

The joint determination of leverage and maturity

Michael J. Barclay*, Leslie M. Marx, Clifford W. Smith Jr.

*W.E. Simon Graduate School of Business Administration, University of Rochester,
Rochester, NY 14627, USA*

Accepted 19 December 2001

Abstract

We examine theories of leverage and debt maturity, focusing on the impact of firms' investment opportunity sets and regulatory environments in determining these policies. Using results on strategic complementarities, we identify sufficient conditions for the theory to have testable implications for reduced-form and structural-equation regression coefficients. Obtaining testable implications for structural equations requires less from the theory but more from the data than the reduced-form specification because it requires an instrumental-variables approach. We examine this trade-off between theory and statistical methods and provide tests using two decades of data for over 5000 industrial firms.

© 2002 Elsevier Science B.V. All rights reserved.

JEL classification: G30

Keywords: Capital structure; Leverage; Debt maturity; Strategic complements

1. Introduction

Capital structures have many facets—for instance, they vary in terms of leverage, maturity, priority, convertibility, and covenants. All of these facets are endogenous and frequently are chosen concurrently. Theoretical and empirical work that explicitly recognizes this simultaneity has the potential to advance our understanding of corporate capital structure decisions. In this paper, we examine the requirements for a theory of a firm's financial policy choices to have empirically testable implications for reduced-form regression coefficients. We provide tests using structural-equation and reduced-form methods and suggest directions for future theoretical and empirical research on capital structure.

* Corresponding author. Tel.: +1-585-275-3916; fax: +1-585-273-1140.

E-mail address: barclay@simon.rochester.edu (M.J. Barclay).

To focus our discussion of the joint determination of multiple facets of corporate capital structure, we examine the choices of leverage and debt maturity. Within a simultaneous system of equations, changing one of the exogenous variables can have both direct and indirect effects on the endogenous variables. For example, a change in a firm's investment opportunities has a direct effect on its choice of debt maturity—an increase in growth options increases the firm's use of short-term debt. However, a shift in investment opportunities also has an indirect effect on debt maturity through its effect on leverage—more growth options result in lower leverage, and this reduced leverage can also change the firm's desired use of short-term debt.

If the theory implies that these effects are reinforcing (that the direct and indirect effects move a policy variable like maturity in the same direction), then the theory implies monotone comparative statics, producing unambiguous sign predictions for reduced-form regression coefficients. However, if these effects are offsetting, then the sign of the reduced-form regression coefficient depends on the relative magnitudes of the effects. Thus, a theory that is not rich enough to predict the relative size of the two effects, in addition to their signs, is not testable with reduced-form regression. In this case, the theory can be tested using a simultaneous system of equations, but then, one must impose more structure on the estimation process to identify the structural coefficients.

When examining financial policy choices, most prior research has focused on explaining a single facet of financial policy. The requirements for monotone comparative statics are normally satisfied readily within models examining a single choice variable. In testing these models, researchers typically have regressed the observed set of financial policy choices on a set of explanatory variables using ordinary least squares (OLS). As examples, [Smith and Watts \(1992\)](#) find that firms with more growth options (as proxied by higher market-to-book ratios) have lower leverage. [Barclay and Smith \(1995\)](#) find that firms with more growth options have less long-term debt. In their analyses, these authors explicitly treat their explanatory variables as either exogenous or predetermined. This allows them to interpret their estimated regression coefficients as reduced forms. Based on these results, they conclude that there is strong support for agency-cost explanations of corporate leverage and maturity choices.

[Stohs and Mauer \(1996\)](#) argue that the Barclay and Smith debt-maturity regressions are misspecified because they do not control for differences in leverage. When Stohs and Mauer add leverage to the right-hand side of their OLS debt-maturity regression, they find that the coefficients on the investment opportunity set variables (such as the market-to-book ratio) decline both in magnitude and statistical significance. Stohs and Mauer thus conclude that there is little support for agency-cost explanations of debt maturity. However, many of the same transactions implement a firm's choices of both leverage and debt maturity. It is clearly inappropriate to treat one as predetermined when analyzing how firms choose the other. The coefficients estimated in an OLS regression of debt maturity on leverage and other variables will suffer from simultaneous-equation bias.

This problem also appears in other work in which researchers regress one corporate policy choice on another using OLS. For instance, [Geczy et al. \(1997\)](#) regress the use of foreign currency derivatives on leverage and managerial compensation variables; [Berger et al. \(1997\)](#) regress leverage on executive compensation variables; [Tufano \(1996\)](#) regresses

hedging activity on leverage; Houston and James (1996) regress the fraction bank debt on leverage; and Fama and French (2002) regress leverage on target payout ratios. All of these regressions suffer, to some degree, from the problems associated with multiple endogenous variables.

Results on strategic complementarities provide a productive method of structuring problems in which firms make several policy choices simultaneously. If two policy choices are strategic complements, then monotone comparative statics are guaranteed. If the policy choices are not strategic complements, then the theory either must impose restrictions on the magnitude of the coefficients or it must be tested using a system of simultaneous equations. By applying the results on strategic complementarities to questions of capital structure, we are able to interpret existing results better, identify limitations of existing theories, and propose additional empirical tests. We examine whether the extant theory justifies the assumptions necessary to insure a monotone relation between the firms' choices of leverage and debt maturity and the firms' investment opportunity sets and regulatory environments.

In Section 2, we discuss the theoretical requirements for monotone comparative statics. In Section 3, we present our empirical results. In Section 4, we conclude.

2. Theoretical monotonicity requirements

To begin, assume that firms choose leverage and debt maturity to maximize firm value given their exogenous firm characteristics. A firm's choice of leverage, denoted as *lev*, is measured as the ratio of debt to total value and is an element of $[0,1]$. We assume that firms choose either short or long maturities for their debt and measure debt maturity, denoted as *mat*, as the fraction of total debt that is long term. Thus, *mat* is also an element of $[0,1]$ with higher values of *mat* indicating more long-term debt.

We characterize firms by their investment opportunity set and regulatory status. We model a firm's investment opportunity set, *i*, as an element of the real line.¹ Higher values of *i* indicate more assets in place and lower values of *i* indicate more growth options.² To denote whether a firm is regulated, we define the variable *r* to be 0 if a firm is not regulated and 1 if it is regulated. Thus, the regulation variable is an element of the set $\{0,1\}$, with the usual order. We characterize firms by the pair (*i*,*r*). We assume that the market knows the firm's investment opportunities and regulatory status and can observe the firm's choice of

¹ Our results remain the same as long as we assume that investment opportunities take on values in a partially ordered set.

² One proxy for a firm's investment opportunity set is the ratio of its book value to its market value. In an efficient stock market, the stock price should capitalize the expected future net cash flows from the exercise of the firm's growth options. Accounting procedures do not recognize the value of these intangible assets. Thus, firms whose value primarily reflects assets in place have high book-to-market ratios, while firms whose value is primarily due to intangible growth opportunities have low book-to-market ratios. (See Schwert, 1981, Section III.B for a discussion of potential problems associated with using the book-to-market ratio as an instrument.)

leverage and debt maturity. Given this information, the market values the firm at $V(\text{lev}, \text{mat}; i, r)$. Thus, firms face the following maximization problem:

$$\max_{\text{lev} \in [0,1], \text{mat} \in [0,1]} V(\text{lev}, \text{mat}; i, r). \quad (1)$$

We write $(\text{lev}'', \text{mat}'') > (\text{lev}', \text{mat}')$ to mean that $\text{lev}'' \geq \text{lev}'$ and $\text{mat}'' \geq \text{mat}'$ and that at least one of the inequalities is strict so that $(\text{lev}'', \text{mat}'') \neq (\text{lev}', \text{mat}')$.

Consider the reduced-form equations:³

$$\text{mat} = \pi_{10} + \pi_{11}i + \pi_{12}r$$

$$\text{lev} = \pi_{20} + \pi_{21}i + \pi_{22}r. \quad (2)$$

If $\text{lev}^*(i, r)$ and $\text{mat}^*(i, r)$ are the solutions to Eq. (1), then the signs of the reduced-form coefficients, π_{11} , π_{12} , π_{21} , and π_{22} , are related to the comparative statics results on lev^* and mat^* with respect to i and r . If lev^* and mat^* are monotonic in i and r , then there is a clear prediction on the sign of the reduced-form coefficients. However, if these functions are not monotonic, then the prediction is ambiguous. Thus, we are interested in conditions guaranteeing monotone comparative statics results.

The literature on strategic complementarities provides sufficient conditions for monotone comparative statics, and thus for unambiguous sign predictions for reduced-form regression coefficients. These conditions (defined in Milgrom and Shannon, 1994) are the *single-crossing property* and *quasi-supermodularity*. In what follows, we define quasi-supermodularity and the single-crossing property in the context of our problem and discuss whether the theory implies that these conditions are satisfied. As shown below, corporate finance theory suggests that the single-crossing property holds, but the quasi-supermodularity does not. We discuss the implications of these results below.

2.1. Single-crossing property

The value function satisfies the single-crossing property in $(\text{lev}, \text{mat}; i, r)$ if for all $(\text{lev}'', \text{mat}'') > (\text{lev}', \text{mat}')$ and $(i'', r'') > (i', r')$:

$$\begin{aligned} V(\text{lev}'', \text{mat}''; i', r') &> [\geq] V(\text{lev}', \text{mat}'; i', r') \text{ implies that} \\ V(\text{lev}'', \text{mat}''; i'', r'') &> [\geq] V(\text{lev}', \text{mat}'; i'', r''). \end{aligned} \quad (3)$$

Finance theory suggests that the single-crossing property holds. For example, if the firm's choice of debt maturity and its regulatory environment are fixed, then condition (3) is satisfied if whenever higher leverage increases value for a firm with investment opportunity set i , then higher leverage also increases value for a firm with a higher (more assets in place) investment opportunity set.⁴ As we argue below, this follows from a firm's incentive to mitigate underinvestment and free-cash-flow problems.

³ In Appendix A, we justify our use of linear reduced-form equations using a Taylor series expansion of the value function.

⁴ Condition (3) is satisfied if either the first inequality does not hold or both inequalities do hold.

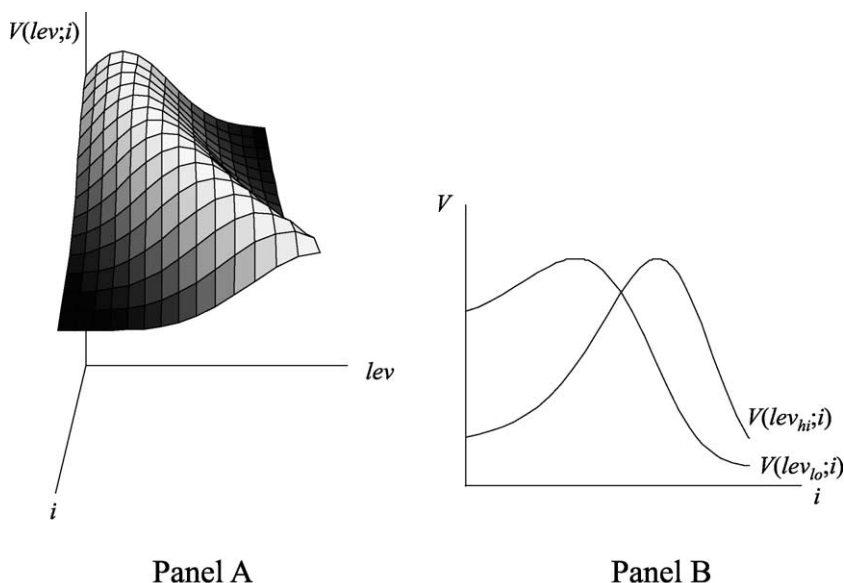


Fig. 1. Illustration of the single-crossing property. The figures depict a case in which the single-crossing property holds with respect to leverage and the investment opportunity set, holding debt maturity and the regulatory environment fixed.

The reason condition (3) is called the single-crossing property is easy to see if we fix debt maturity and the regulatory environment and focus on the effects of leverage and the investment opportunity set on value. The condition says that for any two levels of leverage, $\text{lev}_{hi} > \text{lev}_{lo}$, as i increases, $V(\text{lev}_{hi}; i)$ crosses $V(\text{lev}_{lo}; i)$ at most once and only from below. For example, the relation between leverage and the investment opportunity set in the value function might be as depicted in panel A of Fig. 1. The projection of the value function onto the (i, V) axes, shown in panel B of Fig. 1, illustrates that in this case, the curve associated with higher leverage crosses the curve associated with lower leverage only once and from below. Given these circumstances, value-maximizing leverage is increasing in the investment opportunity set. The single-crossing property would also be satisfied if high leverage or low leverage was preferred for all investment opportunity sets.⁵ The case excluded by the single-crossing property is that in which an increase in the investment opportunity set results in a strict preference for a lower level of leverage, that is, the single-crossing property rules out cases in which $V(\text{lev}_{hi}; i) > V(\text{lev}_{lo}; i)$ for a growth-options firm but $V(\text{lev}_{hi}; i) < V(\text{lev}_{lo}; i)$ for an assets-in-place firm.

Existing theory implies that more growth options in the firm's investment opportunity set increase the conflict between stockholders and bondholders over their exercise. This

⁵ Fig. 1 can be used to illustrate the difference between the single-crossing property and a stronger property, increasing differences, which is also used in the literature on the mathematics of complementarities. Increasing differences requires that the difference $V(\text{lev}_{hi}; i) - V(\text{lev}_{lo}; i)$, which can be seen in Fig. 1B, be increasing in i . In the figure shown, this difference is first negative, then positive and increasing, but then positive and decreasing—therefore, increasing differences is not satisfied.

Table 1

Variation in leverage as a function of the investment opportunity set

	Investment opportunity set	
	Growth opportunities	Assets in place
Cost of debt (underinvestment)	high	low
Benefit of debt (free cash flow)	low	high
Optimal leverage	low	high

conflict between stockholders and bondholders over the firm's investment decisions is labeled the underinvestment problem (Myers, 1977). A corporation can control this conflict by lowering leverage. For firms whose value largely reflects assets in place—few growth options as a fraction of firm value—this problem is less severe because such firms face few discretionary investment decisions.

Moreover, debt can benefit an assets-in-place firm by controlling the free-cash-flow problem (see Jensen, 1986). Such firms generate funds that cannot be reinvested profitably within the firm. To maximize firm value, it must distribute this free cash flow to investors. Putting fixed claims in its capital structure contractually obligates the firm to distribute these excess funds. Thus, in industries that generate substantial cash flow but have few growth opportunities (such as steel or tobacco), leverage has the beneficial effect of dissuading managers from overinvesting. This benefit is small for firms whose value primarily reflects growth options; such firms face profitable investment opportunities in excess of their internally generated operating cash flows. Thus, all else equal, we expect higher leverage to result in lower firm value for firms with more growth opportunities and higher firm value for firms with more assets in place (see Table 1).

Myers (1977) argues that another way to control the underinvestment problem is to shorten the maturity of the firm's debt; if the debt matures before the firm has the opportunity to exercise its real investment options, the firm's potential disincentive to invest is eliminated. Hence, firms whose investment opportunity sets contain more growth options should employ a higher proportion of short-term debt (see also Barnea et al., 1980). For such firms, short maturities preserve financing flexibility as well as its future ability to invest. Moreover, Stulz (1990) and Hart and Moore (1998) argue that firms with few growth options should issue more long-term debt because long-term debt is more effective at limiting managerial discretion (see Table 2).

Thus, all else equal, we expect a low proportion of long-term debt to maximize value for firms with more growth opportunities, and we expect a high proportion of long-term

Table 2

Variation in debt maturity as a function of the investment opportunity set

	Investment opportunity set	
	Growth opportunities	Assets in place
Cost of long-term debt (underinvestment)	high	low
Benefit of long-term debt (limiting managerial discretion)	low	high
Optimal debt maturity	short	long

debt to maximize value for firms with more assets in place. The theory thus suggests that the single-crossing property holds for a fixed regulatory environment. The positive relation between debt maturity and investment opportunity set predicted by the theory is examined in [Barclay and Smith \(1995\)](#). They find a positive relation between debt maturity and investment opportunities, concluding that firms with more growth options use larger proportions of short-term debt in their capital structures.

Allowing the regulatory environment to vary, condition (3) requires that if higher leverage and longer debt maturity increase value in an unregulated environment, then they also increase value in a regulated environment. [Smith \(1986\)](#) argues that regulatory oversight limits managers' discretion over corporate investment decisions and thus controls aspects of the underinvestment problem. Therefore, optimal leverage is expected to be higher and optimal debt maturity is expected to be longer for regulated firms. This argument, together with our previous arguments, implies that the single-crossing property holds.

2.2. Quasi-supermodularity

With both leverage and maturity as choice variables, the single-crossing property is not sufficient to generate monotone comparative statics results because of the potential interactions between the policy variables. When there are two choice variables, monotonicity requires the additional condition of quasi-supermodularity to restrict the interaction between the variables. Together, the single-crossing property and quasi-supermodularity are sufficient to insure that the optimal values of the choice variables are nondecreasing in the investment opportunity set and regulatory environment. If the value function is quasi-supermodular, then changes in the two choice variables are mutually reinforcing.

Requiring that the value be quasi-supermodular is equivalent to requiring that the value function satisfy the single-crossing property in leverage given debt maturity and in debt maturity given leverage, holding the investment opportunity set and regulatory environment constant.⁶ Therefore, a value is quasi-supermodular if for any $\text{lev}_{\text{hi}} > \text{lev}_{\text{lo}}$ and $\text{mat}_{\text{lg}} > \text{mat}_{\text{sh}}$:

$$\begin{aligned} V(\text{lev}_{\text{hi}}, \text{mat}_{\text{sh}}; i, r) &> [\geq] V(\text{lev}_{\text{lo}}, \text{mat}_{\text{sh}}; i, r) \text{ implies that} \\ V(\text{lev}_{\text{hi}}, \text{mat}_{\text{lg}}; i, r) &> [\geq] V(\text{lev}_{\text{lo}}, \text{mat}_{\text{lg}}; i, r), \end{aligned} \quad (4)$$

and

$$\begin{aligned} V(\text{lev}_{\text{lo}}, \text{mat}_{\text{lg}}; i, r) &> [\geq] V(\text{lev}_{\text{lo}}, \text{mat}_{\text{sh}}; i, r) \text{ implies that} \\ V(\text{lev}_{\text{hi}}, \text{mat}_{\text{lg}}; i, r) &> [\geq] V(\text{lev}_{\text{hi}}, \text{mat}_{\text{sh}}; i, r). \end{aligned} \quad (5)$$

Consider the relation between leverage and maturity in a firm's value function. One might expect a relation similar to that depicted in [panel A of Fig. 2](#). In this case, leverage and debt maturity act as substitutes. If an increase in leverage increases (decreases) value, then an increase in debt maturity also increases (decreases) value. Away from the optimum, value can be increased by adjusting either the leverage or debt maturity in

⁶ This equivalence requires that each of the two choice variables be drawn from a completely ordered set such as a subset of the real numbers or a completely ordered finite set.

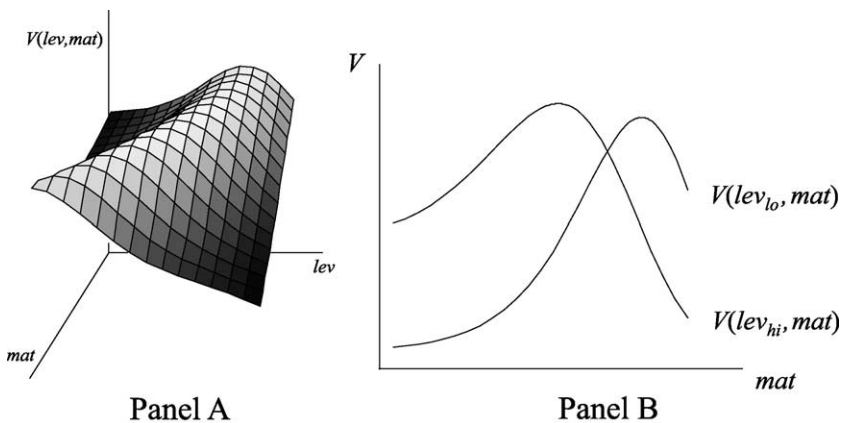


Fig. 2. Illustration of failure of quasi-supermodularity. The figures depict a case in which quasi-supermodularity does not hold. The investment opportunity set and regulatory environment are held fixed.

the same direction. Referring to [panel B of Fig. 2](#), one can see that the curve for high leverage crosses the curve for low leverage from above, violating quasi-supermodularity. In particular, quasi-supermodularity is not satisfied if $V(\text{lev}_{\text{hi}}, \text{ma}) > V(\text{lev}_{\text{lo}}, \text{mat})$ for short debt maturity and $V(\text{lev}_{\text{hi}}, \text{mat}) < V(\text{lev}_{\text{lo}}, \text{mat})$ for long debt maturity.

To see why the quasi-supermodularity is unlikely to hold, consider a firm for which lev_{hi} maximizes firm value for a given mat , i , and r . For this firm, by definition, $V(\text{lev}_{\text{hi}}, \text{mat}; i, r) - V(\text{lev}_{\text{lo}}, \text{mat}; i, r) > 0$. As debt maturity increases for this firm, the underinvestment problem becomes more severe, and the cost of high leverage increases. Thus, $V(\text{lev}_{\text{hi}}, \text{mat}; i, r) - V(\text{lev}_{\text{lo}}, \text{mat}; i, r)$ declines, eventually becoming negative. Because leverage and debt maturity act as substitutes in controlling the underinvestment problem, the quasi-supermodularity condition does not hold, and thus leverage and debt maturity are not strategic complements.

If we consider other exogenous (type) variables, it becomes clearer why quasi-supermodularity can be rejected. For example, suppose the firm's leverage choice is affected by its expected marginal tax rate. If the firm's tax circumstances change in a way that causes an increase in optimal leverage, the underinvestment problems become more severe. To control these problems, the firm might optimally shorten debt maturity. Conditional on an exogenous change in tax circumstances, leverage and debt maturity behave as substitutes rather than complements, and thus the quasi-supermodularity condition is not satisfied.

3. Empirical results

Because our analysis of the firm's financing problem does not imply monotone comparative statics, the theory does not yield testable implications on the signs of the reduced-form coefficients without additional assumptions about the magnitude of the direct and indirect effects. However, even if the reduced-form coefficients do not

yield unambiguous sign predictions, the theory can still be tested using the structural equations.

The structural equations are:

$$\text{mat} = a_0 + a_1 i + a_2 r + a_3 \text{lev}$$

$$\text{lev} = b_0 + b_1 i + b_2 r + b_3 \text{mat}. \quad (6)$$

If the assumptions of quasi-supermodularity and the single-crossing property were to hold, they would restrict the parameters in the reduced-form equations. The single-crossing property, together with the functional-form assumption and the second-order conditions, implies that a_1 and b_1 are positive (more assets in place result in higher leverage and longer debt maturity) and that a_2 and b_2 are also positive (regulation results in higher leverage and longer debt maturity). Quasi-supermodularity, together with the functional-form assumption and the second-order conditions, would imply that a_3 and b_3 are positive (higher leverage lengthens optimal debt maturity and longer debt maturity increases optimal leverage).⁷ However, as noted above, we argue that quasi-supermodularity is not satisfied for this problem. Moreover, even if these two conditions were satisfied, they would not be sufficient to identify this system for statistical estimation purposes. Consequently, to estimate the structural equations, we must impose more structure on the problem.⁸

Our empirical analysis uses data from COMPUSTAT for 5765 industrial firms from 1980 to 1999. Following Smith and Watts (1992) and Barclay et al. (1995), we use the market-to-book ratio as an index of the firm's investment opportunity set.⁹ Regulated firms include railroads before 1981, trucking before 1981, airlines before 1979, telecommunications before 1983, and gas and electric utilities. We measure debt maturity as the fraction of the firm's total debt that matures in more than 3 years, and we measure leverage as the book value of total debt (long-term debt plus debt in current liabilities) divided by the market value of the firm.

3.1. Control variables

In the empirical analysis presented in this section, we control for the firms' investment opportunity set and regulatory environment, as well as seven additional variables, which we view as exogenous or predetermined. These additional control variables are firm size, profitability, asset tangibility, asset maturity, the firms' simulated preinterest marginal tax rate, net-operating loss carryforwards (NOLs), and a dummy variable for firms with

⁷ These results are derived in Appendix A.

⁸ The assumptions of quasi-supermodularity and single-crossing property conditions are inequality constraints and so do not reduce the dimensionality of the set of feasible parameters, and thus do not provide any efficiency gain if they are used in the estimation procedures. For example, constrained-least-squares estimation using Lagrange multipliers does not permit more efficient estimators (see Rothenberg, 1973, p. 38).

⁹ The market-to-book ratio is equal to the market value of assets divided by the book value of assets. We estimate the market value of the firm's assets as the book value of assets minus the book value of equity plus the market value of equity.

commercial paper programs. The additional type variables (discussed more fully below) are included to control for other potentially important determinants of financial policy. Including this additional structure in the system also allows us to identify the structural parameters in Eq. (6) above.

Several previous studies have found firm size (which we measured as the natural log of real sales) to be an important determinant of both the leverage and debt maturity.¹⁰ Large firms tend to have more collateralizable assets and more stable cash flows. Thus, firm size typically is inversely related to the probability of default, which suggests that large firms would be expected to carry more debt. [Diamond \(1993\)](#) also argues that large established firms have better reputations in the debt markets, which also allows them to carry more debt.

[Barclay and Smith \(1995\)](#) document that debt maturity generally increases with firm size, although the relation appears to be nonmonotonic for the largest firms. The positive relation between debt maturity and firm size may be related to the large fixed costs of public debt issues. The fixed costs associated with public debt issues result in significant scale economies. Since smaller firms are not able to take advantage of these scale economies, they often opt for private and/or bank debt. Small firms that choose bank debt over public debt because of the lower flotation costs have more short-term debt. There also are significant scale economies associated with commercial paper programs. The large fixed costs of these programs exclude all but the largest firms from issuing commercial paper. Thus, very large firms with commercial paper programs are also likely to have more short-term debt. Rather than using a nonlinear function of firm size to control for this commercial paper effect, we include a dummy variable for firms with commercial paper programs. Although the use of commercial paper obviously is an endogenous choice, we treat it as predetermined for the estimation of our leverage and maturity regressions. The use of a commercial paper dummy variable is a simple and parsimonious way to control for this effect.¹¹

Previous studies also suggest that firms match the maturity of their assets with the maturity of their liabilities. Thus, firms with long-lived assets are expected to have more long-term debt. We measure the firm's asset maturity as the weighted average of current assets divided by the cost of goods sold, and net property, plant, and equipment divided by depreciation and amortization. These ratios are weighted by the relative size of current assets and net property, plant, and equipment.

[DeAngelo and Masulis \(1980\)](#) and [Graham \(1996a\)](#) argue that the firm's expected marginal tax rate is an important determinant of the firm's capital structure. Other things constant, firms with high-expected taxable income should face higher effective tax rates and have more debt in their capital structures. As a proxy for the firm's marginal tax rate, we use the preinterest estimated marginal tax rate described in [Graham \(1996b\)](#). We also include a dummy variable that is set equal to 1 for firms with net-operating loss carryforwards (NOLs). Firms with NOLs presumably have low or zero marginal tax

¹⁰ In a more complete model of financial policy, firm size would also be endogenous. However, lacking a well-developed theory explaining firm size, we put it on the right-hand side and treat it as predetermined.

¹¹ Note that our basic results are little affected by this specification choice. If we omit the commercial paper dummy variable or if we account for nonmonotonicity by adding a quadratic size variable, the size and significance of the other coefficients are not materially affected.

rates, and thus low tax benefits of debt. Although the NOL variable is motivated by tax considerations, most prior research finds a positive relation between the NOL dummy and firm leverage, which is opposite from the tax-based prediction. These studies generally reinterpret the NOL dummy as an indicator of financial distress.

Most tax and agency-cost models of capital structure predict that leverage will be increasing in profitability. Jensen (1986), for example, argues that high leverage is a valuable mechanism that commits profitable firms to distribute their free cash flow. Profitable firms generally also have high-expected marginal tax rates and high tax benefits of debt. Empirically, the opposite relation often has been found. For example, Titman and Wessels (1988) and Fama and French (2002) document a negative relation between leverage and profitability. Thus, without making a strong prediction on the sign of the relation, we include profitability, which we measure as operating income divided by book assets, as a control in our leverage regression.

Finally, several prior studies have documented that tangible assets provide better collateral for loans, and thus are associated with higher leverage. We measure asset tangibility as the ratio of property, plant, and equipment to total book assets.

Adding error terms, the system of equations to be estimated is:

$$\begin{aligned} \text{mat} = & a_0 + a_1i + a_2r + a_3\text{lev} + a_4\text{size} + a_5\text{asset maturity} \\ & + a_6\text{cp dummy} + \varepsilon_1 \end{aligned} \quad (7)$$

$$\begin{aligned} \text{lev} = & b_0 + b_1i + b_2r + b_3\text{mat} + b_4\text{size} + b_5\text{profitability} + b_6\text{tangibility} \\ & + b_7\text{tax rate} + b_8\text{NOL} + \varepsilon_2. \end{aligned}$$

3.2. Reduced-form regressions

The reduced-form equations in Eq. (2) have only predetermined variables on the right-hand side. Thus, these equations can be estimated consistently using OLS. If we cannot assume quasi-supermodularity, we cannot sign the reduced-form regression coefficients without imposing additional structure on the system. For instance, most previous studies of leverage and debt maturity have argued that π_{11} , π_{12} , π_{21} , and π_{22} are positive (that is, firms with more assets in place and regulated firms have higher leverage and more long-term debt). This argument is equivalent to assuming that the direct effects are larger than the indirect effects. With these additional assumptions, the theory can be rejected by applying OLS to Eq. (2).¹²

¹² Complementarity between leverage and debt maturity implies that conditional correlation coefficients are positive (see Arora, 1996). For example, in our data, the correlation between the residuals from reduced-form regressions of leverage and debt maturity on market-to-book, regulation, log of real sales, profitability, asset tangibility, estimated marginal tax rate, NOLs, asset maturity, and a commercial paper dummy is 0.13 ($p < 0.0001$). The positive conditional correlation may also be due to measurement error in the explanatory variables (such as the investment opportunity set) or omitted variables.

Table 3
Regression results

	Reduced-form OLS regressions		Two-stage least-squares regressions	
	Leverage	Maturity	Leverage	Maturity
Intercept	0.28 (35.22)	– 0.62 (– 40.16)	0.50 (29.46)	– 0.56 (– 25.12)
Market/book	– 0.07 (– 92.57)	– 0.01 (– 7.31)	– 0.07 (– 76.04)	– 0.04 (– 12.50)
Regulation	0.07 (21.14)	0.02 (2.14)	0.05 (11.64)	0.02 (2.44)
Firm size	0.06 (1.53)	0.06 (71.27)	– 0.02 (– 13.62)	0.06 (66.97)
Profitability	– 0.20 (– 29.76)		– 0.16 (– 18.91)	
Tangibility	0.15 (36.74)		0.02 (2.54)	
Simulated marginal tax rate	0.02 (2.02)		– 0.10 (– 8.02)	
NOL carryforwards	0.04 (22.81)		0.05 (20.93)	
Asset maturity		0.02 (44.25)		0.02 (36.51)
Commercial paper dummy		– 0.06 (– 9.68)		– 0.06 (– 9.67)
Leverage				– 0.13 (– 3.10)
Maturity			0.39 (15.21)	
R^2	0.28	0.22	0.23	0.21

The table shows two-stage least-squares and ordinary least-squares regressions of leverage and debt maturity on a proxy for the firm's investment opportunity set, regulatory environment, and other variables (*t*-statistics are in parentheses). Sample: 5765 industrial firms between 1980 and 1999 (37,025 firm-year observations).

The left side of Table 3 reports reduced-form OLS regressions.¹³ These regressions provide a test of the model, which predicts that the coefficients on the market-to-book ratio will be negative and the coefficient on the regulation dummy will be positive in both the leverage and debt-maturity regressions. Consistent with the prior literature, the coefficient on the market-to-book ratio is negative and significant in both regressions and the coefficient on the regulation dummy is positive and significant in both regressions.

Results for the control variables are generally consistent with previous studies. In the leverage regression, the firm-size and marginal tax-rate coefficients are positive but only the tax-rate coefficient is statistically significant. The coefficient on profitability is negative and statistically significant, and the coefficients on tangibility and NOLs are positive and statistically significant. In the maturity regression, all of the control variables

¹³ To make our reduced-form results comparable to the previous literature, we exclude exogenous variables that do not appear in the corresponding structural equations. If we include these variables in our OLS regressions, the coefficients on the variables that we report are largely unaffected.

are significant and have the expected sign. Firm size and asset maturity are associated with more long-term debt, and the commercial paper dummy is associated with less long-term debt.

3.3. Structural-equations regressions

Regardless of whether the theory imposes unambiguous sign predictions on the reduced-form regression coefficients, the theory can be tested by estimating the structural equations in Eq. (6). The single-crossing property, together with the functional-form assumptions and second-order conditions, implies that more assets in place result in higher leverage and more long-term debt (a_1 and b_1 are positive), and that regulation results in higher leverage and more long-term debt (a_2 and b_2 are positive).

With additional restrictions, the coefficients in Eq. (6) can be identified. In particular, in the expanded structural equations in Eq. (7), the coefficients are identified. Thus, adding error terms to Eq. (7), two-stage least squares is appropriate.¹⁴ The two-stage least-squares estimates are reported in Table 3.

As expected, the coefficients on the market-to-book ratio are negative in both the leverage and maturity regressions; thus, more growth options in the investment opportunity set cause the firm to reduce leverage and reduce its fraction of long-term debt. Also, as expected, the coefficients on the regulation dummy are positive in both regressions; regulated firms have more leverage and more long-term debt.

The additional variables used to identify the regressions appear with somewhat mixed success. The maturity regression appears to be well specified. The coefficients on firm size, asset maturity, and the commercial paper dummy are all significant and have the same sign as in the reduced-form regressions. The coefficient on leverage is negative and significant. This negative coefficient confirms our intuition that, even though the simple and conditional correlations between leverage and maturity are positive, leverage and maturity are substitutes in addressing the under- and over-investment problems.

The leverage regression appears less well behaved. In this regression, the coefficients on firm size and the expected marginal tax rate both flip from positive to negative. In addition, the coefficient on debt maturity is positive. From the second-order condition (see Appendix A), the coefficient on debt maturity in the leverage regression and the coefficient on leverage in the debt maturity regression should have the same sign. In our two-stage regressions, they do not.

There are several potential explanations for the puzzling result that the estimated coefficient on leverage in the debt-maturity regression and the coefficient on debt maturity in the leverage regression have different signs. One possibility is that our model is misspecified. For example, we focus on leverage and debt maturity and exclude other endogenous policy variables such as leasing, hedging, payout policy, and executive compensation. The omission of these correlated policy choices might bias our estimated coefficients. We also make strong assumptions about functional forms when

¹⁴ Two-stage least squares is appropriate since we assume a linear relation between the choice variables. For more information on nonlinear instrumental variables procedures, see Athey and Stern (1998).

we linearize the value function. Finally, there might be important exogenous determinants of leverage and maturity that are not captured within our model or included in our regressions.¹⁵

A second potential explanation is that we do not have good empirical proxies for variables in the model, or that we have poor instruments to identify the structural-equation coefficients. For example, we attempt to identify the leverage regressions with three variables, the firm's simulated marginal tax rate, asset tangibility, and NOLs. If these variables fail to explain a significant fraction of the cross-sectional variation in optimal leverage, then our instrument for leverage in the maturity regression is poor.

4. Conclusions

Our analysis suggests three important areas for additional work. First, our difficulties in effectively identifying the leverage equation suggest the development of richer theory to specify additional independent variables that are important in explaining leverage, but not maturity. Second, our exogenous variables are at least partially endogenous. A model that more effectively separates exogenous from endogenous components would increase the power of our methods. Third, to keep our analysis focused, we restrict attention to leverage and debt maturity, but the analysis can be extended to include additional financial-policy choice variables such as covenant restrictions, priority, convertibility, callability, and whether the debt is placed publicly or privately, as well as other policy choices such as dividend or compensation policy. However, such extensions are likely to intensify the statistical identification problems that we encountered. For instance, in focusing just on leverage and maturity, we use taxes to identify the leverage equation because theory suggests taxes should have a material effect on leverage, but not on maturity decisions. However, we expect that taxes, as well as the other determinants of leverage, do affect priority decisions (such as the use of leasing or preferred stock). Thus, we believe that as the set of endogenous policy choices expands, it becomes increasingly difficult to find identifying independent variables for the structural equations.

Finally, results on strategic complementarities have been discussed widely over the past decade. Many papers on the topic note that various facets of an economic system are correlated across economic units. However, these papers often do not offer formal tests of whether the requirements for complementarities are in fact met. Our paper highlights how perilous such a procedure potentially is. Although leverage and maturity are strongly correlated in terms of both unconditional and conditional correlations, our analysis provides reasonably compelling evidence that they are not complements. Incentive contracting theory suggests that they are substitutes, and estimation of the underlying structural equations at best provides mixed support for complementarity. We believe that

¹⁵ We estimated a wide variety of model specifications to examine the robustness of our empirical results. These specifications included different definitions of leverage, different definitions of debt maturity, different levels for the truncation of the outliers, different proxies for the investment opportunity set, different time periods, and different identifying right-hand side variables. Our basic qualitative results were generally robust to these various model specifications.

our results argue for more cautious application of the theoretical requirements for strategic complementarities as well as more careful empirical testing of these formal requirements.

Acknowledgements

We thank Susan Athey, Jeff Campbell, Bruno Gerard, Stacey Kole, Glenn MacDonald, Annette Poulsen (the editor), René Stulz, two anonymous referees, and seminar participants at Northwestern University, the University of Rochester, and the Summer Meetings of the Econometric Society for valuable comments and discussions.

Appendix A

Take a Taylor series approximation to the value function so that it can be written as the weighted sum of lev , lev^2 , mat , mat^2 , $\text{lev} \cdot \text{mat}$, $\text{lev} \cdot i$, $\text{mat} \cdot i$, $\text{lev} \cdot r$, $\text{mat} \cdot r$, and other terms that do not involve lev or mat :

$$V = c_1 \text{lev} + c_2 \text{lev}^2 + c_3 \text{mat} + c_4 \text{mat}^2 + c_5 \text{lev} \cdot \text{mat} + c_6 \text{lev} \cdot i + c_7 \text{mat} \cdot i + c_8 \text{lev} \cdot r + c_9 \text{mat} \cdot r + \dots \quad (8)$$

The first-order conditions for maturity and leverage are:¹⁶

$$\begin{aligned} c_3 + 2c_4 \text{mat} + c_5 \text{lev} + c_7 i + c_9 r &= 0 \\ c_1 + 2c_2 \text{lev} + c_5 \text{mat} + c_6 i + c_8 r &= 0. \end{aligned} \quad (9)$$

We make the usual assumption that the second-order conditions for Eq. (1) hold strictly, i.e. $c_2, c_4 < 0$ and $4c_2 c_4 - c_5^2 > 0$. We can rewrite Eq. (9) as:

$$\begin{aligned} \text{mat} &= a_0 + a_1 i + a_2 r + a_3 \text{lev} \\ \text{lev} &= b_0 + b_1 i + b_2 r + b_3 \text{mat}, \end{aligned} \quad (10)$$

where $a_0 = \frac{-c_3}{2c_4}$, $a_1 = \frac{-c_7}{2c_4}$, $a_2 = \frac{-c_9}{2c_4}$, $a_3 = \frac{-c_5}{2c_4}$, $b_0 = \frac{-c_1}{2c_2}$, $b_1 = \frac{-c_6}{2c_2}$, $b_2 = \frac{-c_8}{2c_2}$, and $b_3 = \frac{-c_5}{2c_2}$. These first-order conditions suggest a regression of leverage on a constant, debt maturity, investment opportunity set, and regulation, and a regression of debt maturity on a constant, leverage, investment opportunity set, and regulation. Unfortunately, the equations in Eq. (10) cannot be estimated consistently with OLS since the equations contain endogenous right-hand-side variables. In addition, the parameters $a_0, a_1, a_2, a_3, b_0, b_1, b_2$, and b_3 in Eq. (10) are not identified, and consequently, they cannot be

¹⁶ This approach faces problems if we view regulation as a discrete variable. If the regulatory environment is considered discrete rather than continuous, then the value function is not differentiable in regulation.

estimated with simultaneous equation techniques without imposing additional restrictions on the problem. For example, given sufficient data (and the theory to back up its use as instruments), an instrumental variables approach can be used to consistently estimate the coefficients in these regressions.

Alternatively, one can consider reduced-form regressions of leverage and debt maturity on a constant, investment opportunity set, and regulation. The following reduced-form equations can be derived from Eq. (10):

$$\begin{aligned} \text{mat} &= \pi_{10} + \pi_{11}i + \pi_{12}r \\ \text{lev} &= \pi_{20} + \pi_{21}i + \pi_{22}r, \end{aligned} \quad (11)$$

where

$$\pi_{10} = \frac{-2c_2c_3 + c_1c_5}{4c_2c_4 - (c_5)^2} = \frac{a_0 + a_3b_0}{1 - a_3b_3}, \quad \pi_{11} = \frac{-2c_2c_7 + c_5c_6}{4c_2c_4 - (c_5)^2} = \frac{a_1 + a_3b_1}{1 - a_3b_3},$$

$$\pi_{12} = \frac{-2c_2c_9 + c_5c_8}{4c_2c_4 - (c_5)^2} = \frac{a_2 + a_3b_2}{1 - a_3b_3}, \quad \pi_{20} = \frac{-2c_1c_4 + c_3c_5}{4c_2c_4 - (c_5)^2} = \frac{b_0 + a_0b_3}{1 - a_3b_3}, \quad \pi_{21} = \frac{-2c_4c_6 + c_5c_7}{4c_2c_4 - (c_5)^2} =$$

$$\frac{b_1 + a_1b_3}{1 - a_3b_3}, \quad \text{and} \quad \pi_{22} = \frac{-2c_4c_8 + c_5c_9}{4c_2c_4 - (c_5)^2} = \frac{b_2 + a_2b_3}{1 - a_3b_3}.$$

Given the second-order condition, $c_5 \neq 2\sqrt{c_2c_4}$, so the reduced-form coefficients are well defined. Then:

$$[\pi_{10} \ \pi_{11} \ \pi_{12} \ \pi_{20} \ \pi_{21} \ \pi_{22}]' = h(a_0, a_1, a_2, a_3, b_0, b_1, b_2, b_3), \quad (12)$$

where the matrix H of partial derivatives of h is:

$$H = \begin{bmatrix} \frac{1}{1-a_3b_3} & 0 & 0 & \frac{b_0+a_0b_3}{(1-a_3b_3)^2} & \frac{a_3}{1-a_3b_3} & 0 & 0 & \frac{a_3(a_0+a_3b_0)}{(1-a_3b_3)^2} \\ 0 & \frac{1}{1-a_3b_3} & 0 & \frac{b_1+a_1b_3}{(1-a_3b_3)^2} & 0 & \frac{a_3}{1-a_3b_3} & 0 & \frac{a_3(a_1+a_3b_1)}{(1-a_3b_3)^2} \\ 0 & 0 & \frac{1}{1-a_3b_3} & \frac{b_2+a_2b_3}{(1-a_3b_3)^2} & 0 & 0 & \frac{a_3}{1-a_3b_3} & \frac{a_3(a_2+a_3b_2)}{(1-a_3b_3)^2} \\ \frac{b_3}{1-a_3b_3} & 0 & 0 & \frac{b_3(b_0+a_0b_3)}{(1-a_3b_3)^2} & \frac{1}{1-a_3b_3} & 0 & 0 & \frac{a_0+a_3b_0}{(1-a_3b_3)^2} \\ 0 & \frac{b_3}{1-a_3b_3} & 0 & \frac{b_3(b_1+a_1b_3)}{(1-a_3b_3)^2} & 0 & \frac{1}{1-a_3b_3} & 0 & \frac{a_1+a_3b_1}{(1-a_3b_3)^2} \\ 0 & 0 & \frac{b_3}{1-a_3b_3} & \frac{b_3(b_2+a_2b_3)}{(1-a_3b_3)^2} & 0 & 0 & \frac{1}{1-a_3b_3} & \frac{a_2+a_3b_2}{(1-a_3b_3)^2} \end{bmatrix}.$$

The rank of the matrix H is less than six, so π_{10} , π_{11} , π_{12} , π_{20} , π_{21} , and π_{22} are unrestricted (see [Rothenberg, 1973, p. 37](#)).¹⁷ The reduced-form equations in Eq. (11) have only predetermined variables on the right-hand-side. Thus, these equations can be estimated consistently using OLS.

The reduced-form coefficients are composites of the underlying parameters in the value function. Even though the second-order condition allows us to sign the denominator, we

¹⁷ The fourth column is a linear combination of the first, second, and third columns and the eighth column is a linear combination of the fifth, sixth, and seventh columns.

require a theory that allows us to sign the numerators in order to have testable predictions about the signs of the reduced-form coefficients.

The second-order condition implies that $c_2, c_4 < 0$ and that $4c_2c_4 - (c_5)^2 > 0$. The single crossing property implies that c_6, c_7, c_8 , and $c_9 > 0$. Quasi-supermodularity implies that $c_5 > 0$. The strict second-order condition for Eq. (1) requires that the matrix of second partial derivatives of V with respect to mat and lev be negative definite, which implies that $c_2 < 0, c_4 < 0$, and that $4c_2c_4 - (c_5)^2 > 0$.

Using the definition of V given in Eq. (8), the quasi-supermodularity conditions, Eqs. (4) and (5), imply that for all $\text{lev}'' > \text{lev}'$ and $\text{mat}'' > \text{mat}'$ and all i :

$$\begin{aligned} c_1 + c_2(\text{lev}'' + \text{lev}') + c_5\text{mat}' + c_6i + c_8r &> [\geq] 0 \text{ implies} \\ c_1 + c_2(\text{lev}'' + \text{lev}') + c_5\text{mat}'' + c_6i + c_8r &> [\geq] 0, \end{aligned} \quad (13)$$

and

$$\begin{aligned} c_3 + c_4(\text{mat}'' + \text{mat}') + c_5\text{lev}' + c_7i + c_9r &> [\geq] 0 \text{ implies} \\ c_3 + c_4(\text{mat}'' + \text{mat}') + c_5\text{lev}'' + c_7i + c_9r &> [\geq] 0. \end{aligned} \quad (14)$$

We focus on the interesting case in which there exists $\text{lev}'' > \text{lev}'$ and $\text{mat}'' > \text{mat}'$ such that for firms with investment opportunity set and regulation (i'', r'') sufficiently large, $V(\text{lev}'', \text{mat}'; i'', r'') > V(\text{lev}', \text{mat}'; i'', r'')$, and for firms with investment opportunity set and regulation $(i', r') < (i'', r'')$ and sufficiently small, $V(\text{lev}'', \text{mat}'; i', r') < V(\text{lev}', \text{mat}'; i', r')$. This implies that there exists $(\hat{i}, \hat{r})$ such that $V(\text{lev}'', \text{mat}'; \hat{i}, \hat{r}) = V(\text{lev}', \text{mat}'; \hat{i}, \hat{r})$. Then c_5 must be strictly positive, since otherwise:

$$c_1 + c_2(\text{lev}'' + \text{lev}') + c_5\text{mat}'' + c_6i + c_8r < 0, \quad (15)$$

in violation of Eq. (13). As similar argument, using Eq. (14) can also be used to show that $c_5 > 0$.¹⁸

Additional restrictions are imposed on the coefficients in Eq. (8) by the single-crossing property, Eq. (3). This property holds if for all mat , $\text{lev}'' > \text{lev}'$, and $(i'', r'') > (i', r')$:

$$\begin{aligned} c_1 + c_2(\text{lev}' + \text{lev}'') + c_5\text{mat} + c_6i' + c_8r' &> [\geq] 0 \text{ implies} \\ c_1 + c_2(\text{lev}' + \text{lev}'') + c_5\text{mat} + c_6i'' + c_8r'' &> [\geq] 0, \end{aligned} \quad (16)$$

and if for all lev , $\text{mat}'' > \text{mat}'$, and $(i'', r'') > (i', r')$:

$$\begin{aligned} c_3 + c_4(\text{mat}' + \text{mat}'') + c_5\text{lev} + c_7i' + c_9r' &> [\geq] 0 \text{ implies} \\ c_3 + c_4(\text{mat}' + \text{mat}'') + c_5\text{lev} + c_7i'' + c_9r'' &> [\geq] 0. \end{aligned} \quad (17)$$

¹⁸ If for all $\text{lev}', \text{lev}'', \text{mat}', \text{mat}'', i$, and r the precedent in both Eqs. (13) and (14) fails to hold, then it is always optimal for firms to choose the lowest feasible leverage and debt maturity. In this case, leverage and debt maturity are trivially nondecreasing in the investment opportunity set. We restrict attention to the interesting case in which it is optimal for some firms to choose leverage and debt maturity above the minimum feasible level.

The single-crossing property also requires that (abbreviating the variable names):

$$\begin{aligned} c_1(l'' - l') + c_2((l'')^2 - (l')^2) + c_3(m'' - m') + c_4((m'')^2 - (m')^2) \\ + c_5(l''m'' - l'm') + c_6l'(l'' - l') + c_7l'(m'' - m') + c_8r'(l'' - l') \\ + c_9r'(m'' - m') > [\geq] 0 \end{aligned}$$

implies

$$\begin{aligned} c_1(l'' - l') + c_2((l'')^2 - (l')^2) + c_3(m'' - m') + c_4((m'')^2 - (m')^2) \\ + c_5(l''m'' - l'm') + c_6l'(l'' - l') + c_7l''(m'' - m') + c_8r''(l'' - l') \\ + c_9r''(m'' - m') > [\geq] 0. \end{aligned}$$

As shown above, we assume there exists $\text{lev}'' > \text{lev}'$ and $\text{mat}'' > \text{mat}'$ and $(\hat{i}, \hat{r})$ such that $V(\text{lev}'', \text{mat}'; \hat{i}, \hat{r}) = V(\text{lev}', \text{mat}'; \hat{i}, \hat{r})$, which implies that the precedent in Eq. (16) holds. Then c_6 must be strictly positive, since otherwise, for $i > \hat{i}$:

$$c_1 + c_2(\text{lev}' + \text{lev}'') + c_5\text{mat} + c_6\hat{i} + c_8\hat{r} < 0, \quad (18)$$

in violation of Eq. (16). Coefficient c_8 must also be strictly positive, since otherwise, for $r > \hat{r}$:

$$c_1 + c_2(\text{lev}' + \text{lev}'') + c_5\text{mat} + c_6\hat{i} + c_8r < 0, \quad (19)$$

again in violation of Eq. (16). Similar arguments using Eq. (17) imply that c_7 and c_9 also have to be strictly positive. Thus, c_6, c_7, c_8 , and $c_9 > 0$.

We have shown that $c_2, c_4 < 0$, c_5, c_6, c_7, c_8 , and $c_9 > 0$, and $4c_2c_4 - (c_5)^2 > 0$. Thus, $\pi_{11} = \frac{-2c_2c_7 + c_5c_6}{4c_2c_4 - (c_5)^2} > 0$, $\pi_{12} = \frac{-2c_2c_9 + c_5c_8}{4c_2c_4 - (c_5)^2} > 0$, $\pi_{21} = \frac{-2c_4c_6 + c_5c_7}{4c_2c_4 - (c_5)^2} > 0$, and $\pi_{22} = \frac{-2c_4c_8 + c_5c_9}{4c_2c_4 - (c_5)^2} > 0$. In addition, $a_1 = \frac{-c_7}{2c_4} > 0$, $a_2 = \frac{-c_9}{2c_4} > 0$, $a_3 = \frac{-c_5}{2c_4} > 0$, $b_1 = \frac{-c_6}{2c_2} > 0$, $b_2 = \frac{-c_8}{2c_2} > 0$, and $b_3 = \frac{-c_5}{2c_2} > 0$.

References

- Arora, A., 1996. Testing for complementarities in reduced-form regressions: a note. *Economic Letters* 50, 51–55.
- Athey, S., Stern, S., 1998. An Empirical Framework for Testing Theories About Complementarity in Organizational Design. Working paper, MIT.
- Barclay, M.J., Smith Jr., C.W., 1995. The maturity structure of corporate debt. *Journal of Finance* 50, 609–631.
- Barclay, M.J., Smith Jr., C.W., Watts, R.L., 1995. The determinants of corporate leverage and dividend policies. *Journal of Applied Corporate Finance* 7, 4–19.
- Barnea, A., Haugen, R., Senbet, L., 1980. A rationale for debt maturity structure and call provisions in an agency theoretic framework. *Journal of Finance* 35, 1223–1234.
- Berger, P.G., Ofek, E., Yermack, D.L., 1997. Managerial entrenchment and capital structure decisions. *The Journal of Finance* 52, 1411–1438.
- DeAngelo, H., Masulis, R.W., 1980. Optimal capital structure under corporate and personal taxation. *Journal of Financial Economics* 8, 3–29.

- Diamond, D.W., 1993. Seniority and maturity of debt contracts. *Journal of Financial Economics* 33, 341–368.
- Fama, E., French, K., 2002. Testing trade-off and pecking order predictions about dividends and debt. *Review of Financial Studies* 15, 1–33.
- Geczy, C., Minton, B.A., Schrand, C., 1997. Why firms use currency derivatives. *The Journal of Finance* 52, 1323–1354.
- Graham, J., 1996a. Debt and the marginal tax rate. *Journal of Financial Economics* 41, 41–73.
- Graham, J., 1996b. Proxies for the corporate marginal tax rate. *Journal of Financial Economics* 42, 187–221.
- Hart, O., Moore, J., 1998. Default and renegotiation: a dynamic model of debt. *Quarterly Journal of Economics* 113, 1–41.
- Houston, J., James, C., 1996. Bank information monopolies and the mix of private and public debt claims. *The Journal of Finance* 51, 1863–1889.
- Jensen, M.C., 1986. Agency costs of free cash flow, corporate finance, and takeovers. *American Economic Review* 76, 323–329.
- Milgrom, P., Shannon, C., 1994. Monotone comparative statics. *Econometrica* 62, 157–180.
- Myers, S., 1977. Determinants of corporate borrowing. *Journal of Financial Economics* 5, 147–175.
- Rothenberg, T.J., 1973. *Efficient Estimation with A Priori Information*. Yale Univ. Press, New Haven, CT.
- Schwert, G.W., 1981. Using financial data to measure effects of regulation. *Journal of Law and Economics* 24, 121–158.
- Smith Jr., C.W., 1986. Investment banking and the capital acquisition process. *Journal of Financial Economics* 15, 3–29.
- Smith Jr., C.W., Watts, R.L., 1992. The investment opportunity set and corporate financing, dividend, and compensation policies. *Journal of Financial Economics* 32, 263–292.
- Stohs, M.H., Mauer, D.C., 1996. The determinants of corporate debt maturity structure. *Journal of Business* 69, 279–312.
- Stulz, R., 1990. Managerial discretion and optimal financing policies. *Journal of Financial Economics* 26, 3–28.
- Titman, S., Wessels, R., 1988. The determinants of capital structure choice. *Journal of Finance* 43, 1–19.
- Tufano, P., 1996. Who manages risk? An empirical examination of risk management practices in the gold mining industry. *The Journal of Finance* 51, 1097–1137.