven quantiles, namely the 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 95^{th} quantiles, using the same list of explanatory variables for each of these quantiles. Table 2 reports the results of estimating Equation 15 using the ratio of total debt to capital as the dependent variable while in Figures 1a-1d, we plot the estimated coefficients against the various quantiles and show the 95% confidence interval constructed using the percentile method with 1000 bootstrap replications.

For comparison purposes, Column 1 in Table 2 reports the OLS estimates. Consistent with other empirical studies, the OLS results suggest that profitability and non-debt tax shields are associated with a lower debt to capital ratio while size and asset tangibility are associated with higher debt to capital ratio. Growth is not significant at the conventional levels.

The OLS estimator, by focusing only on the central tendency of the distribution does not allow for the possibility that the impact of explanatory variables can be different for highly leveraged firms. The conditional quantile estimates reported in Table 2 (columns 2-8) show that this is in fact the case and that the relationship may even change sign across quantiles. The expected different effects of the explanatory variables at the different quantiles of the distribution are reflected in the size, sign and significance of estimated coefficients on the different variables.

[16] To avoid simultaneity, all variables except for growth measures are lagged once.

Regarding the impact of size on the firm's capital structure choice, there is large variation in the magnitude and sign of the estimated coefficients as we move up the conditional distribution. While SIZE1 enters with a significantly positive coefficient at the lower quantiles, it changes sign in the 75th and higher quantiles suggesting that as firms become highly leveraged, they might no longer be able to borrow at favourable terms regardless of their size. In terms of the model of Section 2, for high values of debt ratios, an increase in the size of the firm reduces the marginal agency cost of debt A_B but this effect is more than offset by a large increase in the marginal opportunity cost of the constraint m causing size to have a negative effect on debt. The change of sign illustrates the limits of OLS estimates for heterogeneous samples when the true relationship has characteristics such as those in Section 2, for the significant positive coefficient on size in the OLS equation gives a qualitative result matched only by the quantiles below the 75th quantile and fails to reveal the qualitative relationships experienced in the more highly leveraged firms.

The non-debt tax shield is not significant at lower parts of the distribution, but becomes significant at the 50th quantile with the coefficient on DEP increasing sharply in magnitude as we move up the 90th and 95th quantiles of the debt to capital distribution. This suggests that the relative advantage of resorting to debt as a tax shield alternative to depreciation is lower for high levels of leverage.

Asset tangibility (TANG) enters with a significant and positive coefficient in most parts of the distribution but becomes insignificant at the 90th and 95th quantiles. As suggested in Section 3, although the availability of fixed assets can be used as collateral to reduce the marginal cost of debt, this effect may cease to be valid for high values of debt, when collateral may prove insufficient to ensure that the firm is able to obtain borrowed funds.

Profitability enters with a negative and significant coefficient in all parts of the distribution with the size of the coefficient increasing in absolute value as we move up the debt to capital distribution. This suggests that an increase in internal funds is related to a decrease in leverage and especially so for highly leveraged firms. It is consistent with the view that the Myers and Majluf 'pecking order' hypothesis on the low relative cost of internal finance is valid and the effect they postulate is increasingly important the higher is leverage.

The estimated coefficient on our measures of growth opportunities is not significant for any quantile. However, using alternative measures of the dependent variable, we find that growth enters with a significant positive coefficient at lower quantiles of the distribution but loses significance at the median and higher quantiles (see Table 5). This may occur because at low levels of leverage the asset substitution effect is low but at higher levels the marginal agency costs associated with non-collaterizable assets increase, acting as a disincentive to leverage.

The bootstrap procedure is extended to construct a joint distribution allowing us to devise F-statistics to test for the equality of the estimated coefficients across various pairs of quantiles. [17] Table 3 reports the F-tests and the associated p-values for the equality of quantile slope coefficients across the various pairs of quantiles. The F-tests reject the null hypothesis of homogenous coefficients between all pairs of quantiles indicating that the impact of the explanatory variables is different across all parts of leverage distribution.

To test the robustness of our results, we perform the following additional regressions. First, we use alternative measures of the explanatory variables. Specifically, we use the logarithm of total assets as measure of size (SIZE2); the ratio of EBITDA to total assets (PROF2); and the percentage change of total assets over one year (GROWTH2) as alternative indicators for size, profitability and growth. As can be seen from Table 4, the regression results are very similar to those obtained in Table 2 except for estimated coefficient on PROF2 which is not significant at lower parts of the distribution but gains significance at the 75th quantile and increases in importance as we move up the distribution. We also use the ratio of market value to book value of a company as an alternative indicator for growth opportunities of the firm, replicating the measure used by Rajan and Zingales and others. The regression results were very similar to those of Table 2.[18]

For the dependent variable we used the following alternative indicators of leverage to test whether our results are specific to certain definitions of leverage: the total debt to capital ratio, total debt to assets ratio, net debt to assets ratio and debt to net assets ratios where net assets are defined as assets minus accounts payable and other current liabilities (see Rajan and Zingales, 1995). For space considerations we only report

[17] See Arias, Hallock, and Sosa-Escudero (2001) for a similar application.

[18] For space considerations, we do not report all the results. These are available from the authors upon request.

the regression results for total debt (rather than net debt) to capital ratio in Table 5.[19] As can be seen from this table, the results are similar to those reported previously with some minor exceptions. In the specification that uses debt to capital ratio, GROWTH1 enters with significantly positive coefficient at lower parts of the distribution but loses significance at the 50th quantile onwards indicating that growth opportunities are only important for low leveraged firms. Interestingly, in this specification OLS performs very poorly with only size and profitability entering with significant coefficients while the coefficients on DEP, TANG and GROWTH1 are not significant at the conventional levels.

Finally, we included industry dummies to control for industry specific effects. Each industry may have specific features that affect the debt structure of firms in that industry. These may arise – among other factors - from the different business environments of the industries, the degree of competition in their product markets and the skill composition of the industries' workforces. We classified the firms in the sample into industry groups using the business description reported in *Thomson Datastream*. The results are very similar to those obtained previously with each of the variables following a similar pattern to that of Table 2. [20]

6. Conclusions

Quantile regression estimates using UK data show that non linearities exist in the relation between firms' capital structure and its determinants. This finding of non linearities adds a new dimension to the knowledge of UK firms' financing behaviour reported in existing literature, and suggests the value of using quantile regression techniques in the field of corporate finance.

Aggregate measures of the capital gearing ratios of UK non financial corporations have exhibited marked cycles. Measured at market value a peak occurred in 1991, and, after a trough in 1998, a large upward deviation from trend led to a new high level in 2002.[21] These patterns have potential systemic effects. Because of its effect

[19] The regression results for other specifications are very similar to those obtained previously and are available from authors upon request. The only difference is that in the specification that uses debt to asset ratio, tangibility was found to be significant in all quantiles.

[20] The results with industry dummies are available from authors upon request.

[21] Bunn and Young, 2003, 318,chart 2. Similar cycles are observed in the capital gearing ratio measured at replacement cost (Benito, Whitley and Young, 2001,163, chart 3). Taylor and Rada, 2003,

on corporations' bankruptcy risk, the non financial sector's high leverage can indicate higher risk for the financial sector.[22] And firms' adjustment of balance sheets to achieve equilibrium capital gearing after a shock can have effects on aggregate fixed capital formation as well as financial flows.[23]

The existence of heterogeneity in firms' leverage has implications for estimating those wider effects of gearing for a macroeconomic shock might have unequal effects across the distribution. For example, the fact that '[c]ompanies with the highest gearing levels in 1998 have not been more profitable than others' contributed to Benito and Vleigh's judgement that UK 'data covering the past 25 years suggests some potential risk to financial robustness in the corporate sector' [24].

Our results have a significance much wider than their implications for the United Kingdom. They demonstrate that if the true relation between a firm's capital structure and costs that determine it (plus the non debt tax shield) is non linear then, in the presence of heterogeneity in the leverage ratio, conditional quantile regression yields estimates that are more informative than ordinary least squares, and statistically more sound than OLS applied to segmented samples. Moreover, if in reality firms maximise subject to an upper constraint on debt, the relationship between leverage and its determinants might change sign as leverage increases, and quantile regression enables us to identify such effects within sample.

Our quantile regression estimates are consistent with the existence of such non linearities and ceilings and demonstrate that such a model can provide a firmer foundation for studying firms' capital structure.

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examine cycles in the behaviour of the debt-capital ratio and the equity-capital (Tobin q) ratio, identifying two complete cycles since 1945.

[22] As a contribution to quantifying such risks Benito, Whitley and Young, 2001 use the Bank of England Macro Model to simulate the effect of shocks.

[23] Such adjustments have been estimated by Bunn and Young, 2003 for the UK.

[24] Benito and Vlieghe, 2000, 92

Data Appendix

Measure of leverage

LEV: the net debt to capital ratio.

Net debt is short term debt (*item 309*) plus long term debt (*item 321*) minus cash (*item 375*).

Short term debt (*item 309*) is borrowings repayable within one year.

Long-term debt *(item 321*) is defined as the sum of loans repayable within 5 years, long-term loans, convertible loans and leasing finance.

Capital (*item 322*) is the sum of (i) total share capital and reserves (*item 307*) defined as the sum of total equity capital, reserves and preference capital and (ii) total loan capital (*item 321*) and total provisions (*item 314*).

Measures of size

SIZE1: the logarithm of total sales (*item 104*) defined as sales, exports and overseas sales minus inter-company sales and value added taxes and other duties and taxes.

SIZE2: the logarithm of the total assets *(Item 392)* defined as the sum of net fixed assets, total intangibles, total investments, net current assets and other assets.

Measures of profitability

PROF1: the ratio of operating profits defined as trading profit minus depreciation minus adjustment for assets sold to total assets.

PROF2: the ratio of earnings of a company before total interest expense, depreciation, amortization and provisions (EBITDA) to total assets.

Measure of tangibility

TANG: the ratio of net fixed assets to total assets.

Net fixed assets *(Item 339)* is defined as gross fixed assets (defined as the sum of total land and building, plant machinery and equipment and other fixed assets) minus total depreciation where total depreciation is the depreciation of total land and building, plant machinery and equipment and other fixed assets.

Measure of non-debt tax shield

DEP: the ratio of total depreciation (*Item 136*) to total assets.

Measures of growth opportunities

GROWTH1: annual percentage change in total assets.

GROWTH2: annual percentage change in total sales.

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Table 1- Correlation Matrix of the Variables

	LEV	SIZE1	SIZE2	PROF1	PROF2	TANG	DEP	GRO1	GRO2
LEV	1.00								
SIZE1	0.037	1.00							
SIZE2	0.038	0.938	1.00						
PROF1	-0.061	0.235	0.169	1.00					
PROF2	-0.032	0.101	0.095	0.727	1.00				
TANG	0.116	0.117	0.200	0.021	0.020	1.00			
DEP	0.006	0.035	0.001	-0.018	-0.006	0.302	1.00		
GROWTH1	-0.003	-0.111	-0.046	-0.061	-0.014	-0.021	-0.00	1.00	
GROWTH2	-0.008	-0.096	-0.099	-0.133	-0.003	0.003	0.102	0.230	1.00

LEV is the ratio of net debt to total capital; SIZE1 is natural logarithm of total sales, SIZE2 is natural logarithm of total assets; PROF1 is ratio of operating profit to total assets; PROF2 is EBITDA divided by total assets; TANG is the ratio of net fixed assets to total assets; DEP is the ratio of depreciation expenses to total assets; GROWTH1 is the annual growth of firm's total sales; GROWTH2 is the annual growth of firm's total assets.

Table 2: Regression Results for Net Debt to Capital Ratio, 1988-1998

	(1) OLS	(2) 5th Quant	(3) 10th Quant	(4) 25th Quant	(5) 50th Quant	(6) 75th Quant	(7) 90th Quant	(8) 95th Quant
SIZE1	**0.013** **(0.003)**	**0.046** **(0.004)**	**0.045** **(0.003)**	**0.033** **(0.002)**	**0.019** **(0.002)**	**-0.004** **(0.002)**	**-0.026** **(0.004)**	**-0.044** **(0.006)**
PROF1	**-0.304** **(0.114)**	**-0.124** **(0.063)**	**-0.131** **(0.052)**	**-0.121** **(0.083)**	**-0.295** **(0.105)**	**-0.477** **(0.101)**	**-0.876** **(0.181)**	**-1.139** **(0.208**)
TANG	**0.346** **(0.040)**	**0.878** **(0.035)**	**0.694** **(0.028)**	**0.473** **(0.024)**	**0.280** **(0.020)**	**0.142** **(0.022)**	0.028 (0.050)	0.061 (0.085)
DEP	**-0.098** **(0.049)**	0.011 (0.062)	0.057 (0.049)	-0.0002 (0.032)	**-0.144** **(0.031)**	**-0.161** **(0.030)**	**-0.207** **(0.056)**	**-0.297** **(0.086)**
GROWTH1	-0.0001 (0.0003)	0.0001 (0.002)	0.001 (0.001)	0.001 (0.001)	0.0003 (0.001)	-0.0004 (0.001)	-0.001 (0.002)	-0.001 (0.003)
F-test Time Dummies	5.05***	2.17**	4.33***	2.07**	6.65***	6.54***	3.87***	13.76***

Notes: Bootstrapped standard errors in parentheses except for the OLS equation where figures in parentheses are robust standard errors. The bootstrap standard errors were obtained using 1000 bootstrap replications. All explanatory variables except GROWTH1 are lagged once. The number of observations is 6416 for OLS and all quantile regressions. Bold figures indicate significance at 5% or less. *** indicate significant at the 1% level; ** indicate significance at the 5% level.

Table 3: F-Tests for Equality of Coefficients Across Quantiles

	5	10	25	50	75	90
5						
10	**10.96** *0.00*					
25	**42.52** *0.00*	**25.87** *0.00*				
50	**103.83** *0.00*	**84.38** *0.00*	**42.85** *0.00*			
75	**176.12** *0.00*	**155.21** *0.00*	**103.06** *0.00*	**51.83** *0.00*		
90	**145.95** *0.00*	**143.52** *0.00*	**104.20** *0.00*	**60.55** *0.00*	**19.96** *0.00*	
95	**107.48** *0.00*	**105.53** *0.00*	**80.02** *0.00*	**48.40** *0.00*	**20.68** *0.00*	**5.39** *0.00*

This table presents F-tests of equality of the slope coefficients across quantiles. The F-tests for equality of slope coefficients (in bold) and the corresponding p-values (in italic) are based on the bootstrap method. Bootstrap simulations are based on 1000 replications.

Table 4: Regression Results for Net Debt to Capital Ratio, 1988-1998 Using Different Measures of Explanatory Variables

	(1) OLS	(2) 5th Quant	(3) 10th Quant	(4) 25th Quant	(5) 50th Quant	(6) 75th Quant	(7) 90th Quant	(8) 95th Quant
SIZE2	**0.006**	**0.048**	**0.041**	**0.030**	**0.015**	**-0.008**	**-0.029**	**-0.041**
	(0.003)	**(0.005)**	**(0.003)**	**(0.002)**	**(0.002)**	**(0.002)**	**(0.004)**	**(0.006)**
PROF2	-0.041	-0.032	-0.027	-0.017	-0.156	**-0.384**	**-0.830**	**-1.210**
	(0.032)	(0.039)	(0.045)	(0.122)	(0.173)	**(0.190)**	**(0.260)**	**(0.269)**
TANG	**0.343**	**0.841**	**0.692**	**0.430**	**0.258**	**0.160**	0.069	0.127
	(0.042)	**(0.036)**	**(0.025)**	**(0.023)**	**(0.019)**	**(0.020)**	(0.046)	(0.088)
DEP	**-0.085**	0.034	0.117	0.012	**-0.123**	**-0.175**	**-0.220**	**-0.326**
	(0.048)	(0.071)	(0.047)	(0.029)	**(0.028)**	**(0.031)**	**(0.052)**	**(0.097)**
GROWTH2	-0.002	-0.036	-0.003	0.001	0.0002	-0.0007	-0.007	-0.013
	(0.002)	(0.033)	(0.022)	(0.005)	(0.006)	(0.001)	(0.010)	(0.014)

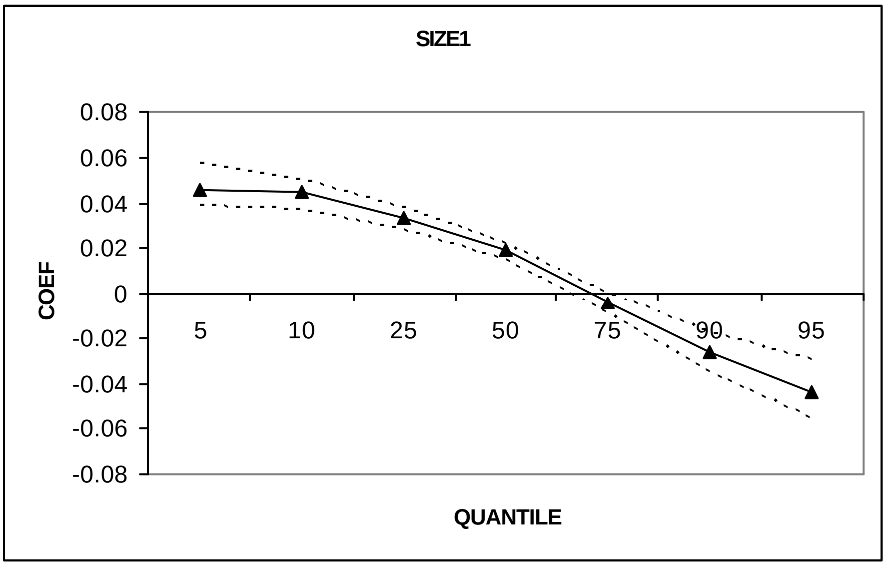
Notes: Bootstrapped standard errors in parentheses except for the OLS equation where figures in parentheses are robust standard errors. The bootstrap standard errors were obtained using 1000 bootstrap replications. All explanatory variables except GROWTH2 are lagged once. The number of observations is 6416 for OLS and all quantile regressions. Bold figures indicate significance at 5% or less. *** indicate significant at the 1% level; ** indicate significance at the 5% level.

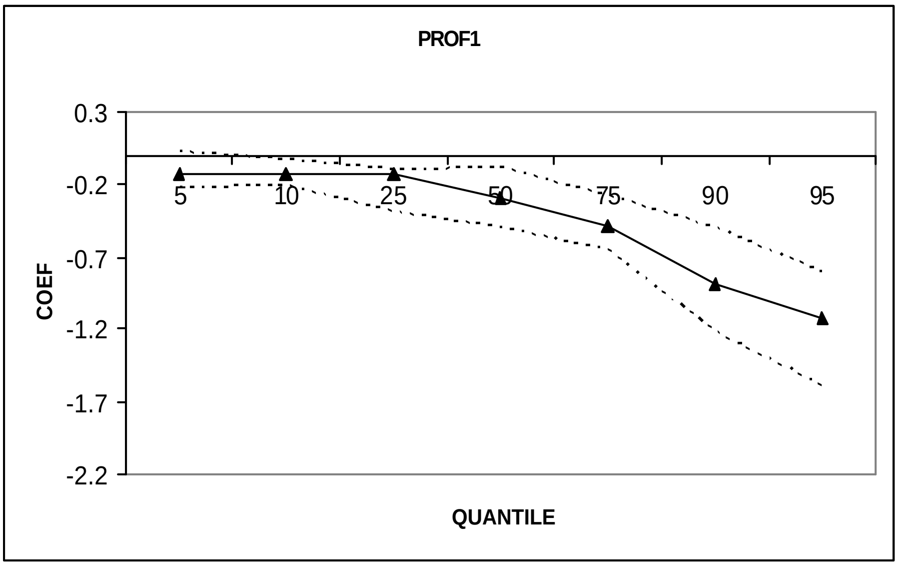
Table 5: Regression Results for Debt to Capital Ratio, 1988-1998

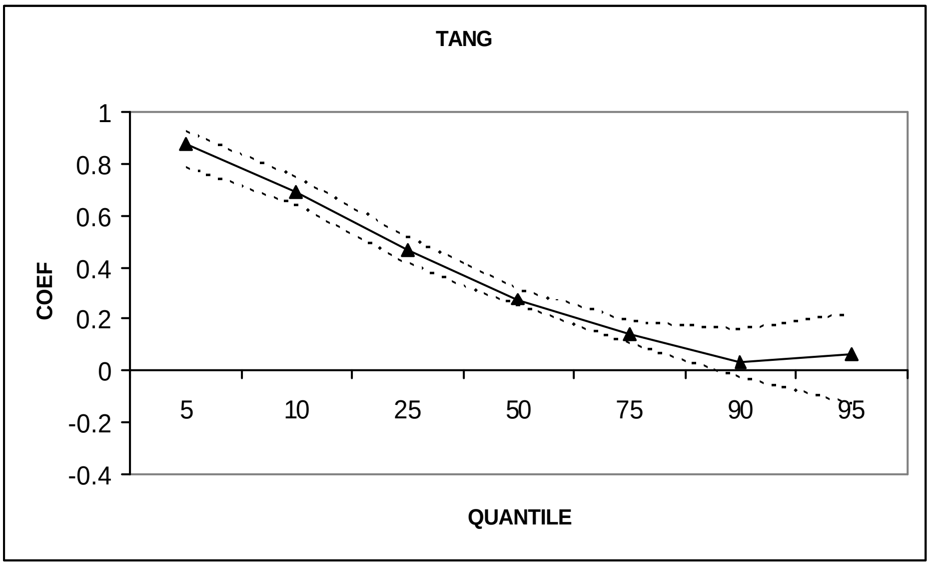
	(1) OLS	(2) 5th Quant	(3) 10th Quant	(4) 25th Quant	(5) 50th Quant	(6) 75th Quant	(7) 90th Quant	(8) 95th Quant
SIZE1	**0.008** **(0.002)**	**0.008** **(0.001)**	**0.016** **(0.001)**	**0.027** **(0.001)**	**0.024** **(0.001)**	**0.008** **(0.002)**	**-0.016** **(0.004)**	**-0.033** **(0.007)**
PROF1	**-0.207** **(0.097)**	**-0.025** **(0.013)**	**-0.055** **(0.173)**	**-0.160** **(0.041)**	**-0.322** **(0.077)**	**-0.515** **(0.089)**	**-0.827** **(0.151)**	**-1.050** **(0.204**)
TANG	0.004 (0.037)	**0.026** **(0.008)**	**0.067** **(0.008)**	**0.110** **(0.012)**	**0.072** **(0.018)**	0.008 (0.021)	-0.127 (0.089)	-0.124 (0.089)
DEP	-0.062 (0.053)	0.007 (0.005)	-0.004 (0.008)	**-0.037** **(0.018)**	**-0.060** **(0.025)**	**-0.123** **(0.034)**	**-0.173** **(0.062)**	**-0.284** **(0.093)**
GROWTH1	-0.0001 (0.0001)	**0.0005** **(0.0002)**	**0.0007** **(0.0002)**	**0.0008** **(0.0003)**	0.0007 (0.008)	0.0001 (0.001)	-0.0006 (0.002)	-0.001 (0.003)

Notes: Bootstrapped standard errors in parentheses except for the OLS equation where figures in parentheses are robust standard errors. The bootstrap standard errors were obtained using 1000 bootstrap replications. All explanatory variables except GROWTH1 are lagged once. The number of observations is 6416 for OLS and all quantile regressions. Bold figures indicate significance at 5% or less. *** indicate significant at the 1% level; ** indicate significance at the 5% level.

Figures 1a-1d






TANG
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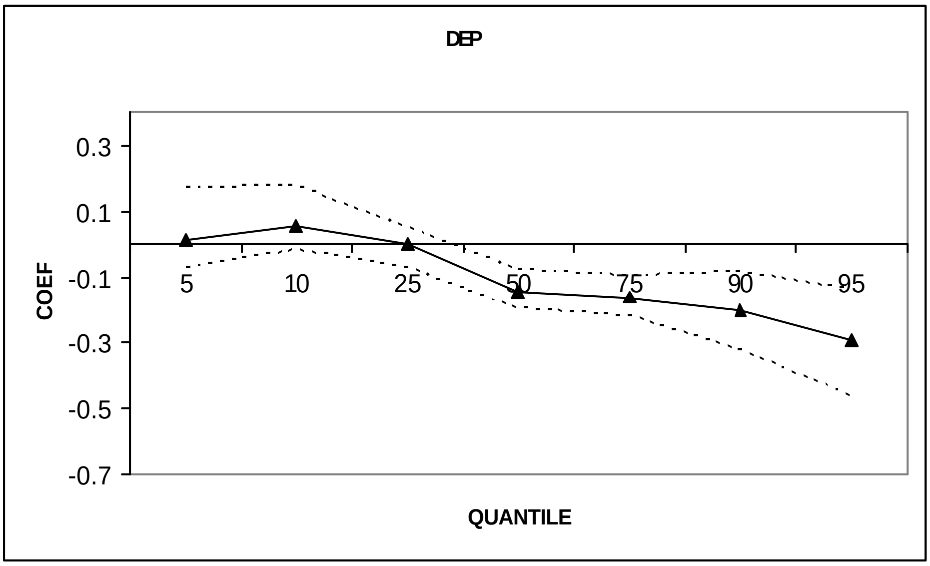
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