An Empirical (S, s) Model of Dynamic Capital Structure *

Arthur Korteweg
Graduate School of Business
Stanford University

Ilya A. Strebulaev
Graduate School of Business
Stanford University
and NBER

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Abstract

We develop and estimate a general (S, s) model of capital structure to investigate the relation between target leverage, refinancing thresholds, and firm characteristics in a dynamic environment. We find that firms' target leverage is pro-cyclical, consistent with dynamic capital structure models, but in contrast to traditional regression results. Companies optimally allow leverage to float within a target zone, which widens during recessions. Most of the time series variation in capital structure policy variables is due to aggregate macroeconomic factors, rather than changes in firm-specific variables. These time series dynamics pinpoint the need for richer dynamic models of the firm.

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Capital structure research has made great strides in expanding our understanding of firms' financial decisions. One important but unresolved recent debate revolves around the dynamics of leverage over the business cycle. Traditional estimates document that average leverage tends to move counter-cyclically (e.g., Korajczyk and Levy (2003), and Halling, Yu, and Zechner (2013)), whereas most dynamic models predict that target leverage should move pro-cyclically.[1] These models also have strong implications regarding the dynamics of refinancing decisions over the cycle, but these predictions have thus far largely gone untested.

Empirical work on the relation between capital structure and macroeconomic conditions has lagged theoretical work, in part because it is difficult to resolve this question with standard regression methodology.[2] While this body of work has provided invaluable insights into many static models of corporate financial structure, we show that in a dynamic setting the conditional mean of leverage (as estimated by regressions) represents a combination of various aspects of the dynamics of capital structure. This has important implications for the interpretation of the regression results, and in particular for the relation between leverage and the macroeconomic cycle.

In this paper, we propose an alternative empirical model that accounts explicitly for capital structure dynamics, and separates the properties of dynamic capital structure that combine to determine mean leverage ratios. We build and estimate a so-called (S, s) model that captures important features of the data-generating process:

[1]Bhamra, Kuehn, and Strebulaev (2010) and Chen (2010)) are two recent examples of models with pro-cyclical target leverage ratios. At the same time, Hackbarth, Miao, and Morellec (2006) predict that firms should follow counter-cyclical target leverage ratios, because bankruptcy costs are assumed constant across the cycle. Altman et al. (2005) document that bond recovery rates are considerably lower during recessions.

[2]Classic early studies are Taggart (1977), Marsh (1982), and Titman and Wessels (1988). For a comprehensive overview of classic empirical studies of capital structure, see Harris and Raviv (1991). Examples of important recent work include Hovakimian, Opler, and Titman (2001), Baker and Wurgler (2002), Fama and French (2002), Korajczyk and Levy (2003), Flannery and Rangan (2006), Kayhan and Titman (2007), Lemmon, Roberts, and Zender (2008), Byoun (2008), Huang and Ritter (2009), Harford, Klasa, and Walcott (2009), Chang and Dasgupta (2009), Frank and Goyal (2009), and Denis and McKeon (2012).

leverage adjustments that are infrequent and lumpy.[3] The (S, s) model, developed originally by Arrow, Harris, and Marshak (1951) to describe the inventory dynamics, has been used in economics to study cash balances, corporate investment decisions, and consumer demand (e.g., Miller and Orr (1966), Caballero (1993), Eberly (1994), Attanasio (2000), Caplin and Leahy (2006, 2010)). The basic economic assumption in developing an (S, s) model for capital structure is shared with its other applications: we posit that firms have a (possibly time-varying) target leverage ratio (L^*_{it}) that they adopt when they refinance. However, due to frictions, they allow leverage ratios to deviate from this target, and only refinance back to the target when leverage hits an upper or lower threshold (L^u_{it} and L^d_{it}, respectively). In other words, firms optimally allow their leverage ratios to float within a target zone, which is the region between L^d_{it} and L^u_{it}, where both thresholds may be time-varying. The presence of such a target leverage policy arises from a trade-off between the benefits and costs of debt financing, which leads to an interior solution at the firm level. The trade-off is driven by a loss function that specifies the cost incurred if the firm deviates from its preferred target leverage ratio. This loss function can in principle be very generic. In capital structure, the losses would include (but are not limited to) lost tax shields,[4] costs of financial distress such as debt overhang and asset substitution, as well as other agency costs.

The (S, s) model complements and enriches the existing empirical methods in several ways. First, it enables us to compare the estimates of leverage determinants obtained by linear regressions and the target leverage from the (S, s) model. To examine these estimates, we apply the (S, s) model to quarterly Compustat data on non-financial firms for the 1988 to 2011 period. We find that in many instances, the estimates of target leverage coefficients have the same sign as the ordinary least squares (OLS) coefficients but are of very different magnitude. In many important cases, though, the qualitative implications are different. Most importantly, while the OLS approach reproduces the counter-cyclical leverage ratios documented in Kora-

[3]Stokey (2009) discusses a plethora of economic environments, in which costly adjustments lead to infrequent changes, and provides a broad theoretical treatment of this approach.

[4]Heider and Ljungqvist (2013) provide evidence of the causal impact of taxes on leverage.

jczyk and Levy (2003), the (S, s) model instead estimates pro-cyclical target leverage ratios. This difference is explained by the fact that firm values drop during recessions, which raises average leverage ratios because many firms do not find it optimal to refinance, even though their target leverage ratios have dropped.

Second, the (S, s) approach enables us to study the determinants of refinancing triggers. This aspect of capital structure policy has received considerably less attention in the literature. We document that the thresholds vary predictably with macroeconomic conditions, as well as with firm characteristics such as the market-to-book ratio, asset tangibility, and research and development expenses.

Third, we find that firms choose a wide target zone (i.e., they allow leverage to float in a wide range around the target leverage ratio), suggesting that either adjustment costs are high or the loss of value from being away from the target is low, at least for moderate leverage ratios. Moreover, we show that the target zone is wider during recessions, when firms wait longer to refinance whether leverage is high or low. This evidence is consistent with Covas and Den Haan (2011), who document the pro-cyclicality of debt and equity issuance for all but the largest firms, and with DeAngelo and Roll (2013), who find that many firms have high and low leverage ratios at different times, indicating a flexible and wide target zone. Denis (2012) also points to the wide variation in leverage ratios as one of the salient characteristics of the data that a feasible empirical model should explain. We provide explicit estimates of the width of the target zone and the extent to which it varies over the cycle.

Overall, our results are consistent with the capital structure predictions of Hackbarth et al. (2006), Bhamra, Kuehn, and Strebulaev (2010), and Chen (2010), which have thus far largely gone untested. In further exploration of firms' capital structure policies over the macroeconomic cycle beyond the extant models, we document that much of the time series variation in capital structure policy variables is due to the aggregate macroeconomic variables, with less of the variation coming from changes in firm-specific variables such as profitability, earnings volatility, or market-to-book ratios. Also, although both the target leverage and the refinancing thresholds rise in the first two years after a recession, they remain relatively low, as firms typically have high growth opportunities during this period. The financial policy variables rise more significantly only in the later stages of the boom period. These results suggest that the dynamics of financial policy in the data are richer than the two-regime dynamic models in the literature.

From a methodological perspective, (S, s) models are consistent with the financial policy of the contingent claims capital structure paradigm that has been actively developed in recent years.[5] At the same time, an important advantage of the empirical (S, s) approach is that we do not need to specify the functional form of frictions or the stochastic process of the underlying model's state variables. The methodology does not rely on the exact economic mechanism, and various conjectures can be comfortably nested together. This benefit comes at a cost, though, because our results are more difficult to interpret in terms of underlying frictions. It is thus important to stress that this methodology complements rather than substitutes for the model-based structural estimation that has been gaining attention recently (e.g., Hennessy and Whited (2005, 2007), Nikolov and Whited (2011)). A structural estimation should produce a better estimate if the assumptions on how firms behave according to a particular dynamic model, prove correct.

Ours is not the first research to enrich traditional empirical methods in capital structure. Strebulaev (2007) shows that popular regressions of profitability on leverage cannot be interpreted as finding the true relation between profitability and target leverage. Morellec et al. (2012) also note that the conditional mean of leverage does not correspond to the target leverage in a contingent claims model of the firm. They use a simulated maximum likelihood approach to estimate their model. This method exploits the entire conditional distribution of leverage but, as a result, is more structural in nature. Our paper also builds on the work by Leary and Roberts (2005), who study the propensity of firms to actively change capital structure as a function of firm characteristics. Finally, Korteweg (2010) present empirical results regarding

[5]Some examples include Fischer, Heinkel, and Zechner (1989), Goldstein, Ju, and Leland (2001), Strebulaev (2007), Bhamra, Kuehn, and Strebulaev (2010a;2010b), and Morellec et al. (2012). See Strebulaev and Whited (2012) for a survey of recent literature.

the present value of adjustment costs, as well as the costs of leverage being away from the minimum of the loss function in dynamic models.

Our results also have implications for the interpretation of estimates from other popular research methods. For example, the ubiquitous differences-in-differences estimator captures the causal response of the average leverage ratio to plausible exogenous shocks, and should be interpreted as such. If the object of interest is the response of target capital structure, however, caution is warranted. The change in the average leverage ratio does not necessarily correspond, and may even be in the opposite direction, to the change in target capital structure. This can happen if the shock is not large enough to drive a substantial fraction of treated firms to refinance. For example, if the experiment shocks firm profitability upwards, average leverage absent a refinancing declines, whereas target leverage rises. Moreover, even when there is a large enough shock for all firms to refinance, the change in the average leverage ratio may be opposite to the change in the target. For example, suppose the experiment causes target leverage to decline, but the treated firms' average leverage prior to the shock was near the lower refinancing threshold. If the shock pushes firms below the threshold, they will lever up to the target capital structure, and the average leverage ratio will therefore rise. Thus, even observing large, active refinancings by firms spurred by a natural experiment does not imply that one has captured a change in target leverage. Similarly, caution is warranted in interpreting the results from an Instrumental Variables (IV) estimation as the change in target capital structure in response to a causal shock, for the same reasons generic regressions do not capture target leverage.

We also suggests a useful set of economically meaningful moments to match in a GMM/SMM estimation of a structural model that closely corresponds to capital structure dynamics in an (S, s) setting: the average leverage ratios immediately before and immediately after refinancing. These moments are informative for separately identifying financial policy from the model's underlying stochastic process.

In developing an (S, s) model for capital structure, we generalize the standard (S, s) model along a number of dimensions to take into account many additional salient features of the leverage data-generating process that are absent in other (S, s) applications. For example, we allow the refinancing thresholds to vary over time, with error components in the upper and lower thresholds that are not necessarily perfectly correlated. Also, many leverage measures are naturally bounded (e.g., the market leverage ratio is less than or equal to 1). We account for all of these features in our (S, s) model. Still, as this is the first paper to introduce the (S, s) model to the capital structure literature, we have chosen a relatively simple model specification that does not capture a number of realistic features. For example, we do not explicitly control for periods when adjustment costs are differentially low, such as when firms need to access capital markets to fund an investment project (Elsas, Flannery, and Garfinkel (2013)), or when free cash flows are large in absolute value (Faulkender et al. (2012)). In important recent work, DeAngelo, Deangelo, and Whited (2011) show that firms can deliberately deviate from target leverage due to investment spikes. While our framework can accommodate these extensions (e.g., by using better empirical proxies for investment spikes and debt maturities, and by introducing another equation to capture deviations from target), as well as to explore other forms of the adjustment cost function such as convex costs, one of our goals is to demonstrate the framework's capabilities with a simple model. It would be important to incorporate these extensions in future work.

Although we only present an application to capital structure in this paper, our method can be applied to a much broader range of topics. In particular, (S, s) models may be useful in settings where the dynamic behavior of agents (firms, consumers, investors, governments) leads to an asymmetric cross-sectional distribution of the variables of interest. The variables of interest could include cash, payout, and corporate investment policies in the presence of adjustment costs, a government economic policy that intervenes only when a certain indicator (e.g., unemployment) rises above a threshold, or workforce adjustments in the presence of hiring and firing costs (e.g., Pfann and Palm, 1993).

The remainder of the paper is structured as follows. In section 1 we develop our empirical model. In Section 2, we describe the data sample, and in Section 3, we discuss our empirical results. We present concluding remarks in Section 4.

1 Empirical (S, s) Model of Capital Structure

We begin by describing a benchmark empirical (S, s) model and then discuss its economic intuition and relation to extant theory. In a general (S, s) model of capital structure, the firm optimally allows leverage to float within a target zone without intervention, until either an upper or lower threshold is reached, which we denote L^u and L^d, respectively. Upon reaching either threshold, the firm refinances to a target leverage ratio, L^*. An example of a time series of leverage observations under this policy is illustrated in Figure 1.

1.1 Base model

We estimate the benchmark capital structure (S, s) model, where for firm i at time t:

$$L^*_{it} = X'_{it}\beta + u^*_{it}, \tag{1}$$

$$L^u_{it} = L^*_{it} + \exp(X'_{it}\theta^u + u^u_{it}), \tag{2}$$

$$L^d_{it} = L^*_{it} - \exp(X'_{it}\theta^d + u^d_{it}). \tag{3}$$

Equation (1) models target leverage, L^*_{it}, and appears analogous to the traditional regression model, which is ubiquitous in extant literature. However, as we discuss next, the identification and interpretation of this equation are quite different in the (S, s) model. The exponential terms in (2) and (3) represent the gap between the upper refinancing threshold, L^u_{it}, and target leverage, and the gap between the lower threshold, L^d_{it}, and target leverage, respectively. The use of the exponential function guarantees that the target leverage is located between the two thresholds. The vector of explanatory variables, X_{it}, is assumed to be the same for the target leverage and the two thresholds.

The distribution of the error terms is assumed to be jointly Gaussian:

$$\begin{bmatrix} u_{it}^{*} \\ u_{it}^{u} \\ u_{it}^{d} \end{bmatrix} \sim \mathcal{N}\left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} (\sigma^{*})^{2} & \rho^{*u}\sigma^{*}\sigma^{u} & \rho^{*d}\sigma^{*}\sigma^{d} \\ \cdot & (\sigma^{u})^{2} & 0 \\ \cdot & \cdot & (\sigma^{d})^{2} \end{bmatrix} \right). \tag{4}$$

The errors are i.i.d. across firms and time and uncorrelated with X_{it}. The likelihood function for this model is derived in the Appendix.

Our empirical model is based on other applications of (S, s) models. For example, Attanasio (2000) uses a similar structure to estimate an (S, s) model for consumers' automobile purchases as a function of time-invariant household characteristics, while imposing a common error term on the upper and lower thresholds. Applying this methodology to capital structure, however, introduces a number of novel features. First, we need to allow for time-varying covariates, which results in time variation in the thresholds. Second, because the upper and lower thresholds on capital structure are driven by fundamentally different considerations, we allow for separate error terms in the upper and lower adjustment thresholds. Third, there are natural bounds on the values that leverage may take, which may differ by measure. For example, market leverage is naturally bounded above by 1, and leverage measures gross of cash are bounded below at 0. It is important to recognize these bounds in the estimation.

The parameters of target leverage, β, are identified from the first observation of leverage following a refinancing event, when the firm returns to L^{*} (similar to the intuition in Hovakimian, Hovakimian, and Theranian (2004)). The error term, u^{*}, captures two sources of error. First, in practice leverage is reported only at discrete intervals, and it may have moved away from the true L^{*} in the period between refinancing and observation. Second, L^{*} may have changed over this period, introducing an additional observation error. Third, u^{*} captures any explanatory variables that are omitted from X.

We can learn about the upper and lower thresholds from the periods of inaction, when firms do not refinance as leverage is within the target zone. For the firms that do not refinance in the current period, the observed end-of-period leverage is between the thresholds, $L_{it}^{d} < L_{it} < L_{it}^{u}$. In discrete time, leverage may still move beyond its current value before the actual refinancing event takes place (even if that happens in the next period), and without further assumptions we can only identify a lower bound on L_{it}^u and an upper bound on L_{it}^d. We estimate the parameters, θ^u and θ^d, that characterize these bounds. In the period before levering up (down), the observed leverage ratio is the best estimate of the upper (lower) bound on L_{it}^d (L_{it}^u), but for statistical efficiency we use all observations of leverage to identify the parameters of these bounds, not just the observations in the period before a refinancing. With a high frequency of observations, the estimated bounds on L_{it}^u and L_{it}^d will be close to the true refinancing thresholds. In the robustness section, we explore an alternative identification assumption that estimates the thresholds exactly, and show that the empirical results are similar. Note that if we are in a static world or a dynamic world without adjustment costs (i.e., $L^d = L^* = L^u$), our model would not converge, as the coefficients in θ^u and θ^d that load on the intercept in X would tend to negative infinity.

We also identify the correlations between u^u and u^*, and between u^d and u^*. When leverage is within the target zone, we learn about L^u (and hence u^u) if leverage is above L^* (as partly determined by the realization of u^*). This reveals information about the correlation between these two error terms. The same argument applies to u^d and u^*. However, the correlation between u_t^d and u_t^u in (4) is not identified, because in no-refinancing periods we learn about either L_{it}^u or L_{it}^d, not both simultaneously. In the benchmark model, we assume this correlation is zero.

1.2 Discussion

The optimality of an (S, s) policy is based on the existence of both a loss function and an adjustment cost function that makes continuous small adjustments suboptimal. The loss function captures the costs that the firm incurs if it deviates from its preferred target leverage ratio. This loss function can be generic in principle, although it is typically assumed to be convex. In capital structure, the losses include (but are not limited to) lost tax shields, costs of financial distress such as debt overhang and asset substitution, and increased agency costs.[6] An important type of cost function that we consider involves fixed adjustment costs. The result that fixed costs lead to an impulse control problem, where the variable of interest follows an exogenously specified stochastic process in the target zone (more generally known as the "inaction region") and is reset when it hits lower and upper triggers, is well-known in the stochastic optimal control literature.[7]

Figure 2 shows an example of the stationary leverage distribution for the case where L follows a geometric Brownian motion in the intermediate periods between refinancings. The figure illustrates the basic and yet fundamental result of this section: leverage distributions are asymmetric around L^*. This asymmetry is driven by two fundamental features of the data. First, leverage ratios tend to drift down in periods between refinancings. This happens because firms tend to grow, which raises the denominator in the leverage ratio. In the presence of adjustment costs, firms choose higher leverage ratios to compensate for the downward trend. Second, the costs of being underlevered are lower than the costs of being overlevered (see, e.g., Korteweg (2010)). Firms are therefore less concerned about being underlevered relative to being overlevered. The implications of such asymmetry are profound. The mean of the asymmetric distribution is not equal to L^*, barring knife-edge type solutions. Instead, the mean is influenced not only by L^*, but also by the refinancing thresholds and the characteristics of the stochastic process of leverage (in this specific example, the mean and volatility of the geometric Brownian motion). Standard regression coefficients therefore reflect a combination of all these components of dynamic capital structure.

In theory, the target and thresholds can arise endogenously, and the resulting

[6] Note that for our purposes, the optimality of "target" leverage and other parameters of interest is immaterial. The distinction between various definitions of leverage is not important either, and in this section we do not specify the term "leverage ratio" any further.

[7] See Harrison, Sellke, and Taylor (1982) for an early development and Stokey (2009) for a textbook treatment. Note that in the presence of adjustment costs, the leverage ratio adopted upon refinancing does not necessarily coincide with the minimum of the loss function. Leary and Roberts (2005) consider other examples of the adjustment cost function, such as convex and fixed plus linear, and our results can be generalized to cover these cases as well.

(S, s) policy is consistent with many contingent claims dynamic models, in which this policy arises endogenously, such as Fischer et al. (1989), Goldstein et al. (2001), Strebulaev (2007), and Morellec et al. (2012). The Morellec et al. paper also derives an expression for the stationary distribution of leverage that is consistent with the distribution in Figure 2.[8]

The (S, s) policy arises as long as adjustment costs are fixed with respect to the size of the adjustment. It is not necessary that the (fixed) costs are the same across firms. In addition, there may be heterogeneity within firms. For example, the (fixed) adjustment cost of levering up may be different from the cost of levering down, and these costs may vary over time, giving rise to time-varying targets and thresholds as modeled in equations (1) through (3). In particular, the covariates in the upper and lower leverage threshold equations (2) and (3) can capture times when adjustment costs are differentially low, temporarily shrinking the target zone, for example when a debt issue matures or when the firm has to access the external capital markets to fund an investment opportunity. The (S, s) policy prevails in all these cases, and the basic insights in this section are unaffected by such time series and cross-sectional variation. One important exception is the recent work by DeAngelo, Deangelo, and Whited (2011), who show that firms sometimes deliberately deviate from target leverage by issuing transitory debt to fund investment opportunities. Although we do not explore this here, the (S, s) model can be extended to allow for such behavior by adding another equation that captures these deliberate deviations from target.

It is important to note that in our empirical results the data determine the location of the thresholds in relation to the target. We do not externally impose any particular

[8] In many of these models, driven by the trade-off between tax benefits and distress costs, the upper leverage threshold is associated with bankruptcy, upon which the firm undergoes reorganization with the ownership transfer from equityholders to debtholders (new equityholders), who then optimally lever the firm up. Because tax benefits are lost in liquidation, reorganization is preferred, ensuring that the upper threshold is not absorbing. The possibility of liquidation can be incorporated into the (S, s) model by introducing a third threshold that triggers liquidation. We do not explore this extension in this paper.

shape on the leverage distribution or whether it is left-skewed or right-skewed. An (S, s) model is essentially a reduced-form approach that relies on the generic economic structure of the problem. It thus complements a more structural approach to studying corporate financial decisions, which may imply the same dynamic (S, s) strategy. One advantage of estimating an (S, s) model is its reliance on fewer assumptions about deep structural parameters that are needed to estimate the dynamic behavior of firms. In particular, we do not make any specific assumptions about the nature or functional form of tax benefits, costs of financial distress, or agency costs. We also make no assumptions about the nature of the driving stochastic process, whereas dynamic models rely on particular processes (e.g., a geometric Brownian motion for EBIT, or an AR(1) process for productivity). For example, Kane, Marcus, and McDonald (1985) show that jumps have important first-order effects on capital structure. We make no assumptions about the presence of jumps in the stochastic process, and our results are therefore robust to their presence in the data. In this sense, the strengths of the (S, s) empirical method also help to pinpoint its weaknesses. Although our approach is more general than a given capital structure model, it does not provide the rich economic content underlying the mechanisms at work, as specific models do so well, nor can it, of course, replace the need for a better understanding of the myriad factors that drive corporate decisions. Thus, a structural model and an (S, s) model should be viewed as closely connected and complimentary approaches that lead to the same ultimate goal.

In a dynamic world with adjustment costs, even differences-in-differences regressions from natural experiments may not correctly identify the impact of an exogenous shock on target capital structure. First, the shock in natural experiments may not be large enough for firms to adjust. This is essentially a "weak instruments" problem. For example, if the experiment shocks a firm's profitability upwards then, absent refinancing, average leverage will decrease, as the market value of the firm increases to reflect the higher future profits. However, if target leverage increases with profitability (as we show in the empirical results), then the experiment will give misleading results about target leverage unless the shock is large enough to induce refinancing.

Second, even if the shock is large enough, there is still no guarantee that the direction of change in average and target leverage is the same. For example, suppose the treated firms are close to the lower refinancing threshold (e.g., due to a series of positive profitability shocks), and the shock from the experiment pushes them below the threshold, so that they lever up to the (post-shock) target. The average leverage ratio thus rises in response to the shock. However, the experiment may in fact have decreased target leverage, but this is not detected by the differences-in-differences estimator. Thus, caution is warranted as observing large, active responses from a natural experiment does not mean that one may interpret the resulting differences-in-differences estimates as accurately capturing a change in target leverage. The experiment may change any and all aspects of dynamic capital structure that, when combined, determine the (conditional) mean leverage.

Instrumental variable (IV) estimators, as used in conditional mean analysis, need to be interpreted with similar caution. These estimators capture changes in average (conditional) leverage ratios, and should be interpreted as such. A change in the average leverage ratio may be very different from a change in target capital structure.

With respect to structural estimation, adding the average leverage ratio immediately before and immediately after refinancing to the set of moments in a GMM or SMM estimation of a structural model can be informative for identifying the drivers of financial policy separately from the model's underlying stochastic process.

2 Data

To assemble the main sample, we start with quarterly data from Compustat for the 1988 (the first year quarterly research and development expenses first became available) to 2011 period. We exclude utilities (SIC codes 4900 through 4999), financial firms (SIC codes 6000 through 6999), and quasi-government firms (SIC codes 9000 through 9999) to avoid companies whose financial policies are largely driven by government regulation. We also exclude non-U.S. firms, subsidiaries, and companies with less than $10 million in book assets, in year 2010 dollars. The measure of leverage that we focus on in the results section is net market leverage, measured as book debt (the sum of short-term debt (DLCQ) and long-term debt (DLTTQ)) minus cash (CHEQ), divided by the sum of book debt and the market value of equity (the product of shares outstanding and price per share at quarter-end, from CRSP[9]).[10] In the robustness tests below, we show that the main results are robust to using other measures of leverage from the literature.

We employ standard firm-level explanatory variables, defined as follows:

- $PROF$: Profitability, measured as EBITDA (OIBDPQ) divided by book assets (ATQ).
- MB: Market-to-book ratio, defined as the sum of the market value of equity and book debt divided by book assets.
- PPE: Property, plant, and equipment (PPENTQ) divided by book assets.
- $DEPR$: Depreciation (DPQ) divided by book assets.
- RD: R&D expense (XRDQ) divided by book assets.
- $RDdum$: An indicator variable that equals 1, if the firm had a non-zero R&D expense in the past quarter, and 0 otherwise.
- $LN(TA)$: Natural log of book assets.
- VOL: Quarterly standard deviation of EBITDA divided by the median book asset value over the past 20 quarters, for which at least 10 quarters are observed.

All firm-level flow variables are reported on a quarterly basis. To minimize the influence of outliers, we trim net market leverage at -1, as well as profitability, depreciation, R&D, and earnings volatility at the 99th percentile; furthermore, we trim profitability at the 1st percentile and the market-to-book ratio at 10.

[9]We have also estimated the model using the market value from Compustat (the product of shares outstanding (CSHOQ) and price per share (PRCCQ)). The results are qualitatively similar.

[10]All abbreviations are the names of variables used in the current version of Compustat.

In addition to the firm-level variables, we also use several macroeconomic explanatory variables, defined as in Frank and Goyal (2009):

- $dGDP$: The annualized, seasonally adjusted real GDP growth rate, based on 2005 dollars, from the U.S. Bureau of Economic Analysis.
- $TERM$: The spread between annualized 10-year and 2-year Treasury note interest rates, from the Federal Reserve Bank of St. Louis.
- $RECESS$: A dummy variable that equals one for economic recession (NBER peak-to-trough) quarters.

Because an (S, s) model is inherently a model of dynamic capital structure, we restrict the sample further to exclude firms with fewer than eight quarters of consecutive data. The final sample is an unbalanced panel of 2,243 firms spanning 74,532 firm-quarters. Table I panels A and B report summary statistics of the firm-specific and macroeconomic covariates, respectively, while Figure 3 depicts the histogram of leverage, which represents a mixture distribution of all firms' capital structure distributions. Requiring at least two years of data inevitably introduces a survivorship bias. Yet, compared with the full sample, there is no material difference in leverage, although in our sample firms are slightly larger and more profitable, and more firms have non-zero R&D expenditures (results not reported).

We define refinancing in a manner that is consistent with prior studies (e.g., Hovakimian, Opler, and Titman (2001), Korajczyk and Levy (2003), Hovakimian (2004), Leary and Roberts (2005), and Frank and Goyal (2009)). A firm is classified as having increased its leverage in a given quarter if net long-term debt issuance (debt issuance (DLTISY) minus debt repurchases (DLTRY)) minus net equity issuance (equity issuance (SSTKY) minus repurchases (PRSTKCY)) over the quarter is greater than 5% of the beginning-of-quarter book value of assets.[11] Conversely, if net equity issuance minus net debt issuance is greater than 5% of book assets, the firm is

[11] Compustat reports debt and equity issuance and repurchase variables on a cumulative basis throughout the fiscal year, so for each variable we first obtain its net contribution for a given quarter.

designated to have reduced its leverage. This definition of refinancing captures not only public but also private debt issuance, the most prevalent form of debt financing (e.g., Houston and James (1996), Bradley and Roberts (2004)). The 5% threshold is chosen to capture financing decisions that are intended to change capital structure; it excludes most "mechanical" issuance and repurchases, such as equity issuance due to the planned exercise of executive stock options. As Leary and Roberts (2005) note, even though this measurement may result in some misclassifications (such as the calling of convertible debt or the transfer of equity accounts from unconsolidated subsidiaries to parents), the 5% classification scheme produces results similar to using new debt and equity issuance data from SDC (see also Hovakimian et al. (2001), Korajczyk and Levy (2003)).

Panel C of Table I reports summary statistics for refinancing activity. Firms increase their leverage in 6.4% of the observed firm-quarters, and the median firm increases leverage once during the sample (once every five quarters). When they increase leverage, firms issue net debt in excess of net equity of 15% of book assets on average (median 9%). Leverage decreases occur in 5.9% of the firm-quarters. The median firm reduces leverage once during the sample period. When firms reduce leverage, they issue net equity in excess of net debt of 36% of book assets on average (median 13%). The distribution of refinancings is skewed: 39.6% of firms do not refinance in the sample period, 8.9% refinance only once, while 12.3% of firms undergo 10 or more refinancings. However, these numbers may overstate the number of true refinancings, as some leverage rebalancings span more than one quarter. In the robustness section, we show that our results are robust when we group consecutive refinancing events together.

3 Empirical Analysis of the (S, s) Model

In this section, we discuss the empirical results of the (S, s) model of leverage. We first concentrate on target leverage, then turn to the results on the refinancing thresholds. We then consider the cross-sectional and time series variation in capital structure policies. Finally, we explore the robustness of these results.

3.1 Target leverage

Table II reports the parameter estimates of the base (S, s) model, where the explanatory variables are lagged by one quarter.[12] The table also shows the coefficients of a standard OLS regression of leverage on the covariates. There are two methodological differences between the (S, s) and OLS models that are critical in interpreting these results. First, the interpretation of the dependent variable is different: it is the average leverage ratio in the OLS model and target leverage in the (S, s) model. The analysis of the β coefficients should take this difference into account. Second, the OLS model allows the firm to adjust only leverage in response to changing covariates, whereas the (S, s) model provides the firm with two additional levels of control: adjustments to the upper and lower refinancing thresholds. Thus, the OLS approach, if taken as a structural model, corresponds to a static world, in which adjustment costs are zero (and thus, firms are always at the "bliss point" that minimizes the loss function). Any explanation in differences between the results on target leverage should thus emphasize the additional flexibility of the (S, s) approach.

We start by comparing the β coefficients reported in Table II with the OLS estimates. The most striking result, perhaps, involves the recession indicator, $RECESS$, which equals one during NBER-defined economic recessions. The OLS coefficient is 0.030 and strongly statistically significant. The interpretation of this coefficient is that during a recession, average leverage is 3% higher than in an expansion, holding all other variables constant. Compared to an average net market leverage ratio of 3%, this is an economically meaningful number. This result is in line with the countercyclicality of observed leverage as documented in Korajczyk and Levy (2003). The target leverage coefficient from the (S, s) model is -0.013 and statistically significant at the 5% level. In other words, target leverage moves pro-cyclically, consistent with

[12] Lagging the explanatory variables by one period is standard practice in the capital structure literature, although defining the explanatory variables to be contemporaneous with leverage instead does not change the results in a material way.

the models of Bhamra, Kuehn, and Strebulaev (2010a,b) and Chen (2010). Target leverage is pro-cyclical in these models, because profits and collateral values are higher and expected bankruptcy costs are lower during periods of economic growth. Observed leverage ratios are counter-cyclical, because adjustment costs deter firms from immediately adjusting to the new target leverage ratios. As a result, when recessions occur, observed leverage ratios rise due to lower equity market values.

The macroeconomic cycle is not only determined by the recession indicator, but also by measures of GDP growth ($dGDP$) and the term spread ($TERM$). Perhaps not surprisingly, GDP growth is strongly correlated with NBER recession periods. The term spread appears to lead recession periods, as it is low leading up to a recession, but rises during the actual recession. The OLS and target coefficients on these variables are of similar sign and magnitude, but do not overturn the results of counter-cyclical average leverage and pro-cyclical target leverage. We discuss this result further in Section 3.3.

Moving on to the firm-specific variables, another striking result involves the profitability coefficient. In standard OLS regressions, profitability reliably has a strong negative relationship to leverage, consistent with prior studies (e.g., Fama and French (2002)).[13] In contrast, the (S, s) model yields a positive relation between target leverage and profitability, albeit not statistically significant for net market leverage. To gain insight into the economic significance of the β estimates, we plot the comparative statics of fitted target leverage, L^* (marked with an "o"), along with the OLS fitted values (marked with an "x") in Figure 4. The top-left plot shows target leverage for values of profitability at the 20th, 50th, and 80th percentiles of the sample data, leaving all the other covariates at their sample median values. The corresponding numerical values are in Table III. The graph shows that, while target leverage slowly increases in profitability, the OLS fitted leverage, in contrast, drops sharply.

The positive loading on profitability in Table II is consistent with a dynamic

[13]Korteweg (2010) and Danis, Rettl, and Whited (2012) also document empirically a positive relation between target leverage and profitability, using different methodologies than the standard regression techniques.

trade-off model with adjustment costs. In that model, positive (negative) shocks to profitability mechanically lower (raise) leverage outside of refinancing episodes. This mechanism can explain the negative OLS coefficient, even though the target leverage ratio is positively related to profitability (Strebulaev (2007)). To explore further whether our results are consistent with this explanation, we study the relationship between profitability and leverage drift. Table IV reports the coefficient estimates of regressions of firm-level leverage drift on profitability and other covariates, where drift is measured across non-refinancing periods. The drift of leverage is indeed significantly lower for more profitable firms, which shifts a greater mass of the leverage distribution towards lower leverage ratios and decreases the mean relative to the target leverage, as illustrated in a toy example in Figure 5.

Table II shows that for several other frequently used determinants of leverage (such as market-to-book, earnings volatility, and size), the β coefficients and the OLS estimates have the same sign, providing support for traditionally given theoretical explanations, which all refer to target leverage. For example, the target leverage β coefficients on market-to-book and R&D expenses are negative. If market-to-book and R&D are interpreted as measures of growth opportunities, this implies that firms with higher growth opportunities choose lower leverage ratios. This explanation is consistent, for example, with debt overhang as an important consideration in active capital structure decisions (Rajan and Zingales (1995), Frank and Goyal (2003, 2009)).

The difference in magnitude between the β coefficients and the OLS estimates, which is both statistically and economically significant for many variables, is driven by two related mechanisms. First, because OLS measures the (conditional) average leverage, the distribution of leverage in the periods between refinancings has an additional impact on the OLS coefficients that does not affect the β estimates. The covariates affect this distribution through their impact on leverage drift and volatility, as shown in Table IV. We already saw one example of this in the relation between profitability and leverage. R&D expenditures is another example: high R&D firms have a strong negative drift of leverage, because high R&D firms are likely riskier

(Carlson, Fisher, and Giammarino (2004)) and thus require a higher expected return on equity. Because book debt stays constant within a refinancing period, the variation in equity values drives the drift in leverage. Higher drift in equity values thus decreases the leverage ratio. The stronger negative leverage drift for higher R&D firms accentuates the negative R&D effect on target leverage within a refinancing period and helps explain why the OLS estimate is more negative than the β coefficient. The second related mechanism is the impact of covariates on refinancing thresholds. For example, as we discuss in more detail in the next section, firms with higher market-to-book delay refinancing by reducing both the upper and lower refinancing thresholds. This change in the distribution of leverage is also reflected in the OLS coefficient, even if it does not affect L^*.

Among the firm-level variables in Table II, one other result stands out. The OLS coefficient on depreciation is positive and statistically significant (as has also been documented in Frank and Goyal (2009)), but the β coefficient is negative, albeit insignificant, in the (S, s) model. The difference between the OLS and β coefficients is statistically significant, and economically large, as shown in Figure 4. With depreciation representing a non-debt tax shield, a negative coefficient is in line with theoretical predictions. The positive OLS coefficient appears to be driven by the positive relation between depreciation and leverage drift, as shown in Table IV, possibly because high depreciation firms tend to be safer and thus exhibit lower expected stock returns.

To highlight the differences between the (S, s) and regression models further, Figure 4 shows that the fitted target leverage from the (S, s) model is larger than the OLS point estimate across all the covariates. The difference is economically large: the median firm's target leverage is 0.16, compared to the OLS point estimate of 0.12. This difference is again driven by the downward trend in leverage during periods when no refinancing occurs, as well as by the location of the refinancing thresholds. The presence of adjustment costs induces companies to adopt higher leverage ratios upon refinancing, which then drifts down due to expected asset growth within a refinancing period. Interestingly, this difference suggests that the underleverage result, widely documented in the literature for observed leverage ratios but interpreted for target leverage, may be less severe than previously thought.

3.2 Refinancing thresholds

The (S, s) approach enables us to introduce direct estimates of the refinancing thresholds into the capital structure literature, and explore their dependence on covariates, as well as their empirical relation to target leverage estimates. Table III reveals that the target zone between the two refinancing thresholds is large: firms allow their leverage ratios to vary between the lower threshold of around -0.46 and an upper threshold of around 0.71.[14] Although the magnitude of the gap is driven to a significant extent by our use of a measure of leverage *net of cash*, it still is notably large for the gross of cash measures. Unreported, for the (gross) market leverage measure, the corresponding lower (upper) thresholds are approximately 0.04 (0.72).

The width of the target zone may be driven by either high costs of adjustment or a low loss of value for being away from the target leverage (these are not mutually exclusive explanations). In particular, the large negative lower threshold indicates that firms are not overly concerned with running large cash balances. This result is consistent with Korteweg (2010), who finds that the present value of the net benefits to leverage is quite flat for a large range of leverage ratios around the target leverage. Korteweg also documents that the size of issuance and repurchase transaction costs alone are not enough to explain the deviations from the target leverage that are observed in the data. Other costs of adjustment, not captured by pure transaction costs, may include asymmetric information costs of selling undervalued securities and management time spent renegotiating or raising capital rather than running the firm (which may be especially high for distressed firms).

The large width of the target zone may nevertheless appear surprising, considering that the median firm appears to refinance once a year, as documented in Table I. However, the distribution of refinancings is highly skewed, with 39.6% of firms choos-

[14]Recall that the "upper" threshold is a leverage-reducing trigger, at which firms opt to refinance when leverage is too high, whereas the "lower" threshold is a leverage-increasing trigger, at which firms opt to refinance when leverage is too low.

ing not to refinance at all over the sample period, and another 8.9% refinancing only once. Only a small fraction of firms rebalance frequently. Moreover, single rebalancing events are often implemented and reported over two consecutive quarters, likely overstating the true number of refinancings, although the quantitative impact of "quarter stretching" is not immediately available to us. Finally, any deliberate, temporary deviations from (S, s) policies, such as those discussed by DeAngelo, DeAngelo, and Whited (2011), may overstate the frequency of true refinancings relative to the (S, s) model we study here.

Consistent with the dynamic models by Hackbarth, Miao, and Morellec (2006), Bhamra, Kuehn, and Strebulaev (2010), and Chen (2010), Table II shows that the gap between the upper refinancing threshold and the target leverage ratio, as captured by the θ^u coefficient, tends to be higher in periods of low GDP growth. This means that firms wait longer to lever down during low-growth periods. The θ^u coefficient on $RECESS$ and $TERM$ are insignificant. The gap between the target leverage and the lower refinancing threshold, captured by θ^d, is not sensitive to $RECESS$ and $dGDP$, but is negative and significant for $TERM$. When the term spread is low, which tends to occur during periods preceding recessions, firms wait longer to lever up. We discuss the variation in the thresholds and the magnitude of the target zone over the macroeconomic cycle in more detail in Section 3.3.

Table II shows that the upper and lower refinancing thresholds exhibit strong sensitivities to the covariates. For example, consider the impact of asset size. Larger firms raise their leverage both directly by increasing target leverage at refinancing, and indirectly by refinancing earlier at the lower threshold. This is consistent with larger firms facing lower refinancing costs. At the same time, larger firms can afford to wait longer before refinancing at the upper threshold. This can be explained by larger firms facing relatively low costs of financial distress due to lower information asymmetries, as large firms have more analyst coverage and are paid more attention to by investors, and due to having more diversified business units both in terms of industries and products, as well as a less concentrated customer base.

Cash flow volatility offers another example of how multiple channels reinforce each other. Higher volatility leads to more conservative behavior in the presence of real options and larger shocks, which is seen in the impact of all three control variables (i.e., target leverage and the two thresholds). Firms lower their target leverage, refinance at lower levels of the lower refinancing threshold (because of the higher value of the real option and the less time it takes to reach any point in the higher volatility environment). Finally, they also decrease leverage at a lower level of the upper refinancing threshold, because larger volatility effectively implies a greater likelihood of distress at any given leverage ratio.

The strong sensitivity of refinancing thresholds to net property, plant, and equipment corroborates the long-standing intuition that this covariate proxies for collateral. Higher values of this variable allow firms to refinance sooner at the lower threshold (i.e., at a higher L^d) because collateral makes debt more attractive, and allows firms to wait longer before refinancing at the upper threshold (firms with more tangible assets face lower distress costs and are less subject to credit rationing, as firms with more pledgeable assets are less constrained by creditors from taking on more debt). The impact of the market-to-book ratio and the two R&D variables are consistent with the debt overhang explanation: firms with higher market-to-book ratios and higher R&D expenses refinance earlier to reduce the costs of debt overhang. Firms with higher R&D expenses also wait longer before refinancing at the lower threshold.

3.3 Cross-sectional and time series variation in capital structure policy

The economic significance results in Table III are based on comparative statics. It is not clear as to how much variation in actual capital structure policies the (S, s) model captures. To explore the cross-sectional variation in capital structures, Figure 6 shows histograms of the target capital structure and the refinancing thresholds across 54 two-digit SIC code industries (excluding financials and any industries with fewer than 1,000 firm-quarter observations). For each industry, we calculate median industry characteristics and enter them into the model using the parameter estimates in Table III, while keeping the macroeconomic covariates at their sample medians throughout. The figure reveals substantial variation not only in the target leverage ratio, but also in the refinancing thresholds across industries. The upper threshold is as low as 0.61 for plastics and chemicals (SIC code 28), an industry characterized by high market-to-book ratios and R&D expenses, many intangible assets, and volatile earnings; it is as high as 0.97 for railroads (SIC code 40), an industry with large firms that are mostly comprised of tangible assets, few growth opportunities, and stable earnings. The lower threshold ranges from -0.53 for lab equipment (SIC code 38), an R&D-intensive industry with few tangible assets, to 0.07 for railroads (SIC code 40).

Next, we consider the time series variation in capital structure policy. Figure 7 shows the time series of the policy variables over the sample period. The solid line shows that there is substantial time variation in all policy variables. Target leverage ranges from 0.05 to 0.10 towards the end of the sample to 0.15 to 0.20 in the pre-2000 period. Target leverage tends to drop during recessions (as indicated by the grey shaded periods in the graph) due to higher costs of financial distress, and rises slightly, although remaining relatively low during the (roughly) two years immediately following a recession. The high growth opportunities that exist when the economy emerges from a recession give rise to debt overhang concerns, which can induce firms to adopt low leverage ratios when they refinance during these periods. In contrast, in the years preceding a recession (i.e., towards the end of the economic growth period), target leverage is high as profits and collateral values are elevated while growth is low.

We also consider the degree to which time variation in target leverage ratios arises from changes in firm characteristics versus the macroeconomic environment. The dashed line in Figure 7 shows the time series of the capital structure policy variables when fixing the macroeconomic variables at their sample medians, allowing only the firm-specific characteristics to vary. The figure shows that the changes in target leverage due to changes in firm-specific variables (such as increases in volatility as has been proposed by some authors, for example, Bates, Kahle, and Stulz (2009)), are responsible for a relatively small portion of the time series variation in target leverage. The macroeconomic variables are responsible for most of the time series variation, in particular in the post-2000 period.

Figure 7 shows that the refinancing thresholds also exhibit considerable time variation, again mostly driven by the variation in macroeconomic variables. The lower threshold drops precipitously during recessions, while the upper threshold remains fairly high. This suggests that during periods of poor economic growth, firms wait to refinance until conditions improve. Figure 8 shows the time series of the target zone (the difference between L^u and L^d), illustrating this pattern very clearly: the zone widens during recession quarters, consistent with the theoretical models in Hackbarth, Miao, and Morellec (2006), Bhamra, Kuehn, and Strebulaev (2010), and Chen (2010).

Turning back to Figure 7, the thresholds follow a similar time series pattern to target leverage: they rise for roughly the first two years when the economy is emerging from a recession, but remain relatively low. This evidence is consistent with the existence of high growth opportunities when the economy improves. In contrast, in the years preceding a recession, the thresholds are high, consistent with low growth, as well as high profits and collateral values.

The evidence presented in this section has important implications for dynamic models of the firm. Given that the time variation in both the target leverage and the leverage thresholds is mostly explained by macroeconomic conditions rather than firm-specific variation, the results suggest that the world follows three regimes that can roughly be characterized as recession, growth, and a "harvest" period of high profits and low growth. This is in contrast to the typical two-regime models used in the literature. Alternatively, one could conceivably calibrate a two-regime model by combining the recession and growth periods into one "recession" period. However, such calibrations should use a recession period that lasts considerably longer than the average recession period commonly identified in the data (such as NBER peak-to-trough periods), as well as a shorter expansion period.

3.4 Robustness

It is important to verify whether our results are driven by specific assumptions about variable construction or the estimation procedure. As a first robustness check, we run an alternative estimation procedure that identifies the leverage thresholds exactly, by assuming that the firm exceeded the threshold in the period prior to refinancing.[15] In this case, θ^u and θ^d have a different interpretation: they specify the exact threshold rather than a bound on the thresholds. This exact identification comes at the cost of assuming that firms do not immediately refinance after hitting the threshold, which is contrary to the intuition of the (S, s) model (though it is possible to rationalize this behavior through, for example, infrequent capital structure evaluation by management). It is, however, reassuring that the results under the two identification strategies turn out to be quantitatively very similar.

In the second robustness test, we set the threshold for refinancing at 3% and 7% of book assets, instead of the 5% used in the main results. The results are largely unaffected. The most noteworthy change is that in the 3% threshold case, the β coefficient on $PROF$ rises to 5% significance (and remains positive), the θ^u loading on $LN(TA)$ flips sign from negative and insignificant to positive and significant, and the θ^d loading on RD becomes statistically significant at the 1% level (from a statistically insignificant loading in the benchmark model).

For our third robustness test, we group consecutive refinancings together to account for cases in which, for example, an equity issue and debt repurchase were split across quarters. Our results are unchanged qualitatively.

In the fourth robustness test, we redefine net debt issuance using the quarter-to-quarter change in book debt from the balance sheet, rather than the debt issuance from the statement of cash flows. This avoids potential issues with debt maturing rather than being repurchased. Our main results are unaffected.

We include short-term debt changes in the definition of refinancing events in the fifth test of robustness. Our main results use long-term debt issuance and repurchase only, since short-term debt is often seasonal and is missing in many cases. Including

[15] Attanasio (2000) uses a similar identification strategy to the one that we consider here.

short-term debt cuts the sample size in half, because of missing observations, but the results are affected very little.

For the sixth robustness test, we consider measures of leverage that are different from the benchmark net market leverage measure. Using net book leverage gives very similar results. The only notable differences are that the β-loading on VOL becomes statistically significant. Using book leverage without subtracting cash in the numerator turns the β-coefficient on RD insignificant, while $TERM$ becomes positive. The θ^u coefficient on $RDdum$ becomes significantly negative while $dGDP$ becomes insignificant, and the θ^d coefficient on $TERM$ becomes insignificant. Using market leverage without subtracting cash gives similar results to book leverage, except that the β-coefficient on $PROF$ becomes statistically significant (and remains positive), the coefficient on RD turns positive, and $TERM$ becomes insignificant. The θ^u coefficient on $RDdum$ becomes significantly negative, while the θ^d coefficient on $DEPR$ and $TERM$ become significantly positive, and $dGDP$ significantly negative.

In the seventh test, we try alternative values for the correlation between u_t^d and u_t^u, different from the benchmark zero correlation. Our results are robust to setting the correlation to either +0.25 or -0.25.

To summarize, we find that our main results are robust when we use a different identification strategy, different measures of leverage, and other variations on data definitions.

4 Conclusion

We propose and estimate a general (S, s) model of capital structure, in which firms allow their capital structure to vary within a target zone, and refinance to a target leverage ratio when leverage hits an upper or lower threshold. With this model we investigate the relationship between target leverage, thresholds, and firm characteristics in a dynamic environment. The (S, s) model separates the target leverage ratio from the thresholds, and is immune to the characteristics of the leverage process in between refinancing events. This is in contrast to traditional empirical capital structure regressions, which represent a simultaneous combination of these forces. The (S, s) model is thus informative about multiple issues at the core of capital structure research, such as target leverage and refinancing behavior. As our empirical results demonstrate, studying refinancing thresholds in addition to target leverage enriches our understanding of how firms make financial decisions.

We present important new insights regarding the behavior of target leverage and the refinancing thresholds over the business cycle. In particular, we find that target leverage ratios are pro-cyclical, whereas observed average leverage ratios are counter-cyclical. With respect to the refinancing thresholds, we find that the target zone widens during recessions, indicating that firms wait longer to refinance during economic downturns. These findings are consistent with predictions of recent dynamic models of capital structure that have not been tested. We also provide new results that have important implications for the further development of such models. For about two years following a recession, both target leverage and the refinancing thresholds tend to remain at an intermediate level, higher than at the depth of the recession, but lower than in the years leading up to the recession. This is consistent with the existence of high growth opportunities during economic recoveries. These dynamics are predominantly of macroeconomic origin, and are not captured by changes in firm-specific covariates. Altogether, these findings suggest a richer regime structure than the current two-regime models allow.

We demonstrate other substantial differences between the traditional mean-based and (S, s) models. For example, target leverage in the (S, s) model is higher than the fitted value from traditional regressions, and target leverage shows a modest increase in profitability, in contrast to the traditional regression results that suggest a strongly negative relation between leverage and profitability. These results are also consistent with dynamic capital structure models, but thus far it has proven difficult to find empirical support for these models.

Because this study is the first to estimate dynamic (S, s) models for capital structure, we have deliberately chosen a simple specification. Our (S, s) model should be viewed as the first step in building the next generation of dynamic empirical models in capital structure and elsewhere in corporate finance. For example, we assume the existence of only fixed costs of adjustment. In the presence of both fixed and variable costs, the return points of target leverage differ between upper and lower refinancing triggers. We also do not allow for predetermined financing events (e.g., when outstanding debt becomes due) or investment-driven financing. These events temporarily reduce the adjustment costs, and the resulting shrinking of the target zone can be captured with various empirical proxies for the occurrence of such events. The (S, s) method can also be extended to allow for separate liquidation and restructuring events, deliberate deviations from target behavior, and many other enriching features in capital structure and, more generally, empirical corporate finance. We believe this methodology is an important avenue for future research.

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Appendix: Likelihood Function

The log-likelihood for leverage for firm i at time t, L_{it}, is:

$$\log f(L_{it}) = \mathbb{I}_{refi} \cdot \log f_{refi}(L_{it}) + \mathbb{I}_{refiup} \cdot \log f_{refiup}(L_{it}) + \\ + \mathbb{I}_{refidown} \cdot \log f_{refidown}(L_{it}) + \mathbb{I}_{norefi} \cdot \log f_{norefi}(L_{it}).$$

Each firm-year falls into one of four cases:

1. Refinancing in this period ("refi").
2. No refinancing in this period and levering up next period ("refi up").
3. No refinancing in this period and levering down next period ("refi down").
4. No refinancing in this period or the next ("no refi").

We show the log-likelihood of each case using our main identification strategy, where L_{it} is bounded above at 1, and the period before refinancing is the best estimate of the threshold. Imposing an additional lower bound for gross of cash leverage measures, or assuming that the firm refinances only after crossing the boundary, is straightforward.

Case 1: Refinancing this period. The observed leverage, L_{it}, is a noisy observation of the target, L^*_{it}, so we have an observation of $u^*_{it} = L_{it} - X'_{it}\beta$. Taking into account that $L^*_{it} \leq 1$, the likelihood is the truncated pdf of u^*,

$$f_{refi}(L_{it}) = \frac{\frac{1}{\sigma^*}\phi\left(\frac{L_{it}-X'_{it}\beta}{\sigma^*}\right) \cdot \mathbb{I}_{\{1-X'_{it}\beta\}}}{\Phi\left(\frac{1-X'_{it}\beta}{\sigma^*}\right)},$$

where $\phi(\cdot)$ is the pdf of a standard normal distribution and $\Phi(\cdot)$ is its cdf.

Case 2: No refinancing in this period and levering up next period. We observe $L_{it} = L^d_{it}$, implying $u^d_{it}|u^* = \log\left(X'_{it}\beta + u^* - L_{it}\right) - X'_{it}\theta^d$. The gap between L^*_{it} and L_{it} must be non-negative, and therefore $u^*_{it} \geq L_{it} - X'_{it}\beta$. Given the upper bound, $L^*_{it} \leq 1$, we also enforce $u^*_{it} \leq 1 - X'_{it}\beta$. The likelihood is:

$$f_{refiup}(L_{it}) = \int_{L_{it}-X'_{it}\beta}^{1-X'_{it}\beta} \frac{1}{\sigma^*}\phi\left(\frac{u^*}{\sigma^*}\right) \cdot \frac{1}{\widehat{\sigma^d}}\phi\left(\frac{\log\left(X'_{it}\beta + u^* - L_{it}\right) - X'_{it}\theta^d - \widehat{\mu^d}}{\widehat{\sigma^d}}\right) du^*.$$

The distribution of u^d inside the integral is conditional on u^*, so $\widehat{\mu^d} = \frac{\sigma_d}{\sigma^*}\rho^{*d}u^*$, and $\widehat{\sigma^d} = \sigma^d\sqrt{1-(\rho^{*d})^2}$.

Case 3: No refinancing in this period and levering down next period. We observe $L_{it} = L^u_{it}$, and therefore $u^u_{it}|u^* = \log\left(L_{it} - X'_{it}\beta - u^*\right) - X'_{it}\theta^u$. Note that the upper bound, $L^u_{it} \leq 1$, is inconsequential because $1 \geq L_{it} \geq L^u_{it}$. Since the gap between L_{it} and L^*_{it} must be non-negative, we also enforce $u^*_{it} \leq L_{it} - X'_{it}\beta$. This subsumes the bound $L^*_{it} \leq 1$. The likelihood is:

$$f_{refidown}(L_{it}) = \int_{-\infty}^{L_{it}-X'_{it}\beta} \frac{1}{\sigma^*}\phi\left(\frac{u^*}{\sigma^*}\right)\cdot\frac{1}{\widehat{\sigma^u}}\phi\left(\frac{\log\left(L_{it} - X'_{it}\beta - u^*\right) - X'_{it}\theta^u - \widehat{\mu^u}}{\widehat{\sigma^u}}\right)du^*,$$

where $\widehat{\mu^u} = \frac{\sigma_u}{\sigma^*}\rho^{*u}u^*$, and $\widehat{\sigma^u} = \sigma^u\sqrt{1-(\rho^{*u})^2}$.

Case 4: No refinancing in this period or next period. We observe $L^d_{it} < L_{it} < L^u_{it}$, so $u^d_{it}|u^* > \log\left(X'_{it}\beta + u^* - L_{it}\right) - X'_{it}\theta^d$, and $u^u_{it}|u^* > \log\left(L_{it} - X'_{it}\beta - u^*\right) - X'_{it}\theta^u$. Note that only one of the two conditions can bind for a given u^*. The bounds on leverage ratios also require $u^u_{it}|u^* \leq \log\left(1 - X'_{it}\beta - u^*\right) - X'_{it}\theta^u$ and $u^*_{it} \leq 1 - X'_{it}\beta$. The likelihood is:

$$\begin{aligned} f_{norefi}(L_{it}) = \int_{-\infty}^{1-X'_{it}\beta} & \frac{1}{\sigma^*}\phi\left(\frac{u^*}{\sigma^*}\right)\cdot \\ & \Bigg\{1 - \mathbb{I}_{\{X'_{it}\beta+u^*-L_{it}>0\}}\cdot\left[1-\Phi\left(\frac{\log\left(X'_{it}\beta + u^* - L_{it}\right) - X'_{it}\theta^d - \widehat{\mu^d}}{\widehat{\sigma^d}}\right)\right] - \\ & \quad - \mathbb{I}_{\{X'_{it}\beta+u^*-L_{it}<0\}}\cdot\left[\Phi\left(\frac{\log\left(1 - X'_{it}\beta - u^*\right) - X'_{it}\theta^u - \widehat{\mu^u}}{\widehat{\sigma^u}}\right) - \right. \\ & \qquad \left. -\Phi\left(\frac{\log\left(L_{it} - X'_{it}\beta - u^*\right) - X'_{it}\theta^u - \widehat{\mu^u}}{\widehat{\sigma^u}}\right)\right]\Bigg\}\,du^*. \end{aligned}$$

Figure 1

Example of leverage time series

This figure illustrates the rebalancing of leverage at the boundaries L^d and L^u. Upon hitting one of the boundaries, the firm rebalances to L^*.

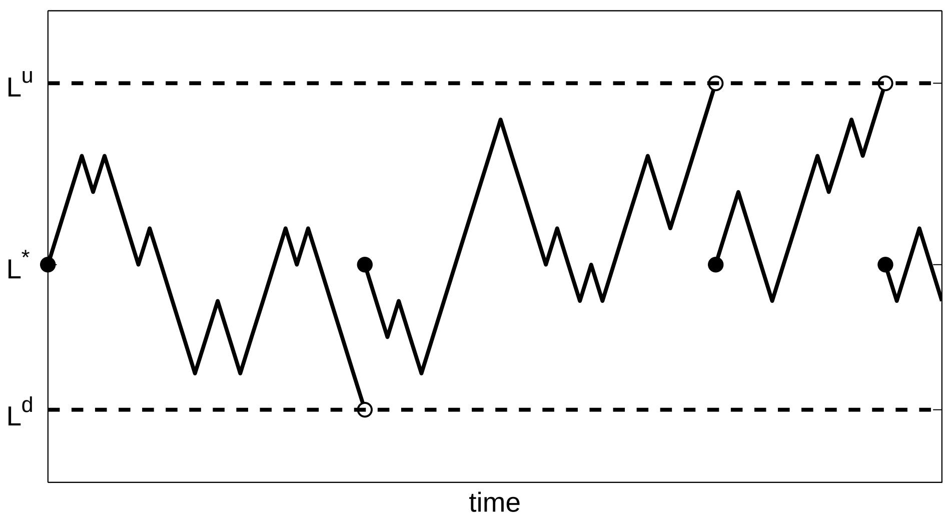

Figure 2

Stationary leverage distribution: Geometric Brownian motion

This figure shows the stationary distribution of leverage, where, between refinancings, the leverage process follows a geometric Brownian motion with drift. L^* is target leverage, L^d is the lower refinancing threshold, and L^u is the upper refinancing threshold.

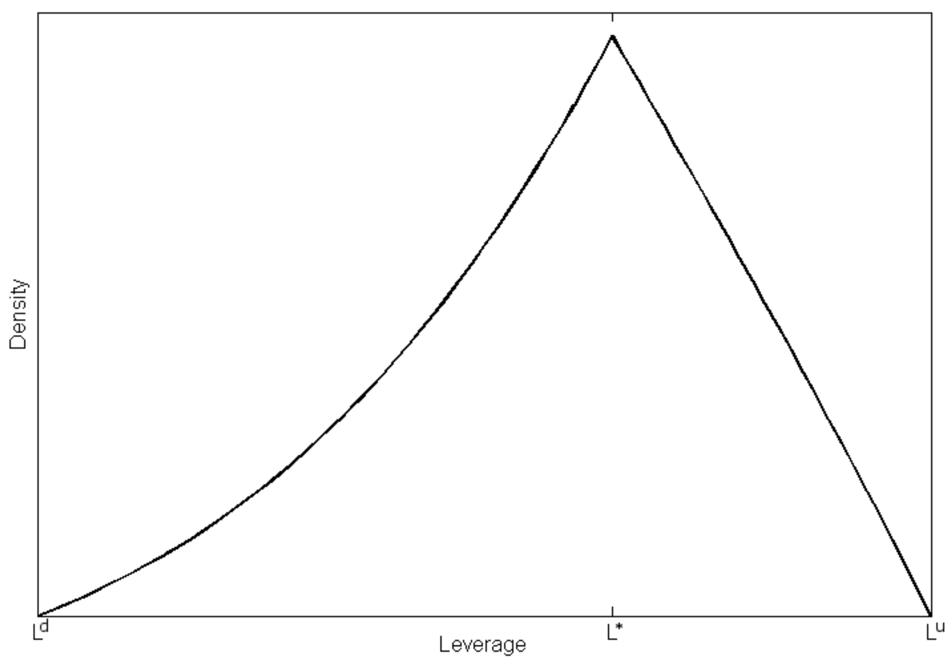

Figure 3

Histogram of leverage

This figure depicts the distribution of leverage across all firm-quarters in the sample. Leverage is measured as defined in Table I.

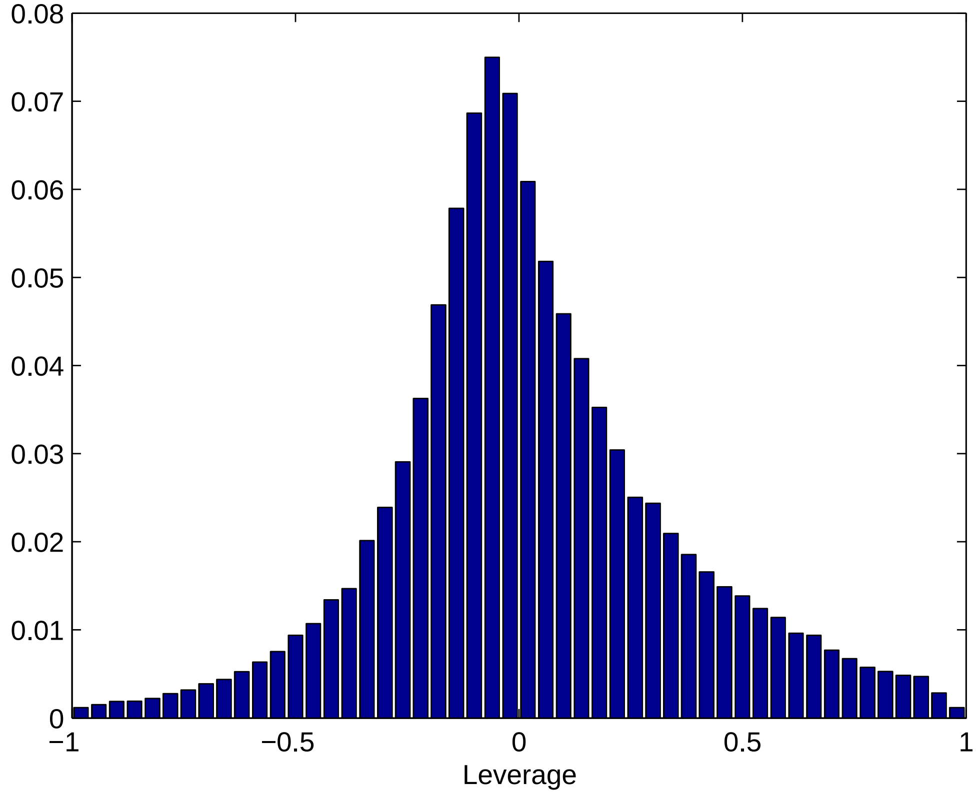

Figure 4
Economic significance

This figure depicts the economic significance of the (S, s) model estimates of Table II. For each covariate, the figure plots the value of target leverage (L^*), denoted by "o," and the OLS fitted leverage, denoted by "x," on the vertical axis, for the values of the covariate at the 20th, 50th, and 80th percentile of the pooled empirical distribution on the horizontal axis, keeping all other covariates at their median values. The covariates are described in Table I. The variable $RDdum$ can only take the value of 0 (no R&D expenses) or 1 (non-zero R&D outlays). For RD, we set $RDdum = 1$ and consider the percentiles of the distribution of positive R&D outlays only. Similarly, $RECESS$ is either 0 (no recession) or 1 (recession).

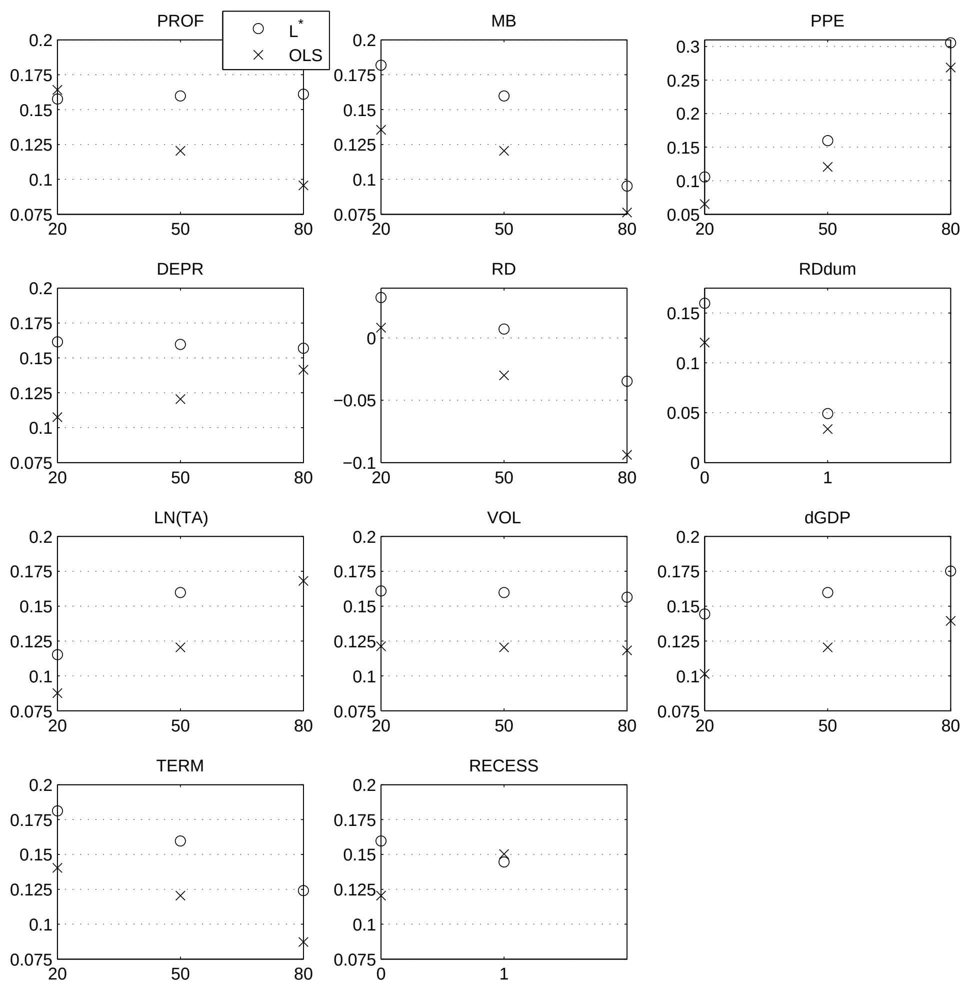

Figure 5

Leverage distribution

This figure depicts the distribution of leverage with fixed L^*, L^u, and L^d but different levels of drift in the leverage ratio in periods in which no refinancing takes place ("High drift" and "Low drift"). Drift is the expected change in leverage from one period to the next in the absence of refinancing.

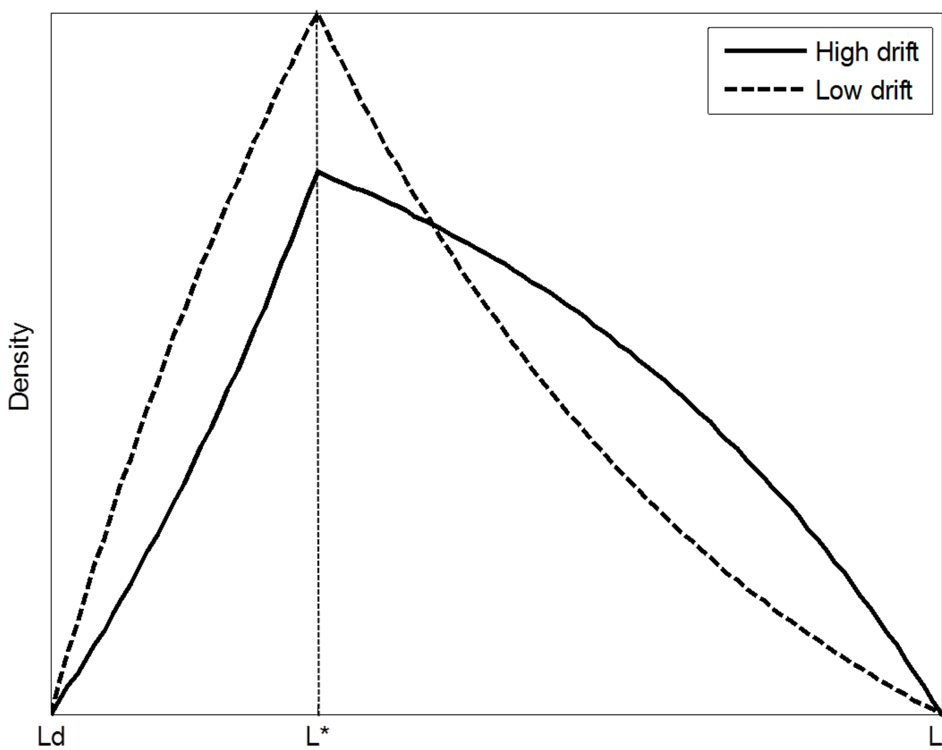

Figure 6

Capital structure policy across industries

This figure depicts histograms of L^*, L^u, and L^d for 54 two-digit SIC code industries with at least 1,000 firm-quarter observations, excluding utilities (two-digit SIC code 49), financials (two-digit codes 60 through 69), and quasi-government firms (two-digit codes 90 through 99), using median industry characteristics and the model estimates from Table II. The macroeconomic variables are fixed at their median values over the sample period.

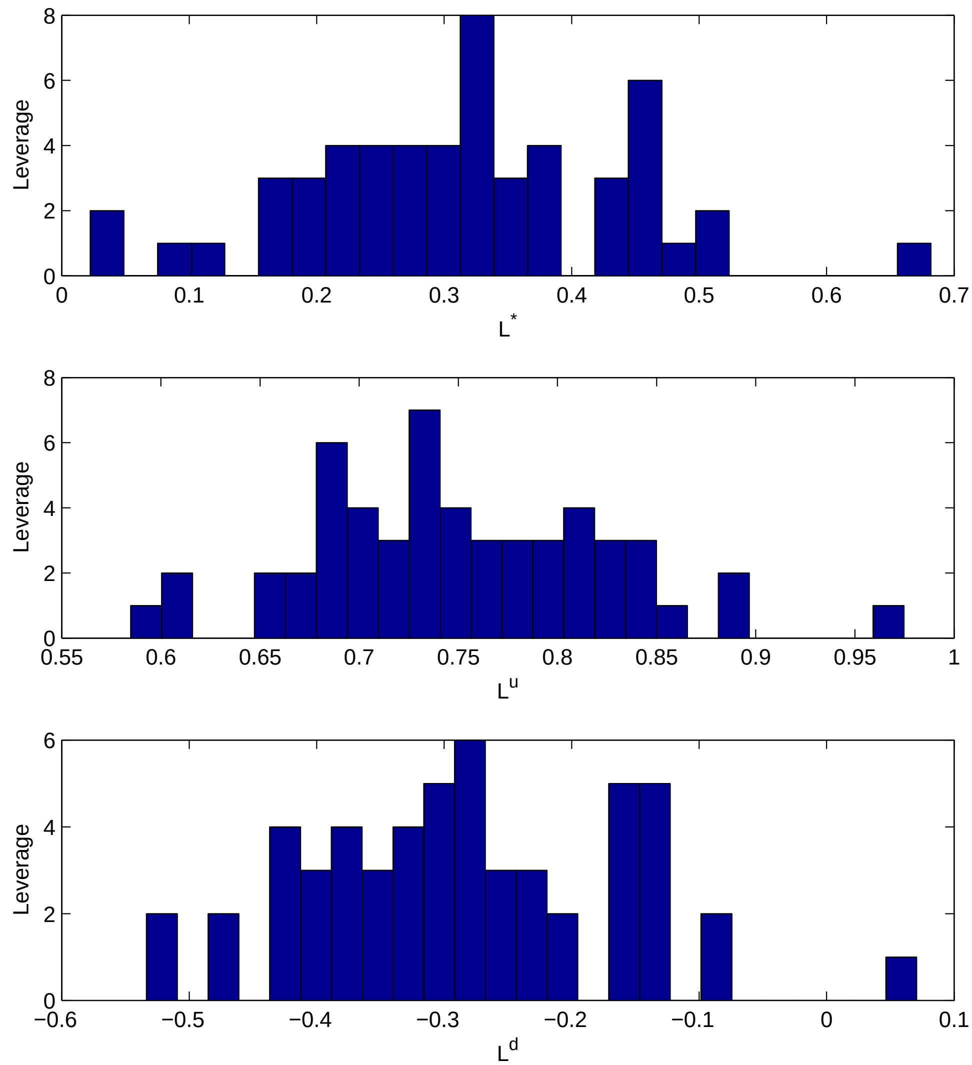

Figure 7

Time series of capital structure policy

This figure shows the time series of estimated L^*, L^u, and L^d. The solid line is based on the model estimates from Table II, using median firm characteristics in each period. The dashed line fixes the macroeconomic variables to their sample medians; thus it only reflects changes in median firm characteristics over time. The grey shaded periods are NBER peak-to-trough recessions.

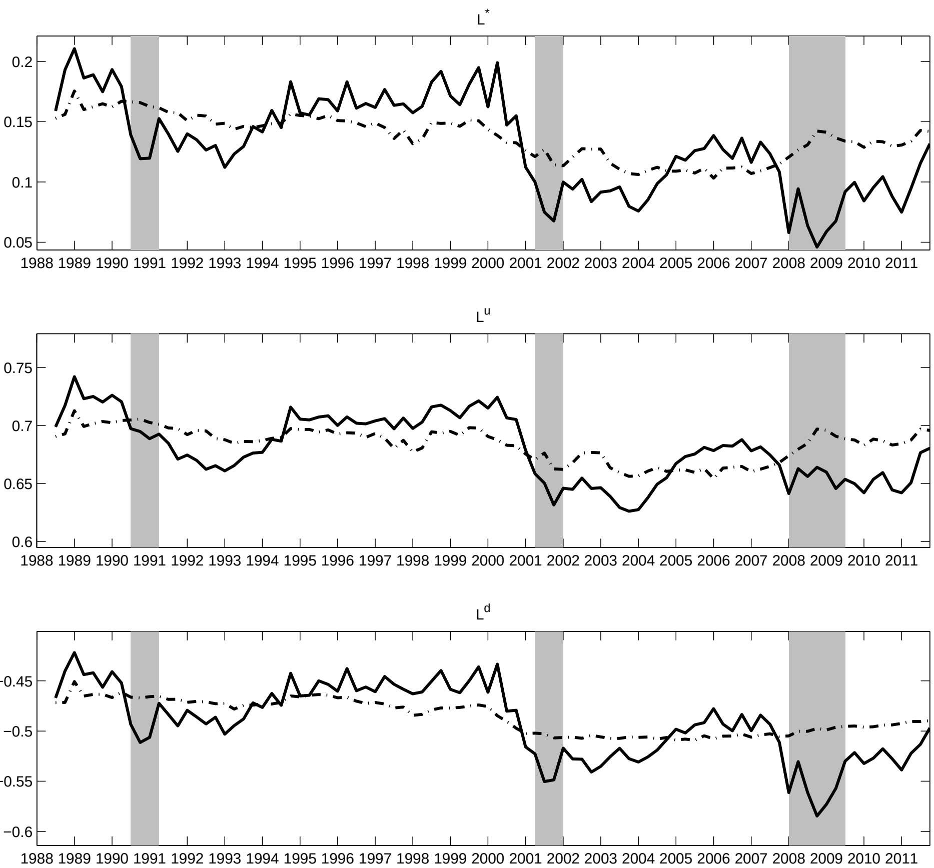

Figure 8

Time series of the target zone

This figure shows the gap between the upper and lower refinancing thresholds, $L^u - L^d$, over time, based on the model estimates from Table II. The grey shaded periods are NBER peak-to-trough recessions.

Table I

Summary statistics

This table reports summary statistics for leverage and firm-level explanatory variables (Panel A), macroeconomic explanatory variables (Panel B), and refinancing activity (Panel C). The sample consists of 74,532 firm-quarters for 2,243 firms between 1988 and 2011. Leverage is defined as book debt (the sum of short and long-term debt) minus cash, divided by the sum of book debt and the market value of equity. $PROF$ is EBITDA divided by book assets; MB is the market-to-book ratio, the sum of the market value of equity and book debt divided by book assets; PPE is property, plant, and equipment divided by book assets; $DEPR$ is depreciation divided by book assets; RD is R&D expense divided by book assets; $RDdum$ is an indicator variable that equals one if the firm reported non-zero R&D expenses in the quarter; $LN(TA)$ is the natural log of book assets (in $m); and VOL is the standard deviation of quarterly profitability over the past 20 quarters divided by median book assets over the same period. For RD we report the summary statistics for the subset of firms that report positive R&D expenses. All firm-level flow variables are reported on a quarterly basis. $dGDP$ is the annualized, seasonally adjusted real GDP growth rate; $TERM$ is the spread between annualized 10-year and 2-year Treasury interest rates; and $RECESS$ is a dummy variable that equals one in NBER peak-to-trough recession quarters. A leverage increase (decrease) occurs when the net debt (equity) issuance minus net equity (debt) issuance exceeds 5% of book assets. The median duration is the median number of quarters between refinancing events of the same type (e.g., for leverage increases it is the median number of quarters between leverage increases). Median adj per firm is the median number of refinancings (of a given type) on a per firm basis. Issuance amount is the amount of net long-term debt minus net equity issued in the refinancing, scaled by beginning-of-period book assets.

Panel A: Leverage and Firm-level explanatory variables

	Mean	Std. Dev.	percentile		
			10	50	90
Leverage	0.03	0.32	-0.34	-0.01	0.47
PROF	0.02	0.05	-0.04	0.03	0.07
MB	1.70	1.30	0.60	1.30	3.34
PPE	0.23	0.20	0.04	0.17	0.54
DEPR	0.01	0.01	0.00	0.01	0.02
RD	0.03	0.02	0.00	0.02	0.06
RDdum	0.73				
LN(TA)	5.32	1.82	3.15	5.07	7.84
VOL	0.03	0.03	0.01	0.02	0.05

Table I - Continued

Panel B: Macroeconomic explanatory variables

	Mean	St. Dev.	10	50	90
dGDP	0.03	0.03	0.00	0.03	0.06
RECESS	0.10				
TERM	0.01	0.01	-0.00	0.01	0.02

Panel C: Refinancing data

Adjustment type	Number of adjustments	Percent of quarters	Median duration	Median adj per firm	Issuance amount	
					Mean	Median
Leverage change	9,220	12.37	4	2	-0.09	0.05
Leverage increase	4,801	6.44	5	1	0.15	0.09
Leverage decrease	4,419	5.93	4	1	-0.36	-0.13

Table II

Parameter estimates

This table shows the maximum likelihood parameter estimates of the (S, s) model. For firm i at time t,

$$\begin{aligned} L_{it}^{*} &= X_{it}'\beta + u_{it}^{*}, && \text{(Target leverage)} \\ L_{it}^{u} &= L_{it}^{*} + \exp(X_{it}'\theta^{u} + u_{it}^{u}), && \text{(Upper refinancing threshold)} \\ L_{it}^{d} &= L_{it}^{*} - \exp(X_{it}'\theta^{d} + u_{it}^{d}), && \text{(Lower refinancing threshold)} \end{aligned}$$

where L is the market leverage net of cash, and σ^{*}, σ^{u}, and σ^{d} are the standard deviations of u^{*}, u^{u}, and u^{d}, respectively, and the ρ's refer to their correlations (the correlation between u^{u} and u^{d} is not identified). The covariates, X_{it}, are as defined in Table I, and are lagged by one quarter. The marginal effects on L^{u} and L^{d} are shown in the third and fifth column, respectively, and are evaluated for median values of X_{it}. The OLS column shows OLS regression coefficients, and the standard deviation of OLS residuals is shown in the σ^{*} row. Standard errors are in brackets, and are adjusted for heteroscedasticity and autocorrelation for OLS. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable: Net market leverage

	β	θ^{u}	$\partial L^{u}/\partial X$	θ^{d}	$\partial L^{d}/\partial X$	OLS
macroeconomic variables:						
RECESS	-0.013	0.016	-0.003	0.000	-0.013	0.030
	(0.006)**	(0.013)	(0.009)	(0.015)	(0.010)	(0.007)***
dGDP	0.569	-0.786	0.132	0.091	0.513	0.705
	(0.206)***	(0.149)***	(0.081)	(0.156)	(0.095)***	(0.072)***
TERM	-2.299	0.178	-2.200	-0.708	-1.868	-2.142
	(0.487)***	(0.383)	(0.213)***	(0.360)**	(0.217)***	(0.266)***
Firm-level variables:						
PROF	0.034	-0.030	0.017	-0.068	0.075	-0.641
	(0.098)	(0.115)	(0.064)	(0.114)	(0.069)	(0.060)***
MB	-0.034	-0.006	-0.037	-0.048	-0.005	-0.022
	(0.004)***	(0.003)*	(0.003)***	(0.003)***	(0.003)*	(0.002)***
PPE	0.402	-0.274	0.250	-0.032	0.422	0.409
	(0.025)***	(0.016)***	(0.010)***	(0.019)*	(0.012)***	(0.018)***
DEPR	-0.257	0.367	-0.053	-0.856	0.263	1.982
	(0.696)	(0.405)	(0.226)	(0.403)**	(0.243)	(0.452)***
RD	-2.047	-1.881	-3.091	0.010	-2.053	-3.102
	(0.288)***	(0.233)***	(0.146)***	(0.202)	(0.144)***	(0.165)***

Table II - Continued

RDdum	-0.108	0.087	-0.058	-0.040	-0.084	-0.087
	(0.012)***	(0.007)***	(0.005)***	(0.007)***	(0.005)***	(0.008)***
LN(TA)	0.023	-0.001	0.022	0.003	0.021	0.017
	(0.003)***	(0.001)	(0.001)***	(0.001)***	(0.001)***	(0.001)***
VOL	-0.106	-0.162	-0.196	0.001	-0.106	-0.071
	(0.120)	(0.159)	(0.088)**	(0.141)	(0.086)	(0.094)
Intercept	0.025	-0.528		-0.452		-0.012
	(0.022)	(0.006)***		(0.006)***		(0.014)
σ^*	0.297			0.266		
σ^u	0.200					
σ^d	0.285					
ρ^{*u}	-0.509					
ρ^{*d}	0.175					

Table III

Economic significance

This table shows the economic significance of the (S, s) model estimates of Table II. For each covariate, it reports the value of target leverage (L^*), the upper and lower refinancing thresholds (L^u and L^d), and the OLS fitted leverage ($\hat{L}$ (OLS)) for the values of the covariate at the 20th, 50th, and 80th percentile of the pooled empirical distribution, keeping all other covariates at their median values. The covariates are as described in Table I. The variables $RDdum$ and $RECESS$ can only take the value of zero (no R&D expenses, or no recession) or one (non-zero R&D outlays, or recession), and the outcomes are shown under the 20th and 50th percentiles, respectively. For RD, we set $RDdum = 1$ and consider the percentiles of the distribution of positive R&D outlays only. Similarly, $RECESS$ is either 0 (no recession) or 1 (recession).

	L^*			L^u			L^d			$\hat{L}$ (OLS)		
	20	50	80	20	50	80	20	50	80	20	50	80
macroeconomic variables:												
RECESS	0.157	0.145	-	0.713	0.709	-	-0.464	-0.476	-	0.120	0.150	-
dGDP	0.142	0.157	0.173	0.709	0.713	0.716	-0.477	-0.464	-0.450	0.101	0.120	0.140
TERM	0.179	0.157	0.122	0.733	0.713	0.678	-0.446	-0.464	-0.492	0.140	0.120	0.087
Firm-level variables:												
PROF	0.155	0.157	0.159	0.711	0.713	0.713	-0.469	-0.464	-0.461	0.164	0.120	0.096
MB	0.181	0.157	0.088	0.738	0.713	0.637	-0.461	-0.464	-0.475	0.136	0.120	0.076
PPE	0.103	0.157	0.303	0.679	0.713	0.806	-0.521	-0.464	-0.310	0.065	0.120	0.269
DEPR	0.159	0.157	0.155	0.713	0.713	0.712	-0.465	-0.464	-0.461	0.107	0.120	0.141
RD	0.032	0.007	-0.035	0.629	0.590	0.526	-0.564	-0.589	-0.631	0.008	-0.030	-0.094
RDdum	0.157	0.049	-	0.713	0.655	-	-0.464	-0.547	-	0.120	0.034	-
LN(TA)	0.114	0.157	0.220	0.670	0.713	0.774	-0.503	-0.464	-0.407	0.088	0.120	0.168
VOL	0.158	0.157	0.154	0.715	0.713	0.707	-0.462	-0.464	-0.467	0.121	0.120	0.118

Table IV

Leverage drift and volatility regressions

This table reports cross-sectional OLS regressions results, with the drift and volatility of net market leverage as the dependent variables. Drift is calculated as the firm-level average change in leverage in non-refinancing periods. Volatility is calculated as the firm-level standard deviation of changes in leverage across non-refinancing periods. Only firms with at least five observed leverage changes are included. The explanatory variables are firm-level medians, as defined in Table I. Standard errors are in parentheses, and are adjusted for heteroscedasticity and autocorrelation. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Drift	Volatility
PROF	-0.135	-0.481
	(0.016)***	(0.048)***
MB	0.001	-0.023
	(0.000)***	(0.001)***
PPE	0.006	-0.054
	(0.002)***	(0.008)***
DEPR	0.122	0.403
	(0.065)*	(0.170)**
RD	-0.113	0.236
	(0.026)***	(0.067)***
RDdum	0.001	0.025
	(0.001)	(0.004)***
LN(TA)	-0.001	-0.003
	(0.000)***	(0.001)***
VOL	0.081	0.311
	(0.019)***	(0.049)***
Intercept	0.003	0.131
	(0.002)	(0.004)***
R^2-adj	0.074	0.243
N	2,234	2,234
F	23.237***	90.426***