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Do Firms Rebalance Their Capital Structures?

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ABSTRACT

We empirically examine whether firms engage in a dynamic rebalancing of their capital structures while allowing for costly adjustment. We begin by showing that the presence of adjustment costs has significant implications for corporate financial policy and the interpretation of previous empirical results. After confirming that financing behavior is consistent with the presence of adjustment costs, we find that firms actively rebalance their leverage to stay within an optimal range. Our evidence suggests that the persistent effect of shocks on leverage observed in previous studies is more likely due to adjustment costs than indifference toward capital structure.

A TRADITIONAL VIEW IN CORPORATE FINANCE is that firms strive to maintain an optimal capital structure that balances the costs and benefits associated with varying degrees of financial leverage. When firms are perturbed from this optimum, this view argues that companies respond by rebalancing their leverage back to the optimal level. However, recent empirical evidence has led researchers to question whether firms actually engage in such a dynamic rebalancing of their capital structures.

Fama and French (2002), among others, note that firms' debt ratios adjust slowly toward their targets. That is, firms appear to take a long time to return their leverage to its long-run mean or, loosely speaking, optimal level. Moreover, Baker and Wurgler (2002) document that historical efforts to time equity issuances with high market valuations have a persistent impact on corporate capital structures. This fact leads them to conclude that capital structures are the cumulative outcome of historical market timing efforts, rather than the result of a dynamic optimizing strategy. Finally, Welch (2004) finds that equity price shocks have a long-lasting effect on corporate capital structures as well. He concludes that stock returns are the primary determinant of capital structure changes and that corporate motives for net issuing activity are largely a

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mystery. These findings share the common theme that shocks to corporate capital structures have a persistent effect on leverage, which the last two studies interpret as evidence against firms rebalancing their capital structures toward an optimum.

Most empirical tests, however, implicitly assume that this rebalancing is costless: in the absence of adjustment costs, firms can continuously rebalance their capital structures toward an optimal level of leverage. However, in the presence of such costs, it may be suboptimal to respond immediately to capital structure shocks. If the costs of such adjustments outweigh the benefits, firms will wait to recapitalize, resulting in "extended excursions away from their targets" (Myers (1984)). These periods of financing inactivity, induced by the presence of adjustment costs, have several implications for the dynamic behavior of capital structures and empirical studies seeking to understand corporate financial policy.

The goal of this paper is threefold. First, we explore the implications of costly adjustment for the interpretation of recent studies arguing against rebalancing. Is the persistence that these studies find a consequence of firms failing to rebalance their capital structures in response to various shocks, or a consequence of costly adjustment? Second, we examine whether, empirically, adjustment costs impact the financing decisions of firms. Direct evidence on external financing costs (e.g., Altinkilic and Hansen (2000)) provides several implications for the temporal behavior of financing decisions that we test. Finally, we address the question of whether firms rebalance their capital structures by looking at the motivation behind incremental financing decisions in a framework that accounts for costly adjustment.

We begin by showing that the presence of adjustment costs results in shocks having a persistent effect on leverage, despite active rebalancing behavior by firms. In light of this, we reexamine the conclusions of Baker and Wurgler (2002) and Welch (2004) and find that the persistence revealed by their empirical tests is more likely due to adjustment costs, as opposed to indifference toward capital structure. Specifically, we find that the effect of Baker and Wurgler's key market timing variable on leverage attenuates significantly as adjustment costs decline, illustrating that adjustment costs appear to dictate the speed at which firms respond to leverage shocks. Our nonparametric and duration analyses show that the effect of equity issuances on firms' leverage is erased within two years by debt issuances. Similarly, the effect of large positive (negative) equity shocks on leverage is erased within the two to four years subsequent to the shock by debt issuances (retirements). When we estimate Welch's empirical model using simulated data from a dynamic tradeoff model, we obtain results that are quantitatively and qualitatively similar to his, suggesting that his empirical model has little power to distinguish among alternative theories.

We then show that firms are often inactive with respect to their financial policy, but when they do issue or repurchase debt and equity, they do so in clusters. In almost 75% of our sample's firm-quarter observations, companies neither issue nor repurchase their own securities. However, they are still quite active, issuing or repurchasing securities once a year, on average. Further, when firms do decide to visit the capital markets, they tend to do so in several closely spaced, often consecutive, quarters. This temporal pattern in financing decisions is consistent with the recent empirical evidence of Altinkilic and Hansen (2000), who show that debt and equity issuance costs consist of both a fixed cost and a convex variable cost. This pattern is also consistent with the provisions of SEC rule 10b-18, which restricts the timing and amount of share repurchases on any given day.

Finally, we find that the motivations behind corporate financing decisions are consistent with a dynamic rebalancing of leverage. Specifically, we find that firms are significantly more likely to increase (decrease) leverage if their leverage is relatively low (high), if their leverage has been decreasing (accumulating), or if they have recently decreased (increased) their leverage through past financing decisions. Our rebalancing evidence is consistent with elements of both the dynamic tradeoff model of Fischer, Heinkel, and Zechner (1989) and the modified pecking order discussed in Myers and Majluf (1984) and Myers (1984). Our finding of a significant response to both low or decreasing leverage and high or increasing leverage is consistent with the existence of a target range for leverage, as in the dynamic tradeoff model. However, the asymmetric magnitude of this effect is consistent with the dynamic pecking order's prediction that firms are more concerned about excessively high leverage than excessively low leverage. In addition, we find that more profitable firms and firms with greater cash balances are less likely to use external financing, while firms with large anticipated investment expenses are more likely to use external financing. These results suggest that both the bankruptcy costs associated with debt financing and the information asymmetry costs associated with equity financing are important determinants of capital structure decisions. However, more research focused specifically on the predictions of the pecking order is needed in order to distinguish between the modified pecking order and traditional tradeoff theories.

More broadly speaking, our results are also consistent with the survey evidence of Graham and Harvey (2001), who show that 71% of the CFOs in their sample responded to having a target range for their debt-equity ratio and another 10% indicated having a "strict" target debt ratio. Graham and Harvey also show that managers are concerned with the costs and benefits of debt financing (credit ratings, cash flow volatility, and tax shields are "important" or "very important" to almost half of those CFOs surveyed). Finally, our rebalancing result is consistent with previous empirical work that finds mean reversion in leverage using partial adjustment models (e.g., Jalilvand and Harris (1984), Roberts (2001), and Fama and French (2002)). It also explains why the rate at which leverage reverts to its target is often characterized as slow; firms do not rebalance every period and when they do, it is to a target range rather than a specific level. When we estimate a partial adjustment model using simulated data from a tradeoff model with adjustment costs, we obtain reversion rates for the leverage process similar to those reported in previous empirical studies. Hence, shocks to leverage have lasting effects despite active rebalancing.

The remainder of the paper proceeds as follows. Section I discusses the empirical implications of adjustment costs on the dynamics of financing behavior. Section II examines the results of previous studies in light of these implications. Section III motivates our empirical approach and details the model, which addresses the issue of costly adjustment. Section IV discusses our data and sample selection procedure, in addition to presenting summary statistics. Section V presents the estimation results and their implications for adjustment costs and theories of capital structure. Section VI concludes.

I. Implications of Adjustment Costs

Depending on the form of adjustment costs, the implications for leverage dynamics can be significant. Most empirical treatments have implicitly assumed that either financing is costless or the cost function is strictly convex. This assumption generates financing behavior that occurs continuously through time (i.e., every period) and is the motivation behind the partial adjustment model found in many studies.[1] However, in the presence of a fixed or proportional cost, continuous adjustment may no longer be optimal.

The effect of different adjustment costs on the dynamic behavior of optimizing agents has been shown in many contexts, including inventory management (Harrison (1985)), cash management (Miller and Orr (1966)), investment policy (Caballero and Engle (1999)), portfolio selection (Constantinides (1979)), and capital structure (Fischer, Heinkel, and Zechner (1989)). The most apparent effect of adjustment costs is generally periods of inactivity, as agents wait for the benefits of adjustment to become sufficient to offset the costs. For example, in the context of the tradeoff model of Fischer, Heinkel, and Zechner (1989), firms wait until the increased tax benefits offset the debt issuance costs before increasing their leverage.[2] Regardless of the costs and benefits associated with different financing decisions, the resulting size and frequency of external financings depends, in large part, upon the structure of the adjustment cost function.

Figure 1 presents leverage ratios simulated under three different adjustment cost scenarios: a fixed cost (Panel A), a proportional cost (Panel B), and a fixed cost plus a weakly convex cost component (Panel C). The simulations are carried out using a reduced form model of capital structure, which is parameterized to match various moments in the data. The details of the simulation procedure may be found in Appendix A.

Under a fixed cost regime, as in Fischer, Heinkel, and Zechner (1989), the optimal control policy is to make one large adjustment upon reaching a boundary, thereby returning leverage to its initial level (L^*). The intuition for this

[1] See studies by Jalilvand and Harris (1984), Roberts (2001), Roper (2002), and Fama and French (2002) for explicit partial adjustment models. First-order autoregressions also implicitly assume a continuous adjustment process, as they are a reparameterization of partial adjustment models.

[2] A recent paper by Strebulaev (2004) presents another theoretical tradeoff model incorporating adjustment costs that has similar implications.

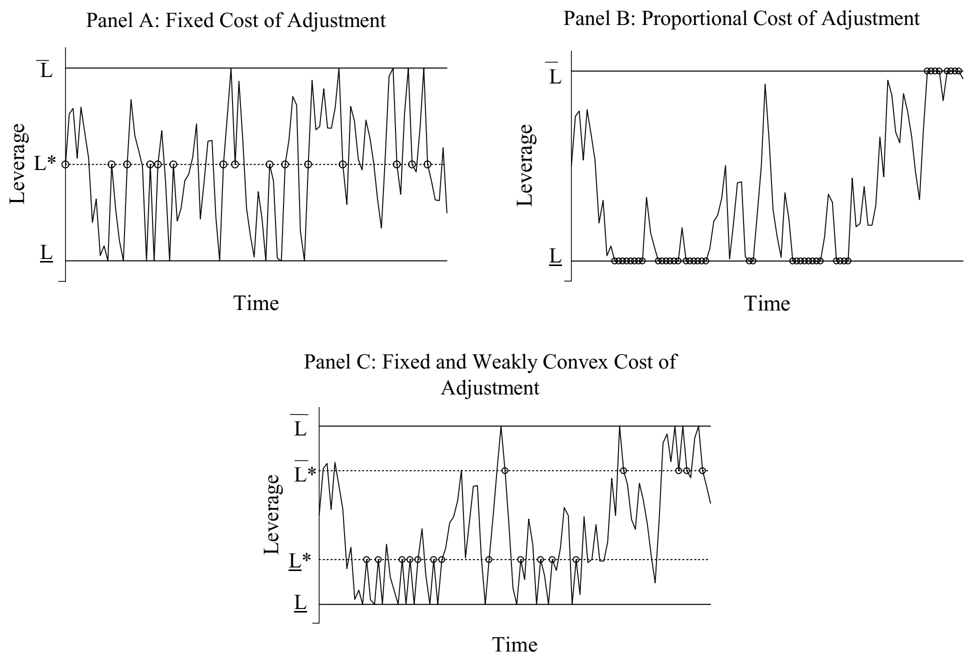

Figure 1. Simulated leverage dynamics under different adjustment cost regimes. The figure presents simulated data under three different adjustment cost scenarios: fixed (Panel A), proportional (Panel B), and fixed plus (weakly) convex (Panel C). The details of the simulations are discussed in Appendix A. Each figure presents an optimal leverage range, defined by lower ($\underline{L}$) and upper ($\bar{L}$) boundaries, in which the firm is inactive with respect to its capital structure. Only when leverage touches (or crosses) a boundary does the firm initiate a recapitalization, the points of which are denoted by the circles. The point to which the firm recapitalizes is dictated by the type of adjustment cost so that a fixed cost results in adjustments that return leverage to the initial value (L^*); a proportional cost results in adjustments that keep leverage at the nearest boundary ($\underline{L}$ or $\bar{L}$); and, a fixed and weakly convex cost function returns leverage to a point in the interior of the optimal leverage range (either $\underline{L}^*$ or $\bar{L}^*$).

policy is that once the benefits from adjustment outweigh the costs, the firm can make as large an adjustment as it desires because the cost and size of the adjustment are independent of one another. The outcome of this policy is illustrated in Panel A. Each time leverage touches a boundary ($\underline{L}$ or $\bar{L}$), the firm issues or retires debt to return leverage to its initial value (L^*). Points of recapitalization are denoted by the circles on the dotted line. The resulting leverage behavior is best described as "lumpy," as firms irregularly make one relatively large adjustment. Thus, the defining characteristics of a fixed cost and the corresponding recapitalization policy is that leverage adjustments are large and occur infrequently.

Panel B presents the results of the optimal control policy under a proportional cost function.[3] This cost structure penalizes each additional dollar so that

[3] Constantinides (1979) implements such a policy in the context of portfolio selection.

cost-minimizing firms respond by making tiny leverage adjustments upon reaching a recapitalization boundary. These small adjustments return leverage to just inside the no-recapitalization region (defined by $\underline{L}$ and $\bar{L}$) and lead to leverage adjustments that are highly clustered in time.

Panel C presents the results for a cost function consisting of both fixed and weakly convex components. The optimal control policy in this case lies between that of the previous two. When leverage reaches a boundary, the size of the adjustment is such that leverage returns to somewhere between the fixed cost optimum and the closest boundary. For example, when leverage hits the upper boundary $\bar{L}$, firms adjust so that leverage returns to $\bar{L}^*$. The fixed cost induces firms to make a large enough adjustment so that the benefit of adjusting overcomes the fixed component of the cost function. However, the convex cost penalizes each additional dollar. Thus, the size and frequency of leverage adjustments fall somewhere in between the two extremes illustrated in Panels A and B.

Figure 1 reveals several implications of adjustment costs that are relevant for the empirical analysis of capital structure. First, the persistence of shocks on the leverage process is insufficient to reject the notion that firms dynamically rebalance their capital structures. Under each cost regime discussed above, shocks to leverage do not induce a response as long as the leverage process remains in the no-recapitalization region. Further, the size of the response need not completely offset the shock, thereby returning leverage to its preshock level. Second, the structure of adjustment costs dictates the size and frequency of adjustments. As adjustment costs transition from fixed (Panel A), to fixed plus convex (Panel C), to proportional (Panel B), we see the size of adjustment decrease and the frequency of adjustment increase. Finally, examination of the temporal or cross-sectional variation in the level of (or change in) leverage can be misleading when it comes to inferring financing behavior. Two otherwise identical firms, both following the same dynamic optimizing strategy, can have different leverage dynamics and debt ratios simply due to different random shocks to their capital structures. In order to understand the motives behind corporate financial policy, we must focus on the determination of the adjustments themselves (i.e., why firms adjust when they do).

II. Recent Empirical Evidence in Light of Adjustment Costs

A. Market Timing

The fact that firms time markets in their security issuance decisions is well documented.[4] However, the contention of Baker and Wurgler (2002) is that equity market timing has an important and lasting impact on corporate capital structure. Specifically, they argue that firms fail to rebalance their leverage after issuing equity in an attempt to time the market. Consequently, capital structure is the cumulative result of attempts to time equity markets and firms

[4] See the introductory discussion in Baker and Wurgler (2002).

are no more or less likely to adjust their leverage in response to these timed equity issuances.[5]

We look more closely at Baker and Wurgler's conclusions by performing a nonparametric analysis of the leverage response of equity issuing firms, as well as examining the impact of introducing adjustment costs into their empirical framework. To do so, we begin by replicating, as closely as possible, the sample of firms from the annual COMPUSTAT files used by Baker and Wurgler.[6]

A.1. Equity Issuers vs. Nonissuers

For each year, we stratify the sample into four portfolios based on the median asset size of the firm (big and small) and the median market-to-book ratio of the firm (high and low), where the market-to-book ratio is defined as the ratio of total assets minus book equity plus market equity all divided by total assets. Within each of these portfolios, the sample is split between those firms that issued equity during the year and those that did not. (Our identification of equity issuances is discussed in detail below.) Holding the firms in these portfolios constant, we track the average difference between the leverage of the issuers and nonissuers over the next five years. To clarify, in 1990, for example, we form four size/market-to-book portfolios based on 1989 end-of-year characteristics. Within each portfolio, we then compute the average difference in leverage between those firms that issued equity in 1990 and those that did not. We follow these same portfolios of firms over the next five years, recomputing the difference in leverage at each point in time. We also present the difference in leverage for the year prior to the issuance. We repeat this exercise for all other years in the sample (1975–1995) and then average across event times (i.e., start of the issue period, end of the issue period, one year after the issue period, etc.). The goal of this exercise is to determine if equity issuers in each of the four portfolios respond to the issuance by subsequently increasing their leverage relative to the nonissuers, which act as a control group.[7]

Panel A of Figure 2 presents the results, which reveal that following the drop at issuance, the leverage of the equity issuers in each portfolio gradually increases relative to the nonissuers. For example, among large firms with low market-to-book ratios, equity issuers have an average leverage that is 6.2% lower than their nonissuing counterparts immediately after the issuance (period zero). Two years later, that difference is reduced to 1%. Within four years

[5] We note that the recent paper by Hennessy and Whited (2005) generates empirical implications similar to those identified by Baker and Wurgler in a framework absent opportunistic behavior.

[6] Specifically, we start with all nonfinancial, nonutility firms listed on COMPUSTAT prior to 2000 and drop firms with missing values for book assets or with a minimum value for book assets of less than $10 million. We verify the similarity of our sample to Baker and Wurgler's by closely reproducing most of their major findings.

[7] We perform this analysis in two ways. First, we control for survivors so that the portfolios are unchanged for the entire period of observation (i.e., before the issuance through the following six years). These results are presented in Figures 2 through 4. Second, we allow firms to drop out of the sample (e.g., due to bankruptcy). The results are similar and, as such, not presented.

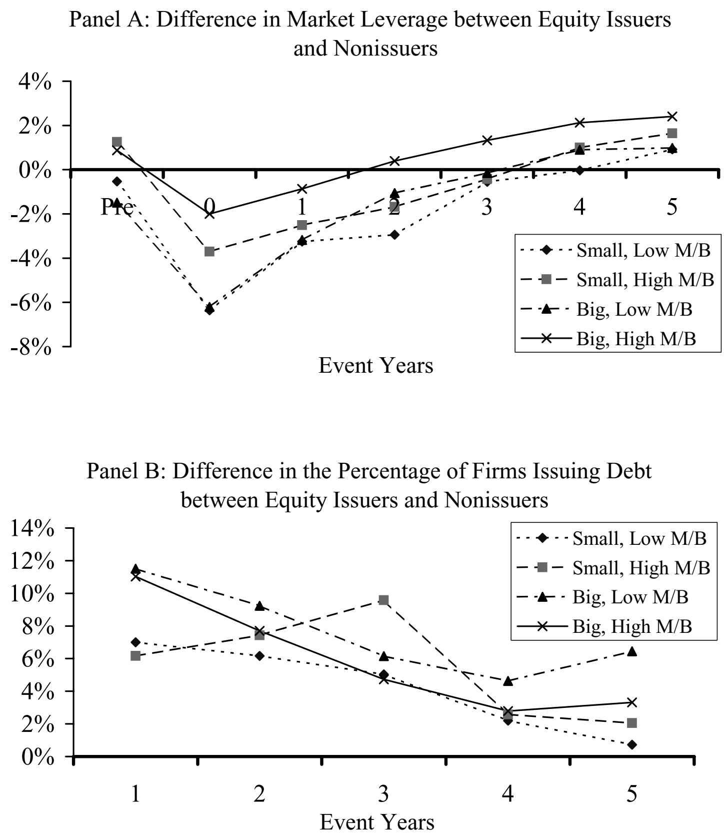

Figure 2. Response to equity issuances. The sample is selected from annual COMPUSTAT data in a manner consistent with Baker and Wurgler (2002). Specifically, we start with all nonfinancial, nonutility firms listed on COMPUSTAT prior to 2000 and drop firms with missing values for book assets or with a minimum value for book assets of less than $10 million. Each year, the entire sample is stratified into four portfolios based on the median asset size (big and small) and median market-to-book ratio (high and low) of the firm. Within each of these portfolios, the sample is split between those firms that issued equity and those that did not. Holding the firms in these portfolios constant, we track the average difference between the market leverage of the issuers and nonissuers over the next 5 years. To clarify, in 1990, for example, we form four size/market-to-book portfolios based on firm characteristics at the end of 1989 and compute the average difference in leverage between those firms that issued equity in 1990 and those that did not within each of the four portfolios. We then follow these same portfolios of firms over the next 5 years (and previous year), recomputing the difference in the leverage at each point in time. We repeat this exercise for each year from 1975 through 1995 and then average across event times (i.e., start of the issue period, end of the issue period, 1 year after the issue period, etc.). These results are presented in Panel A. Panel B presents the difference of the fraction of firms among the equity issuers and nonissuers that subsequently issue debt.

after the issuance, all four groups of equity issuers have rebalanced away any effects of the issuance, relative to their control group of nonissuers. Panel B shows that this increase in leverage among equity issuers is due, at least in part, to debt issuance activity. Panel B compares the fraction of equity issuers, relative to nonissuers, that subsequently issue debt in each year after the equity issuance. The interpretation is that those firms that issue equity are subsequently more likely to issue debt, relative to similar nonissuing counterparts, in the years following the equity issuance.[8] This is precisely what dynamic rebalancing predicts.

Given the rebalancing evidence in Figure 2, we examine whether Baker and Wurgler's market timing variable, the external finance-weighted average market-to-book ratio (*EFWA*), is capturing something other than just historical market timing efforts.[9] We begin by illustrating the intuition of their result in Panel A of Figure 3, which presents a comparison of leverage for firms with high and low *EFWA* (relative to the median). The figure shows that high *EFWA* firms tend to have relatively low leverage for an extended period.

Using an approach inspired by the recent study of Kayhan and Titman (2003), Panels B, C, and D replicate the analysis of Panel A, comparing, respectively, the leverage of groups distinguished by their past equally weighted average market-to-book ratio (high versus low), the number of times per year they have issued equity in the past (many versus few), and the size of past equity issuances (large versus small). As before, we use medians to distinguish between each group. Panel B shows that in general, firms with a high historical average market-to-book tend to have persistently low leverage. However, when we compare the leverage of those firms that have done a lot of equity issuing with those that have not (Panel C), we see a negligible difference in leverage that is eventually erased for all but one of the portfolios. Similarly, comparing firms that issue large and small amounts of equity reveals that differences in leverage are modest and are erased fairly quickly, except for small low market-to-book firms. Thus, the Baker and Wurgler result is not one of unresponsiveness to equity issuances (clear from Figure 2), but rather a natural tendency for firms with high average market-to-book ratios to maintain low levels of leverage.

A.2. Adjustment Costs and Market Timing

We now examine the impact that adjustment costs have on the empirical results of Baker and Wurgler (2002). Their primary analysis consists of cross-sectional regressions of leverage on *EFWA* and several empirical proxies for determinants of capital structure.[10] The statistical (and economic) significance

[8] Note that equity issuing firms may still be more likely to issue equity again relative to their nonissuing counterparts. This outcome is a natural consequence of the clustering of adjustments discussed earlier in the context of Figure 1, and says nothing about whether or not firms are rebalancing. Rather, the relevant comparison is whether equity issuing firms are more likely to issue debt *after* issuing equity than before.

[9] The *EFWA* is defined as

$$\sum_{s=0}^{t-1} \frac{\text{Net Equity Issued}_s + \text{Net Debt Issued}_s}{\sum_{r=0}^{t-1} \text{Net Equity Issued}_r + \text{Net Debt Issued}_r} \cdot \left(\frac{\text{Market Value of Assets}_s}{\text{Book Value of Assets}_s} \right). \tag{A4}$$

[10] The proxies that they include in their regressions are profitability (earnings before interest, taxes, and depreciation divided by total assets), size (log of net sales), asset tangibility (net plant, property, and equipment divided by total assets), and the market-to-book ratio defined above.

of the *EFWA* variable over various horizons is interpreted as evidence that the effect of historical valuations is large and distinct from other determinants of capital structure. Additionally, Baker and Wurgler argue that the effect is also persistent, showing that historical market-to-book variation remains a strong determinant of the cross-sectional variation in leverage ratios even after 10 years have passed.

The discussion in the previous section suggests that persistence in the leverage process is a natural consequence of costly adjustment but this persistence may be mitigated for firms facing lower costs of adjustment. That is, firms with a relatively low cost of adjustment will be more likely to respond to shocks, all else being equal, than firms with high costs of adjustment. Visually, low adjustment cost firms have recapitalization boundaries ($\underline{L}$ and $\bar{L}$ in Figure 1) that are relatively close together.

We can translate this prediction into Baker and Wurgler's empirical framework outlined above by examining the impact of adjustment costs on the *EFWA* coefficient. For firms with high (low) adjustment costs associated with debt

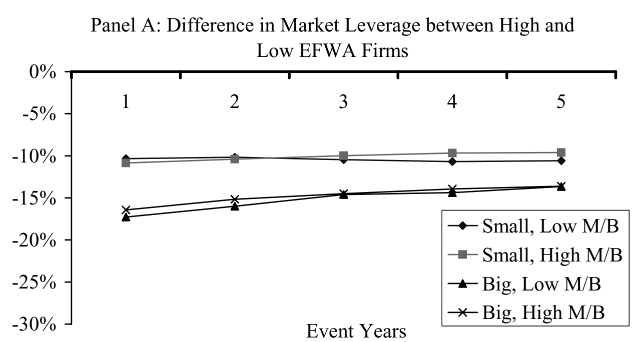

Figure 3. The leverage of high and low *EFWA* firms. The sample is selected from annual COMPUSTAT data in a manner consistent with Baker and Wurgler (2002). Specifically, we start with all nonfinancial, nonutility firms listed on COMPUSTAT prior to 2000 and drop firms with missing values for book assets or with a minimum value for book assets of less than $10 million. Each year, the entire sample is stratified into four portfolios based on the median asset size of the firm (big and small) and the median market-to-book ratio of the firm (high and low). Within each of these four portfolios, the sample is split between those firms with a high and low (above and below median) lagged value for Baker and Wurgler's (2002) external finance-weighted average market-to-book (*EFWA*). Holding firms in the four size/market-to-book portfolios constant, we track the average difference between the market leverage of these two groups within each of the four portfolios over the next four years. To clarify, in 1990, for example, we form four size/market-to-book portfolios based on firm characteristics at the end of 1989 and compute the average difference in leverage between the high and low *EFWA* firms in each of the four portfolios. We then follow these same portfolios of firms over the next four years, recomputing the difference in the leverage at each point in time. We repeat this exercise for each year from 1975 through 1995 and then average across event times. These results are presented in Panel A. Panels B, C, and D replicate the analysis of Panel A, comparing, respectively, the leverage of groups distinguished by the average of their historical market-to-book values (high versus low), the number of times per year they have issued equity in the past (many versus few), and the average size of past equity issuances relative to book assets (large versus small). We use medians to distinguish between groups within each portfolio.

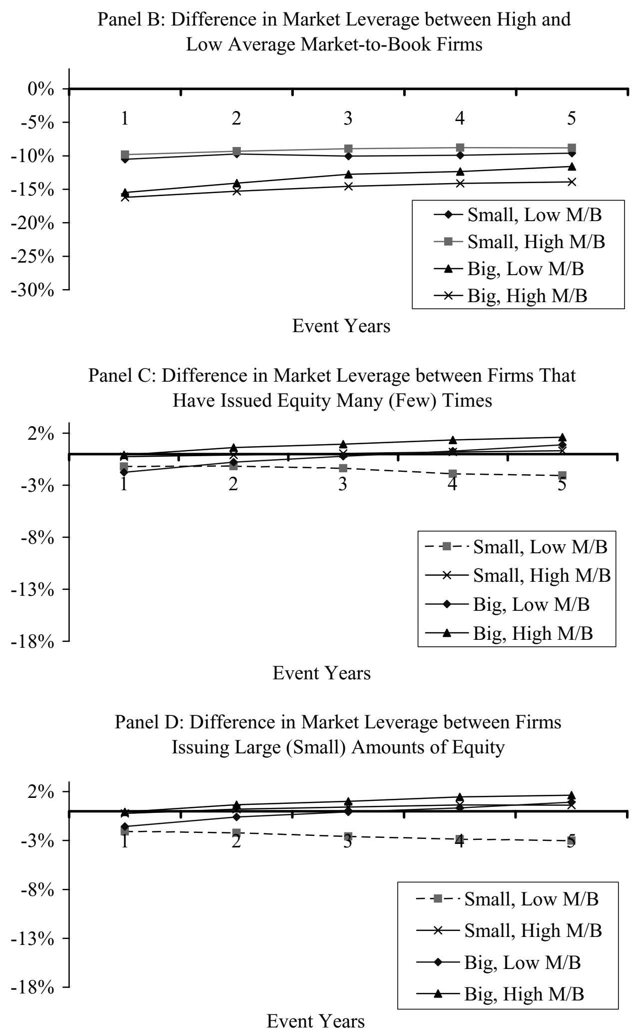

Figure 3. (Continued).

issuances, we would expect the persistence in leverage to be high (low) and, consequently, the magnitude of this coefficient to be large (small). In other words, the coefficient on *EFWA* should attenuate with decreasing debt issuance costs because firms can more easily respond to any decrease in leverage induced by large values of *EFWA*. Panel A of Table I presents our replication of Baker and Wurgler's estimated *EFWA* coefficient (their "All Firms" row of Panel A in Table III). While not identical, the results are similar enough to ensure that we have closely approximated their sample selection and methodology.

We then split their sample into portfolios based on each of three different proxies for the adjustment costs associated with issuing debt: estimated underwriter

Table I
Persistence of Market-to-Book Effects

The sample is selected from annual COMPUSTAT data in a manner consistent with Baker and Wurgler (2002). Specifically, we start with all nonfinancial, nonutility firms listed on COMPUSTAT prior to 2000 and drop firms with missing values for book assets or with a minimum value for book assets of less than $10 million. Panel A presents our replication of Baker and Wurgler's (2002) analysis ("All Firms" row of Panel A in Table III), which is a Fama–MacBeth regression in which a cross-sectional regression is run each year from 1980 through 1999 of book leverage in year t on the year $t-1$ values of the following variables: MA/BA, defined as the ratio of total assets minus book equity plus market equity to total assets; *EFWA*, defined as the weighted average of MA/BA from the first year COMPUSTAT reports market value data for that firm through year $t-1$, where the weights are the proportion of the firm's total external finance (net equity issued plus net debt issued) raised in each year; PPE/A, defined as net property, plant, and equipment divided by assets; EBITDA/A, defined as earnings before interest, taxes, and depreciation divided by assets; and, Size, defined as the log of net sales. Reported coefficients are the time-series average of the estimated cross-sectional coefficients. Panel B presents the results from running the same regression on subsamples determined by adjustment cost proxies: estimated underwriter spread, Altman's Z-score, and debt credit rating. Since the other coefficients are largely unaffected and our focus is on the impact of adjustment costs on the *EFWA* parameter, the other coefficients and t-statistics are suppressed. For the first two proxies, the portfolios are formed using the lower, middle, and upper third of the proxy distribution. For the credit rating proxy, we form the portfolio based on an above or below investment grade credit rating.

Panel A: Replication of Baker and Wurgler (2002) Results

	Intercept		EFWA		MA/BA		PPE/A		EBITDA/A		Size		
	Coeff	t	Coeff	t	Coeff	t	Coeff	t	Coeff	t	Coeff	t	r^2
Full Sample	48.99	36.31	−8.07	−20.96	3.19	4.19	0.03	3.02	−0.58	−10.06	2.64	11.94	0.22

Panel B: Portfolios by Adjustment Costs

		EFWA	
Cost Proxy		Coeff	t
	Low Cost	−5.18	−13.20
Estimated spreads	Med Cost	−7.42	−12.97
	High Cost	−10.04	−16.18
	Low Cost	−5.64	−10.15
Z-score	Med Cost	−8.94	−17.75
	High Cost	−8.15	−6.54
Credit rating	Low Cost	−6.39	−16.34
	High Cost	−9.32	−7.17

spread, credit rating, and Altman's Z-Score. Altinkilic and Hansen (2000) estimate an empirical model of debt underwriter spreads, which we use to generate estimated spreads for Baker and Wurgler's sample of firms.[11] We also use credit ratings as a proxy for debt issuance costs, as suggested by Lee et al. (1996).[12] In a similar spirit, we use Altman's Z-score (1968) though we note that Z-score (and credit ratings) may also capture expected costs of financial distress.[13] For the estimated underwriter spread and Altman's Z-score, the portfolios are formed based on the lower, middle, and upper third of the variable's distribution. For the credit rating proxy, we form two portfolios based on an above or below investment grade credit rating. The same regression from Panel A is then run separately on each portfolio and the results are presented in Panel B.

For each proxy, the magnitude of the *EFWA* coefficient attenuates as the cost of issuing debt decreases. This relation is monotonic in all three cases except for a negligible increase in going from the high cost to the medium cost Z-score portfolio. We conduct paired t-tests, for each cost proxy, of the hypothesis that the coefficients in the high- and low-cost portfolios are the same, against the alternative hypothesis that the coefficient in the low-cost portfolio is lower. For estimated spreads and credit ratings, the differences are statistically significant at the 1% level. For Z-score, the difference is statistically significant at the 5% level. These results show that for firms for which adjustment is relatively inexpensive, leverage is less persistent in the context of Baker and Wurgler's model, a result counter to the implications of market timing but consistent with dynamic rebalancing.[14]

B. Inertia

The inertia theory put forth by Welch (2004) argues that despite fairly active net issuing activity, firms fail to rebalance their capital structures in response to shocks to the market value of their equity, similar to the implication of market timing. Thus, Welch concludes that variation in equity prices is the primary determinant of capital structure and "corporate issuing motives themselves remain largely a mystery (p. 107)."

B.1. The Response to Equity Shocks

Our first examination of Welch's conclusions is very similar to that presented in Figure 2. Using an annual COMPUSTAT sample selected to match the one

[11] For details on the construction of the spread measure, see Section V.A.1.

[12] Faulkender and Petersen (2004) offer a slightly different interpretation of the credit rating variable, but still consistent with the market friction interpretation, as a proxy for access to debt markets.

[13] We modify Altman's Z-score to be defined as the reciprocal of assets divided by the sum of 3.3 times earnings before interest and taxes plus sales plus 1.4 times retained earnings plus 1.2 times working capital. A similar measure is employed in Mackie-Mason (1990) and Graham (1996).

[14] In unreported analysis, we stratify the sample by both adjustment cost proxy and *EFWA* quantiles, in order to control for potential correlation between market timing opportunities and our cost proxies. The results show a similar attenuation in the magnitude of the *EFWA* coefficient within each *EFWA* stratum.

used in Welch (2004), we stratify the sample into four portfolios based on size and market-to-book for each year.[15] "Large" positive and negative equity shocks are then identified as equity returns at least one standard deviation above or below the firm-specific average return.[16] We then compare the average leverage of those firms that experienced a large equity shock to those that did not. This comparison is performed in the year preceding the shock (period "Pre"), the year of the shock (period zero), and the following five years. Panel A of Figure 4 looks at the response to positive shocks; Panel C looks at the response to negative shocks.

Two observations are worth noting. First, leverage noticeably decreases (increases) as a result of the positive (negative) equity shock, suggesting that firms do not respond immediately to the shock. Second, the response to equity shocks is gradual, in the sense that more and more firms respond over the subsequent five years. As time goes by since the equity shock, the leverage of those experiencing the shock approaches the leverage of those that did not (i.e., the control group). These results highlight the gradual response of leverage to equity shocks and the corresponding persistence of leverage, on which the inertia theory is predicated.

However, Panels A and C do show a response, while Panels B and D confirm that the leverage adjustment is the result of firms actively responding via debt policy. Firms that experience a positive shock are more likely to subsequently issue debt (Panel B), while firms that experience a negative shock are more likely to subsequently retire debt (Panel D). Thus, Figure 4 illustrates that firms do indeed respond to equity shocks, although such response appears asymmetric and less pronounced than the response to equity issuances presented above. As we will see below, firms respond to equity shocks only insofar as they effect leverage in a significant manner.

B.2. Adjustment Costs and Inertia

To test his theory, Welch uses ordinary least squares and the Fama–MacBeth (1973) method to estimate the following model of leverage dynamics:

$$\frac{D_{t+k}}{D_{t+k} + E_{t+k}} = \alpha_0 + \alpha_1 \cdot \frac{D_t}{D_t + E_t} + \alpha_2 \cdot \frac{D_t}{D_t + E_t \cdot (1 + r_{t,t+k})} + \varepsilon_{t,t+k}, \quad (1)$$

where D_t is the book value of debt, E_t is the market value of equity, and $r_{t,t+k}$ is the percent price change in the market value of equity between t and $t+k$. The inertia hypothesis predicts that $\alpha_1 = 0$ and $\alpha_2 = 1$, implying that any change in leverage between t and $t+k$ is due to changes in the market value of equity

[15] Specifically, we start with all nonfinancial, nonutility firms listed on both COMPUSTAT and CRSP from 1962 to 2000 and exclude those firm-years for which the market value of equity at the beginning of the year is less than the level of the S&P 500 Index divided by 10 (in $ millions). To ensure that our sample resembles that used by Welch (2004), we closely reproduce a number of his results.

[16] We also examine large equity shocks defined as a 1.5- and 2-standard deviation return. There is little effect on our results.

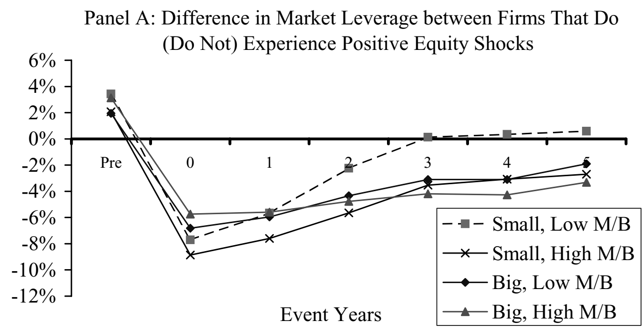

Figure 4. Response to equity shocks. The sample is selected from annual COMPUSTAT data in a manner consistent with Welch (2004). Specifically, we start with all nonfinancial, nonutility firms listed on both COMPUSTAT and CRSP from 1962 to 2000 and exclude those firm-years for which the market value of equity at the beginning of the year is less than the level of the S&P 500 Index divided by 10 (in $ millions). Each year, the entire sample is stratified into four portfolios based on the median asset size (big and small) and median market-to-book ratio (high and low) of the firm. Within each of these portfolios, the sample is split between those firms that experience a positive (negative) equity shock and those that did not, where a shock is defined as an equity return at least one standard deviation above (below) the firm-specific mean. Holding the firms in these portfolios constant, we track the average difference between the market leverage of these two groups within each of the four portfolios over the next 5 years (and previous year). To clarify, in 1990, for example, we form four size/market-to-book portfolios based on firm characteristics at the end of 1989 and compute the average difference in leverage between firms that experience a positive (negative) shock in 1990 and those that did not in each of the four portfolios. We then follow these same portfolios of firms over the next 5 years (and previous year), recomputing the difference in the leverage at each point in time. We repeat this exercise for each year from 1975 through 1995 and then average across event times (i.e., year prior to shock, year of the shock, 1 year after the shock, etc.). The results for positive (negative) shocks are presented in Panel A (C). Panel B presents the difference in the fraction of firms that do (do not) experience a positive equity shock and subsequently issue debt. Panel D presents the difference in the fraction of firms that do (do not) experience a negative equity shock and that subsequently retire debt.

over that period, as opposed to adjustment to the start-of-period leverage ratio. Welch finds that over various time horizons, $\hat{\alpha_2}$ is close to one and dominates any other terms in the regression, including alternative proxy variables (e.g., profitability, marginal tax rate, etc.) used in an expanded specification. Thus, Welch concludes that firms fail to rebalance their capital structures, even over horizons as long as five years.

Table II reproduces Welch's estimation results of equation (1) (Panel B of Table III in his paper), along with four other sets of estimation results obtained using simulated data. The second through fourth sets of results are obtained using the simulated debt and equity data from the reduced form model presented in Figure 1. The last set of results is obtained using data simulated from the structural tradeoff model of Fischer, Heinkel, and Zechner (1989). The details of the simulations and estimation procedure are discussed in Appendix A.

Before commenting on the implications for Welch's empirical model, we briefly note the similarity in results obtained using data simulated from the

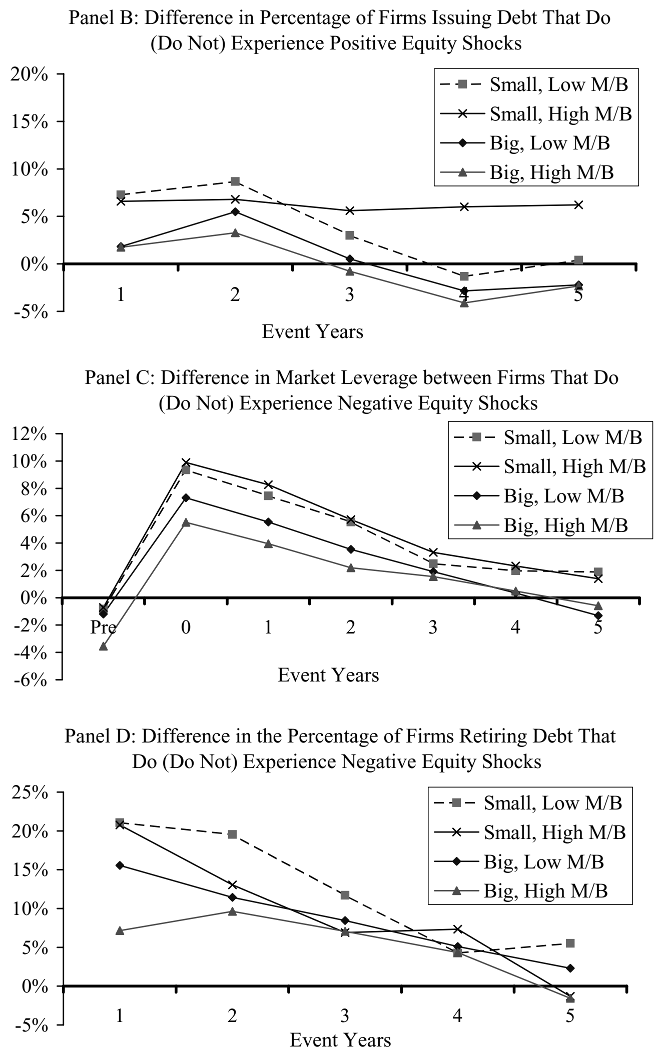

Figure 4. (Continued).

fixed cost reduced form model and those obtained from the Fischer, Heinkel, and Zechner model, which also assumes a fixed cost of adjustment. This similarity is reassuring in that our reduced form model behaves as one might expect.

From a broad perspective, all five sets of results are similar. Each set exhibits α_2 estimates that have a value of approximately 1 for the one-year horizon model and then decline as the horizon increases. Additionally, the intercepts are all relatively similar in magnitude and exhibit a positive association with the model horizon. Finally, all of the R^2 estimates exhibit an inverse relation with the model horizon.

Table II

The Impact of Stock Returns on Leverage

The table presents Fama–MacBeth (1973) estimates of parameters and R^2 from Welch's (2004) empirical model of leverage,

$$\frac{D_{t+k}}{D_{t+k}+E_{t+k}} = \alpha_0 + \alpha_1 \cdot \frac{D_t}{D_t+E_t} + \alpha_2 \cdot \frac{D_t}{D_t+E_t\cdot(1+r_{t,t+k})} + \varepsilon_{t,t+k},$$

where D_t is the firm's debt value, E_t is the firm's equity value, $r_{t,t+k} = (E_{t+k} - E_t)/E_t$ is the equity price appreciation, $\varepsilon_{t,t+k}$ is a random error, and k is the horizon measured in years. The table presents first a reproduction of the results from Panel B of Table 3 in Welch (2004). The second through fourth results use data simulated according to a reduced-form model in which firms rebalance their leverage while facing a fixed cost, a proportional cost, and a fixed plus convex cost of adjustment. The final set of results uses data generated from the dynamic tradeoff model of Fischer, Heinkel, and Zechner (1989). The details of the simulations may be found in Appendix A.

Horizon (k)	α_0	α_1	α_2	R^2
		Welch (2004) Results		
1-year	0.03	−0.05	1.02	0.91
3-year	0.07	−0.04	0.94	0.78
5-year	0.09	−0.01	0.87	0.70
10-year	0.14	0.07	0.71	0.56
		Simulated Data (Fixed plus Convex Cost)		
1-year	0.04	−0.12	1.02	0.98
3-year	0.09	−0.15	0.90	0.94
5-year	0.13	−0.19	0.83	0.89
10-year	0.21	−0.25	0.68	0.78
		Simulated Data (Proportional Cost)		
1-year	0.03	−0.11	1.02	0.99
3-year	0.08	−0.14	0.91	0.95
5-year	0.13	−0.18	0.83	0.92
10-year	0.20	−0.24	0.70	0.82
		Simulated Data (Fixed Cost)		
1-year	0.13	−0.36	1.02	0.78
3-year	0.26	−0.39	0.70	0.56
5-year	0.31	−0.37	0.52	0.43
10-year	0.34	−0.24	0.30	0.25
		Simulated Data from Fischer, Heinkel, and Zechner (1989) (Fixed Cost)		
1-year	0.05	−0.26	1.11	0.52
3-year	0.16	−0.21	0.66	0.32
5-year	0.19	−0.18	0.49	0.23
10-year	0.22	−0.12	0.33	0.15

When we look more closely, however, we can see differences across the results that highlight the effect of different adjustment cost functions on the dynamics of leverage. Across the reduced form simulations (sets two through four), we see a more rapid decline in α_2 estimates and R^2s as we move from proportional costs, to a fixed plus convex cost, to just a fixed cost of adjustment. This pattern is simply a manifestation of the different degrees of persistence underlying the simulated leverage processes. Visually from Figure 1, proportional costs generate the most persistent behavior, followed by a fixed plus convex cost, and finally just a fixed cost, which generates the least amount of persistence.

We also note that the data generated assuming a proportional cost or a fixed and convex cost of adjustment match the results found by Welch (2004) more closely than those generated assuming just a fixed cost of adjustment. This finding hints that firms in COMPUSTAT may be facing one of these two cost functions, a conjecture confirmed by our duration analysis below.

C. Partial Adjustment Models and Slow Adjustment

As noted in the introduction, several studies have commented on the slow adjustment of leverage toward its target.[17] Indeed, Fama and French (2002) characterize the rate of mean reversion in leverage as "a snail's pace." This inference typically comes from the estimation of a partial adjustment model such as

$$\Delta y_t = \alpha + \lambda(y_{t-1} - \mu_{t-1}) + \varepsilon_t, \tag{2}$$

where y is a measure of leverage and μ is the leverage target, itself often a function of other variables. Fama and French estimate λ as -0.10 and -0.16 for dividend payers and nonpayers, implying an annual adjustment of only 10% and 16%, respectively.

While such estimates seem to suggest that firms adjust their leverage slowly, this conclusion is more a result of model misspecification than an accurate description of the adjustment process. Using the simulated data discussed earlier (and in Appendix A), we estimate equation (2) assuming that μ_{t-1} is a constant. Under a proportional, fixed plus convex, and just fixed adjustment cost, the estimated reversion rates are 15%, 17%, and 39% per year, respectively. These estimates are similar to those found in many previous studies and highlight the difficulty in interpreting the rate of reversion in partial adjustment models when adjustments do not occur every period and each adjustment is not to μ.

In sum, the empirical findings of Baker and Wurgler (2002) and Welch (2004) are consistent with firms following a tradeoff strategy with costly adjustment and not necessarily managerial market timing or inertia, respectively. Additionally, the inferences concerning dynamic behavior made from partial adjustment models is suspect when the adjustment process is not continuous. Of course, it remains to be seen if, empirically, adjustment costs do indeed impact financing decisions and, after accounting for the presence of adjustment costs, whether firms dynamically rebalance their capital structures. While the above analysis

[17] While these earlier studies typically focus on reversion to firm-specific targets, MacKay and Phillips (2004) note a similar slow adjustment toward industry medians. However, a recent paper by Flannery and Rangan (2004) argues that adjustment speeds increase once one accounts for expected equity price changes in the target.

is suggestive, we require a more formal setting to adequately address these issues.

III. Duration Analysis

At this point, we turn to the second and third goals of this study: identifying whether adjustment costs impact financing decisions and whether firms dynamically rebalance their capital structures. To do so, we require an empirical framework that can identify the motivation behind financing decisions, while also accounting for costly adjustment. A natural choice is duration analysis, which provides a reduced form model corresponding to the theoretical framework depicted in Figure 1. This section begins by introducing our empirical approach and illustrating the link between the hazard function and adjustment costs. We then develop the duration model and empirical implications of a dynamic rebalancing strategy before turning to the implementation of the model and discussion of the results in subsequent sections.

A. The Hazard Function

We begin by briefly outlining the intuition behind our statistical approach. The discussion here is informal and given in the context of capital structure adjustment. For a more thorough treatment of duration analysis, see Lancaster (1990) or Kalbfleisch and Prentice (2002).

Let T be a random variable measuring the duration or time between capital structure adjustments. The period of financing inactivity between adjustments is referred to as a spell and is analogous to an unemployment spell. The hazard function is defined as

$$h(t) = \lim_{m \to 0} \frac{\Pr(t \leq T < t + m \mid T \geq t)}{m} \tag{3}$$

and specifies the instantaneous rate at which a firm adjusts its capital structure conditional on not having done so for time t. Less formally, $h(t)m$ tells us the probability that a firm will adjust its capital structure in the next m units of time, conditional on not having adjusted up to time t. For example, the hazard function for debt issuances at $t = 4$ tells us the probability that a firm will issue debt during the next quarter ($m = 1$), conditional on not having done so during the last four quarters ($t = 4$). Thus, by modeling the time between issuing (or repurchasing) activities, the hazard function provides a description of the dynamic behavior of financing decisions made by the firm.

The hazard function can offer insight into the structure of adjustment costs faced by firms. Figure 5 presents three estimated hazard functions using the simulated leverage data presented in Figure 1. Under each of the three adjustment cost regimes, we estimate the hazard curve for leverage-increasing adjustments (i.e., adjustments in response to hitting the lower barrier, $\underline{L}$). That is, we model the time between leverage-increasing adjustments. To clearly convey the effect of different adjustment costs on the hazard function, we parameterize $h(t)$

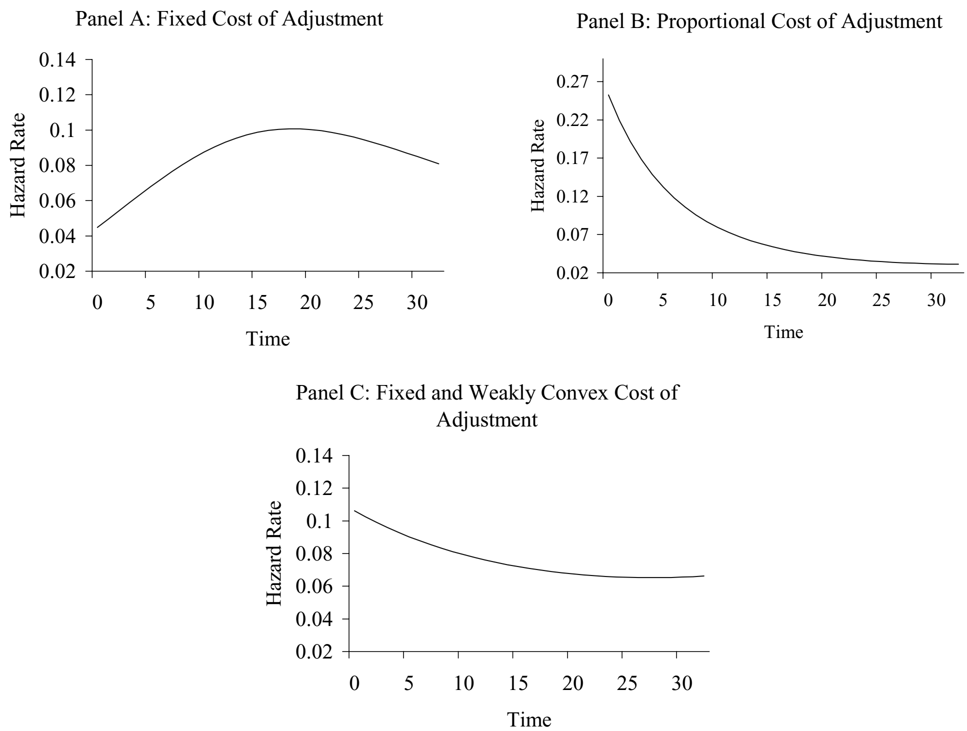

Figure 5. Simulated hazard curves under different adjustment cost regimes. The figure presents hazard curves estimated from simulated data under three different adjustment cost regimes: fixed (Panel A), proportional (Panel B), and fixed plus (weakly) convex (Panel C). The details of the simulations are discussed in Appendix A. The hazard curve for leverage-increasing adjustments is parameterized as a cubic polynomial and estimated via maximum likelihood, assuming that the durations are independent and exponentially distributed. Estimated hazard curves for leverage decreasing adjustments yield similar results.

as a cubic polynomial in t and estimate the parameters using maximum likelihood assuming that durations are independent and exponentially distributed.[18]

Panel A of Figure 5 reveals that under a fixed cost of adjustment, the hazard rate is increasing in time. This suggests that the longer the firm has gone without adjusting its leverage upward, the more likely it is to do so.[19] Panel A of Figure 1 reveals the intuition behind this result. Immediately after a firm increases its leverage, returning it to L^*, the firm is relatively unlikely to strike the lower boundary again anytime soon. As time progresses and the leverage

[18] Estimated hazard curves for leverage-decreasing adjustments are similar.

[19] We note that the hazard curve eventually levels off after 17 periods and then turns slightly downward. However, the number of observations with durations greater than 17 periods is relatively small and decreasing with the duration. Thus, the estimates of the far right tail of the hazard curve can be quite imprecise.

process wanders, the probability that it hits the lower boundary in the near future increases. Thus, large, infrequent adjustments induced by a strictly fixed cost of adjustment result in an upward-sloping hazard curve.

Panel B of Figure 5 reveals that proportional adjustment costs induce a steeply downward-sloping hazard curve, suggesting that as time passes since the last adjustment, the likelihood of making another adjustment declines rapidly. In light of Panel B in Figure 1, proportional adjustment costs lead to tiny adjustments, so that the leverage process is still next to the lower boundary. This proximity suggests that the likelihood of striking the same boundary again is very high. Thus, tiny adjustments induced by a proportional cost result in a steeply downward-sloping hazard curve.

Finally, Panel C of Figure 5 shows that a fixed plus a weakly convex cost of adjustment results in a more moderately downward-sloping hazard curve, relative to a proportional cost. Again, the intuition is found by referring back to Panel C of Figure 1 and recognizing that the moderate adjustments made by firms lead to a higher likelihood of striking the same boundary soon after adjusting. But the probability is significantly less in comparison to that under a proportional cost.

We also mention a few final notes on the relation between the hazard curve and adjustment costs. The general level of the hazard curve reflects the overall frequency of adjustments: the higher the level, the more frequently adjustments occur, suggesting lower costs of adjustment, and vice versa. Unfortunately, the hazard curve in and of itself does not enable us to identify or disentangle the different adjustment costs facing the firm. It merely provides us with a description of the dynamic behavior of corporate financial policy, which we use to infer the adjustment cost structure firms face, as Whited (2003) does in the context of investment. While not a substitute for studies focusing explicitly on the costs of adjusting (e.g., Altinkilic and Hansen (2000)), the hazard curve analysis is complimentary in the sense that it enables us to determine whether direct costs are reflected in the financing decisions of firms.

However, more important than the insight on adjustment costs, the duration model enables us to understand the motivation behind capital structure decisions by modeling the time between those decisions. As such, there is a close relation between duration models and discrete choice models. Therefore, it is not surprising that our results, discussed below, are broadly consistent with those of Hovakimian, Opler, and Titman (2001) who employ discrete choice models in their analysis of capital structure decisions, albeit with annual data. Though, there are a number of advantages of the duration approach taken in this paper that we discuss in the next subsection.

B. A Semiparametric Duration Model

Starting from the definition in equation (3), we parameterize the hazard function of the j^{th} spell for firm i as

$$h_{ij}(t \mid \omega_i) = \omega_i h_0(t) \exp\{x_{ij}(t)'\beta\}, \tag{4}$$

where ω_i is a random variable representing unobserved heterogeneity, $h_0(t)$ is a step function referred to as the baseline hazard, $x_{ij}(t)$ is a vector of covariates, and β is an unknown parameter vector. As in Meyer (1990) and Whited (2003), we assume that the unobserved heterogeneity has a gamma distribution and perform the estimation using maximum likelihood.[20] A detailed derivation of the likelihood function is provided in Appendix B.

Intuitively, ω_i is analogous to an error term in a regression and, similarly, represents the cumulative effect of any omitted covariates. Its presence, along with the covariates, is important in ensuring that the estimated hazard curves are unaffected by unmodeled heterogeneity (see Keifer (1988)). The fact that ω_i is constant across adjustments made by the same firm generates a dependence among financing decisions. This assumption corresponds to the notion that within-firm observations (i.e., financing decisions) are likely to be correlated.

In interpreting our results, we note the following. The baseline hazard is a measure of the hazard function when all covariates are zero. Therefore, all covariates are transformed by subtracting the median value across all firms for each quarter. This transformation enables the baseline hazard to be interpreted as the hazard rate for the median firm in our sample.[21] The specification is analogous to Cox's (1972, 1975) proportional hazard in that variation in the covariates or unobserved heterogeneity results in proportional shifts of the baseline hazard. So, a change in a covariate instantly shifts the hazard curve up or down, depending on the sign of the estimated coefficient. However, this specification restricts the covariates from having any effect on the slope or curvature of the hazard curve. This restriction aids in the tractability of the model and simplifies the interpretation of estimated coefficients. In sum, the model is similar in spirit to a nonlinear dynamic panel regression with firm-specific random effects. It enables us to address the statistical concerns, while accurately testing the hypotheses discussed below.

Though this methodology, perhaps in more restrictive forms, has been used throughout the economics and finance literature, we briefly mention some of the advantages of this model. First, the model is dynamic; we are able to incorporate the complete time path of covariates into the model, rather than averaging covariates over time as in a static discrete choice setting. Second, all of the parameters are estimated simultaneously, thereby avoiding both the inefficiency associated with the two-step estimation procedures used in Hovakimian, Opler, and Titman (2001), Hovakimian (2004), and Korajczyk and Levy (2003), and the introduction of estimation error into the parameter estimates. Finally, the model retains the flexibility of a nonparametric approach by specifying the baseline hazard, $h_0(t)$, as a step function, thereby ensuring that our estimated hazard curves are not artifacts of an assumed functional form.

[20] As a robustness check, we also assume an inverse Gaussian distribution for the unobserved heterogeneity with no effect on our results.

[21] In unreported analysis, we center the covariates around their means and find little difference in the estimation results.

C. Adjustment Cost Proxies

We use several proxies for adjustment costs. The proxies for debt issuance costs (estimated underwriter spreads, Altman's Z-score, and credit ratings) were discussed earlier when we examined the implications of these costs for market timing. Similar to debt issuance costs, we proxy for equity issuance costs using the estimated model of equity underwriter spreads from Altinkilic and Hansen (2000), which we discuss in more detail below.

A recent study by Cook, Krigman, and Leach (2003) shows that most equity repurchase programs adhere to the provisions of SEC Rule 10b-18, which provides a safe harbor for firms against certain charges of stock price manipulation. The Rule imposes restrictions on the timing, price, and amount of shares that firms may repurchase on any given day. Most relevant for our discussion is that nonblock purchases for a day cannot exceed the greater of one round lot and the number of round lots closest to 25% of the security's trading volume. In so far as this restriction is binding, it may be viewed as imposing a significant variable cost since shares purchased in excess of the prescribed limit are in violation of an SEC rule and thus subject to legal action. As such, we use the maximum turnover during the period as a measure of the restrictiveness of the volume provision. Greater turnover implies greater freedom in repurchasing shares and thus lower costs.

Unfortunately, we have little help from past research regarding the cost of debt retirement. This is not to say that early retirement of debt is free of any direct costs. In the case of privately placed debt, early retirement can often incur penalties, renegotiation costs, and other fees.[22] Publicly placed debt retirement faces a different difficulty in the form of illiquid secondary markets (see, for example, the discussion in Chen, Lesmond, and Wei (2003)). While we have no specific proxies for the direct costs of retiring debt, our hope at this point is that our analysis can lend some insight into the form of any costs firms may face. An explicit examination of this issue, however, is beyond the scope of this study.

D. Implications of Dynamic Rebalancing

Using the dynamic rebalancing framework illustrated in Figure 1 as a motivation for the empirical analysis results in three clear predictions concerning financing decisions. The underlying theme of these predictions is that any force that moves leverage closer to a particular recapitalization boundary increases the likelihood of hitting that boundary and, therefore, increases the probability of making a particular adjustment (leverage increase or decrease). Thus, the higher the level of leverage, all else being equal, the more likely that leverage will hit the upper boundary in the next period, and the firm will decrease its leverage. The lower the level of leverage, the more likely that leverage will

[22] We thank Steven Roberts of Toronto Dominion and Rob Ragsdale of First Union for their insight on commercial lending.

hit the lower boundary and the firm will increase its leverage. Simply put, we expect a negative (positive) association between the level of leverage and the probability of a leverage-increasing (decreasing) adjustment.

Similarly, an accumulation (decrease) in leverage should result in a greater likelihood of decreasing (increasing) leverage. Thus, we also expect a negative (positive) association between the change in leverage and the probability of a leverage increasing (decreasing) adjustment.

Finally, past leverage adjustments will also affect the likelihood of adjustment. To illustrate, consider an overlevered firm that strikes the upper recapitalization boundary and issues equity as a result. Assuming that firms face a fixed plus a convex cost of adjustment, for example, the equity issuance will be relatively small in the sense that the level of leverage will still be closer to the upper boundary than the lower boundary after the issuance. As a result, the firm is more likely to issue equity again, relative to issuing debt. However, the implication that we wish to test is whether the firm is more likely to increase its leverage after the equity issuance relative to before the equity issuance. This is the response that must be present in order for firms to rebalance their capital structures after previous financing decisions, since, following our example, the firm's leverage is closer to the lower boundary just after the equity issuance than it was just before. Thus, we expect a positive association between past leverage-increasing (decreasing) decisions and the likelihood of future leverage-decreasing (increasing) decisions.

E. The Costs and Benefits of Debt

Though our focus is on the dynamics of financial decisions, we must also account for the perceived costs and benefits of these decisions. To avoid using information not yet known at the time of the adjustment decision, we lag all covariates ($x_{ij}(t)$ in equation (4)) one quarter except for the ratio of capital expenditures to book assets. We use the one-period future value of this variable in order to capture anticipated financing needs, assuming that firms have a reasonably good idea of those needs over short horizons such as one quarter.

The static tradeoff theory views the costs of debt as corresponding to bankruptcy costs, both direct (e.g., legal fees and administrative costs) and indirect (e.g., customer flight and reputation loss). To proxy for bankruptcy costs, we use several measures suggested by previous studies, such as Titman and Wessels (1988) and Rajan and Zingales (1995): the volatility of cash flows (measured by the absolute value of the change in net income normalized by book assets), product uniqueness (measured as the ratio of selling expenses to total sales), asset tangibility (measured by the fraction of total assets attributable to property, plant, and equipment), and firm size (measured by firm sales in period t divided by the total sales of our sample during period t).[23] The benefits of debt include the tax shield that it provides. We use depreciation and amortization as a fraction of total assets (see DeAngelo and Masulis (1980) and

[23] The normalization is used to correct for the nonstationarity of the sales variable.

Titman and Wessels (1988)) to measure nondebt tax shields that offset the tax benefits of debt financing.

Agency-based models associate the costs of debt with asset substitution (Jensen and Meckling (1976)) and underinvestment (Myers (1977)). Thus, firms with large growth or investment opportunities, as measured by capital expenditures relative to total assets (Titman and Wessels (1988)) and the market-to-book ratio, should be less likely to use debt financing.[24] The benefits of debt in an agency cost framework come from its ability to constrain managerial discretion and mitigate the free cash flow problem (Jensen and Meckling (1976) and Zwiebel (1996)). More profitable firms, measured by after-tax operating income divided by total assets, are thus more likely to use debt financing.

The pecking order provides an alternative interpretation of the profitability variable mentioned above. More profitable firms are less likely to require external financing and, as such, we would expect a negative association between external financing decisions and profitability. Similarly, we would expect a negative association between internal reserves (measured by the ratio of cash and marketable securities to total assets) and external financing decisions. Finally, for completeness, we incorporate several additional variables that have been used in previous studies, such as Lemmon and Zender (2004). To capture any macroeconomic effects (Korajczyk and Levy (2003)), we incorporate year and quarter binary variables into the analysis. Similarly, two-digit SIC code binary variables are included to capture any industry-specific variation in financing choices.

In sum, our control variables represent a fairly comprehensive set of those variables used in previous studies. To avoid potential data errors and minimize the influence of extreme observations, we perform several modifications to the measures mentioned above. First, we trim the upper and lower one percentile of each variable's distribution. Second, we restrict leverage to lie in the unit interval. Finally, we restrict the market-to-book ratio to lie between 0 and 10, as in Baker and Wurgler (2002).[25] All variables, with the exception of the market-to-book ratio and Altman's Z-score, are measured in percentages.

IV. Data, Sample Selection, and Summary Statistics

The data are taken from the combined quarterly research, full coverage, and industrial COMPUSTAT files for the years 1984 to 2001.[26] We also extract return data from the Center for Research in Security Prices (CRSP) monthly stock price file. All regulated (SICs 4900–4999) and financial firms (SICs 6000–6999) are removed from the sample to avoid financial policy governed by regulatory

[24] The market-to-book ratio may also capture the effect of stock prices on a firm's financing decisions. Indeed, Baker and Wurgler (2002) use a weighted average of historical market-to-book ratios as the basis for their market timing hypothesis. In an effort to better isolate the effect of stock price movements on corporate decisions, we also examine the effect of the previous year's equity return.

[25] Using a maximal value for market-to-book of 20 produces no substantive change in our results.

[26] This start date is chosen since our key equity issuance and repurchase variables are not available at a quarterly frequency prior to 1984.

requirements and maintain consistency with earlier studies (e.g., Fama and French (2002), Frank and Goyal (2003), and Korajczyk and Levy (2003)). Any observations with missing data for the book value of assets, stock issuances, stock repurchases, short-term debt, or long-term debt are deleted because these variables are required to determine whether an issuance or repurchase has occurred. Finally, since the emphasis of this study is on dynamic capital structure, we restrict our attention to firms with at least four years of contiguous observations.[27] The final data set is an unbalanced panel containing 127,308 firm-quarter observations: 3,494 firms each with a time series of observations ranging in length from 16 to 71 quarters.[28]

A. Capital Structure Adjustments

To define when a change in capital structure has occurred, we follow the approach used by Hovakimian, Opler, and Titman (2001), Hovakimian (2004), and Korajczyk and Levy (2003). An issuance or repurchase is defined as having occurred in a given quarter if the net change in equity or debt, normalized by the book value of assets at the end of the previous period, is greater than 5%. For example, a firm is defined as having issued debt in quarter t when the change in the total value of debt from quarter $t-1$ to t, divided by the book value of assets at the end of quarter $t-1$, exceeds 5%. We define four basic types of financing "spikes": equity issuances, equity repurchases, debt issuances, and debt retirements, each of which is represented mathematically by a binary variable indicating whether or not a spike has occurred for firm i in period t. With the exception of equity repurchases, all spike definitions use the 5% cutoff. Equity repurchases use a 1.25% cutoff to avoid missing the numerous smaller-sized repurchase programs in place.[29]

While there may be instances of misclassification using this scheme, such as when convertible debt is called or when an equity account is transferred from a subsidiary to a parent, Hovakimian, Opler, and Titman (2001) show that analysis carried out using new debt and equity issue data from SDC produces results similar to analysis using the 5% classification scheme. Korajczyk and Levy (2003) also confirm the accuracy of this classification scheme. We present additional accuracy checks below and note that Whited (2003) uses a similar approach to identify investment decisions. This classification also allows us to capture changes in total debt due to private debt net issuing activity that may not be tracked by the SDC database. As Houston and James (1996) and Bradley and Roberts (2003) show, the majority of corporate debt is comprised of private placements.

In addition to the four basic types of financing spikes, we examine two additional measures of capital structure adjustment that we refer to as

[27] We relax and tighten this restriction to three and five years with no effect on our results.

[28] The maximal time-series length is not 72 (18×4) quarters because of the inclusion of lagged data.

[29] We thank Roni Michaely and Ray Groth for bringing our attention to this issue.

Table III

Capital Structure Adjustment Summary Statistics

The sample consists of quarterly COMPUSTAT data from 1984 to 2001 and is restricted to firms with at least four years of contiguous data and no missing values for equity issuances, equity repurchases, long-term debt, short-term debt, or book assets. Financial firms (SICs 6000–6999) and utilities (SICs 4900–4999) are excluded. The table presents summary information on four basic financing spikes (Debt Issue, Debt Retirement, Equity Issue, Equity Repurchase) and two leverage adjustments (Leverage Increase and Leverage Decrease). The basic financing spikes are defined as a net security issuance or repurchase of at least 5% of book assets. The leverage adjustments are defined as a difference in net debt issued and net equity issued that is greater in magnitude than 5% of book assets. The duration measures the time, in quarters, between financing spikes or leverage adjustments of the same type. Right-censored spells are the number of financing spikes or leverage adjustments with a right-censored duration. There are a total of 127,308 firm-quarter observations and the average firm has approximately 36 quarterly observations.

Adjustment Type	Number of Adjustments	Percent of Periods	Right-Censored Spells	Median Duration	Adjustments per Firm Mean	Min	Median	Max
No Adjustment	92,159	72.39	–	–	–	–	–	–
Debt Issue	16,021	12.58	3,114	3	4.19	0	3	41
Debt Retirement	10,920	8.58	3,087	4	2.80	0	2	23
Equity Issue	6,867	5.39	3,344	5	1.88	0	1	30
Equity Repurchase	5,723	4.50	3,390	3	2.81	0	1	43
Leverage Increase	16,385	12.87	3,122	3	4.23	0	3	41
Leverage Decrease	15,113	11.87	2,977	4	3.73	0	3	27

leverage-increasing decisions and leverage-decreasing decisions (or, more succinctly, as leverage increase and leverage decrease). Since our focus is on corporate decisions that impact leverage, we require measures that can isolate the effect of financial decisions on leverage, while ignoring those financing decisions that have no impact. For example, a firm that issues debt and equity in proportions equal to the firm's previous debt–equity ratio does not affect its leverage, despite the fact that it has undertaken a large amount of net issuing activity. To isolate those decisions that impact leverage, we define a leverage increase as net debt issuance minus net equity issuance, divided by book assets, in excess of 5%. Similarly, we define a leverage decrease as net equity issuance minus net debt issuance, divided by book assets, in excess of 5%. As with the four financing spikes, the mathematical representation of each of these leverage adjustments is a binary variable.

As a robustness check, we also perform all of our analysis using 3% and 7% cutoffs in defining the various financing spikes (0.5% and 3% for equity repurchases). These changes have a negligible effect on our results.

Table III presents summary statistics for each type of adjustment. Perhaps the most striking result is that in 72% of the quarters in our sample no adjustment occurs. That is, a majority of the time firms are inactive with respect to their capital structures. However, since we are examining quarterly data, a 72% inactivity rate implies that firms adjust their capital structures approximately once a year, on average. Thus, financing activity is actually quite frequent but far from continuous. This inactivity is consistent with the presence of adjustment costs, but could also be consistent with the alternative hypothesis that firms are indifferent toward leverage, as market timing or inertia would predict. A more thorough examination of these alternatives is postponed until the formal modeling below.

The most common form of adjustments is debt issuance, which accounts for over 40% of all capital structure adjustments.[30] This is followed by debt retirements (28%), stock issuances (17%), and stock repurchases (14%). On a per firm basis, we see a similar pattern. The average firm has approximately 36 quarters' worth of data and experiences 4.2 debt issuances, 2.8 debt retirements, 1.9 equity issuances, and 2.8 equity repurchases. We also note that there are a significant number (2,219) of joint stock issuance and debt retirement observations, which are captured by the leverage decrease measure but not explicitly reported in the table.

Table III also presents summary information on financing spell durations. The median duration of each type of spell ranges from three quarters for debt issuances to five quarters for equity issuances. However, we refrain from drawing any conclusions from these durations, as they represent unconditional estimates from a heterogeneous sample containing censored durations and are likely quite biased. Because the sample ends in 2001 and some firms drop out of the sample prior to 2001 (e.g., bankruptcy), there are a number of right-censored spells. Right censoring occurs when a spell is still ongoing at the end of a firm's data series. For example, a firm that issues debt in the first quarter of 2000 and then does not issue debt again before the end of the sample period has a right-censored debt issuance spell with a duration of seven quarters. For right-censored spells, we can only place a lower bound on the duration of the spell. The consequence of right censoring is a downward bias in the unconditional duration estimates, which we address in the formal modeling. Because the first spell is measured with respect to the first observed financing spike, there is no left censoring, as well as no IPOs.[31]

The bottom two rows of Table III present summary information concerning leverage adjustments. Firms tend to increase their leverage more often than they decrease it (12.9% compared to 11.9%). If, on average, firms experience a positive drift in their equity values, then leverage has a natural tendency to decline. To counteract this tendency, firms will lever up more often than down if they are rebalancing their debt ratios. Thus, this preliminary evidence suggests that firms counteract the natural tendency of equity values to rise over time.

[30] We note that these issuances are not rollovers of debt, except in the unlikely situation that there is a delay between retirement and issuance that forces the recording of each event to occur in separate quarters.

[31] We also perform all of our analysis on a subsample of firms that have IPO dates in either Security Data Corporations' (SDC) Global New Issue Database or Jay Ritter's IPO database (we thank Andrew Roper for providing these data). The IPO data enable us to establish a time origin for each firm, albeit a public one, independent of the occurrence of the first spell. The results are unchanged from those presented.

Table IV

Capital Structure Adjustment Magnitudes

The sample consists of quarterly COMPUSTAT data from 1984 to 2001 and is restricted to firms with at least four years of contiguous data and no missing values for equity issuances, equity repurchases, long-term debt, short-term debt, or book assets. Financial firms (SICs 6000–6999) and utilities (SICs 4900–4999) are excluded. The table presents summary information on the magnitude of four basic financing spikes: Debt Issue, Debt Retirement, Equity Issue, and Equity Repurchase, each defined as a net security issuance or repurchase of at least 5% of book assets. All dollar values are in millions and inflation adjusted to 2001 dollars using the all urban CPI. The top one percentile of each variable's distribution is trimmed.

		Median	Mean	Std Dev
Debt issue	Issue size	7.81	54.48	147.66
	Book assets	76.33	504.03	1491.57
	Issue size/Book assets	0.10	0.16	0.17
	Issue size/Market capitalization	0.12	0.23	0.33
Debt retirement	Retirement size	6.62	44.42	120.06
	Book assets	66.12	498.93	1534.71
	Retirement size/book assets	0.09	0.13	0.12
	Retirement size/Market capitalization	0.15	0.40	0.83
Equity issue	Issue size	3.55	19.93	42.42
	Book assets	15.14	154.03	597.65
	Issue size/Book assets	0.20	0.41	0.58
	Issue size/Market capitalization	0.09	0.14	0.17
Equity repurchase	Repurchase size	11.20	55.90	112.46
	Book assets	348.22	1661.63	3142.95
	Repurchase size/Book assets	0.03	0.04	0.03
	Repurchase size/Market capitalization	0.02	0.03	0.04

Table IV presents summary statistics on the magnitude of the different types of adjustments. All dollar values are inflation adjusted to 2001 dollars using the All Urban CPI. We focus our discussion of these results on medians because of the large skew in each measure's distribution. Debt issuances and retirements are comparable in magnitude, with median sizes of $7.8 million and $6.6 million, respectively. Median equity issuances are quite small ($3.6 million), while equity repurchases represent the largest adjustment ($11.2 million). Though equity issuances (repurchases) represent the smallest (largest) adjustment in terms of dollar magnitude, they represent the largest (smallest) adjustment in terms of magnitude relative to total assets. Additionally, because of the large number of small firms in our sample, the average and median issuance and retirement figures appear quite small. However, when we look at the subsample of our firms that meet the sample selection criteria of Altinkilic and Hansen (2000), the average and median size of equity issuances, for example, are comparable.

V. Estimation Results

For presentation purposes, we discuss our estimates of equation (4) in two parts. The first part corresponds to the implications of the estimated baseline hazard and adjustment cost proxy coefficients for capital structure adjustment costs. The second part corresponds to the implications of the other estimated covariate parameters for theories of capital structure.[32] Though presented separately, all parameters are estimated simultaneously using maximum likelihood.

A. Baseline Hazards and Adjustment Costs

Estimates of the baseline hazard ($h_0(t)$) are presented in Figure 6. Each panel contains two estimates: the jagged curve corresponds to a step function and the smooth one to a cubic polynomial. Also presented in each panel are the parameter estimates and t-statistics of the estimated cubic polynomial. Each point on the curve(s) may be loosely interpreted as the probability of an adjustment in that period, conditional on no prior adjustment, for the median firm in our sample.

To mitigate the problem of a declining sample size as t increases, we define the width of each step in the baseline hazard function as corresponding to one decile of the duration distribution. The benefit of this approach is that each section of the hazard function has approximately the same number of observations, which permits more reliable statistical inference at longer durations. It also reduces the number of estimated parameters, leading to a more parsimonious model and increased statistical power. The cost of this approach is a decrease in the resolution of the hazard curve, particularly for larger t, where more durations are grouped together. To ensure that our estimated hazard curves are not an artifact of this grouping, we reestimate all of the models assuming a step function where each step width is one quarter. The general features (slope and curvature) of these hazard curves are very similar to those in Figure 6 and, as such, the one-quarter width results are not presented.

A.1. Issuance Costs

We now examine the estimated hazard curves in order to determine if observed issuance decisions are consistent with the behavior implied by the estimated cost functions in Altinkilic and Hansen (2000). These authors document several empirical facts regarding issuance costs, as measured by underwriter spreads. First, equity issuance costs are, on average, 5.38% of the issue proceeds, while debt issuance costs average only 1.09%. This finding implies that equity issuances will occur less frequently than debt issuances, assuming firms minimize costs. Second, equity and debt issuance costs contain both a fixed cost

[32] There is an ancillary parameter of the model associated with the scale of the unobserved heterogeneity distribution, θ. This parameter is statistically significant in all of the estimated models suggesting that unobserved heterogeneity is present. This finding reinforces the importance of accounting for such heterogeneity.

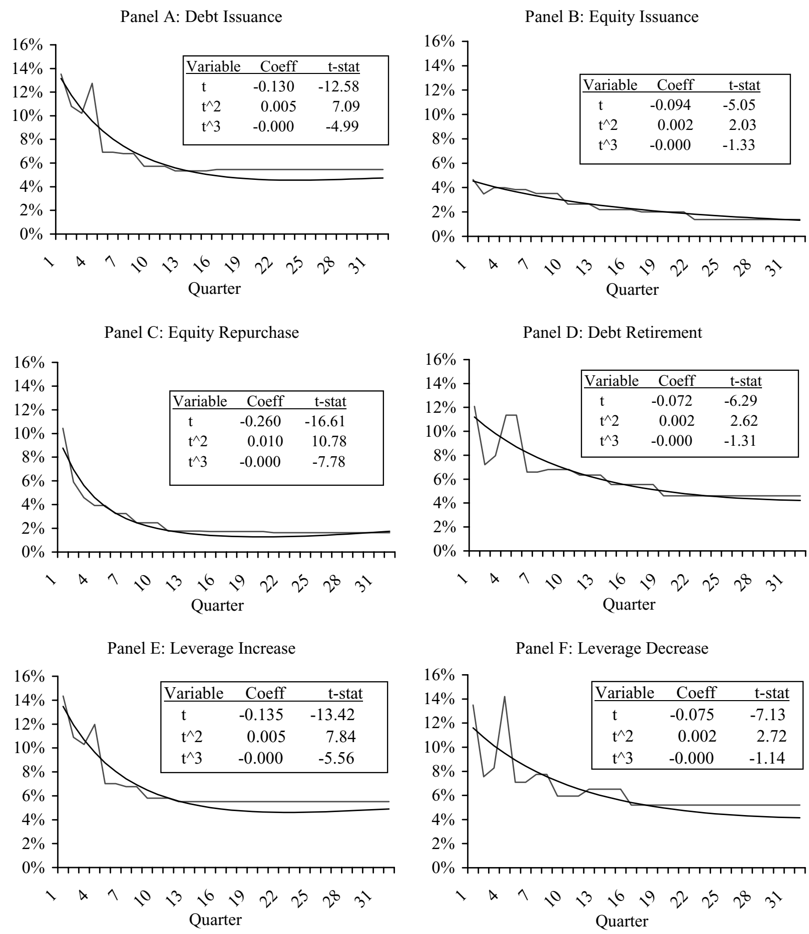

Figure 6. Estimated hazard curves. The sample consists of quarterly COMPUSTAT data from 1984 to 2001 and is restricted to firms with at least 4 years of contiguous data and no missing values for equity issuances, equity repurchases, long-term debt, short-term debt, or book assets. Financial firms (SICs 6000–6999) and utilities (SICs 4900–4999) are excluded. The four basic financing spikes (Debt Issue, Debt Retirement, Equity Issue, Equity Repurchase) are defined as a net security issuance or repurchase of at least 5% of book assets. The two leverage adjustments (Leverage Increase and Leverage Decrease) are defined as a difference in net debt issued and net equity issued that is greater in magnitude than 5% of book assets. The figures present estimates of the baseline hazard curve ($h_0(t)$ in equation (4)). The jagged curve presents the step function estimate. The smooth curve presents the cubic polynomial estimate, the parameters and t-statistics of which are presented in the accompanying boxes.

and convex cost component. This finding implies that the estimated hazard curves should resemble Panel C of Figure 5. Finally, for similar firms, in terms of size and risk, equity issuance costs exhibit relatively higher fixed costs and greater convexity than debt issuances. The greater fixed cost implies that equity issuances will be relatively larger and less frequent, leading to lower and flatter hazard curves. However, the impact of greater convexity on the hazard curve is ambiguous.[33]

Table III shows that debt issuances occur more frequently than equity issuances, a fact that is also captured by the estimated hazard curves. Panels A and B of Figure 6 show that the general level of debt issuances is noticeably higher than that for equity issuances. The debt issuance hazard curve begins at approximately 0.13 and flattens out after approximately five years at just over 0.04. The equity issuance hazard, however, is below 0.04 for all durations. This result is consistent with significantly larger equity issuance costs.

We also see that both hazard curves are downward sloping for all durations. This fact is quantified by the slope coefficients of the cubic approximation presented in the inset boxes. Referring back to Figure 5, this result suggests that the cost structure is best approximated by either a proportional cost, or a fixed and weakly convex issuance cost. Because proportional costs imply minimal issuance sizes (see Panel B of Figure 1), when, in fact, relative issuance sizes are nontrivial (see Table IV), we suspect that the estimated issuance hazard curves best reflect financing behavior in the presence of both a fixed and convex cost. This result is also consistent with the findings of Altinkilic and Hansen.

Turning to Panel B of Table V, we now examine the estimated coefficients on the underwriter spreads in the debt and equity issuance models. Underwriter spreads enter the model by assuming that the relevant spread in any period is the actual spread for the next issuance. That is, we assume that the spread preceding any issuance is just the spread that is ultimately realized.[34] This assumption gives us both the gross proceeds and market capitalization required for computing the spread using the estimated models of Altinkilic and Hansen (2000).[35]

To aid interpretation of the coefficients, Hazard Impacts (HI) are also presented. This measure transforms the coefficient in the following manner:

$$\text{Hazard Impact} = (\exp\{\beta\} - 1) \times 100, \tag{5}$$

and gives the percentage shift in the hazard curve in response to a one-unit change in the corresponding covariate. The debt issuance spread shows a significantly negative association, consistent with adjustment costs inhibiting

[33] On the one hand, increasing the convexity of the cost curve increases the slope of the cost curve, which, all else being equal, would lead to smaller issuances as each dollar issued is penalized more heavily. Simultaneously, the increased convexity results in a cost curve that lies strictly above the existing curve, which has an effect similar to increasing the fixed cost component. That is, issuances will be larger, all else being equal. The net effect is thus ambiguous, requiring a structural model to determine which effect dominates.

[34] This definition creates the problem that censored durations do not have a spread since there is no issuance. Thus, we use the preceding realized spread or the firm-specific average spread for any censored observations. Our results are similar under both assumptions, so we present results for the former.

[35] The estimated equity spread model is found in Table II of Altinkilic and Hansen (2000),

$$\text{Equity Spread} = 4.04 + 25.65(1/\text{Gross Proceeds}) + 2.64(\text{Gross Proceeds}/\text{Market Capitalization}).$$

The estimated debt spread model is found in Table V,

$$\text{Debt Spread} = 0.50 + 25.17(1/\text{Gross Proceeds}) + 4.63(\text{Gross Proceeds}/\text{Market Capitalization}).$$

Table V

Determinants of Financing Decisions

The sample consists of quarterly COMPUSTAT data from 1984 to 2001 and is restricted to firms with at least four years of contiguous data and no missing values for equity issuances, equity repurchases, long-term debt, short-term debt, or book assets. Financial firms (SICs 6000–6999) and utilities (SICs 4900–4999) are excluded. All variables are normalized by total assets and measured at time $t-1$, unless otherwise noted, and are defined as follows: *Size* is the ratio of sales for firm i in quarter t to the sum of sales for all firms in quarter t; *MA/BA* is the ratio of total assets minus book equity plus market equity to total assets; *CapEx* $(t+1)$ is capital expenditures in quarter $t+1$; *Cash* is cash and short-term marketable securities; *DepAmort* is depreciation and amortization; *Tangibility* is the value of tangible assets; *Profitability* is net operating income; *Volatility* is the absolute value of the change in net income; *Z-score* is the sum of 3.3 times earnings before interest and taxes plus sales plus 1.4 times retained earnings plus 1.2 times working capital, all divided by total assets; *Selling Expense* is selling expenses as a fraction of sales; *Equity Return* is the cumulative four-quarter stock return; Δ*Leverage* is the change in leverage; *Leverage* is the ratio of total debt to the sum of total debt and the market value of equity; *LeverDown* is a binary variable equal to one after a leverage decreasing event occurs during a spell; *LeverUp* is a binary variable equal to one after a leverage increasing event occurs during a spell; *Estimated Spreads* represents the estimated underwriter spread for the issuance that ends each spell, calculated using estimated equations for debt and equity issuance spreads from Altinkilic and Hansen (2000). For right-censored spells, this is replaced by the estimated spread for the issuance or repurchase that ended the previous spell; *Turnover* is the maximum daily turnover during the quarter. Binary variables corresponding to years, quarters, and two-digit SIC codes are included in the estimation but not reported. The hazard impact (*HI*) is defined as $100 \times (\exp\{\beta\} - 1)$, where β is the estimated coefficient, and measures the percentage shift in the hazard curve due to a one-unit change in the covariate. Finally, t-statistics are presented in parentheses below the corresponding estimate. Statistical significance at the 1% (5%) level is indicated by two (one) asterisks.

Panel A: Leverage Adjustments

	Leverage Increase		Leverage Decrease	
Coefficient	Estimate	HI (%)	Estimate	HI (%)
Size	−0.0031**	−0.31	−0.0094**	−0.94
	(−2.72)		(−5.03)	
MA/BA	0.0379*	3.87	0.1868**	20.54
	(2.5)		(13.06)	
CapEx $(t+1)$	0.0804**	8.37	0.0021	0.21
	(15.64)		(0.27)	
Cash	−0.0278**	−2.74	−0.0152**	−1.51
	(−17.67)		(−9.85)	
DepAmort	−0.06**	−5.82	0.0417	4.26
	(−2.94)		(1.92)	
Tangibility	−0.0034**	−0.34	−0.0116**	−1.16
	(−3.27)		(−9.27)	
Profitability	−0.0245**	−2.42	−0.0004	−0.04
	(−5.29)		(−0.1)	
Volatility	0.0072	0.72	0.0221**	2.24
	(1.42)		(4.53)	
Z-score	0.0000	0.00	−0.0008**	−0.08
	(0.24)		(−6.6)	
Selling expense	0.0004	0.04	0.0013*	0.13
	(0.62)		(2.01)	
Equity return	0.0004	0.04	0.0023**	0.23
	(1.37)		(8.05)	

(*continued*)

Table V—*Continued*

Panel A: Leverage Adjustments

	Leverage Increase		Leverage Decrease	
Coefficient	Estimate	HI (%)	Estimate	HI (%)
ΔLeverage	−0.0057** (−2.94)	−0.57	0.0057** (2.82)	0.57
Leverage	−0.0076** (−8.83)	−0.76	0.0159** (18.02)	1.60
LeverDown	0.3855** (12.03)	47.03		
LeverUp			0.5023** (12.77)	65.26

Panel B: Basic Financing Spikes

	Debt Issuance		Equity Issuance		Debt Retirement		Equity Repurchase	
Coefficient	Estimate	HI (%)	Estimate	HI (%)	Estimate	HI (%)	Estimate	HI (%)
Size	−0.0079** (−5.64)	−0.79	−0.0358** (−4.62)	−3.52	−0.0073** (−3.55)	−0.73	0.0063** (5.21)	0.63
MA/BA	0.0206 (1.29)	2.08	0.1934** (10.28)	21.33	0.1098** (5.03)	11.61	0.0431 (1.64)	4.40
CapEx (t + 1)	0.0869** (16.83)	9.08	0.0499** (5.08)	5.12	−0.0287** (−2.76)	−2.83	−0.0374* (−2.53)	−3.67
Cash	−0.0359** (−19.93)	−3.52	−0.0161** (−7.1)	−1.59	−0.0204** (−8.97)	−2.02	0.0084** (4.43)	0.84
DepAmort	−0.06** (−2.9)	−5.82	0.0717* (2.09)	7.43	0.0241 (0.88)	2.44	−0.0138 (−0.32)	−1.37
Tangibility	−0.004** (−3.75)	−0.40	−0.0054* (−2.55)	−0.54	−0.0134** (−8.77)	−1.33	0.0032 (1.55)	0.32
Profitability	−0.0313** (−6.82)	−3.08	−0.0265** (−3.7)	−2.62	0.0129* (2.19)	1.30	0.0305* (2.4)	3.10
Volatility	0.0029 (0.56)	0.29	−0.0063 (−0.72)	−0.62	0.0357** (6.13)	3.64	0.0065 (0.51)	0.65
Z-score	−0.0003* (−2.38)	−0.03	−0.0012** (−6.91)	−0.12	−0.0004* (−2.19)	−0.04	0.0015** (3.12)	0.15
Sell Exp	0.0007 (1.16)	0.07	0.0004 (0.48)	0.04	0.0002 (0.21)	0.02	−0.004* (−2.28)	−0.40
Equity return	0.0009** (3.48)	0.09	0.0051** (11.28)	0.52	0.0015** (4.21)	0.15	−0.0014** (−2.59)	−0.14
ΔLeverage	−0.0044* (−2.26)	−0.44	−0.0071 (−1.65)	−0.71	0.0063** (2.79)	0.63	−0.0024 (−0.49)	−0.24
Leverage	−0.0081** (−9.07)	−0.80	0.0020 (1.06)	0.20	0.0181** (17.01)	1.83	−0.018** (−8.95)	−1.78
LeverDown	0.3675** (11.41)	44.41					−0.0177 (−0.34)	−1.76
LeverUp			0.2525** (3.68)	28.73	0.5439** (12.24)	72.28		
Estimated spread	−0.0018** (−2.96)	−0.18	0.0027** (3.23)	0.27				
Turnover							0.0004 (1.43)	0.04

debt issuances, and a hazard impact of 0.18%. Though not presented, credit ratings (measured by an indicator variable for investment grade debt) reveal a negative association with debt issuance, although the sample size is dramatically reduced due to missing data.

Equity issuance costs, though relatively larger than debt issuance costs according to the direct evidence, show a positive association with the likelihood of issuance. This perverse result could be due to the extrapolation of Altinkilic and Hansen's equity underwriter spread estimates outside of their sample, which consists of significantly larger firms. Perhaps the underwriter spread for the smaller firms in our sample is determined by a different process than that estimated by Altinkilic and Hansen.

With the exception of the equity issuance cost proxy, our results concerning issuance decisions appear generally consistent with the implications of the direct evidence on issuance costs. Costs are relatively larger for equity than debt, and both decisions behave as though facing a cost function consisting of both a fixed and convex cost of issuance. Thus, firms tend to issue the same security in clusters, a fact further confirmed in unreported analysis showing that after issuing equity (debt), the probability of issuing equity (debt) in the next period is greater than switching to debt (equity). Of course, this clustering says nothing about the rebalancing behavior of firms, which we investigate below.

A.2. Retirement Costs

Panel C of Figure 6 shows that equity repurchases have a steeply downward-sloping hazard curve, similar to Panel B of Figure 5. This result suggests that equity repurchases are highly clustered in time, particularly relative to other capital structure adjustments. In light of the provisions of Rule 10b-18, this result is not surprising. Firms spread their equity repurchase decisions over the duration of the repurchase program in order to remain in accord with the Rule's provisions.[36] Examination of the estimated turnover coefficient in Panel B of Table V shows evidence consistent with the adjustment cost interpretation, although statistically weak. Specifically, those firms experiencing greater share turnover during the quarter can more easily repurchase a larger fraction of their shares. As a result, these firms are more likely to engage in share repurchases.

The interpretation of the debt retirement hazard is confounded by the natural life cycle of debt securities. That is, the debt retirement decisions of firms may just be a consequence of the maturity structure of their debt. However, given that debt instruments are often retired prior to maturity, there may be relevant costs, as previously discussed. The estimated debt retirement hazard curve in Panel D shows that retirement decisions occur fairly frequently (the high level of the curve) and are clustered in time, but not to the extent of equity repurchases, for example. This dynamic behavior suggests a cost structure similar to that

[36] While Cook, Krigman, and Leach (2003) find that firms do violate the repurchase provisions on occasion, they conclude that "... firms are generally in compliance with the safe harbor guidelines for all repurchasing activity." (p. 291)

of equity issuances, but at a lower overall cost as indicated by the relative frequency of the two actions. Whether this behavior is a consequence of direct costs is left to future research, however.

B. Dynamic Rebalancing

The evidence in support of dynamic rebalancing is quite strong; almost all of the empirical predictions are verified by the estimation results. We begin by examining the impact of market leverage on capital structure adjustments. Focusing on the leverage increase and decrease models in Panel A of Table V, we see that the level of and change in market leverage have a negative (positive) effect on the probability of making a leverage increasing (decreasing) change, even after controlling for other determinants. Firms with high leverage (relative to that implied by the included determinants), or with leverage that has been accumulating, are less likely to increase their leverage and more likely to decrease their leverage. These effects are both highly statistically and economically significant. A 1% increase in the level of leverage shifts down the leverage increase hazard curve by 0.76% and shifts up the leverage decrease hazard curve by 1.60%. Similarly, a 1% increase in the change in leverage shifts down the leverage increase hazard curve by 0.57% and shifts up the leverage increase hazard curve by the same amount. Thus, financing decisions are sensitive to both the level of and change in leverage. And, since both of these measures are constructed with market equity, financing decisions are also sensitive to any shocks to market equity that resonate through these measures.

Turning to Panel B of Table V, we see that debt policy is sensitive to the level of and change in leverage in a manner consistent with rebalancing. The estimated hazard impacts for the level of leverage in the debt issuance and retirement models are −0.80% and 1.83%, suggesting that firms are less likely to issue debt and even more likely to retire debt when their leverage is relatively high. Similarly, the change in leverage has a statistically significant impact on debt issuance and retirement decisions (hazard impacts of −0.44% and 0.63%, respectively). Equity repurchases are negatively related to the level of and change in leverage, as they should be if firms are rebalancing, although the coefficient on the change in leverage is statistically insignificant. These results are consistent with recent survey evidence on payout policy in Brav et al. (2003), who find that a number of firms say they use equity repurchases to move their leverage ratio closer to a target, and that high debt firms are more likely to use equity repurchases to manage credit ratings (and implicitly leverage ratios) than low debt firms. Equity issuances, on the other hand, show no significant association with the level of or change in leverage. Thus, while firms rebalance their capital structure in response to the level of and change in leverage, they do so only through debt policy and equity repurchases.

Financing decisions are also sensitive to past financing decisions. Returning to the leverage increase model, the binary variable *LeverDown* is one after a leverage-decreasing adjustment occurs during a leverage increase spell and zero otherwise. The positive coefficient implies that when firms decrease their leverage, they are subsequently more likely to increase their leverage than they were before the decrease. The hazard impact suggests that they are 47% more likely to increase their leverage following the decrease. Analogously, when we examine the coefficient on *LeverUp* in the leverage decrease model, we see that firms are 65% more likely to decrease their leverage following leverage-increasing actions. This sensitivity of leverage adjustments to previous financing decisions is precisely what is expected in the dynamic rebalancing framework outlined in Section I. After each adjustment, leverage is closer to, and thus more likely to strike, the opposite boundary than it was prior to the adjustment.

The debt and equity policy models in Panel B reveal results that have implications similar to those of the level of and change in leverage. Firms rebalance their capital structures in response to past leverage increases and decreases using debt policy. The hazard impact for *LeverDown* in the debt issuance model implies that firms are 44% more likely to issue debt after having decreased their leverage. Analogously, firms are 72% more likely to retire debt after having increased their leverage. The effect of *LeverDown* on equity repurchases is directionally inconsistent, but statistically insignificant, with a rebalancing effort. Finally, past leverage increases have a significant positive effect on the likelihood of an equity issuance, consistent with rebalancing. Despite this consistency, we refrain from arguing that equity issuances are used as a tool for capital structure rebalancing because of the importance of other determinants in the equity issuance model, which we discuss below. So, while firms respond to past leverage adjustments, they do so primarily through debt policy.

In sum, firms appear to choose their financial policy in a manner that is consistent with dynamic rebalancing. The level of leverage, change in leverage, and past financing decisions are all important determinants in future financing decisions and their impact on those decisions coincides with a rebalancing effort by firms. Coupled with the evidence on adjustment costs, firms appear to behave as if attempting to maintain leverage within a desired range. Closer inspection reveals that firms actively rebalance their capital structures by issuing and retiring debt and, to a lesser extent, by repurchasing equity. Equity issuances, on the other hand, appear to be primarily driven by stock price considerations (measured by the *market-to-book ratio* and *equity return*), as opposed to factors associated with rebalancing efforts. Thus, despite apparent timing of equity issuances, firms do indeed rebalance their capital structures via debt policy.

C. The Duration of Responses to Stock Issuances and Equity Shocks

In this subsection we revisit the market timing and inertia hypotheses by estimating how long it takes for firms to adjust their capital structures in response to stock issuances and equity shocks. Visual inspection of Figures 2 and 4 suggests that the impact of an equity issuance on leverage is erased within two years, depending on the characteristics of the firm. Similarly, equity shocks are erased in anywhere from two to more than four years, depending upon the type of shock (positive or negative). We now compute a more formal estimate of this response time using our duration framework.

Ideally, we would like to estimate the expected time from a stock issuance or positive (negative) equity shock until the next leverage-increasing (decreasing) adjustment occurs using the model in equation (4). Unfortunately, this is an exceedingly complex task because of the dynamic nature of the model.[37] Instead, we compute this estimate using a slightly less complex model that is similar in spirit to that presented in equation (4). We estimate the following model:

$$h(t) = \omega_i h_0(t) \exp\{\alpha\}, \qquad (6)$$

where duration now measures the time between a stock issuance or equity shock and the appropriate rebalancing adjustment. As before, ω_i is an unobserved heterogeneity term with a gamma distribution, and $h_0(t)$ is the unspecified baseline hazard. The key distinction between equations (4) and (6) is that the latter has no time-varying covariates, $x_{ij}(t)$, and as such is a static model. Maximum likelihood estimation reveals that the median (average) time that it takes a firm to increase its leverage in response to a stock issuance is 4.4 (8.6) quarters. Note the consistency of this estimate with the results in Panel A of Figure 2. Similarly, the median (average) time to respond to a large positive and negative equity shock is 5.3 (8.5) and 5.4 (12.9) quarters, respectively. Thus, while firms do not respond *immediately* to changes in their capital structure, possibly because of adjustment costs, they do respond within a reasonably short time frame.

D. Other Financing Motives

The results presented thus far show that when firms make adjustments to their capital structures they do so, in large part, with rebalancing motives in mind. We now examine what other factors motivate the financing decisions of our firms, in the context of alternative theories of capital structure.

The pecking order, formalized by Myers and Majluf (1984) and Myers (1984), states that firms have a preference ranking over sources of funds for financing based on the corresponding information asymmetry costs. Internal funds avoid such costs entirely and, as such, are at the bottom of the pecking order. This source is followed by riskless and then risky debt. Finally, equity is at the top of the pecking order as a residual source of financing. Though not traditionally viewed as a tradeoff theory, the so-called modified pecking order discussed in the last section of Myers and Majluf (1984) and conclusion of Myers (1984) introduces bankruptcy costs, which offset debt's lower adverse selection costs relative to equity.

Table V shows two key results consistent with this theory. First, firms with a lot of internal equity or large cash flows are less likely to use external financing.

[37] Computation of the expected duration in our model (equation (4)) requires integration of the full hazard, $h(t)$, and then integration of the resulting duration density, $f(t) = h(t)\exp\{-\int h(s)\}$.

This result is represented by the negative coefficients on the *Cash* and *Profitability* variables in the debt and equity issuance models. Second, firms with large capital expenditures (*CapEx(t*+1)) are more likely to issue debt or equity. This dependency on internal funds and investment demand is consistent with the implications of the pecking order theory.

With respect to traditional tax-bankruptcy and agency-based tradeoff theories, the evidence is mixed. The impact of bankruptcy costs is clear, as debt retirements are highly sensitive to high levels of leverage or accumulating leverage. However, the effect of leverage on debt policy appears asymmetric in that debt issuances are less, though still significantly, sensitive to the level and change in leverage, as well as past leverage decreases. Additionally, the negative coefficient on profitability in the debt issuance model casts some doubt on the static tradeoff view that firms use debt as a tax shield for operating profits or to mitigate free cash flow problems.

Unfortunately though, the modified pecking order has predictions for the dynamics of capital structure adjustments that are similar to those of the tradeoff theory. As leverage increases, firms are more likely to issue equity or repurchase debt to avoid bankruptcy costs and preserve future debt capacity, but do not do so immediately due to the costs of the adjustment. Similarly, as leverage decreases, debt capacity increases. Firms are then more likely to fund investment opportunities by issuing debt, but may still refrain from doing so (by using internally generated funds) due to the direct costs (and information costs in the case of risky debt) of external security issuance. Our tests, being primarily designed to detect such rebalancing behavior, have low power to distinguish this scenario from a more traditional tax–bankruptcy cost tradeoff model. Thus, while our results suggest that information asymmetry costs may be an important concern in firms' financing decisions, future research focused explicitly on the predictions of the pecking order is required for a clearer distinction between the two theories.

VI. Conclusion

We analyze whether corporate financial policy is consistent with dynamic rebalancing, after accounting for costly adjustment. We begin by illustrating how shocks to leverage can have a persistent effect when firms are faced with adjustment costs, implying that leverage is a noisy measure of firms' financial policies. We then show that firms tend to make capital structure adjustments relatively infrequently (on average once a year) but in clusters. This temporal pattern in financing decisions is largely consistent with the direct evidence describing adjustment costs.

Using a dynamic duration model of firms' financing decisions, we are able to understand the motivation behind actual leverage adjustments (i.e., why firms adjust when they do). Our results are strongly supportive of a rebalancing effort by firms. However, our results are inconsistent with the conclusions of Baker and Wurgler (2002) and Welch (2004), both of which are predicated in large part on the persistence of the leverage process. Firms do indeed respond to equity issuances and equity price shocks by appropriately rebalancing their leverage over the next two to four years. Thus, the persistent effect of shocks on leverage documented by previous studies is more likely due to optimizing behavior in the presence of adjustment costs, as opposed to indifference toward capital structure.

Interestingly, we also find evidence consistent with the predictions of the modified pecking order in that firms are less likely to utilize external capital markets when they have sufficient internal funds, but are more likely when they have large investment needs. Thus, while firms appear to follow a dynamic rebalancing strategy, adverse selection costs may be an important determinant in their financing decision. However, since our tests are designed primarily to detect rebalancing behavior, as opposed to distinguishing between tradeoff and pecking order behavior, future work on this distinction is needed.

Appendix A: Simulation Details

This appendix describes the simulation procedures used to generate the leverage data discussed throughout the paper. For the reduced form model, we begin by specifying an upper ($\bar{L}$) and lower ($\underline{L}$) bound for leverage that defines the optimal leverage range. We choose these boundaries to match the medians of the firm-specific maximum (0.60) and minimum (0.15) leverage in a sample selected from the annual COMPUSTAT database.[38] We then simulate a series of 100 annual equity returns based on a Euler-discretized geometric Brownian motion, parameterized to match the mean (12%) and standard deviation (46%) of equity returns for the median firm in the sample. Using this leverage range and series of equity returns, we generate a corresponding path of leverage (debt divided by the sum of debt and equity) observations in the following manner.

We assume that the leverage process starts at the midpoint of the optimal range, L^*, though this assumption is innocuous. We then update leverage for each period based on the simulated equity return. If leverage lies within the optimal range, no debt is issued or retired. If the equity return for period t results in a leverage ratio below the lower bound (above the upper bound), the firm calculates the quantity of debt to issue (retire) in order to bring leverage to its optimal post-adjustment level, L_{adj}, which is determined by the type of adjustment costs the firm faces. The issuance or retirement is made in period $t+1$, according to

$$\Delta\text{Debt}_{t+1} = \left(\frac{L_{\text{adj}}}{1 - L_{\text{adj}}}\right) \times 1.12\ \text{Equity}_t - \text{Debt}_t,$$

which takes into account the firm's expected equity value in period $t+1$.

[38] We select the sample in a manner consistent with Welch (2004), as described above in footnote 15 and in Table II. In order to ensure reasonable time-series properties, we limit the sample to those firms with at least four years of data when matching moments. The use of sample selection criteria found in other studies has no impact on the results.

Referring to Figure 1 and the discussion in Section I, the optimal post-adjustment leverage in the case of only a fixed cost is $L_{\text{adj}} = L^*$, that is, the firm issues or retires enough debt to return leverage (in expectation) to its initial level. For a proportional adjustment cost, L_{adj} equals the nearest boundary, either $\underline{L}$ or $\bar{L}$. Finally, for a fixed and convex cost, $L_{\text{adj}} = \underline{L}^*$ or $\bar{L}^*$, where $\underline{L}^*$ and $\bar{L}^*$ are chosen such that the resulting median debt issuances and retirements, relative to the sum of debt and market equity, match those found in the COMPUSTAT sample of firms: 0.11 and 0.08, respectively.

To estimate Welch's (2004) empirical model, we repeat the simulation 1,000 times in order to generate a panel of data corresponding to 1,000 firms, each with a time series of 100 observations. Using the simulated leverage and equity returns data, we construct the elements of Welch's regression (equation (1)) and estimate the parameters and R^2 using the Fama–MacBeth methodology. This process of simulation and estimation is repeated 500 times in order to generate a series of parameter estimates and R^2, which we then average and present in Table II. For the estimated hazard curves in Figure 5, we follow the same procedure of simulating a panel of data, estimating the hazard curve, repeating, and finally averaging, at each point on the curve, over the resulting series of hazard curves.

We also simulate data from the dynamic tradeoff model of Fischer, Heinkel, and Zechner (1989). Specifically, we simulate 100 annual observations of equity returns and leverage, assuming the following parameters: a corporate tax rate of 50%, a personal tax rate of 35%, an asset value variance of 5%, a transaction cost of 1%, a riskless interest rate of 2%, and a fractional value loss in bankruptcy of 20%. All of these parameters are "base case" values, except for the cost of bankruptcy (base case value of 5%). We employ their model under this higher bankruptcy cost in order to ensure that leverage adjustments occur in both directions (increases and decreases), which is consistent with the data.

As before, the simulation is repeated 1,000 times resulting in a panel of data on which Welch's model is estimated. The process is repeated 500 times and the average of the resulting parameter and R^2 series is presented in Table II.

Appendix B: Likelihood Function

Let T_{ij} be a random variable corresponding to the duration of the j^{th} capital structure adjustment for firm i and define $F_{ij}(t)$ and $f_{ij}(t)$ to be the corresponding distribution and density functions, respectively. Also define the survival function, $S_{ij}(t) = 1 - F_{ij}(t)$, and note that from the definition of the hazard function in equation (3), $h_{ij}(t) = f_{ij}(t)/S_{ij}(t)$. The survivor function will prove useful in expressing the likelihood function.

Recall the conditional hazard specification in equation (4),

$$h_{ij}(t \mid \omega_i) = \omega_i h_0(t) \exp\{x_{ij}(t)'\beta\},$$

where ω_i is a random variable representing unobserved heterogeneity, $h_0(t)$ is a step function referred to as the baseline hazard, $x_{ij}(t)$ is a vector of covariates, and β is an unknown parameter vector. To ease the discussion, we define $h_{ij}(t) = h_0(t)\exp\{x_{ij}(t)'\beta\}$, which enables us to write the conditional hazard more compactly as

$$h_{ij}(t \mid \omega_i) = \omega_i h_{ij}(t).$$

From their definitions, the hazard and survival functions are related by

$$h_{ij}(t \mid \omega_i) = \frac{-d \ln S_{ij}(t \mid \omega_i)}{dt}.$$

Given this relation,

$$\begin{aligned} S_{ij}(t \mid \omega_i) &= \exp\left\{\int_0^t h_{ij}(u \mid \omega_i)\, du\right\} \\ &= \exp\left\{-\omega_i \int_0^t \frac{f_{ij}(u)}{S_{ij}(u)}\, du\right\} \\ &= [S_{ij}(t)]^{\omega_i}, \end{aligned} \tag{B1}$$

where $S_{ij}(t)$ is the survival function corresponding to $h_{ij}(t)$.

To obtain the likelihood function, we compute the firm-level conditional likelihoods and then integrate out the random variable ω_i. Assume that we have $i = 1, \ldots, N$ firms, each with $j = 1, \ldots, n_i$ observations consisting of a start time (t_{0ij}), an end time (t_{ij}), and an adjustment indicator

$$d_{ij} = \begin{cases} 1 & \text{if adjustment occurs} \\ 0 & \text{if censored.} \end{cases}$$

Note that while a financing duration may last several quarters, for the purpose of estimation we model each observation as a separate duration that either ends in a financing spike, in which case $d_{ij} = 1$, or is censored, in which case $d_{ij} = 0$. This allows us to use information on the complete time path of covariates in our estimation. Though not explicit, the hazard and survival functions are both conditional on the observed covariates, $x_{ij}(t)$.

The conditional likelihood contribution of the j^{th} spell for the i^{th} firm is given by

$$\begin{aligned} L_{ij}(\omega_i) &= \frac{S_{ij}(t_{ij} \mid \omega_i)}{S_{ij}(t_{0ij} \mid \omega_i)} h_{ij}(t_{ij} \mid \omega_i)^{d_{ij}} \\ &= \left[\frac{S_{ij}(t_{ij})}{S_{ij}(t_{0ij})}\right]^{\omega_i} [\omega_i h_{ij}(t_{ij})]^{d_{ij}}, \end{aligned}$$

where the second equality follows from the relation in equation (B1). Conditional on the unobserved heterogeneity, each observation for the i^{th} firm is independent. Thus, the likelihood contribution for the i^{th} firm, conditional on the unobserved heterogeneity, is

$$L_i(\omega_i) = \prod_{j=1}^{n_i} \left[\frac{S_{ij}(t_{ij})}{S_{ij}(t_{0ij})} \right]^{\omega_i} [\omega_i h_{ij}(t_{ij})]^{d_{ij}}.$$

The unconditional likelihood function for the i^{th} firm is

$$L_i = \int L_i(\omega_i)\, dG(\omega_i),$$

where $G(\omega_i)$ is the distribution function of ω_i. When $G(\omega_i)$ is a gamma distribution with mean 1 and variance θ, the unconditional log likelihood contribution for the i^{th} firm is equal to[39]

$$\ln L_i = \sum_{j=1}^{n_i} d_{ij} \ln h_{ij}(t_{ij}) - \left(\theta^{-1} + D_i\right) \ln \left[1 - \theta \sum_{j=1}^{n_i} \ln \frac{S_{ij}(t_{ij})}{S_{ij}(t_{0ij})} \right]$$
$$+ D_i \ln[\theta] + \ln\left[\Gamma\left(\theta^{-1} + D_i\right)\right] - \ln[\Gamma(\theta^{-1})], \qquad \text{(B2)}$$

where $D_i = \sum_{j=1}^{n_i} d_{ij}$ is the number of observations for firm i and $\Gamma(\cdot)$ is the gamma function. When we assume that ω_i is distributed inverse Gaussian with a mean of 1 and variance of θ, the unconditional log likelihood contribution of the i^{th} firm is

$$\ln L_i = \theta^{-1}\left(1 - R_i^{-1}\right) + B(\theta R_i, D_i) + \sum_{j=1}^{n_i} d_{ij} [\ln h_{ij}(t_{ij}) + \ln R_i], \qquad \text{(B3)}$$

where

$$R_i = \left[1 - 2\theta \sum_{j=1}^{n_i} \ln \frac{S_{ij}(t_{ij})}{S_{ij}(t_{0ij})} \right]^{-0.5}$$

and $B(x, y)$ is defined as

$$B(x, y) = x^{-1} + 0.5[\ln(2\pi^{-1}) - \ln(x)] + \ln[Bk(0.5 - y, x^{-1})].$$

$Bk(a, b)$ is known as the BesselK function (see Wolfram (1999)). The complete unconditional log likelihood is obtained by simply summing equation (B2) or (B3) over the N firms.

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