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Abstract

This paper studies capital structure adjustment mechanisms of firms that experience substantial changes in leverage. Adjustments appear to be asymmetric among firms with large increases and those with large decreases in debt ratios. The different adjustments are not due to differences in leverage targets or industry distributions between the samples. Speeds of adjustment are found to be affected by market timing opportunities. The persistence of equity market timing opportunities slows some firms' rebalancing process.

JEL classification: G32
Bank classification: Financial markets; International topics

Résumé

L'auteure examine les mécanismes d'ajustement de la structure du capital des entreprises qui subissent d'importantes modifications du levier financier. Ces entreprises s'ajustent à des rythmes différents selon que leur ratio d'endettement augmente ou diminue beaucoup. Cette asymétrie du rythme d'ajustement ne résulte pas de la présence d'écarts entre les ratios cibles d'endettement ni de différences dans la composition sectorielle des échantillons. La vitesse de l'ajustement apparaît plutôt influencée par les possibilités avantageuses de financement sur les marchés boursiers. Dans certaines entreprises, la persistance de ces possibilités ralentit le rééquilibrage.

Classification JEL : G32
Classification de la Banque : Marchés financiers; Questions internationales

I. Introduction

Whether firms adjust toward a target leverage level has become an essential question in evaluating the credibility of competing capital structure theories. The static and dynamic trade-off theories predict that firms will quickly revert to their optimal debt ratio whenever there are deviations in their capital structures. In contrast, the pecking order, market timing, and inertia theories all include the argument that firms do not have a market-value leverage target, and therefore they will not adjust quickly toward the optimum.

Previous research differentiates between these competing capital structure theories by estimating firms' speed of adjustment using a partial adjustment model.[1] A fast speed of adjustment is interpreted as a support for the trade-off theories, while a slow adjustment is viewed as being consistent with no target capital structure theories. For example, Flannery and Rangan (2006) find the speed of adjustment is 34.1% per year and argue that this fast adjustment is consistent with the dynamic trade-off theory. Fama and French (2002) show firms adjust at a "snail" pace, which supports the pecking order theory. Huang and Ritter (2005) interpret the slow speed of adjustment (11.3%) to be consistent with the market timing theory. A flaw of these studies is that they estimate the speed of adjustment using all firms contained in the COMPUSTAT database regardless of their actual leverage ratios relative to their target. They implicitly assume that firms follow a uniform adjustment rule and the speed of adjustment is symmetric. However, these assumptions are not plausible.

This paper shows that firms do not adopt the same capital structure adjustment mechanism. They react differently to positive and negative past leverage changes. The speed of

[1] A partial adjustment model is a dynamic model that estimates how fast firms adjust their leverage toward the desired level. Detailed description of the model is in Section III.

adjustment appears to be asymmetric. In addition, firms do not make adjustment when they are at their optimal debt ratios. They also may not rebalance all the time due to the presence of adjustment costs. They are less likely to respond to small fluctuations in their leverage ratios. Therefore, estimating the partial adjustment model using all firms, whether they need to rebalance their capital structures or not, may bias the estimated speed of adjustment, which may lead to an incorrect rejection of the alternative capital structure theories. This paper, by contrast, studies the adjustment mechanism of firms that experience substantial changes in their leverage ratios. This approach takes into account that at or close to their optimal leverage level, firms may not need to adjust their capital structures.

The closest empirical design to that used in this study is the one that Baker and Wurgler (2002) employed in their examination of subsequent adjustments to a firm's initial public offering (IPO). Clearly, an IPO leads to an infusion of equity and a significant downward adjustment to a firm's debt ratio. However, as Xu (2005) shows, in order for the adjustment coefficient to correctly measure the speed of adjustment, one must assume that the optimal debt ratios of private and public firms are equal. Xu (2005) shows that such an assumption is implausible, in that while private firms' debt ratios are determined by characteristics similar to those of public firms, the absolute debt ratio is higher, thus biasing the empirical design against the static trade-off model. However, the research design used in this study has the potential to circumvent such bias.

This paper identifies firms having a substantial increase or decrease in their leverage ratios and then groups them into a positive and a negative sample. Ideally, these significant changes are exogenous shocks moving firms away from their optimal debt ratios and the subsequent adjustment would reflect the importance of the leverage target. A fast adjustment would indicate the first order importance of the target. However, ex ante, it is hard to determine whether the leverage changes are shocks away from target or adjustments back to target. We can only see from the samples, ex post, that positive changes appear to be debt issues moving firms toward target and negative changes in leverage ratios appear to be equity issues resulting in a deviation from target. The unpredictability of significant changes, especially the negative changes, using logit models indicates "exogeneity" of these changes.[2]

Firms in both positive and negative samples are found to time the market by issuing equity at high market values, although the timings are different. However, the subsequent capital structure adjustments following the equity market timing are different. Firms in the positive sample quickly adjust back to the leverage target through debt issues and then maintain the optimum, which is consistent with the trade-off theories. In contrast, firms in the negative sample seem to only gradually rebalance away the market timing effects. The difference in the adjustments is not due to the differential leverage targets of firms in the two samples. Furthermore, there is no significant difference in the industry distributions of firms in the two samples.

The annual speed of adjustment for firms in the negative sample, estimated from the partial adjustment model using the system Generalized Method of Moments (system GMM), is 14%.[3] To understand why these firms rebalance slowly, I examine the effect of adjustment

[2]It is hard to identify truly exogenous shocks on capital structure that will not shift the firm's optimal debt ratio, especially for book leverage ratios. Every financing decision that affects a firm's leverage ratio is chosen by the firm, which is not exogenous, strictly speaking.

[3]Hsiao (2003) and Baltagi (2005) show that the usual techniques, such as OLS and fixed-effects estimates, give biased estimates for the coefficients of the partial adjustment model because the lagged leverage ratio, as an explanatory variable, is correlated with the error term. Specifically, OLS tends to *underestimate* the

costs on the speed of adjustment. Adjustment costs are found not to be the main reason that prevents firms from adjusting quickly toward the leverage target. A further analysis of these slow-rebalancing firms reveals that some firms keep timing the equity market to take advantage of their persistently high market values, resulting in an even further deviation from the target leverage level. For these firms, taking advantage of the "window of opportunity" offered by the high market values is more important than quickly moving back toward the leverage target. The existence of these persistent equity market timers slows the estimated speed of adjustment. Failing to recognize that market timing is not a "one shot" deal will bias the estimate against the trade-off model. To my knowledge, this paper is the first to show empirically that firms adopt different adjustment mechanisms and the speed of adjustment is affected by equity market timing opportunities.

The paper is organized as follows. Section II discusses capital structure theories and their predictions. Section III describes the samples and summary statistics. Section IV estimates the speed of adjustment from the partial adjustment model. Section V studies the cumulative adjustment of the capital structure. Section VI presents robustness checks. Section VII studies factors that affect the speed of adjustment, and Section VIII concludes.

II. Capital Structure Theories and Predictions

The existing capital structure theories have different predictions about firms' adjustment mechanism toward a target leverage level. The static trade-off theory argues that firm value is

speed of adjustment and the fixed-effects model tends to *overestimate* the speed. As Blundell and Bond (2000), Bond (2002), and Baltagi (2005) suggested, the system GMM provides unbiased estimates for the $AR(1)$ panel data regression model.

maximized at an optimal debt ratio, which is based on the trade-off between tax benefits and the expected bankruptcy costs of debt. When shocks cause deviations from this optimum, firms will quickly rebalance toward the target. In a frictionless world, the adjustment will be immediate and complete.

However, the adjustment will be incomplete in the presence of adjustment costs. The dynamic trade-off theory suggests that adjustment costs preclude the firm from adjusting its leverage ratio frequently.[4] The firm must trade off these adjustment costs against the costs of operating with a suboptimal capital structure (deviation costs). The firm will readjust when the deviation costs outweigh the adjustment costs. Since firms value the leverage target in a trade-off world, deviations from the target leverage are usually temporary, and the speed of adjustment is relatively fast.

In contrast, the adjustment in response to a shock will be slow when firms are indifferent about leverage ratios. The pecking order, market timing, and inertia theories all predict that firms will not quickly rebalance away the effect of leverage shocks because there is no target leverage ratio. Myers and Majluf (1984)'s pecking order theory argues that firms finance themselves in the order of internal funds, debt, and equity. Equity issues occur only as a last resort because of the adverse selection costs that arise as a result of information asymmetries between managers and investors. Consequently, the debt ratio becomes an "accident", resulting from internal cash flows and investment needs. Baker and Wurgler (2002)'s market timing theory claims that firms issue equity when they are overvalued, and

[4] See Fischer, Heinkel, and Zechner (1989), Strebulaev (2004), Hennessy and Whited (2005), and Leary and Roberts (2005). Note that the original Modigliani and Miller (1958) model explicitly assumes perfect capital markets; otherwise their homemade leverage argument will not arbitrage capital structure differences across firms.

capital structures are then a cumulative outcome of their market timing behaviour. As a result, the debt ratio is simply an "accident" of market timing. From a different perspective, Welch (2004)'s inertia theory states that managers do not respond to stock return changes, so that most of the variation in market value debt ratios can be explained by past return fluctuations. Consequently, all of these three theories imply a slow or non-existent speed of adjustment.

Hence, the speed of adjustment is essential to differentiate among the competing capital structure theories. However, there is no consensus in the literature about the speed of adjustment. For example, Fama and French (2002), and Huang and Ritter (2005) suggest that firms slowly adjust toward their leverage target, while Jalilvand and Harris (1984) and Flannery and Rangan (2006) suggest a fast adjustment. The discrepancy in the estimated speeds of adjustment between these empirical tests has different implications for the determinants of capital structure. A slow adjustment indicates that past financing activities play a role in determining the current capital structure. It suggests that either firms do not have a leverage target or achieving the target is not of prime importance. By contrast, quick adjustment implies that history has no role and that the trade-offs between the costs and benefits associated with financial policies will determine the optimal capital structure.

To study the importance of target leverage ratio, this paper identifies firms experiencing significant changes in leverage to see how fast they readjust. This approach has the potential to avoid averaging the asymmetric speeds of adjustment. The selected firms are not IPO issuers in order to avoid creating potential bias against the trade-off theory in empirical design.

III. The Samples

A. Data and Summary Statistics

The data used in this study are from COMPUSTAT. The sample contains firms appearing in COMPUSTAT between January 1, 1970 and December 31, 2004. Utility (SIC 4900-4999) and financial (SIC 6000-6999) firms, firms involved in major mergers (COMPUSTAT footnote code AB), and firms that reported format codes 4, 5, or 6 are excluded from the sample, as are firms with a book value of total assets less than $10 million.

The final samples are formed by identifying firms that experience substantial (more than 20%) changes in both book and market leverage ratios.[5] Firms with a significant decrease in leverage are grouped in the negative sample, and those with a significant increase comprise the positive sample.[6] Table I presents summary statistics for the firm characteristics and financing decisions of the negative and positive samples. Year 0 is the event year when the leverage shocks happen. Year -1 is one year prior, and Years 1 to 5 are the subsequent fiscal years.[7] The variables defining firm characteristics are listed in Appendix A. Since values for

[5]Firms are required not to have substantial changes in book and market leverage one year prior. Alternative cutoff points (e.g., 10% and 30%) are also tested. The results are similar. Also, a restriction that firms with a minimum 5% pre-event year leverage does not change the results.

[6]If a firm appears in the negative sample, then it is not allowed to be in the positive sample during the study period. However, allowing the firm appear in both samples during the study period does not affect the results.

[7]The results may be subject to survivorship bias, since the samples contain firms with 7 years of consecutive data. However, samples having firms with 5 years of consecutive data (from Year -1 to Year 3) yield similar results. The survivorship bias may not be very important in this study.

firm-year observations are often ratios and skewed, extreme outliers are deleted.[8]

Table I shows that the positive change in leverage is mainly due to debt issues and the negative change is a result of equity issue and debt retirement. The most striking observation from the summary statistics is that firms with significantly negative and positive changes in leverage do not exhibit the same rebalancing behaviour. Firms in both the negative and the positive samples issue equity at a high market-to-book ratio and high stock return, although the timings of equity issues are different: firms in the negative sample time the market in Year 0, while those in the positive sample do it in Year -1. These firms use the money raised to retire a substantial amount of debt. As a result of both the equity issues and the debt retirement, firms in the negative and the positive samples have low average book leverage ratios of 19.93% and 20.55%, respectively. However, the subsequent adjustments following market timing equity issues are different. Firms in the negative sample adjust slowly back to the long-run mean or, loosely speaking, their target debt ratio, while firms in the positive sample use the debt issue to reach the target quickly. Firms in the negative sample retrace 53% of the way back to their starting debt ratio in Year 5.[9] The debt issues of firms in the positive sample in Year 0 raise their average book leverage ratio substantially from 20.55% to 33.90%. This increase in their debt ratio moves these firms to a desired leverage level, and they do not make any subsequent adjustment to their capital structures. The observed difference in the adjustment mechanisms adopted by firms in the two samples indicates that the speed of adjustment is asymmetric.

Figure 1 Panel A visually shows the different adjustment patterns observed in the two

[8] Observations outside the 1^{st} and 99^{th} percentiles are deleted to avoid the influence of outliers.

[9] The book leverage drops from 32.69% to 19.93% in Year 0 and then increases to 26.73% in Year 5. The deviation is closed by (26.73-19.93)/(32.69-19.93)=53% within 5 years.

samples. Both the book leverage ratio and the market leverage ratio exhibit the same rebalancing pattern. Firms in the negative sample appear to offset the shock and increase their debt ratios gradually over time, while firms in the positive sample appear to move fast to the optimum and then try to maintain the ratio for several years. Panel B presents the leverage adjustments of 5-year before and 5-year after the significant changes. Note that this figure only includes firms that have 11 years of consecutive data, which may not be the best representative of firms in the sample.[10] The figure shows that the debt ratio of firms in the negative sample increases slightly (from 32% to 36%) from 5-year to 1-year before the large decreases in leverage and then adjusts gradually to the long-run mean leverage ratio, while that of firms in the positive sample decrease gradually until they reach the "boundary" in the pre-event year (from 30% to 21%) and they make a one step adjustment back to the target and then they just maintain the optimal ratio in the subsequent 5 years. Then, the question is: what causes the observed difference in adjustment?

B. The Industry Distributions

A potential reason for the observed difference in adjustment could be because firms in the two samples come from different industries and the adjustment difference simply reflects industry difference. To explore this possibility, the percentage of firms in each industry is graphed in Figure 2. As shown, firms in the two samples are basically from the same industries, although some industries have more firms with large changes in debt ratios than other industries. For example, 10.06% (9.11%) of firms in the positive (negative) sample

[10]Figure 1 Panel B represents 368 (27%) firms in the positive sample and 572 (33%)firms in the negative sample.

are from Industrial Machinery and Equipment industry, and 1.19% (1.03%) of firms in the positive (negative) sample are from Health Service industry. There is no significant difference in the industry distributions of firms in the two samples. Industry difference does not explain the observed adjustment difference.

C. The Optimal Leverage Ratios

Another possible reason for the difference in adjustment behaviour could be that firms in the negative and positive samples have different optimal debt ratios, leading them to make different adjustments. To test this hypothesis, I first estimate the leverage determinant regression model using firms in the full sample.[11]

$$L_t = \gamma + \beta_1 \left(\frac{M}{B}\right)_{t-1} + \beta_2 \left(\frac{EBITDA}{A}\right)_{t-1} + \beta_3 log(S)_{t-1} + \beta_4 \left(\frac{PPE}{A}\right)_{t-1} + v_t. \qquad (1)$$

where L_t is the leverage ratio at time t; market-to-book ratio, operating profitability, size, and tangibility are the previous period firm characteristic variables that have been identified as the major determinants of capital structure by prior research (Rajan and Zingales (1995), Booth, Aivazian, Demirguc-kunt, and Maksimovic (2001)).

In the second step, the means of the firm characteristics from the summary statistics are plugged into the estimated model, which enables us to obtain the predicted optimal leverage ratios. Table II presents the year-by-year predicted optimal book debt ratios for firms in the negative and positive samples. The optimal debt ratios of firms in the two samples appear to be similar and stable over time, around 33%. However, the actual leverage ratio

[11]The sample contains both firms that make substantial leverage changes and those that do not. Additionally, using only firms with substantial changes in leverage to estimate the model do not change the results.

are significantly different between firms in the two samples. The similarity of optimal debt ratios indicates the difference in the observed adjustment mechanisms followed by firms in the two samples is not driven by the difference in their target leverage ratios.

D. Prediction of Significant Changes in Leverage

The summary statistics show that firms in the positive and negative samples exhibit different adjustment patterns. An interesting question is whether we can predict the types of firms more likely to increase or decrease their leverage by more than 20%. Two separate logit models are estimated to answer this question.

$$Pr(y = 1) = \frac{1}{1 + e^{\alpha+\beta X}}. \tag{2}$$

where $y = 1$ if a firm increases its debt ratio by more than 20%, $y = 0$ if the change in debt ratio is less than 20% but more than -20%; and $y = 1$ if a firm decreases its debt ratio by more than 20%, $y = 0$ if the change in debt ratio is more than -20% but less than 20%; and X are pre-event year firm characteristic variables, including the debt ratio, the market-to-book ratio, operating profitability, size, tangibility, investment, research and development expenditures, and the cash rate.[12]

Table III shows that the impact of the explanatory variables are generally statistically significant. However, the odds ratios of most explanatory variables are very close to one, indicating the probabilities of an increase (decrease) and no change in leverage ratio are almost equal. The relationship between the firm characteristic variables and the probability of a significant change in leverage is very weak. The relatively low pseudo R^2s also suggest a low predictability of substantial changes in leverage using the firm characteristic variables.

[12]The cash tax rate is excluded because it is highly correlated with $EBITDA$ (0.61).

The pseudo R^2 is especially low when predicting the negative changes. The unpredictability of substantial decreases in leverage implies that the negative leverage shock is likely to be "exogenous".

IV. Speed of Adjustment

A. The Partial Adjustment Model

Table I shows that firms in the leverage decreasing sample rebalance their capital structures gradually after the shock. The question is: how fast do these firms adjust? The analysis focuses on negative sample because firms in the positive sample have reached their optimal debt ratios and do not make subsequent adjustments and also the negative change in leverage is more "exogenous".

The speed of adjustment is still an unsettled issue in the literature (Frank and Goyal (2007)). The speed of adjustment can be estimated using a standard partial adjustment model:

$$L_{it} - L_{it-1} = \alpha(L^*_{it} - L_{it-1}). \tag{3}$$

where L_{it} is the leverage ratio of firm i at year t, and L^*_{it} is firm i's target leverage; α measures how the change in leverage is affected by deviations of the observed leverage ratio from the target. The partial adjustment model can be used to test whether firms have a long-run target leverage ratio and to estimate the speed at which the observed leverage ratio adjusts toward the target.

Alternatively, the adjustment model of equation (3) can be written as

$$L_{it} = (1 - \alpha)L_{it-1} + \alpha L^*_{it}. \tag{4}$$

showing that the observed leverage ratio at time t is a weighted average of the optimal and lagged leverage ratios with α and $(1 - \alpha)$ as weights, respectively.

Unfortunately, the target leverage ratio is unobservable. The most commonly used proxy is the prediction from the beginning-of-period firm characteristics of the form:

$$L^*_{it} = \gamma + \beta X_{it-1} + (\eta_t + u_i + v_{it}). \tag{5}$$

where X_{it-1} is a vector of firm characteristics that determine a firm's leverage ratio, η_t is time series effects, u_i captures individual firm effects, and v_{it} is the disturbance term. With the above specification, the target debt ratio may vary both across firms and over time (Fama and French (2002), Flannery and Rangan (2006), and Huang and Ritter (2005)). The reduced form partial adjustment model is then:

$$\begin{aligned} L_{it} &= (1 - \alpha)L_{it-1} + \alpha\beta X_{it-1} + \alpha\gamma + \epsilon_{it} \qquad (6) \\ \epsilon_{it} &= \alpha(\eta_t + u_i + v_{it}) \end{aligned}$$

In this model, α measures the speed of adjustment toward the target; $0 < \alpha < 1$ would indicate a partial adjustment; $\alpha = 0$ would imply no adjustment, and $\alpha = 1$ would indicate a complete adjustment.

B. Estimation Methods

There are several ways to estimate the speed of adjustment. For example, Shyam-Sunder and Myers (1999) use OLS, while Flannery and Rangan (2006) control for firm fixed effects when estimating the partial adjustment model. However, note that in the reduced form partial adjustment model of equation (6), the lagged dependent variable L_{it-1} is an explanatory variable. Since a firm's leverage L_{it-1} is a function of the individual firm effects u_i, the lagged dependent variable is correlated with the error term $\alpha(\eta_t + u_i + v_{it})$.[13] As a result, the OLS estimate of $(1 - \alpha)$ will be biased. Specifically, the coefficient on L_{it-1} tends to be overestimated.[14] Thus, the speed of adjustment α will be *underestimated.*

The fixed-effects estimator is also biased. The fixed-effects estimator uses a within-firm transformation to wipe out the individual firm effects u_i. Specifically, the observations are expressed as deviations from their corresponding individual firm means, and then OLS is applied to the transformed data. Although this de-mean transformation removes individual firm effects, it induces a non-negligible correlation between the transformed lagged dependent variable and the transformed error term. Baltagi (2005) shows $(L_{it-1} - \overline{L}_{it-1})$, where $\overline{L}_{it-1} = (\sum_{t=2}^{T} L_{it-1})/(T-1)$, is still correlated with $v_{it} - \overline{v}_{it}$, where $\overline{v}_{it} = (\sum_{t=2}^{T} v_{it})/(T-1)$, even if the v_{it} are not serially correlated. The correlation is because L_{it-1} is correlated with $\overline{v}_{it}$ by construction. The correlation between the transformed lagged dependent variable and the transformed error term is shown to be negative and does not disappear as the number of firms increases (Nickell (1981)). Thus, the fixed-effects estimate for $(1 - \alpha)$ tends to be seriously biased downwards, especially for the short time dimension.[15] The speed of adjustment is

[13]Lemmon, Roberts, and Zender (2005) show the unobserved firm specific effects explain major variation in capital structure.

[14]See Hsiao (2003) for the derivation of the bias in the OLS estimator.

[15]Judson and Owen (1999) show that even for $T = 30$, this bias could be as much as 20% of the true value of the coefficient of interest. This bias increases with the value of the coefficient on the lagged dependent variable and deceases with T. Bond (2002) shows that the bias of the fixed effects estimator can be very severe. A true coefficient of 0.5 can become almost zero when N=500 and T=4.

then *overestimated*.

Since both the OLS and the fixed-effects estimators are biased for the $AR(1)$ panel data model, Arellano and Bond (1991) develop a "differenced GMM" estimator.[16] They first difference the equations to eliminate the individual firm effects, which solves the problem of having correlations between some regressors (e.g., L_{it-1}) and the individual firm effects (u_i), and they then use lagged levels of the series (e.g., L_{it-2}, L_{it-3}, $\cdots$) as instruments for the differenced predetermined or endogenous variables (e.g., $\Delta L_{it-1} = L_{it-1} - L_{it-2}$), which solves the problem of having correlation between the differenced regressors and the differenced disturbance. A critical assumption of the differenced GMM estimator is that the disturbances v_{it} in the levels equations are not serially correlated, which can be tested by testing for negative first-order correlation and zero second-order correlation in the first-differenced residuals. An advantage of the GMM over other techniques is that it can control for both individual heterogeneity and potential endogeneity issues.

However, the lagged levels are often weak instruments for the first difference variables when a series is highly persistent. Particularly, the Arellano-Bond estimator is subject to serious finite sample biases when L_{it} is highly persistent and the number of time series observations is moderately small. The estimate of the coefficient on L_{it-1} will be severely biased downwards when the coefficient is large because the correlation between ΔL_{it-1} and $L_{it-2}, L_{it-3}, \cdots$ drops as the coefficient approaches 1.[17] Arellano and Bover (1995) and Blundell and Bond (1998) develop a "the system GMM" estimator, which adds the levels equations

[16]Davidson and Mackinnon (1993) show that one important feature of the partial adjustment model is that it can be rewritten in many different ways without changing the least squares parameter estimates. The GMM provides consistent estimators for the $AR(1)$ regression model.

[17]See Blundell and Bond (2000) and Ahn and Schmidt (1995), for example.

and the additional moment conditions to the differenced equations. The system GMM uses the contemporaneous first differences (ΔL_{it-1}) of the dependent variables as instruments for equations in the levels and all available lags of variables in the levels ($L_{it-2}, L_{it-3}, \cdots$) as instruments for equations in first differences.[18] The system GMM has been shown to have a much smaller finite sample bias and more efficiency than the differenced GMM because it uses the extra information from the untransformed model.[19]

C. Results

Table IV presents the estimation results of the partial adjustment model, equation (6), using OLS, the fixed-effects panel estimate, the differenced GMM, and the system-GMM.[20] Firm characteristic variables include the market-to-book ratio, operating profitability, size, and tangibility. The GMM results are one-step GMM estimates, with heteroskedasticity-consistent asymptotic standard errors.[21] The firm characteristic variables are assumed to be predetermined.

Table IV reports the estimates of the speed of adjustment for firms in the negative sample. As expected, in the presence of firm-specific effects, OLS appears to give an upward-biased estimate of the coefficient on L_{it-1} ($1 - \alpha = 0.89$), while the fixed-effects estimate appears

[18] Appendix B shows the moment conditions for the system GMM estimators.

[19] Bond (2002) provides a good review of these estimators.

[20] The data starting from year 0 are used to estimate the speed of adjustment after the event. The estimates of constant and year dummies are not presented in the table.

[21] Arellano and Bond (1991) recommend using the one-step GMM results for inference on coefficients. The two-step standard errors tend to be biased downward in small samples. Blundell and Bond (1998) show that inferences based on the one-step GMM asymptotic variance matrix are more reliable than the asymptotically, more-efficient, two-step estimator.

to be biased downwards ($1 - \alpha = 0.43$). The gap between the OLS and the fixed-effects estimates, which are biased in opposite directions, is large. The differenced GMM estimate of ($1-\alpha$) (=0.41) is also biased towards zero, suggesting the possibility of serious finite sample bias.[22] The system GMM estimate, which corrects for the finite sample bias, is between the OLS and the fixed-effects estimates. The test statistics ($m1$ and m2) show that there is a first-order serial correlation and no second-order autocorrelation in the first-differenced residuals, which satisfies the essential assumption for the GMM of no serial correlation in the disturbances v_{it}. The Sargan-Hansen test also reveals that the instruments used in the GMM estimation are valid.

The system GMM estimate of the speed of adjustment is 14% ($1-\alpha = 0.86$) per year for book leverage, implying that about 14% of the discrepancy between the desired and actual leverage levels is eliminated within a year.[23] Assuming a constant speed of adjustment, it indicates that firms will adjust about half of the deviation caused by the shock within 5 years, which is consistent with the pattern observed in the summary statistics. This speed of adjustment is much slower than that estimated by Flannery and Rangan (2006) (34.1% per year). Flannery and Rangan use lagged book leverage as instruments for lagged market leverage to address the bias caused by the correlation between a panel's lagged dependent variable and the error term. As Huang and Ritter (2005) point out, lagged book leverage may not be a valid instrument for lagged market leverage because both are likely to be affected by the same shocks. Huang and Ritter (2005) also find a slow speed of adjustment

[22]The numbers in parentheses are the coefficients for the book leverage ratios.

[23]Although system GMM estimate is close to OLS estimate for this capital structure partial adjustment model, it is not always the case for any dynamic panel data model.

using transformed maximum-likelihood and minimum-distance estimators.[24]

V. The Cumulative Adjustment Model

The partial adjustment model, equation (6), estimates the annual speed of adjustment, assuming a constant annual adjustment. In reality, firms may not make adjustments every year and the speed of adjustment may be different each year. A cumulative adjustment model can estimate the extent to which the leverage changes from the event year are explained by deviations of the event year leverage ratio from the target.

$$L_{it} - L_{i0} = \alpha(L^*_{it} - L_{i0}). \tag{7}$$

where L_{it} is the leverage ratio of firm i at year t, L_{i0} is the leverage ratio of firm i at event year 0, and L^*_{it} is firm i's target leverage; α measures the cumulative speed of adjustment since the event year.

The reduced-form, cumulative adjustment model is then:

$$L_{it} = (1-\alpha)L_{i0} + \alpha L^*_{it} \tag{8}$$

or

$$L_{it} = (1-\alpha)L_{i0} + \alpha\beta X_{it-1} + \alpha\gamma + \epsilon_{it} \tag{9}$$

$$\epsilon_{it} = \alpha(\eta_t + u_i + v_{it})$$

where η_t is time series effects, u_i captures individual firm effects, and v_{it} is disturbance.

[24] A drawback of the maximum-likelihood approach is that the estimates heavily rely on the assumptions made about the distribution of the initial conditions. Different assumptions about the initial conditions will lead to different likelihood functions and possible inconsistent maximum-likelihood estimators if the initial conditions are misspecified. GMM estimates avoid this shortcoming.

Table V presents the estimates of the cumulative speed of adjustment for firms in the negative sample. The OLS estimators are used because the lagged differenced leverage and the previous lagged leverage levels that the system GMM estimators require as instruments are not available. The OLS estimators could be reasonable approximations for the GMM estimates because the OLS estimates are very close to the system GMM estimates, as shown in Table IV. Table V indicates that firms adjust at a speed of 16% for the book leverage ratio one year after a significant drop in leverage. In subsequent years, the speed of adjustment slows down. Firms adjust by 38% of the deviation in 5 years.

VI. Robustness

A. Alternative Target Proxies

In equation (6), the leverage target is predicted by firm characteristic variables. Since the trade-off theory does not explicitly specify the target leverage ratio, researchers have disagreed about what is a good proxy for the target. Commonly used proxies include the industry median debt ratio as in Hovakimian (2004); the fitted values from the estimates of equation (5), and the historical 3-year average of leverage for each firm as in Marsh (1982) and Shyam-Sunder and Myers (1999). In Table VI regression (1), the industry median debt ratio is used as a proxy for the leverage target to estimate equation (4).[25] In regression (2), a two-step procedure is used. In the first step, the fitted leverage value is estimated from equation (5) and in the second step, the fitted value is used as a proxy for the leverage

[25] An industry is defined as firm with the same two-digit SIC code.

target.[26] Both regressions (1) and (2) are estimated using the system GMM.

Table VI shows that with different specifications of the target, the estimated speed of adjustment for firms in the leverage-decreasing sample is still relatively slow. The adjustment speed is between 15% and 18%. The results also show that both the industry median leverage ratio and the fitted values affect the current debt ratio significantly, suggesting that the leverage target affects firms' current capital structures. The significance of the leverage target and the slow speed of adjustment indicate that while most firms have a leverage target, moving back to the target appears to be not of primary importance. This result is consistent with Graham and Harvey (2001)'s survey findings that many firms claim to have a leverage target, but achieving the target is not their major concern.

B. Different Leverage Measures

In the literature, leverage has been defined in many ways. Table VII re-estimates equation (6) using three alternative leverage measures. In regression (1), book debt is defined as current liabilities (COMPUSTAT Annual Item 34) plus long-term debt (Item 9) minus marketable securities (Item 238).[27] Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). In regression (2), leverage is defined as current liabilities plus long-term debt divided by total assets. In regression (3), book debt is defined as liabilities (Item 181)

[26]The estimation that uses the historical 3-year average of leverage as a proxy for the leverage target is not reported because this variable includes L_{t-1}, which will causes collinearity between the independent variables. Bearing this bias in mind, the estimated speed of adjustment is also slow.

[27]Marketable securities are deducted because they are applied against debt. This measure gives an overall impression of a firm's debt situation and is commonly used by investment bankers. Cash is not subtracted because it is needed during the normal course of business.

plus preferred stock (Item 10 or Item 56 if Item 10 is missing) minus deferred taxes (Item 35) and convertible debt (Item 79). Book equity is total assets (Item 6) minus book debt. Market leverage is the ratio of corresponding book debt to the market value of assets (Item 25 times Item 199 plus book debt).[28]

The estimated speed of adjustment is still relatively slow (16-19% for book leverage and 14-15% for market leverage) using three alternative leverage measures. Using these leverage measures, firms adjust relatively faster toward the book leverage ratio than toward the market leverage ratio, which is consistent with the fact that the book-based target is the ratio to which firms adhere.[29]

VII. Determinants of the Speed of Adjustment

A. Adjustment Costs

Firms in the negative sample are found to have a slow speed of adjustment. This section examines why these firms revert slowly to the target leverage level. Adjustment costs could be a factor affecting the speed of adjustment.[30] It may be costly for firms to adjust their capital structures because of transaction costs. Firms with low adjustment costs should adjust more

[28] The difference in the number of observations occurs because of the difference in the number of firms that are identified as experiencing a significant decrease in their leverage ratios using different leverage measures.

[29] Graham and Harvey (2001) states that most practitioners do not strictly adhere to market-based debt targets, which would require costly, frequent re-balancings because the market values of debt and equity fluctuate daily.

[30] Lee, Lochhead, Ritter, and Zhao (1996) report that for U.S. firms from 1990 to 1994, the average direct costs of IPOs are 11% of the proceeds and those of seasoned equity offerings (SEOs) are 7.1%. The average direct costs of straight debt issues are 2.2%, which is much smaller than those of equity issues.

quickly. Large firms generally have better access to both debt and equity markets and suffer lower asymmetric information costs because of more publicly available information. Large firms, therefore, are expected to have relatively lower transaction costs and adjust relatively faster toward their leverage target than their small counterparts.

Shelf registration (Securities Exchange Commission Rule 415) allows firms to file a master registration statement of new issues two years in advance, which gives firms an opportunity to sell the registered issues quickly in favorable market conditions.[31] With a registration on the shelf, firms only need to file short statements when they want to sell any of the approved securities during the period. Bhagat, Marr, and Thompson (1985) and Blackwell, Marr, and Spivey (1990) found that issuers pay lower underwriting fees by using shelf registration. Therefore, shelf issuers are expected to adjust relatively faster because of lower adjustment costs.

To test whether large and small firms and firms with and without shelf-registration have different speeds of adjustment, the following model is estimated:

$$L_{it} - L_{it-1} = \alpha_1(L^*_{it} - L_{it-1}) + \alpha_2(L^*_{it} - L_{it-1})D. \tag{10}$$

where D is the dummy variable which is 1 for large firms and 0 for small firms in regression (1) and is 1 for shelf issuers and 0 for non-shelf issuers in regression (2). The differential slope coefficient, α_2, captures the potential difference in the speeds of adjustment for firms with different adjustment costs. Substituting equation (5) yields the reduced-form model:

$$\begin{aligned} L_{it} &= (1-\alpha_1)L_{it-1} - \alpha_2 L_{it-1} \times D + \alpha_1\beta X_{it-1} + \alpha_2\beta X_{it-1} \times D \\ &\quad + \alpha_1\gamma + \alpha_2\gamma \times D + \epsilon_{it} \end{aligned} \tag{11}$$

[31] The securities could be common stocks, debt, or preferred stocks. Firms with a shelf registration can issue securities more easily, and they normally renew the registration all the time.

$$\epsilon_{it} = \alpha_1(\eta_t + u_i + v_{it}) + \alpha_2(\eta_t + u_i + v_{it}) \times D.$$

Table VIII regression (1) reports the impact of firm size on the speed of adjustment.[32] The differential slope coefficients are insignificant, implying that large firms do not appear to adjust at a significantly different speed than small firms. Welch (2004) also shows that large firms are no more likely to readjust their debt ratios than small firms.

Table VIII regression (2) compares the speeds of adjustment for shelf and non-shelf issuers.[33] In terms of book leverage ratio, firms with shelf-registration adjust 9% faster than firms without shelf-registration. In terms of market leverage ratio, the speed of adjustment for shelf issuers is found to be insignificantly different from that for non-shelf issuers.

Overall, the low significant levels of the differential slope coefficients imply that recapitalization costs are not the main factor that impedes an immediate adjustment toward the leverage target, which challenges the adjustment costs based explanations.[34] The observed slow speed of adjustment is not caused by the dominance of firms with high transaction costs

[32] Firms with logarithm of total assets bigger than the median are defined as large firms, otherwise they are small firms. Large firms could also be defined as firms with logarithm of net sales bigger than the median. The results are robust to this alternative measure. The coefficients on $X_{it-1} \times D$, time dummy, and constant are not reported in the table.

[33] Shelf registration data are from Securities Data Company (SDC) database. It includes shelf registration for common stocks, debt and preferred stocks. However, shelf registration data is only available since 1982 when the Securities and Exchange Commission (SEC) first introduced it. This lack of data could possibly bias the estimates. However, Hansen (1986) and Denis (1993) suggest that shelf issuers have lower borrowing costs regardless of the registration method used because it is firm characteristics determine the lower costs. Therefore, using shelf registration indicates that a particular firm has lower adjustment costs.

[34] Graham and Harvey (2001) find that chief financial officers do not care much about transaction costs. Few of them would delay debt issuance or retirement simply because of such costs.

in the negative sample.

B. Firm Characteristics

Firm characteristics also could determine rebalancing behaviour. Among firms that experience more than a 20% decrease in leverage, some may have different speeds of adjustment due to their firm characteristics. That is, some may revert to the target debt ratio more quickly than others. To examine this, for each year following the negative leverage shock, firms in the slow-adjusting sample are ranked according to the changes in their book leverage ratio and assigned to a quintile; the 5-year averages of firm characteristics in each quintile are reported in Table IX. The first quintile consists of firms that greatly reduce their leverage ratios, and the fifth quintile has those that greatly increase their leverage ratios.

An interesting finding is that firms in the first quintile are noticeably "overvalued" so that they keep timing the equity market, resulting in a decline in their already very low level of debt. Instead of trying to move back to the target leverage level, these firms further reduce their book leverage ratios to an average of 9.35% and their market leverage ratios to an average of 7.19%. These firms have the highest market-to-book ratio, the highest stock return, the highest profitability, the most cash, the highest R&D, the highest Z-score, and the highest cash tax rate. They are the smallest firms and pay the lowest dividends. In comparison, firms in the fourth and fifth quintiles do issue debt to adjust toward the target. These firms are relatively larger, less profitable, and have lower market-to-book ratio. Moreover, firms in the third quintile make the smallest changes in their leverage ratios because they are already close to the long-run mean leverage level. They are the largest firms with the lowest market-to-book ratio and R&D.

This analysis of firms in the slow-rebalancing sample reveals that some firms' market values are persistently high enough that they keep taking advantage of the "window of opportunity" offered by a high market-to-book ratio, so they deviate even further away from the target leverage ratio. The opportunistic behaviour of market timing is not a "one shot" deal.[35] For these firms, market-timing opportunities are more important than moving back toward the leverage target. For firms that do not have persistent market timing opportunities, they do adjust quickly toward the target. However, the existence of persistent equity market timers slows the overall estimated speed of adjustment in the sample.

VIII. Conclusions

This paper finds that adjustments of firms experiencing substantial increases and those with decreases in leverage ratios are asymmetric. The positive changes appear to be debt issues that move firms with a below optimal leverage ratio back to their target. After reaching their optimum, these firms just try to maintain the ratio. This adjustment is consistent with the prediction of the trade-off theories. The negative changes appear to be market timing equity issues that move firms away from their target. Subsequently, these firms exhibit slow rebalancing behaviour.

The asymmetric adjustments are not because these firms have different leverage targets; not because they are from different industries. Adjustment costs are also not the main

[35] For example, *Financial Post* (2004) reported that Research in Motion Ltd., the maker of BlackBerry wireless email device, raised US$153.8 million shares in October of 1999 and issued another US$612 million equity at US$102 just one year later. RIM's stock price rose from US$8.88 in February 1999 to above US$100 in October 2000.

reason for a slow adjustment. It is the presence of "window of opportunity" offered by their persistently high market values that delay some firms' rebalancing process. A noteworthy fact is that the opportunistic behaviour of market timing is not a "one shot" deal and failing to recognize this biases the empirical estimate against the trade-off model.

Table I: Summary Statistics for Firm Characteristics and Financing Decisions

This table reports the means and the standard deviations of main variables. Book leverage L is book debt divided by invested capital. Book debt is defined as current liabilities (COMPUSTAT Annual Item 34) plus long-term debt (Item 9). Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). Book debt plus book equity is defined as invested capital. Market leverage $MKTL$ is the ratio of book debt to market value of assets (Item 25 times Item 199 plus book debt). Market-to-book ratio M/B is defined as book debt plus market equity divided by total assets. Dividend and split-adjusted stock return, RET, is, defined as [(Item 199+Item 26)/(Item 27)]/[lag(Item 199)/lag(Item 27)]. $EBITDA/A$ is earnings before interest, taxes, and depreciation (Item 13) divided by total assets (Item 6). $log(S)$ is the logarithm of net sales (Item 12). PPE/A denotes net property, plant and equipment (Item 8) divided by total assets. R&D is research and development expenditure (Item 46, replaced by zero if missing). INV/PPE is capital expenditures (Item 128) normalized by net property, plant and equipment. DIV/E is common dividends (Item 21) divided by book equity. $CASH/A$ is defined as cash and short-term investments (Item 1) divided by total assets. Newly retained earnings $\Delta RE/A$ is defined as the change in retained earnings (Item 36) divided by total assets. Cash tax TAX/S is income tax (Item 16) minus deferred tax (Item 50)) and then divided by sales. Net debt issues d/IC is defined as the change in book debt divided by invested capital. Net equity issues e/IC is the change in book equity minus the change in retained earnings divided by invested capital. All variables except M/B and $log(S)$ are in percentage term.

Panel A: Firms with more than a negative 20% change in leverage

Year	N	L	MKTL	M/B	RET	EBITDA/A	log(S)	PPE/A	R&D	INV/PPE	DIV/E	CASH/A	ΔRE/A	TAX/S	d/IC	e/IC
-1	1745	32.69	29.52	1.13	1.24	14.51	4.82	32.75	2.53	25.72	2.01	9.19	2.23	2.64	5.61	2.04
		(20.18)	(21.21)	(0.78)	(0.60)	(9.28)	(1.40)	(19.52)	(5.31)	(16.04)	(2.76)	(10.78)	(9.14)	(2.91)	(12.81)	(7.94)
0	1745	19.93	15.77	1.34	1.61	17.56	4.96	31.77	2.44	23.29	1.96	11.47	5.64	3.26	-11.97	7.87
		(15.15)	(14.26)	(0.97)	(0.88)	(8.71)	(1.39)	(18.92)	(4.55)	(14.02)	(2.62)	(11.72)	(6.88)	(2.76)	(12.09)	(14.64)
1	1745	21.60	17.85	1.26	1.22	16.83	5.10	31.84	2.48	27.12	2.10	11.02	4.96	3.30	4.43	3.07
		(16.39)	(16.16)	(0.88)	(0.64)	(8.93)	(1.39)	(19.01)	(4.63)	(14.92)	(2.58)	(11.84)	(7.25)	(2.84)	(12.16)	(9.68)
2	1745	23.51	20.09	1.22	1.18	15.55	5.23	32.31	2.46	26.95	2.20	10.58	3.76	2.95	4.36	2.39
		(17.94)	(18.19)	(0.84)	(0.56)	(9.26)	(1.41)	(19.30)	(4.50)	(14.44)	(2.61)	(11.82)	(7.72)	(2.89)	(12.20)	(8.62)
3	1745	25.09	22.00	1.18	1.17	14.85	5.34	32.72	2.51	25.86	2.20	10.56	2.85	2.69	3.64	2.64
		(18.97)	(19.40)	(0.80)	(0.53)	(9.20)	(1.42)	(19.62)	(4.75)	(13.97)	(2.65)	(12.15)	(9.71)	(2.78)	(12.63)	(9.40)
4	1745	26.08	23.18	1.17	1.20	14.42	5.44	32.58	2.49	24.13	2.20	10.48	2.61	2.54	2.63	2.25
		(19.65)	(20.45)	(0.81)	(0.69)	(8.89)	(1.43)	(19.58)	(4.59)	(13.34)	(2.66)	(12.19)	(8.79)	(2.78)	(12.04)	(8.75)
5	1745	26.73	23.35	1.16	1.21	13.81	5.52	32.47	2.52	23.76	2.22	10.66	1.77	2.43	1.47	2.54
		(21.23)	(21.15)	(0.78)	(0.75)	(9.36)	(1.45)	(19.85)	(4.60)	(13.51)	(2.79)	(12.26)	(10.01)	(2.76)	(12.63)	(8.97)

Panel B: Firms with more than a positive 20% change in leverage

Year	N	L	MKTL	M/B	RET	EBITDA/A	log(S)	PPE/A	R&D	INV/PPE	DIV/E	CASH/A	ΔRE/A	TAX/S	d/IC	e/IC
-1	1342	20.55	16.01	1.43	1.25	16.72	5.12	32.94	2.07	28.54	2.36	11.06	4.67	3.28	-1.77	9.49
		(14.80)	(14.85)	(1.00)	(0.58)	(8.03)	(1.62)	(18.79)	(4.11)	(16.87)	(2.85)	(12.18)	(7.06)	(2.76)	(10.79)	(18.51)
0	1342	33.90	29.69	1.16	0.97	13.55	5.30	34.24	2.10	29.90	2.36	8.35	2.05	2.61	18.24	1.45
		(18.73)	(20.86)	(0.75)	(0.42)	(8.19)	(1.60)	(19.22)	(4.43)	(15.84)	(2.70)	(10.26)	(8.31)	(2.62)	(12.68)	(8.13)
1	1342	35.41	33.34	1.07	1.09	13.60	5.45	34.76	2.08	24.50	2.28	7.63	2.06	2.20	4.31	2.14
		(18.74)	(22.64)	(0.68)	(0.52)	(7.91)	(1.59)	(19.44)	(4.11)	(13.01)	(2.75)	(9.34)	(8.56)	(2.41)	(11.93)	(8.17)
2	1342	36.01	34.23	1.04	1.17	13.24	5.53	34.61	2.08	21.83	2.27	8.03	1.57	2.06	2.15	1.66
		(19.49)	(22.68)	(0.69)	(0.67)	(8.05)	(1.59)	(19.53)	(4.27)	(12.16)	(2.83)	(9.48)	(7.88)	(2.47)	(11.98)	(7.75)
3	1342	35.93	33.93	1.03	1.22	13.17	5.61	34.52	2.02	21.42	2.25	8.39	1.23	2.00	1.07	2.23
		(19.68)	(22.55)	(0.67)	(0.86)	(7.65)	(1.59)	(19.65)	(3.97)	(12.42)	(2.82)	(10.07)	(8.58)	(2.39)	(12.22)	(8.22)
4	1342	35.73	33.40	1.04	1.20	13.05	5.69	34.69	2.11	21.36	2.19	8.30	1.03	1.94	0.84	1.96
		(20.05)	(22.54)	(0.69)	(0.63)	(8.57)	(1.60)	(19.72)	(4.30)	(12.36)	(2.74)	(10.33)	(8.79)	(2.31)	(11.84)	(7.41)
5	1342	36.06	32.94	1.06	1.23	13.04	5.77	34.37	2.09	21.41	2.22	8.43	1.12	1.97	1.52	2.19
		(21.11)	(22.79)	(0.71)	(0.77)	(8.86)	(1.60)	(19.55)	(4.15)	(12.40)	(2.82)	(10.39)	(9.01)	(2.32)	(12.47)	(8.36)

Table II: Compare Predicted Optimal Book Debt Ratios in the Negative and Positive Samples

This table compares the predicted optimal book debt ratios and the firms actual book debt ratios in the negative and positive samples. The optimal debt ratio is predicted using a two step procedure. In the first step, the leverage determinant regression model is estimated using the full sample.

$$L_t = \gamma + \beta_1 \left(\frac{M}{B}\right)_{t-1} + \beta_2 \left(\frac{EBITDA}{A}\right)_{t-1} + \beta_3 log(S)_{t-1} + \beta_4 \left(\frac{PPE}{A}\right)_{t-1} + v_t.$$

where L_t is leverage ratio at time t; market-to-book ratio, operating profitability, size, and tangibility are previous period firm characteristic variables. In the second step, the means of firm characteristics in the negative and positive sample from the summary statistics are plugged into the estimated model to predict the optimal debt ratios year by year. The actual debt ratios are from the summary statistics.

	Negative		Positive	
Year	Predicted L^*	Actual L	Predicted L^*	Actual L
-1	—	32.69	—	20.55
0	33.61	19.93	31.75	33.90
1	31.32	21.60	35.10	35.41
2	32.31	23.51	35.95	36.01
3	33.39	25.09	36.36	35.93
4	34.20	26.08	36.57	35.73
5	34.56	26.73	36.77	36.06

Table III: Prediction of Significant Change in Leverage using Logit Model

This table reports results of prediction of significant changes in leverage by estimating two logit models.

$$Pr(y=1) = \frac{1}{1+e^{\alpha+\beta X}}.$$

where $y = 1$ if a firm increases its debt ratio by more than 20%, $y = 0$ if the change in debt ratio is less than 20% but more than -20%; and $y = 1$ if a firm decreases its debt ratio by more than 20%, $y = 0$ if the change in debt ratio is more than -20% but less than 20%; and X are pre-event year firm characteristic variables. The odds ratios are reported. Book leverage L is book debt divided by invested capital. Book debt is defined as current liabilities (COMPUSTAT Annual Item 34) plus long-term debt (Item 9). Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). Book debt plus book equity is defined as invested capital. Market-to-book ratio M/B is defined as book debt plus market equity (Item 25×Item 199) divided by total assets. $EBITDA/A$ is earnings before interest, taxes, and depreciation (Item 13) divided by total assets (Item 6). $log(S)$ is the logarithm of net sales (Item 12). PPE/A denotes net property, plant and equipment (Item 8) divided by total assets. R&D is research and development expenditure (Item 46, replaced by zero if missing). INV/PPE is capital expenditures (Item 128) normalized by net property, plant and equipment. $CASH/A$ is defined as cash and short-term investments (Item 1) divided by total assets. $YEAR$ dummy controls for macroeconomic conditions. $INDUSTRY$ dummy controls for industry fixed effects. Absolute value of t-statistics are in bracket. $**$ or $*$ indicate significance at 1% and 5% levels, respectively.

	Positive	Negative
L_{t-1}	0.96***	0.99***
	[24.34]	[10.01]
M/B_{t-1}	0.97	0.77***
	[1.00]	[7.40]
$EBITDA/A_{t-1}$	1.04***	1.04***
	[11.20]	[14.08]
$log(S)_{t-1}$	1.11***	0.95***
	[5.87]	[3.01]
PPE/A_{t-1}	1.00	1.00***
	[0.01]	[3.95]
INV	1.00	1.00***
	[0.09]	[2.87]
$R\&D$	0.97***	1.02***
	[3.90]	[4.80]
$CASH$	0.96***	0.97***
	[14.50]	[13.15]
N	48094	48499
$PseudoR^2$	0.10	0.04

Table IV: The Partial Adjustment Model

This table reports results of partial adjustment model for firms with negative 20% change in leverage.

$$L_{it} = (1-\alpha)L_{it-1} + \alpha\beta X_{it-1} + \alpha\gamma + \epsilon_{it}$$

$$\epsilon_{it} = \alpha(\eta_t + u_i + v_{it}).$$

Book leverage is book debt divided by invested capital. Book debt is defined as current liabilities (COMPUSTAT Annual Item 34) plus long-term debt (Item 9). Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). Book debt plus book equity is defined as invested capital. Market leverage is the ratio of book debt to market value of assets (Item 25×Item 199 plus book debt). Market-to-book ratio is defined as book debt plus market equity divided by total assets. $EBITDA/A$ is earnings before interest, taxes, and depreciation (Item 13) divided by total assets. $log(S)$ is logarithm of net sales (Item 12). PPE/A denotes net property, plant and equipment (Item 8) divided by total assets. η_t is time series effects, u_i captures individual effects, and v_{it} is disturbance. The estimates of constant and year dummies are not reported. Absolute value of t-statistics are in bracket. m1 and m2 are tests for first-order and second-order serial correlation, asymptotically N(0,1). GMM results are one-step estimates. Sargan-Hansen is a test of the overidentifying restrictions for the GMM estimators, asymptotically χ^2. P-values are reported for m1, m2 and Sargan-Hansen test. Absolute value of t-statistics are in bracket. ** or * indicate significance at 1% and 5% levels, respectively.

	Book Leverage				Market Leverage			
	OLS	FE	DIF-GMM	SYS-GMM	OLS	FE	DIF-GMM	SYS-GMM
L_{t-1}	0.89**	0.43**	0.41**	0.86**	0.88**	0.41**	0.35**	0.84**
	[137.04]	[37.37]	[12.55]	[46.20]	[122.50]	[34.27]	[10.96]	[49.72]
M/B_{t-1}	-0.20	-0.08	-0.40	0.37	-0.26	0.16	0.09	0.69*
	[1.40]	[0.37]	[0.92]	[1.15]	[1.70]	[0.66]	[0.25]	[2.35]
$EBITDA/A_{t-1}$	-0.07**	-0.05*	0.08*	-0.04	-0.06**	-0.13**	-0.07	-0.09**
	[4.81]	[2.12]	[2.10]	[1.14]	[3.76]	[5.61]	[1.56]	[2.64]
$log(S)_{t-1}$	0.16*	0.08	-1.39	-0.27	0.08	3.00**	4.02**	0.18
	[2.03]	[0.19]	[1.03]	[0.77]	[1.70]	[6.77]	[2.80]	[0.51]
PPE/A_{t-1}	0.03**	0.14**	0.16*	0.12**	0.02**	0.13**	0.09	0.10**
	[4.55]	[6.61]	[2.26]	[4.99]	[4.15]	[5.97]	[1.13]	[4.30]
N	8725	8725	8725	8725	8725	8725	8725	8725
R^2	0.73	0.24	-	-	0.72	0.25	-	-
$m1$	-	-	0.00	0.00	-	-	0.00	0.00
$m2$	-	-	0.54	0.51	-	-	0.32	0.74
$Sargan-Hansen$	-	-	-	1.00	-	-	-	0.53

Table V: The Cumulative Adjustment Model

This table reports results of cumulative adjustment model using OLS for firms with a negative more than 20% change in leverage.

$$L_{it} = (1-\alpha)L_{i0} + \alpha\beta X_{it-1} + \alpha\gamma + \epsilon_{it}$$

$$\epsilon_{it} = \alpha(\eta_t + u_i + v_{it}).$$

Book leverage is book debt divided by invested capital. Book debt is defined as current liabilities (COMPUSTAT Annual Item 34) plus long-term debt (Item 9). Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). Book debt plus book equity is defined as invested capital. Market leverage is the ratio of book debt to market value of assets (Item 25×Item 199 plus book debt). Market-to-book ratio is defined as book debt plus market equity divided by total assets. $EBITDA/A$ is earnings before interest, taxes, and depreciation (Item 13) divided by total assets. $log(S)$ is logarithm of net sales (Item 12). PPE/A denotes net property, plant and equipment (Item 8) divided by total assets. η_t is time series effects, u_i captures individual effects, and v_{it} is disturbance. The estimates of constant and year dummies are not reported. Absolute value of t-statistics are in bracket. Absolute value of t-statistics are in bracket. $**$ or $*$ indicate significance at 1% and 5% levels, respectively.

	Book	Leverage					Market	Leverage		
Year	1	2	3	4	5	1	2	3	4	5
L_0	0.84**	0.77**	0.68**	0.64**	0.62**	0.84**	0.74**	0.69**	0.68**	0.62**
	[49.80]	[34.21]	[25.98]	[22.79]	[19.90]	[41.60]	[26.33]	[22.09]	[19.97]	[17.18]
M/B_{t-1}	-0.39	-0.30	-0.59	-0.74	-0.37	-0.30	-0.53	-0.84	-0.71	-0.46
	[1.48]	[0.85]	[1.43]	[1.68]	[0.76]	[0.97]	[1.25]	[1.77]	[1.39]	[0.83]
$EBITDA/A_{t-1}$	-0.06*	-0.08*	-0.11*	-0.17**	-0.16**	-0.07*	-0.07	-0.11*	-0.12*	-0.10
	[2.13]	[2.17]	[2.48]	[3.46]	[2.93]	[2.37]	[1.73]	[2.31]	[2.34]	[1.92]
$log(S)_{t-1}$	-0.01	-0.01	-0.07	0.13	0.54	-0.30	-0.18	-0.41	-0.52	-0.08
	[0.04]	[0.04]	[0.24]	[0.44]	[1.61]	[1.61]	[0.72]	[1.40]	[1.66]	[0.24]
PPE/A_{t-1}	0.02	0.04*	0.06**	0.05*	0.05	0.02	0.04*	0.06**	0.06**	0.06*
	[1.74]	[2.33]	[3.03]	[2.02]	[1.90]	[1.21]	[2.00]	[2.73]	[2.69]	[2.52]
N	1745	1745	1745	1745	1745	1745	1745	1745	1745	1745
R^2	0.62	0.43	0.32	0.26	0.22	0.58	0.36	0.30	0.26	0.20

Table VI: Different Proxies for The Target Leverage

This table estimates the speed of adjustment with different proxies for the target leverage using the system GMM.

$$L_{it} = (1-\alpha)L_{it-1} + \alpha L^*_{it}$$

Book leverage is net book debt divided by invested capital. Net book debt is defined as debt in current liabilities (COMPUSTAT Annual Item 34) plus long-term debt (Item 9). Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). Net book debt plus book equity is defined as invested capital. Market leverage is the ratio of book debt to market value of assets (Item 25×Item 199 plus book debt). L_{ind} is industry median leverage. L_{fitted} is the fitted value from estimates of equation (5). L_{ind} is assumed to be exogenous since the industry median leverage is likely not affected directly by shocks affecting individual firms. L_{fitted} is assumed to be predetermined since it is affected by previous individual firm shocks. Market-to-book ratio is defined as net book debt plus market equity divided by total assets. $EBITDA/A$ is earnings before interest, taxes, and depreciation (Item 13) divided by total assets. $log(S)$ is logarithm of net sales (Item 12). PPE/A denotes net property, plant and equipment (Item 8) divided by total assets. The estimates of constant and year dummies are not reported. Absolute value of t-statistics are in bracket. Absolute value of t-statistics are in bracket. $**$ or $*$ indicate significance at 1% and 5% levels, respectively.

	Book	Leverage	Market	Leverage
	(1)	(2)	(1)	(2)
L_{t-1}	0.82**	0.84**	0.85**	0.82**
	[48.12]	[42.00]	[40.94]	[44.65]
$L_{ind,t}$	0.30**		0.26**	
	[15.35]		[12.38]	
$L_{fitted,t}$		0.23**		0.19**
		[3.41]		[4.15]
N	8725	8725	8725	8725
$m1$	0.00	0.00	0.00	0.00
$m2$	0.35	0.45	0.58	0.74
$Sargan - Hansen$	1.00	1.00	0.89	0.94

Table VII: The Partial Adjustment Model using Alternative Leverage Measures

This table reports results of partial adjustment model using different leverage measures.

$$L_{it} = (1-\alpha)L_{it-1} + \alpha\beta X_{it-1} + \alpha\gamma + \epsilon_{it}$$

$$\epsilon_{it} = \alpha(\eta_t + u_i + v_{it}).$$

Book leverage is book debt divided by the sum of book debt and book equity. In regression (1), book debt is defined as debt in current liabilities (COMPUSTAT Annual Item 34) plus long-term debt (Item 9) minus marketable securities (Item 238). Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). In regression (2), leverage is defined as debt in current liabilities (Item 34) plus long-term debt (Item 9) divided by total assets. In regression (3), book debt is defined as liabilities (Item 181) plus preferred stock (Item 10 or Item 56 if Item 10 is missing) minus deferred taxes (Item 35) and convertible debt (Item 79). Book equity is total assets (Item 6) minus book debt. Market leverage is the ratio of corresponding book debt to market value of assets (Item 25×Item 199 plus book debt). Market-to-book ratio is defined as book debt plus market equity divided by total assets. $EBITDA/A$ is earnings before interest, taxes, and depreciation (Item 13) divided by total assets. $log(S)$ is logarithm of net sales (Item 12). PPE/A denotes net property, plant and equipment (Item 8) divided by total assets. η_t is time series effects, u_i captures individual effects, and v_{it} is disturbance. The estimates of constant and year dummies are not reported. Absolute value of t-statistics are in bracket. m1 and m2 are tests for first-order and second-order serial correlation, asymptotically N(0,1). GMM results are one-step estimates. Sargan-Hansen is a test of the overidentifying restrictions for the GMM estimators, asymptotically χ^2. P-values are reported for m1, m2 and Sargan-Hansen test. Absolute value of t-statistics are in bracket. ** or * indicate significance at 1% and 5% levels, respectively.

	Book	Leverage		Market	Leverage	
	(1)	(2)	(3)	(1)	(2)	(3)
L_{t-1}	0.84**	0.84**	0.81**	0.86**	0.85**	0.85**
	[39.31]	[53.23]	[38.36]	[43.49]	[54.40]	[42.11]
M/B_{t-1}	0.50	0.36	-0.28	1.12**	0.64*	0.86**
	[1.35]	[1.42]	[0.92]	[3.36]	[2.30]	[2.58]
$EBITDA/A_{t-1}$	-0.07	-0.01	-0.18**	-0.13**	-0.06*	-0.16**
	[1.92]	[0.24]	[4.63]	[3.46]	[2.01]	[3.87]
$log(S)_{t-1}$	-0.08	-0.30	0.12	0.62	0.05	0.32
	[0.18]	[1.26]	[0.33]	[1.45]	[0.15]	[0.81]
PPE/A_{t-1}	0.13**	0.12**	0.06**	0.10**	0.11**	0.05*
	[4.68]	[6.48]	[2.87]	[3.98]	[4.78]	[2.33]
N	6815	10910	4985	6815	10910	4985
$m1$	0.00	0.00	0.00	0.00	0.00	0.00
$m2$	0.99	0.78	0.15	0.12	0.88	0.02
$Sargan - Hansen$	0.99	1.00	0.97	0.41	0.54	0.75

Table VIII: Partial Adjustment with Adjustment Costs

This table reports results of partial adjustment model using different proxies for adjustment costs.

$$L_{it} = (1-\alpha_1)L_{it-1} - \alpha_2 L_{it-1} \times D + \alpha_1\beta X_{it-1} + \alpha_2\beta X_{it-1} \times D + \alpha_1\gamma + \alpha_2\gamma \times D + \epsilon_{it}$$

$$\epsilon_{it} = \alpha_1(\eta_t + u_i + v_{it}) + \alpha_2(\eta_t + u_i + v_{it}) \times D.$$

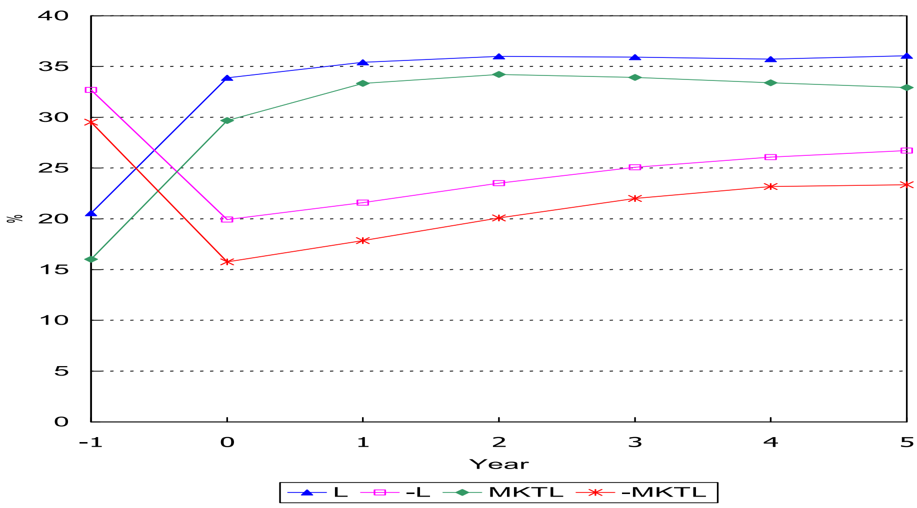
Book leverage is book debt divided by invested capital. Book debt is defined as debt in current liabilities (COMPUSTAT Annual Item 34) plus long-term debt (Item 9). Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). Book debt plus book equity is defined as invested capital. Market leverage is the ratio of corresponding book debt to market value of assets (Item 25×Item 199 plus book debt). Market-to-book ratio is defined as book debt plus market equity divided by total assets. D is represented by $Size$ and $Shelf$, respectively, in the table. $Size$ is a dummy variable that is 1 for large firms and 0 for small firms. $Shelf$ is a dummy variable that is 1 for firms with shelf registration and 0 for firms without shelf registration. $EBITDA/A$ is earnings before interest, taxes, and depreciation (Item 13) divided by total assets. $log(S)$ is logarithm of net sales (Item 12). PPE/A denotes net property, plant and equipment (Item 8) divided by total assets. η_t is time series effects, u_i captures individual effects, and v_{it} is disturbance. The estimates of the coefficients on $X_{it-1} \times D$, constant and year dummies are not reported. Absolute value of t-statistics are in bracket. m1 and m2 are tests for first-order and second-order serial correlation, asymptotically N(0,1). GMM results are one-step estimates. Sargan-Hansen is a test of the overidentifying restrictions for the GMM estimators, asymptotically χ^2. P-values are reported for m1, m2 and Sargan-Hansen test. Absolute value of t-statistics are in bracket. $**$ or $*$ indicate significance at 1% and 5% levels, respectively.

	Book	Leverage	Market	Leverage
	(1)	(2)	(1)	(2)
L_{t-1}	0.84**	0.88**	0.81**	0.85**
	[29.32]	[41.74]	[34.89]	[47.33]
$Size \times L_{t-1}$	-0.01	-	0.05	-
	[0.31]	-	[1.64]	-
$Shelf \times L_{t-1}$	-	-0.09*	-	-0.04
	-	[2.45]	-	[1.25]
M/B_{t-1}	0.53	-0.09	0.46	0.50
	[1.33]	[0.27]	[1.20]	[1.51]
$EBITDA/A_{t-1}$	-0.02	-0.01	-0.08*	-0.07*
	[0.67]	[0.41]	[2.43]	[2.10]
$log(S)_{t-1}$	-0.61	-0.35	0.26	0.33
	[1.16]	[0.99]	[0.51]	[1.05]
PPE/A_{t-1}	0.05*	0.08**	0.06*	0.09**
	[1.97]	[3.67]	[2.16]	[3.73]
N	8725	8725	8725	8725
$m1$	0.00	0.00	0.00	0.00
$m2$	0.48	0.52	0.75	0.74
$Sargan - Hansen$	1.00	1.00	1.00	1.00

Table IX: Characteristics of Firms with Different Adjustment

This table reports the means of characteristic variables for firms with different adjustment in the slow rebalancing sample. In each year after the negative leverage shock, firms are ranked according to changes in book leverage ratio and assigned to a quintile, then the 5-year averages of firm characteristics in each quintile are reported. Book leverage L is book debt divided by invested capital. Book debt is defined as debt in current liabilities (COMPUSTAT Annual Item 34) plus long-term debt (Item 9). Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). Book debt plus book equity is defined as invested capital. Market leverage $MKTL$ is the ratio of book debt to market value of assets (Item 25×Item 199 plus book debt). Market-to-book ratio M/B is defined as book debt plus market equity divided by total assets. Dividend and split-adjusted stock return, RET, is, defined as [(Item 199+Item 26)/(Item 27)]/[lag(Item 199)/lag(Item 27)]. $EBITDA/A$ is earnings before interest, taxes, and depreciation (Item 13) divided by total assets (Item 6). $log(S)$ is the logarithm of net sales (Item 12). PPE/A denotes net property, plant and equipment (Item 8) divided by total assets. R&D is research and development expenditure (Item 46, replaced by zero if missing). INV/PPE is capital expenditures (Item 128) normalized by net property, plant and equipment. DIV/E is common dividends (Item 21) divided by book equity. $CASH/A$ is defined as cash and short-term investments (Item 1) divided by total assets. Newly retained earnings $\Delta RE/A$ is defined as the change in retained earnings (Item 36) divided by total assets. Cash tax TAX/S is income tax (Item 16) minus deferred tax (Item 50)) and then divided by sales. $Z-score$ is defined as $3.3 \times EBIT$ (Item 170+Item 15)/total assets (Item 6)+0.99×net sales (Item 13)/total assets+0.6×market value of equity (Item25×Item 199)/total liabilities (Item 181)+1.2×working capital (Item 179)/total assets+1.4×retained earnings (Item 36)/total assets. Net debt issues d/IC is defined as the change in book debt divided by invested capital. Net equity issues e/IC is the change in book equity minus the change in retained earnings divided by invested capital. All variables except M/B and $log(S)$ are in percentage term.

Quintile	L	MKTL	M/B	RET	EBITDA/A	log(S)	PPE/A	R&D	INV/PPE	DIV/E	CASH/A	ΔRE/A	TAX/S	Z-score	d/IC	e/IC
1	9.35	7.19	1.47	1.40	17.63	5.05	27.92	3.24	26.39	1.70	15.67	6.20	3.45	6.14	-7.95	6.31
2	22.40	19.05	1.17	1.25	17.38	5.43	33.68	2.15	22.45	2.36	10.89	5.08	3.28	4.64	-3.12	2.16
3	32.80	30.17	1.01	1.12	14.49	5.62	35.14	1.89	22.61	2.36	7.85	2.74	2.37	3.72	1.44	1.32
4	35.76	31.49	1.05	1.10	13.38	5.50	35.63	2.05	25.59	2.28	6.75	1.40	2.03	3.51	8.67	1.05
5	30.43	25.24	1.17	1.11	12.67	5.25	31.97	2.66	29.28	2.23	8.49	0.29	2.50	3.79	17.48	1.99



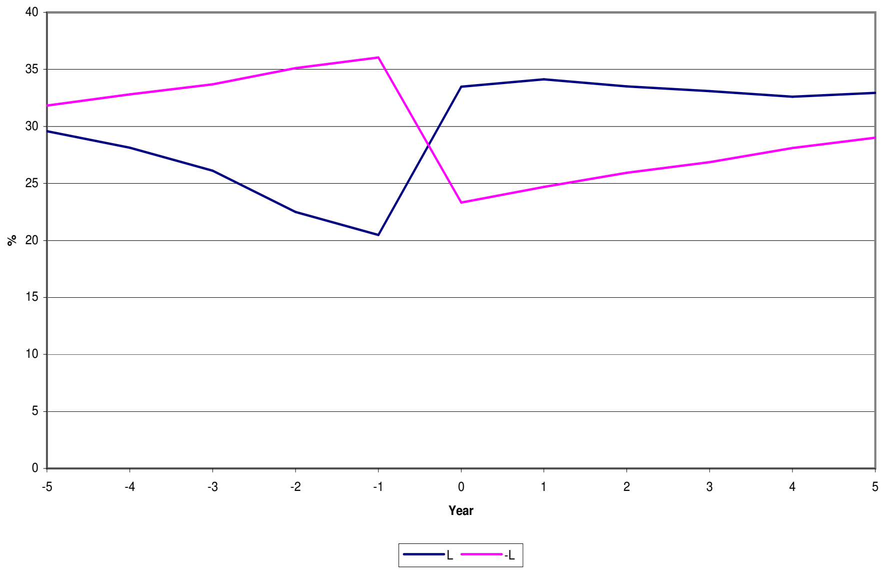


Figure 1: Comparison of Book and Market Leverage Adjustment Patterns. Top: Capital structure adjustment from 1 year before to 5 years after the significant change in leverage ratio. There are 1342 firms in the positive sample and 1745 firms in the negative sample. **Bottom:** Capital structure adjustment from 5 years before to 5 years after the the significant change in leverage ratio. There are 368 firms in the positive sample and 572 firms in the negative sample. L, $-L$ and $MKTL$, $-MKTL$ are book and market leverage of firms experiencing more than 20% increase and decrease in debt ratio, respectively. Book leverage is book debt divided by invested capital. Book debt is defined as debt in current liabilities (Item 34) plus long-term debt (Item 9). Book equity is stockholders' equity (Item 216) plus minority interest (Item 38). Book debt plus book equity is defined as invested capital. Market leverage is the ratio of book debt to market value of assets (Item 25×Item 199 plus book debt).

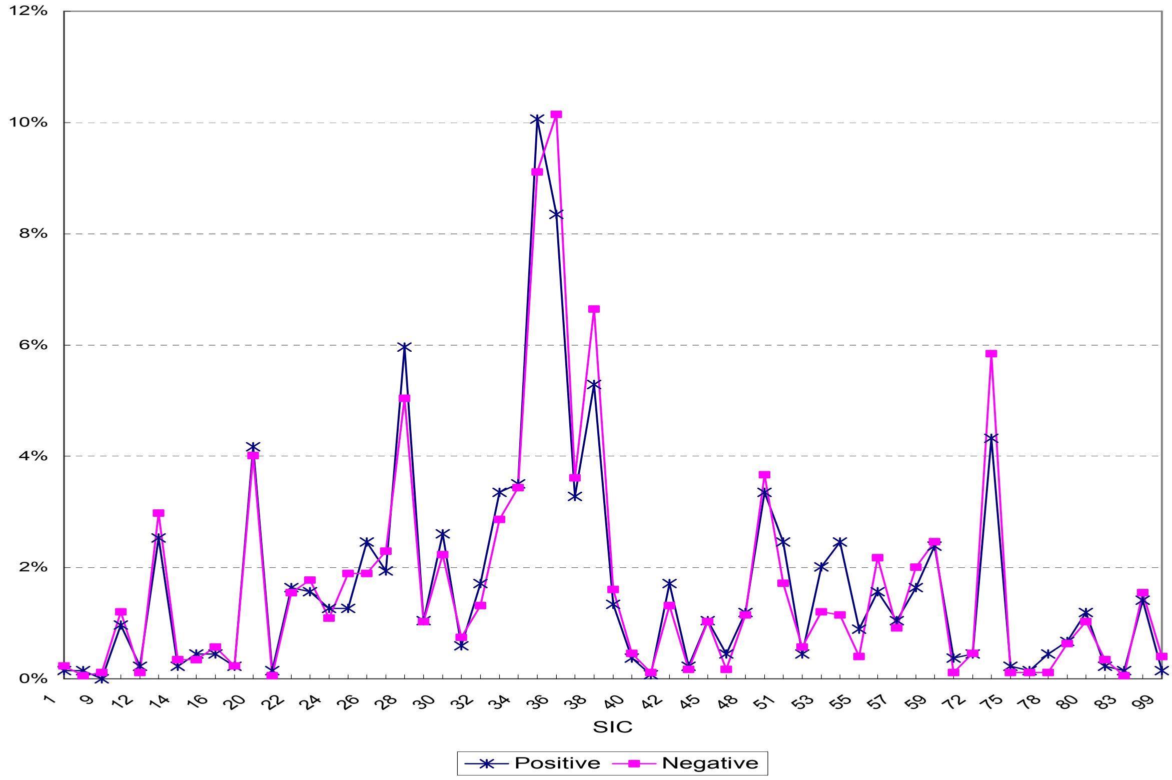


Figure 2: Comparison of Industry Distribution. Positive and Negative give the industry distributions for firms in the positive and negative sample, respectively. The X-axis has two-digit SIC code and the Y-axis has the percentage of firms in each industry.

Appendix A: Definitions of Variables

D(book debt)	Debt in current liabilities (Item 34)+long-term debt (Item 9)
E(book equity)	Shareholder's equity (Item 216)+minority interest (Item 38)
Market equity	Common shares outstanding (Item 25)×share price (Item 199)
IC	Invested capital=book debt+book equity
L	Book leverage=book debt/(book debt+book equity)
M	Market value of assets=book debt+market equity
MKTL	Market leverage=book debt/market value of assets
M/B	Market-to-book ratio=market value of assets/total assets (Item 6)
EBITDA/A	Earnings before interest, taxes, and depreciation (Item 13)/total assets
log(S)	logarithm of net sales (Item 12)
PPE/A	Net property, plant and equipment (Item 8)/total assets
R&D	Research and development expenditure (Item 46, replaced by zero if missing)
INV/PPE	Capital expenditures (Item 128)/PPE
DIV/E	Common dividends (Item 21)/book equity
CASH/A	Cash and short-term investments (Item 1)/total assets
ΔRE/A	Change in retained earnings (Item 36)/total assets
TAX/S	(Income tax (Item 16)-deferred tax (Item 50))/net sales
Z-score	3.3×$EBIT$ (Item 170+Item 15)/total assets +0.99×net sales (Item 12)/total assets +0.6×market value of equity(Item25×Item 199)/total liabilities (Item 181) +1.2×working capital (Item 179)/total assets +1.4×retained earnings (Item 36)/total assets
d/A	Net debt issues=change in book debt/total assets
e/A	Net equity issues=(Δbook equity-Δretained earnings)/total assets
RET	Dividend and split-adjusted stock return=(Item 199+Item 26)/(Item 27) divided by lag(Item 199)/lag(Item 27)

Appendix B: the system GMM estimator

This appendix shows the moment conditions of the system Generalized Method of Moments (GMM) estimator for the partial adjustment model

$$\begin{aligned} L_{it} &= (1-\alpha)L_{it-1} + \alpha\beta X_{it-1} + \alpha\gamma + \epsilon_{it} \\ \epsilon_{it} &= \alpha(\eta_t + u_i + v_{it}) \end{aligned} \tag{B-1}$$

for $i = 1, \cdots, N$ and $t = 2, \cdots, T$, where L_{it} is firm i's leverage ratio at time t, X_{it-1} is a vector of firm characteristics that determine a firm's leverage ratio, η_t is time series effects, u_i captures individual firm effects, and v_{it} is disturbance.

Since the explanatory variable L_{it-1} is correlated with the individual firm effect u_i in the error term, we need to eliminate the individual firm effect and find instrumental variables that correlate with the explanatory variable L_{it-1}, but not with the error term. The first-difference transformation eliminates the individual firm effect u_i from equation (B-1)

$$\begin{aligned} \Delta L_{it} &= (1-\alpha)\Delta L_{it-1} + \alpha\beta\Delta X_{it-1} + \Delta\epsilon_{it} \\ \Delta\epsilon_{it} &= \alpha(\Delta\eta_t + \Delta v_{it}) \end{aligned} \tag{B-2}$$

for $i = 1, \cdots, N$ and $t = 2, \cdots, T$, where $\Delta L_{it} = L_{it} - L_{it-1}$. Though first-differencing eliminates the individual firm effects, it introduces correlation between the explanatory variables and the error term. Therefore, OLS estimator for equation (B-2) is inconsistent since Δv_{it}, as a component of the error term, includes v_{it-1} that correlates with the explanatory variable ΔL_{it-1}. Arellano and Bond (1991) develop a differenced GMM estimator, which uses L_{it-2} and earlier lagged values as instruments for the transformed explanatory variable ΔL_{it-1} under the assumption of no serial correlation of the disturbance v_{it}. For the first-differenced

GMM estimator, with the assumption of predetermined firm characteristic variables X_{it-1}, the moment conditions are

$$E(Z'_{dLi}\Delta\epsilon_i) = 0$$

$$E(Z'_{dXi}\Delta\epsilon_i) = 0$$

where Z_{dLi} is an instrument matrix of the form

$$Z_{dLi} = \begin{bmatrix} L_{i1} & 0 & 0 & \cdots & 0 & \cdots & 0 \\ 0 & L_{i1} & L_{i2} & \cdots & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & L_{i1} & \cdots & L_{iT-2} \end{bmatrix}$$

and Z_{dXi} is an instrument matrix of the form

$$Z_{dXi} = \begin{bmatrix} X_{i1} & 0 & 0 & \cdots & 0 & \cdots & 0 \\ 0 & X_{i1} & X_{i2} & \cdots & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & X_{i1} & \cdots & X_{iT-2} \end{bmatrix}$$

and $\Delta\epsilon_i$ is a vector $(\Delta\epsilon_{i3}, \Delta\epsilon_{i4}, \cdots, \Delta\epsilon_{iT})'$.

However, the lagged levels are often weak instruments for the first difference variables when the series are highly persistent, because the correlation between ΔL_{it-1} and L_{it-2} drops as the coefficient approaches 1. The differenced GMM estimator is therefore subject to serious finite sample biases and less precision in simulation studies. Arellano and Bover (1995) and Blundell and Bond (1998) develop a the system GMM estimator, which adds the levels equations (instrumented using lagged first differences) to the differenced equations (instrumented using lagged levels). For the system GMM estimator, the moment conditions are

$$E(Z'_{Li}\epsilon_i) = 0$$

$$E(Z'_{Xi}\epsilon_i) = 0$$

where Z_{Li} is an instrument matrix of the form

$$Z_{Li} = \begin{bmatrix} Z_{dLi} & 0 & 0 & \cdots & 0 \\ 0 & \Delta L_{i2} & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & \Delta L_{iT-1} \end{bmatrix}$$

and Z_{Xi} is an instrument matrix of the form

$$Z_{Xi} = \begin{bmatrix} Z_{dXi} & 0 & 0 & \cdots & 0 \\ 0 & \Delta X_{i2} & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & \Delta X_{iT-1} \end{bmatrix}$$

and ϵ_i is a vector $(\Delta\epsilon_i, \epsilon_{i3}, \cdots, \Delta\epsilon_{iT})'$.

The consistency of the system GMM depends on the critical assumption of no serial correlation in the disturbance v_{it}, which can be tested by testing for negative first-order correlation and zero second-order correlation in the first-differenced residuals ($m1$ and $m2$ tests). The validity of the instruments can be tested by the Sargan-Hansen test.

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