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Presidential Address: Collateral and Commitment

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ABSTRACT

Optimal dynamic capital structure choice is fundamentally a problem of commitment. In a standard trade-off setting with shareholder-debtholder agency conflicts, full commitment counterfactually predicts the firm would rely almost exclusively on debt financing. Conversely, absent commitment a Modigliani-Miller-like value irrelevance and policy indeterminacy result holds. Thus, the content of dynamic trade-off theory must depend on the commitment technology. In this context, collateral is valuable as a low-cost commitment device. Because ex ante optimal commitments are likely to be suboptimal ex post, observed capital structure dynamics will exhibit hysteresis and depart significantly from standard predictions.

DESPITE DECADES OF RESEARCH, the determinants of capital structure dynamics remain elusive. The traditional trade-off and pecking-order theoretical frameworks provide primarily static predictions that are unable to explain much of the observed cross-sectional and time-series variation in leverage. Capital structure is not static, but rather evolves over time as an aggregation of sequential decisions in which shareholders have an incentive to act strategically, maximizing the share price at the potential expense of creditors. I analyze a setting in which investors anticipate this behavior and set prices accordingly. Building on related work, I demonstrate that when trade is frequent, this price feedback is sufficient to destroy *all* benefits from leverage. Optimal dynamic capital structure thus becomes, fundamentally, a commitment problem. Viewing it through this lens provides new insights into the dynamics of leverage, its impact on firm valuation, and especially the importance and value of collateral and alternative commitment technologies.

My goal in this address is to demonstrate why commitment must be a primary determinant of capital structure. Specifically, in a standard trade-off model I show that when the firm cannot commit to its future capital structure

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choices, the optimal leverage policy is indeterminate and does not benefit current shareholders, providing a Modigliani-Miller-like irrelevance result even in the presence of tax benefits and other standard frictions. Thus, to capture the potential benefits of leverage, firms must commit ex ante to constrain their future choices. These constraints imply that observed capital structures will be both path dependent and ex post inefficient. As a result, similar firms may have very dissimilar leverage levels and dynamics, even when both are behaving optimally. In this context, collateral endogenously emerges as a critical determinant of capital structure because of its commitment value.

To demonstrate these results, I develop a simple stylized model in which tax benefits and/or pricing differentials (due to liquidity or market segmentation) provide potential valuation gains from the use of leverage. These gains must be balanced against the investment distortions and default costs associated with excessive leverage. In other words, the model represents a standard trade-off setting.

In standard static trade-off theory, capital structure is a one-time decision made at the birth of the firm. In that context, there exists a unique optimal debt level that the firm should choose. Much of the empirical literature on capital structure seeks to explain the variation in actual firm leverage based on comparative statics from such a model. In a dynamic context, however, the static predictions of trade-off theory do not apply. Moreover, equilibrium outcomes depend almost entirely on the commitment technology available to firms. At one extreme, suppose that the firm can commit ex ante to its future leverage decisions. Then, by committing to reduce leverage whenever profitability declines, the firm can avoid the expected costs of financial distress. In other words, the "trade-off" of the trade-off theory disappears, and full commitment implies the following counterfactual prediction: firms should be almost exclusively debt financed and avoid default via a commitment to issue equity and quickly deleverage in the event of a downturn.[1]

At the other extreme, suppose that the firm cannot commit ex ante, and instead actively manages its capital structure at each point in time to maximize the firm's share price. In this case the leverage ratchet effect, highlighted in Admati et al. (2018), implies that firms will *never* choose to actively reduce leverage.[2] Instead, they would prefer to issue new debt even when doing so would be detrimental to total firm value. In anticipation, creditors raise their required yield even when leverage is low, making debt issuance less attractive. Drawing on the methodology in DeMarzo and He (2019) and DeMarzo, He, and Tourre (2019) (hereafter, DH19 and DHT19), I show that when the firm borrows using unsecured debt, this behavior fully dissipates any funding cost advantages of debt. In particular, although the firm actively manages leverage toward a target level, the expected rate of debt issuance raises the credit

[1] In theory, with full commitment default should never occur unless the firm's value drops instantaneously to the point of insolvency. In practice, firm value declines gradually, with firms often *increasing* their total indebtedness during the period leading up to bankruptcy.

[2] See also Bulow and Rogoff (1991) and Bizer and DeMarzo (1992) for related results in the context of sovereign or individual borrowing.

spread to exactly offset the gains from trade. Lack of commitment thus prevents shareholders from capturing any valuation gain from debt. As a result, despite the availability of tax or funding cost benefits from debt, similar firms may optimally pursue very different leverage policies, with no effect on their ex ante equity values.

In short, at the two extremes of commitment, the "trade-off" of trade-off theory either disappears, or becomes irrelevant. The reason commitment is so consequential stems from the nonexclusivity of creditors' claims. The value of an unsecured debt claim depends on the overall health of the firm, which depends in turn on its *total* indebtedness. Early creditors raise their required yield in anticipation of the depreciation of the debt's value resulting from future debt issuance.[3] Surprisingly, with frequent trading this higher cost of debt exactly offsets the available gains from trade.[4]

The above observations imply that the set of available commitment mechanisms is a crucial determinant of capital structure dynamics. As an example, I show that the ability to secure debt claims with collateral provides a natural resolution to the nonexclusivity problem. In the context of the model, while the optimal issuance of unsecured debt is both indeterminate and value-irrelevant, the firm is able to capture the benefits of leverage using secured debt and will choose to do so whenever collateralizable assets are available or acquired.

The idea that balance sheet and collateral constraints are an important determinant of firm financing is of course not new. For example, in Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Rampini and Viswanathan (2010, 2013), and numerous related models, collateral is necessary to enforce or incentivize the future repayment of claims. In these models, equity and unsecured financing are generally unavailable. But empirically, collateral matters even for firms with access to other forms of financing. Earlier literature has considered collateral's role in protecting against investment distortions for firms with high leverage: Secured financing may limit asset substitution (Smith and Warner (1979)) or help overcome debt overhang (Stulz and Johnson (1985)). The focus here is on another role of collateral, emphasized more recently by Donaldson, Gromb, and Piacentino (2017, 2018), namely, its ability to shield creditors from the future dilution of their claims. Specifically, while claims against cash flows suffer from nonexclusivity, claims against collateral do not. Thus, collateral is useful in resolving agency problems on the liability side of the balance sheet, even for firms with currently low leverage.

To be clear, my goal in this address is *not* to provide a unique or definitive theory of collateral. Rather, it is to reframe the question of capital structure as first and foremost a commitment problem: In a dynamic context, commitment mechanisms *must* be a first-order determinant of the evolution of corporate

[3] Importantly, this depreciation goes beyond the simple dilution of claims in default. Even without such direct dilution, the firm's total leverage affects the timing of default by determining shareholders' willingness to pay (or invest).

[4] Note that the firm *does* earn tax benefits from the debt, and the debt is fairly priced. Thus, the tax or other benefits of leverage are offset by the expected costs of the investment distortions (including default) from leverage.

leverage. Collateral is of course not the only commitment mechanism available to the firm; I discuss several others in Section III. But its relatively low cost and high effectiveness likely make it ubiquitous. More costly commitment mechanisms involve additional trade-offs, and the optimal balance of these trade-offs depends on the context at the time they are put in place. Importantly, by their very nature, these commitment mechanisms themselves generate both path dependence and ex post inefficiencies in observed capital structure choices. As an illustrative example, I conclude by showing that regulatory policies designed to limit leverage provide an external commitment mechanism that may instead lead firms to borrow more. In addition, tightening already-binding regulatory constraints can improve firm value.

Empirical Challenges, and an Example

Existing capital structure theories face a number of empirical challenges. First and foremost, taxes appear to matter less than they should. Given the large potential benefits from debt tax shields on corporate cash flows, and relatively modest apparent bankruptcy costs, static trade-off theory predicts that firms should choose much higher levels of leverage than we commonly observe. Indeed, Graham (2000) and Strebulaev and Yang (2013) document that many firms have almost no leverage despite large potential tax savings. Korteweg (2010) and van Binsbergen, Graham, and Yang (2010) further show that those firms that do use leverage capture only a small net benefit (on the order of a few percent of firm value).[5]

There is also large unexplained variation in capital structure. Lemmon, Roberts, and Zender (2008) document persistent firm fixed effects in capital structure choices that cannot be explained by observable characteristics. Even within the same firm, leverage can vary significantly over time (see, e.g., DeAngelo and Roll (2015)), with firms adjusting leverage only slowly, if at all, toward a target. Welch (2004) finds that much of the variation in market leverage is passive, while Baker and Wurgler (2002) document significant path dependence of leverage even after a decade. Perhaps most problematic for the standard trade-off model is the apparent negative correlation between profitability and leverage.[6] Although this relation can be a consequence of large fixed costs associated with debt issuance (Fischer, Heinkel, and Zechner (1989)), it survives even when restricting attention to high-frequency debt issuers (Eckbo and Kisser (2018)).

In contrast to these negative results regarding the relation between leverage and cash flow, it is well documented that the firm's asset base, especially its

[5] Heider and Ljungqvist (2015) document an asymmetric impact of tax rates on leverage, with higher rates leading to an increase in leverage, but not vice versa, consistent with the leverage ratchet dynamics analyzed here.

[6] See, for example, Titman and Wessels (1988) and Frank and Goyal (2015).

tangible collateral, is a key driver of debt issuance.[7] Collateral also affects debt maturity choice (Benmelech (2009)) and the timing of debt issuance, which is often coincident with new investment. These findings present an important puzzle: Why are the firm's assets a more important determinant of leverage than the cash flows generated by those assets?

In this address, I develop a simple dynamic trade-off model of capital structure that highlights the role of commitment and can explain many of the empirical findings above. In the model, firms have a net funding cost advantage in debt markets due to the presence of debt tax shields or pricing differentials.[8] The firm's cash flows evolve stochastically, and there is a real cost associated with default (though this cost may be small). The firm can issue or repurchase securities at any time without cost and without retiring existing claims.[9] The firm periodically invests in capital to exploit new growth opportunities and at all times maximizes the current value of equity.

Figure 1 summarizes the key results. The figure depicts the unlevered value of a firm together with its total capital stock (collateral) over time.[10] It also shows the total debt of the firm under three alternative leverage policies. Under the first policy, debt tracks the firm's available collateral: the firm issues secured debt backed by its available collateral at the time of each new investment, and this debt is paid off as the collateral depreciates. Under the second policy, the firm issues secured debt as before, but also issues long-term unsecured debt. Unsecured debt is issued gradually, and although total debt now increases with profitability, because it increases slowly, leverage declines. Finally, under the third policy, the firm issues secured debt plus *short*-term unsecured debt. In this case, the firm levers up more rapidly when its profitability and valuation increase. Debt also declines rapidly, due to maturity, when profitability falls.

Despite the significant qualitative differences between these policies, I show that:

- All three policies are, in fact, optimal equilibrium choices for the firm. Thus, firms with similar characteristics may choose very different leverage policies.
- All three policies imply the *same* initial value for equity, despite the large differences in average leverage and corresponding tax shields. Indeed,

[7] See, for example, Graham (1996), Graham and Leary (2011), Campello and Giambona (2013), and Rampini and Viswanathan (2013). The effect is stronger if we consider leases as a form of collateralized finance, as emphasized by Eisfeldt and Rampini (2009).

[8] Differences in the cost of capital across debt and equity markets may be related to differences in liquidity or contracting costs, or due to market segmentation. That said, it is sufficient to assume a tax benefit.

[9] This assumption differentiates the model from the majority of existing dynamic capital structure literature, which is based on dynamic inaction due to large fixed costs of issuance and/or requirements that existing claims be retired whenever capital structure is rebalanced (e.g., Leland (1998), Goldstein, Ju, and Leland (2001), Strebulaev (2007), Danis, Rettl, and Whited (2014)). In the model developed here, firms are always actively adjusting leverage.

[10] In the general model introduced later, only a portion of the value of the firm's capital will be pledgeable as collateral. We ignore that distinction in this example.

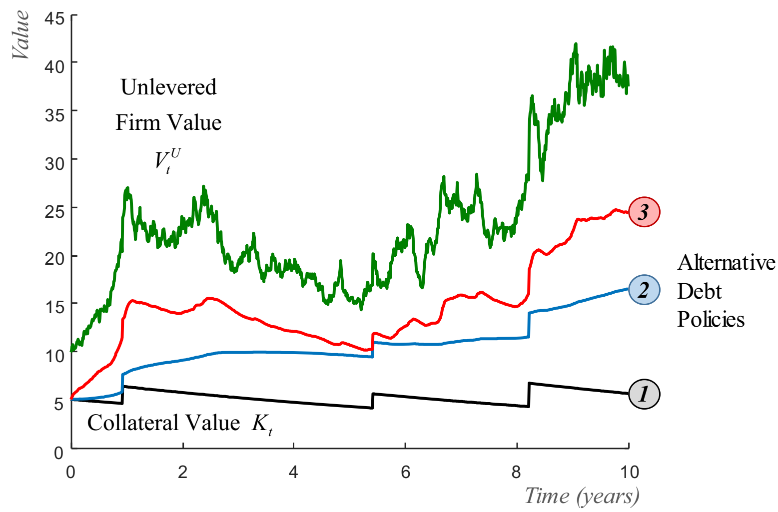

Figure 1. Three alternative leverage policies given unlevered firm value V^U and capital/collateral K. Despite the large difference in leverage (and corresponding tax benefits), the initial value of equity is unaffected by the policy choice. The only common component across the policies is their responsiveness to collateral.

under each strategy, shareholders are indifferent to the rate of issuance of unsecured debt.[11]

- Each of these policies features slow (or no) adjustment of leverage toward a target, even though there are no fixed costs of adjustment. Profitability and leverage are therefore negatively contemporaneously related.
- The only common feature across the three policies is the importance of collateral: In each case, the firm funds new investment with secured debt. Because collateral protects secured creditors against future debt issuance, secured debt is favorably priced and firm value is enhanced.

In what follows, I develop the theoretical underpinnings of these results and show how they follow from a single friction—the firm's inability to commit to its future leverage decisions. Section I considers cash flow–based borrowing and demonstrates the irrelevance of leverage when the firm can choose to adjust leverage continuously without commitment. Section II incorporates investment and collateral, and shows that only collateralized borrowing allows the firm to capture the benefits from leverage. Section III discusses other commitment mechanisms and their potential implications, including regulatory debt limits.

[11] By rate of issuance, I specifically mean changes of order dt. Issuing a large block of unsecured debt would be suboptimal.

I. Cash Flow–Based Borrowing

In this section, I examine a setting in which the firm can borrow only against its future cash flow. For the purpose of this address, I focus on a simplified setting/example, relying on more general results established in related work. As we will see, in equilibrium the firm will have substantial debt capacity using unsecured debt. But, despite the funding cost advantage of debt, absent commitment, shareholders do not benefit from leverage and will be indifferent to the firm's debt maturity and leverage choice.

Consider a firm with a project that does not require capital investment. Let Y_t be the rate at which the project generates after-tax cash flow on date t, and suppose the project's profitability grows at expected rate μ, with volatility σ, according to

$$dY_t = \mu Y_t dt + \sigma Y_t dZ_t,$$

where Z_t is a standard Brownian motion.

The firm can finance the project with equity or debt. Debt contracts pay a coupon rate c and amortize at rate $m \geq 0$. If $m > 0$, the remaining face value of the loan is repaid at rate m, and thus declines proportionally to e^{-mt}. We can therefore interpret $1/m$ as the average maturity of the debt.

The firm may have the opportunity to issue or repurchase debt over time. Let G_t be the cumulative issuance process, so that dG_t is the rate of debt issuance on date t. The firm's debt level thus evolves as

$$dF_t = -mF_t dt + dG_t.$$

Suppose the firm has a fixed marginal tax rate $\pi \geq 0$ and let $c^* = c(1 - \pi)$ be the after-tax coupon rate. Let p_t be the market price of debt on date t (to be determined in equilibrium as a function of the firm's leverage). Then the firm generates payouts to equity equal to its after-tax earnings plus any proceeds or expenditures from debt issuance or repurchases:

$$Y_t - (c^* + m)F_t + p_t dG_t.$$

Shareholders have the option to default at any time. In the event of default, the project is terminated and all cash flows cease. For now, assume that the liquidation value of the firm in default is zero. In Section I.C, I discuss implications of a positive liquidation value (perhaps associated with transferable rights to future cash flows).

Debtholders discount expected cash flows at risk-free rate $r > 0$. Equity holders discount expected cash flows at risk-free rate $r^* = r(1 + \eta)$.[12] The difference, η, may reflect differential investor-level tax treatment for equity versus debt securities (as in Miller (1977)). It may also incorporate pricing differentials due

[12] For simplicity I assume risk-neutrality throughout. See DeMarzo, He, and Tourre (2019) for an analysis with risk-averse investors.

to market segmentation or a potential "moneyness" premium associated with debt. Assume the tax rate and discount rate differential satisfy

$$\pi + \eta > 0, \text{ and either } \eta \geq 0 \text{ or } c \geq r, \tag{1}$$

which implies a net funding cost advantage associated with debt. As a result, the firm faces a trade-off between the funding advantages of debt and the loss of the project cash flows in the event of default.

A. Deterministic Case

To provide intuition, consider a simple setting in which the cash flows are deterministic ($\sigma = 0$) and, to ensure default risk, decline faster than the debt matures ($\mu + m < 0$). Although this setting is admittedly special, in Section I.B I show that all of the key results carry over to the general case.

I begin with the familiar static trade-off setting in which the firm chooses its debt level initially and can never issue or repurchase the debt in the future. I then consider the effect of increasing the frequency at which the firm can adjust its capital structure and show the consequences for the firm's leverage choice and valuation.

A.1. No Leverage Adjustment

Suppose the firm has debt in place and but cannot issue or repurchase debt in the future. Instead, its leverage evolves passively in response to profitability changes and debt maturity. The firm receives the project cash flows and pays interest and principal on the debt until the time shareholders choose to default. Hence, given initial profitability Y_0 and debt level F_0, the *no-adjustment value* of the firm's equity is given by[13]

$$V^0(Y_0, F_0) = \max_{\tau} E\left[\int_0^{\tau} e^{-r^* t}\left(Y_t - (c^* + m)F_t\right) dt\right]. \tag{2}$$

Because the project's cash flow declines faster than the debt matures, it is optimal for shareholders to default as soon as the firm's after-tax earnings drop to zero. That is, the firm will default when $Y_t = (c^* + m)F_t$ (Figure 2). Equivalently, if we define $f_t \equiv F_t/Y_t$ to be the firm's current debt-income ratio, the optimal default time is the first time the debt-income ratio reaches the default threshold

$$f_B \equiv \frac{1}{c^* + m}. \tag{3}$$

Denote by $\tau^0(f)$ the time to default given current leverage f and no future trade.

[13] Although the expectation operator is unnecessary in the current nonstochastic setting, I allow $\sigma > 0$ shortly.

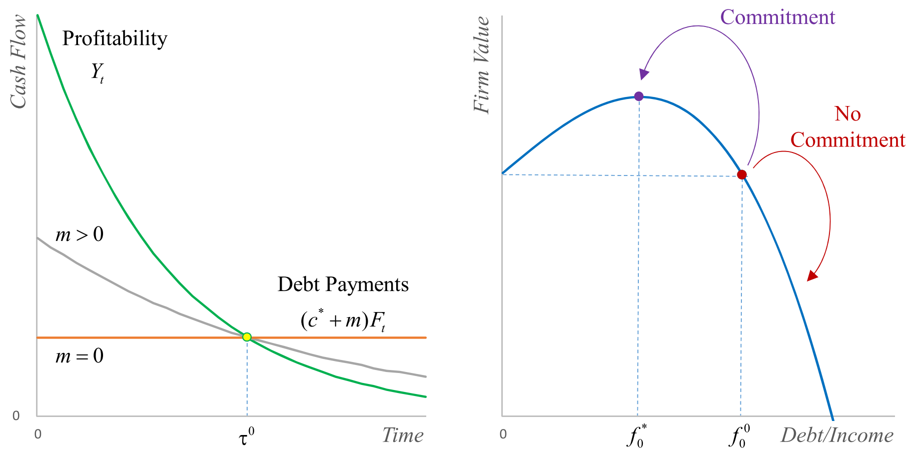

Figure 2. Optimal default and leverage choices with deterministic cash flows. The left panel shows the profit rate and required debt payments with perpetual debt ($m = 0$), or amortizing debt ($m > 0$), with default time τ^0. The right panel shows total firm value (debt plus equity) as a function of the initial debt-income ratio, which is maximized at f_0^*. Also shown is how the firm would adjust leverage starting from a point, such as f_0^0, at which leverage is already excessive.

Because the default decision depends only on the debt-income ratio, the value function V^0 is homogeneous of degree one and hence can be written as

$$V^0(Y, F) \equiv v^0(f)Y.$$

Thus, it is sufficient to characterize v^0, the equity value per unit of unlevered cash flow, in terms of the firm's debt-income ratio.

PROPOSITION 1 (No-adjustment valuation): *Let $\bar{v}(f)$ be the perpetuity value of equity absent default, $\bar{v}(f) \equiv \frac{1}{r^*-\mu} - \frac{c^*+m}{r^*+m} f$. Then, the no-adjustment value function is*

$$v^0(f) = \bar{v}(f) - E\left[e^{-(r^*-\mu)\tau^0(f)}\right]\bar{v}(f_B) = \bar{v}(f) \underbrace{-\left(\frac{f}{f_B}\right)^{\hat{\gamma}} \bar{v}(f_B)}_{\text{default option value}>0}, \tag{4}$$

where $\hat{\gamma} = -\frac{r^*-\mu}{\mu+m} > 1$.

PROOF: Because profitability declines faster than the debt matures ($\mu < -m$), the time to default given current leverage f can be calculated directly in the deterministic case to satisfy $e^{-(\mu+m)\tau^0(f)} f = f_B$. Note that $\mu + m < 0$ implies $\bar{v}(f_b) < 0$ and $\hat{\gamma} > 1$. ■

The price of the firm's debt equals the present value of the debt payments received prior to default. Therefore, with no leverage adjustment, the market price of debt will be equal to

$$p^0(f) = E\left[\int_0^{\tau^0(f)} e^{-(r+m)t}\,(c+m)\,dt\right].$$

The next result establishes that, absent further trade, there is a funding cost advantage associated with debt.

PROPOSITION 2 (Net funding advantage): *Given assumption (1) regarding the tax and discount rate differentials between debt and equity, then for $f < f_B$, the no-adjustment debt price exceeds the marginal cost of debt to equity holders:*

$$p^0(f) > -v^{0\prime}(f) = E\left[\int_0^{\tau^0(f)} e^{-(r^*+m)t}\left(c^*+m\right)dt\right] = \frac{c^*+m}{r^*+m}\left(1-\left(\frac{f}{f_B}\right)^{\hat{\gamma}-1}\right). \quad (5)$$

PROOF: We need to show

$$p^0(f) + v^{0\prime}(f) = \int_0^{\tau^0(f)} e^{-(r^*+m)t}\left[e^{\eta r t}(c+m) - (c^*+m)\right]dt > 0.$$

Because $c^* = c(1-\pi) < c$, if $\eta \geq 0$ the integrand is positive and the result holds immediately. If $\eta < 0$, the integrand is positive and then negative, and so it suffices to show the result for $\tau = \infty$, that is,

$$\frac{c+m}{r+m} > \frac{c^*+m}{r^*+m},$$

or equivalently, $(c+m)(r^*+m) - (c^*+m)(r+m) = (\pi+\eta)rc + (\pi c + \eta r)m > 0$, which follows from assumption (1). The final expression for the marginal cost of debt follows as in (4). ■

A.2. Static Trade-Off Theory

In the standard static trade-off theory, an initially unlevered firm chooses a level of debt to maximize total firm value, without the possibility of future debt issuance or buybacks. In other words, the firm chooses an initial debt-income ratio f to maximize the value of equity plus the proceeds from the debt issuance assuming no further trade:

$$\max_f v^0(f) + p^0(f)f. \quad (6)$$

Figure 2 illustrates the familiar static trade-off theory relation between total firm value and leverage, with an interior optimum that balances the funding cost advantage of debt against the present value of default costs. This

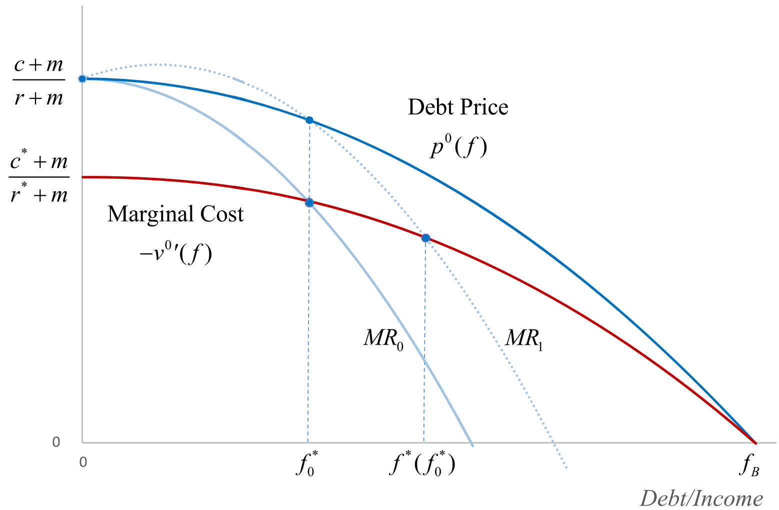

Figure 3. Debt price, marginal revenue, and marginal cost for a one-time adjustment. Starting with zero leverage, the gains from trade, and thus the share price, are maximized by increasing leverage to f_0^*. But given leverage f_0^*, shareholders face the residual marginal revenue curve MR_1, and hence would gain by increasing leverage further to $f^*(f_0^*)$.

optimum can be characterized in terms of the standard first-order condition for a monopolist,

$$\overbrace{-v^{0\prime}(f)}^{\substack{\text{marginal cost}\\ \text{of debt}}} = \overbrace{p^0(f) + p^{0\prime}(f)f}^{\substack{\text{marginal revenue}\\ \text{from debt issuance}}}, \tag{7}$$

illustrated in Figure 3. If we define

$$d(f) \equiv \frac{p^0(f) + v^{0\prime}(f)}{-p^{0\prime}(f)} > 0$$

to be the net funding cost advantage of debt scaled by its price sensitivity to additional leverage (which is positive from (5) and the fact that p^0 is strictly decreasing in f), then the static trade-off theory optimum is a fixed point of d:

$$f_0^* = d\left(f_0^*\right). \tag{8}$$

A.3. One-Time Adjustment

Recall that under the current parameter assumptions, the project's profitability declines faster than the debt matures. Hence, even absent trade, the firm's debt-income ratio will increase gradually over time. As a result, despite an optimal *initial* issuance decision, the firm will be at the static optimum level of leverage, f_0^*, only momentarily.

Now suppose that at a future date, the firm has the opportunity to make a one-time adjustment to its leverage. What leverage adjustment will the firm choose? Absent commitment, the firm will adjust leverage to maximize its current share price. Thus, given current leverage f, the firm will optimally choose new leverage f^* to solve

$$f^*(f) = \arg\max_{f'} v^0(f') + p^0(f')(f' - f). \tag{9}$$

The next result contrasts this outcome with a setting in which the firm commits ex ante, at the time of its initial debt issuance, to a one-time adjustment of its debt at a future date.

PROPOSITION 3 (Debt adjustment): *Suppose a firm with current leverage $f \in (0, f_B)$ has the opportunity to make a one-time adjustment to its debt. The leverage choice $f^*(f)$ that maximizes the firm's current share price increases with, and exceeds, its current leverage:*

$$f^{*\prime}(f) > 0 \quad \text{and} \quad f^*(f) = f + d(f^*(f)) > f. \tag{10}$$

If instead the firm could commit up front to the future adjustment it will make when leverage equals f, then to maximize its initial share price it would commit to choose leverage $f^c < f^*(f)$. Moreover, if $\eta \geq 0$, it would choose $f^c \leq f_0^*$, subject to limited liability.

PROOF: Absent commitment, the firm will choose leverage to solve (9). The fact that f^* is increasing in f follows from the strict supermodularity of the objective in (9) with $p^{0\prime} < 0$. Analogous to (8), at the solution we have $f^* - f = d(f^*) > 0$, and so the firm will choose to issue additional debt and increase leverage.

Alternatively, with initial debt face value F_0, leverage will equal f on date T such that $e^{-(\mu+m)T} F_0/Y_0 = f$. If the firm commits to the debt adjustment $dG_T = \Delta \cdot Y_T$, the initial value of equity is equal to

$$V_0 = \int_0^T e^{-r^* t}\left(Y_t - (c^* + m)F_t\right)dt + e^{-r^* T}\left[v^0(f + \Delta) + p^0(f + \Delta)\Delta\right]Y_T,$$

with initial debt proceeds of

$$\begin{aligned} p_0 F_0 &= \left[\int_0^T e^{-(r+m)t}(c + m)\,dt + e^{-(r+m)T} p_t\right] F_0 \\ &= \left[\int_0^T e^{-(r+m)t}(c + m)\,dt\right] F_0 + e^{-rT} p^0(f + \Delta) f\, Y_T. \end{aligned}$$

Thus, if the firm's initial owners could commit the firm to the leverage adjustment it will make on date T, they would choose Δ to maximize $V_0 + p_0 F_0$, or equivalently, to maximize

$$e^{-r^* T}\left[v^0(f + \Delta) + p^0(f + \Delta)\Delta\right] + e^{-rT} p^0(f + \Delta) f,$$

subject to the limited liability constraint that the cost of any debt buyback does not exceed the value of equity:[14]

$$LLC = \{\Delta : v^0(f+\Delta) \geq -p^0(f+\Delta)\Delta\}.$$

Therefore, the optimal adjustment under commitment is given by

$$\Delta^c = \arg\max_{\Delta \in LLC} v^0(f+\Delta) + p^0(f+\Delta)(e^{\eta r T} f + \Delta).$$

Assuming that the limited liability constraint does not bind (i.e., f is not too high), then if $\eta = 0$ this optimization is equivalent to (6) and is maximized by $f^c = f_0^*$. If $\eta > 0$, the firm will put additional weight on the price impact and hence $f^c < f_0^*$. If limited liability does bind, it can be shown that the objective is single-peaked and thus the firm would commit to adjust leverage as closely as possible to f^c subject to limited liability. In any case, with commitment there is greater weight on the price impact than without commitment, so $f^c < f^*(f)$. ■

Proposition 3 demonstrates that with commitment, the firm would readjust leverage back toward the ex ante optimum f_0^* given the opportunity to do so. The commitment to reduce leverage in the future lowers anticipated default costs and allows the firm to secure a higher price for its debt up front. The idea that the firm will adjust leverage over time toward the value-maximizing level is the basis for standard empirical tests of traditional trade-off theory (see Figure 2).

Absent commitment, however, shareholders will always choose to issue additional debt, *no matter how excessive* the firm's current leverage. This result is a manifestation of the leverage ratchet effect, highlighted by Admati et al. (2018): Once debt is in place, shareholders do not gain from leverage reductions but always prefer instead to borrow against existing earnings and increase leverage further, even if the new debt would reduce total firm value. Anticipating this behavior, creditors will demand a higher premium on the firm's initial debt.

The leverage ratchet effect can also be understood from the perspective of Proposition 2. Because of the funding cost advantage of debt, the debt price exceeds its marginal cost to equity holders, and thus there is always a temptation to issue more—just as a monopolist would like to sell additional units once the original monopoly quantity has been sold (see Figure 3).

A.4. Frequent Trade

I now consider the effect of increasing the frequency of trade by supposing that the firm can adjust its leverage at regular intervals.

First note that with commitment, the optimal policy is qualitatively straightforward. Given deterministically declining cash flows, the firm will borrow

[14] Though they may have committed to a buyback, shareholders still have the right to default ex post.

as much as possible up front with a commitment to gradually reduce debt in the future so as to delay default. As the frequency of trade increases, in the limit the first-best—100% debt financing with no default risk—can be achieved.[15] That is, with full commitment, the "trade-off" of trade-off theory disappears.

In contrast, without commitment, the pattern is reversed. The firm will issue debt gradually over time until it eventually defaults, as shown in the following result.

PROPOSITION 4 (Frequent trade): *Suppose the firm can issue (or repurchase) debt at intervals of length $dt > 0$ and there is no commitment to future debt issuance. Let $p(f)$ be the equilibrium debt price function. In the unique such equilibrium, the firm issues a positive amount of debt at each opportunity to trade. As the time interval $dt \to 0$, the firm issues debt at rate $dG_t = g(f_t)Y_t\,dt$, where*

$$g(f) = \frac{\pi c + \eta r p(f)}{-p'(f)} > 0. \tag{11}$$

PROOF: To evaluate the optimal issuance on date t, let $V(Y_t, F_t)$ and $p(Y_t, F_t)$ be the equilibrium equity value and debt price once the date t issuance decision has been made. Then

$$dG_t = \arg\max_{\Delta} V(Y_t, F_{t-} + \Delta) + p(Y_t, F_{t-} + \Delta)\Delta, \tag{12}$$

which has first-order condition $V_{F,t} + p_t + p_{F,t}\Delta_t = 0$, where Δ_t is the optimal issuance and $V_{F,t}$ the derivative with respect to the debt level on date t. Evaluating $V_{F,t}$ up to order dt terms,

$$V_{F,t} = -(c^* + m)dt + (1 - r^*dt)(1 - mdt)\left[V_{F,t+dt} + p_{F,t+dt}\Delta_{t+dt}\right], \tag{13}$$

that is, the marginal cost of debt equals the cost of the additional coupon and principal payments plus the discounted marginal impact of having additional debt on date $t + dt$. From the first-order condition at date $t + dt$, (13) can be rewritten as

$$V_{F,t} = -(c^* + m)dt + (1 - r^*dt)(1 - mdt)\left[-p_{t+dt}\right]. \tag{14}$$

Next, note that optimal debt pricing implies

$$p_t = (c + m)dt + (1 - rdt)(1 - mdt)\left[p_{t+dt}\right]. \tag{15}$$

[15] For intuition, consider the case in which $c = r$, so that the debt is issued at par, and suppose the debt is perpetual. By committing to buy back debt at rate $-\mu$, leverage will remain constant and the firm will pay dividends at rate $Y(1 - r(1 - \pi)f + \mu f)$. As long as the dividend rate is weakly positive, the firm will not default and hence the firm can borrow up to the first-best value, $Y_0/(r(1 - \pi) - \mu)$. Of course, ex post shareholders would prefer to renege on the buyback commitment to earn the no-adjustment value $v^0(f)Y$ instead. (Note that in this simple deterministic case, commitment could be enforced via debt maturity by setting $m \geq -\mu$, which we rule out for now.)

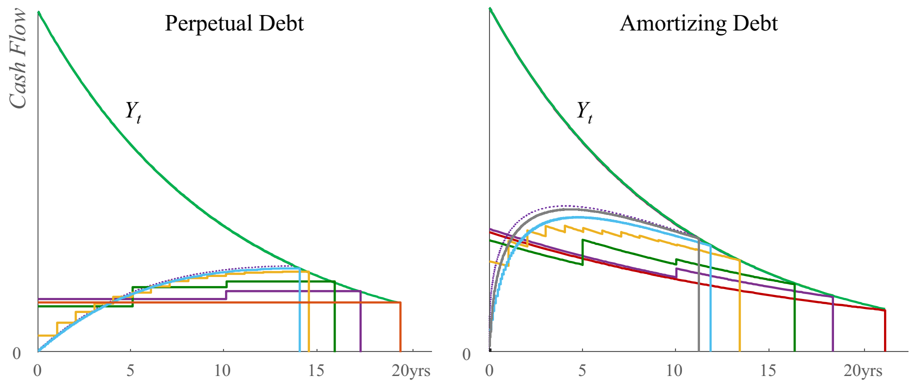

Figure 4. Equilibrium cash flows and debt payments with perpetual and amortizing debt for different adjustment frequencies. Adjustments are one-time, every 10 years, five years, one year, one month, one week, or continuous trading, and debt amortization is 5%/year. Debt issuance is always positive (though might not exceed the rate of amortization). Issuance becomes smooth, and shortens the time to default, as the frequency of trade increases.

Combining (14) and (15), again ignoring higher order dt terms, we have

$$V_{F,t} + p_t = (\pi c + \eta r p_t)\, dt > 0. \tag{16}$$

Equation (16) captures the flow rate of the net funding cost benefit of debt, which is clearly positive if $\eta \geq 0$. If $\eta < 0$, then $c \geq r$ by (1) and hence $r p_t \leq r\frac{c+m}{r+m} \leq c$, so $\pi + \eta > 0$ implies that (16) is positive. Thus, the solution to (12) satisfies

$$\Delta_t = \frac{V_{F,t} + p_t}{-p_{F,t}} = \frac{\pi c + \eta r p_t}{-p_{F,t}} dt, \tag{17}$$

which, given $p_F(Y, F) = p'(F/Y)/Y$, confirms (11). Because the debt price depends only on $f_t = F_t/Y_t$, which must strictly increase over time, we can compute $p(f)$ uniquely via backward induction in f, and verify that p' is both bounded and strictly negative. ■

Figure 4 plots the path of equilibrium debt payments for different frequencies of trade and alternative debt maturities. Note that as the frequency of trade increases, the amount of debt issued each period decreases, but the ultimate debt level is higher and the time to default is shorter. In the limit the debt issuance policy is smooth. The rate of debt issuance slows as leverage increases, and if the debt amortization rate is positive, the face value of debt may decline prior to default. Finally, debt maturity has a significant impact on both the rate of issuance and the degree of leverage.

Consider next the impact of frequent trade on the value of the firm's securities. Figure 5 plots the equilibrium value of equity for an initially unlevered firm that follows the optimal leverage policy. Note that, given any fixed trading frequency, shorter debt maturity enables the firm to take greater advantage of the lower funding cost associated with debt, and thus leads to

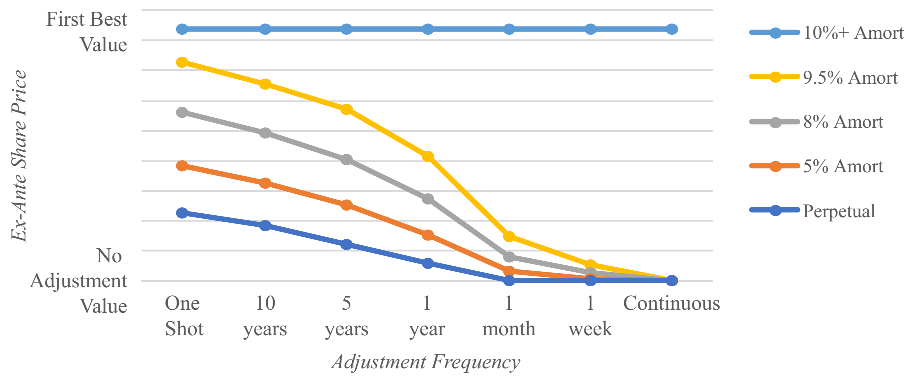

Figure 5. Ex ante share price given the equilibrium strategies in Figure 4. If the amortization rate exceeds the rate that profitability declines (10%), then debt is risk free and the first-best is obtained. Otherwise, as trading becomes continuous, all gains from trade are dissipated and the equity value collapses to the no-adjustment value.

higher firm value. However, for all debt maturities with $m < -\mu$, as the frequency of trade increases, the initial value of equity falls, eventually collapsing to the no-adjustment value (which, if $f_0 = 0$, equals the unlevered value).

PROPOSITION 5 (Limit valuation): *As the time interval between trading opportunities $dt \to 0$, equity valuation converges to the no-adjustment value, $v(f) \to v^0(f)$, in (4), and the debt price converges to the marginal cost of debt in the no-adjustment case,*

$$p(f) \to -v^{0\prime}(f) = \frac{c^* + m}{r^* + m}\left(1 - \left(\frac{f}{f_B}\right)^{\hat{\gamma}-1}\right). \tag{18}$$

PROOF: As established in (16), the difference between price and marginal cost satisfies

$$v'(f) + p(f) = \big(\pi c + \eta r p(f)\big)\, dt \to 0.$$

The gain from trade each period is equal to the quantity traded, Δ, times the difference between price and marginal cost, both of which are of order dt. Thus, the gain from trade each period is of order dt^2, and so as $dt \to 0$, the cumulative gain from trade converges to zero and $v \to v^0$. ■

This result is analogous to the Coase Conjecture for durable goods monopoly. With repeated opportunities to trade, the monopolist will keep selling as long as price exceeds marginal cost. Anticipating this behavior, buyers will wait for the price to fall, eliminating the monopolist's ability to capture any gains from trade.

Here, the firm is tempted to issue additional debt as long as it has a funding cost advantage. In equilibrium, the expectation of future debt issuance accelerates the expected time to default, causing the current price of debt to fall to the point that the funding cost advantage is eliminated. In particular, if $\tau^0(f)$ is the time to default absent future trade, then with continuous trading the equilibrium default time accelerates to $\tau^*(f)$, such that the debt price equals the no-trade marginal cost:[16]

$$p(f) = \frac{c+m}{r+m}\left(1 - e^{-(r+m)\tau^*(f)}\right) = -v^{0\prime}(f) = \frac{c^*+m}{r^*+m}\left(1 - e^{-(r^*+m)\tau^0(f)}\right). \quad (19)$$

In other words, the tax and discount rate benefits of debt are fully dissipated by the acceleration of default due to future debt issuance. Hence, although the firm is able to, and does, borrow substantially against its future cash flows, shareholders do not capture any gains from trade associated with debt financing.[17]

B. Stochastic Cash Flows

I now relax the assumption of deterministic cash flows and assume instead that $\sigma > 0$. Previously, cash flows were assumed to decline faster than the debt amortization rate to ensure default. But if cash flows are risky, there is always a positive probability of default and this requirement becomes unnecessary: the firm's cash flows can have a positive expected growth rate (as long as $\mu < r^*$, so the valuation remains finite) with no restriction on the amortization rate m. Despite this increased generality, I use the results of DH19 and DHT19 to show that the key consequences of frequent trading observed in the deterministic model continue to hold.

PROPOSITION 6 (Stochastic cash flows): *Suppose the unlevered earnings process Y_t is stochastic with $\sigma > 0$ and the debt price depends only on the debt-income ratio f. Then, given any growth rate $\mu < r^*$ and amortization rate m, the equilibrium value of equity with continuous trading is equal to the no-adjustment value, $v(f) = v^0(f)$, in (4). The equilibrium debt price is $p(f) = -v^{0\prime}(f)$, given by (18). The optimal default boundary f_B satisfies $\bar{v}((1-\hat{\gamma}^{-1})f_B) = 0$, where $\hat{\gamma} > 1$ is the positive root of*

$$\tfrac{1}{2}\sigma^2\hat{\gamma}^2 - \left(\mu + m + \tfrac{1}{2}\sigma^2\right)\hat{\gamma} - (r^* - \mu) = 0. \quad (20)$$

Equilibrium debt issuance follows (11), and the debt level adjusts gradually toward the target $f_m^* Y_t$ according to

$$F_{t+dt}^{\hat{\gamma}-1} = (1 - \phi\, dt)\, F_t^{\hat{\gamma}-1} + \left(f_m^* Y_t\right)^{\hat{\gamma}-1}\phi\, dt, \quad (21)$$

where $f_m^* > 0$ is the steady-state leverage level at which the issuance rate equals the rate of amortization, $g(f_m^*) = m f_m^*$, and the speed of adjustment is $\phi = \eta r + (\hat{\gamma} - 1)m$.

[16] Note that using (19) to determine $\tau^*(f)$, we can compute f_t from $\tau^*(f_t) = \tau^*(0) - t$. One can then show directly $\partial f/\partial t = -(\pi c + \eta r p)/p' - (\mu + m) f$, confirming (11).

[17] The Coasian dynamics described here are not unique to debt. See, for example, DeMarzo and Urošević (2006) for a related result in the context of trading by a large shareholder.

PROOF: See DH19 for a general proof that with continuous trading, given any initial leverage f, the equilibrium value of equity equals the no-adjustment value. DHT19 generalize this result to allow for differing discount rates (as well as a time-varying risk premium). To calculate the no-adjustment value, we must solve for the optimal default threshold f_B and the corresponding discount factor $h(f) = E[e^{-(r^*-\mu)\tau_B}]$. The discount factor is increasing in f and satisfies the Hamilton–Jacobi–Bellman (HJB) equation,

$$(r^* - \mu)h = -(\mu + m)fh' + \tfrac{1}{2}\sigma^2 f^2 h'',$$

which implies that $\hat{\gamma}$ must solve (20). The threshold f_B follows from the smooth pasting condition $h'(f_B) = 0$. The debt price equals the marginal cost of debt, as in (18), and the issuance policy (11) is then necessary to rationalize the debt price, as it implies

$$p'(f_t)\frac{dG_t}{Y_t} = p'(f_t)g(f_t)dt = -\left(\pi c + \eta r p(f_t)\right)dt,$$

so that the rate of debt devaluation associated with new issuance offsets the net funding cost advantage of debt. Finally, (21) follows from (11) using the methods in DHT19. ■

Proposition 6 demonstrates that the firm maintains significant debt capacity even when cash flows are risky. The firm will adjust its leverage ratio slowly toward a target, with the target level and adjustment speed dependent on the debt's maturity and cash flow volatility.[18]

Importantly, although there is a funding cost advantage associated with debt, shareholders are again unable to capture these benefits. In equilibrium, the firm's anticipated future debt issuance depresses the current debt price sufficiently to offset any gains from trade. The expected value of the debt tax shields, and the lower discount rate associated with debt, are dissipated through increased default costs.

In particular, note that for an initially unlevered firm, the value of equity is equal to its unlevered value *independent of the debt maturity*. Consider, for example, the two panels in Figure 4. With continuous trade, the initial debt level rises faster and higher with amortizing debt compared to perpetual debt, allowing the firm to shield more of its income from taxes. But default also occurs earlier with amortizing debt, and the higher default cost offsets the additional tax benefits.

Thus, while different debt maturities will have a large impact on equilibrium debt dynamics via the target leverage f_m^* and the speed of adjustment, shareholders will be indifferent to this choice. Moreover, for an initially

[18] The speed of adjustment slows with an increase in debt maturity or cash flow volatility. Although volatility reduces target leverage, the relation of the target to debt maturity is U-shaped. See DH19 for further details.

unlevered firm, issuing *zero* debt and remaining unlevered is also an equilibrium outcome.[19]

C. Liquidation Value

Thus far, I have assumed that all cash flows cease and the firm has zero value in the event of default. Suppose instead that if the firm defaults on date τ, it has liquidation value $L_\tau \geq 0$, which may depend on the firm's profitability (or other firm characteristics, such as collateral) at the time of default. How will this liquidation value be split between security holders, and how will this split affect the valuation of debt and equity?

With a single class of unsecured debt, absent any protection we should expect a violation of absolute priority. By issuing new debt just prior to default and using the proceeds to pay a liquidating dividend, the firm can effectively steal any residual value from creditors.[20] Without an enforcement mechanism to prevent such behavior, the firm could dilute prior creditors' claims essentially to zero. We can model this extreme case by assuming that creditors have zero recovery value, while shareholders capture the liquidation value L_τ via a final liquidating dividend.[21]

This extreme violation of absolute priority is, of course, highly stylized. In practice, there are limits on debt issuance and dividend payouts near default. In DH19, we consider a general setting in which unsecured creditors do have some protections available. The firm may choose between different bankruptcy regimes that trade off the total deadweight loss in default with the recovery rate creditors obtain.[22] Importantly, none of the key conclusions of Proposition 6 are changed by these considerations: the value of equity equals the no-adjustment value, the price of debt equals its marginal cost, and leverage adjusts gradually, according to (11), toward a target level.[23] Rather than incorporate this more

[19] Specifically, because the gain from trade disappears, remaining at $f = 0$ is also a Markov-perfect equilibrium (MPE) if trade is continuous. This equilibrium is not possible in discrete time, and is the only alternative MPE (in f) with continuous trade.

[20] Indeed, suppose a firm with debt $F_{\tau-}$ issues additional debt Δ_τ prior to default. Because the new creditors capture a pro rata share of the default value L_τ, the firm could raise $p_\tau \Delta_\tau = \Delta_\tau L_\tau/(F_{\tau-} + \Delta_\tau)$ from the new debt and use the proceeds to pay a dividend. Taking the limit as Δ_τ grows, shareholders receive the entire liquidation value.

[21] Dilution is not the only means shareholders have to subvert absolute priority. For example, shareholders could engage in risky gambles with L_τ to obtain a small probability of a large payoff, again capturing value at creditors' expense. Note also that this asset substitution would overcome seniority provisions intended to block dilution. We discuss seniority provisions as an alternative commitment mechanism in Section III.

[22] See also DHT19, where we develop a model in which the debtor continues to pay post-default, but negotiates partial debt forgiveness with some sacrifice of future cash flows.

[23] Of course, the no-adjustment equity value and the debt price will depend on their recovery in default, as will the optimal default threshold f_B. For example, if L_τ is some fraction $l < 1$ of the unlevered value of the firm, and if debtholders recover $bp(0)$ with $b < 1$, then the default threshold becomes $f_B^{l,b} = f_B(1-l)/(1-b)$ and the debt price is $p^{l,b}(f) = \frac{c^*+m}{r^*+m}(1-(1-b)(\frac{f}{f_B^{l,b}})^{\hat{\gamma}-1})$. The optimal issuance policy follows (11) with this revised price.

detailed model of bankruptcy, for analytic simplicity, I maintain the extreme assumption that existing unsecured creditors have zero recovery in default, but this assumption is not qualitatively important.

II. Investment and Collateral

I now introduce the possibility that the firm may grow by making new investments. Some portion of this investment may be in the form of assets that can serve as collateral. The presence of collateral implies that the firm may use secured debt financing in addition to unsecured debt. After extending the prior model to incorporate investment, I show that, by allowing the firm to secure some creditors to the exclusion of others, collateral can restore the firm's ability to capture the funding cost advantages of leverage.

A. Capital and Secured Financing

To distinguish the role of collateral from that of cash flow in the determination of leverage, we need a simple model in which the dynamics of each are sufficiently distinct. Here, I adapt a standard neoclassical model of the firm to allow for discrete projects of differing vintages.

The firm has a sequence of investment projects indexed by $i = 0, 1, 2, \ldots$. Projects arrive stochastically, with project i's initiation date denoted by t_i, where $t_0 = 0$ and $t_i > t_{i-1}$. Each project requires initial investment I^i in new capital, which depreciates at rate δ once installed. Hence, the capital associated with project i on date t is given by

$$K_t^i = \begin{cases} 0 & \text{if } t < t_i \\ e^{-\delta(t-t_i)} I^i & \text{if } t \geq t_i \end{cases}.$$

The after-tax profitability of project i on date t is given by $Y_t^i \equiv A_t^i K_t^i$, where the project's productivity process $A_t^i \equiv a^i A_t$ can be separated into a permanent project-specific component a^i and a time-varying firm-level component A_t. The firm-level productivity shock evolves according to

$$dA_t = (\mu + \delta) A_t dt + \sigma A_t dZ_t,$$

where Z_t is a standard Brownian motion, independent of all other variables.

The firm's aggregate capital stock on date t is therefore equal to $K_t \equiv \sum_i K_t^i$, with aggregate profitability

$$Y_t \equiv \sum_i Y_t^i = A_t \sum_i a^i K_t^i.$$

Let $N_t \equiv \max\{i : t_i \leq t\}$ be the counting process indexing the most recent project launched. Then the firm's aggregate profitability evolves according to

$$dY_t = \mu Y_t dt + \sigma Y_t dZ_t + \theta_t Y_{t-} dN_t, \tag{22}$$

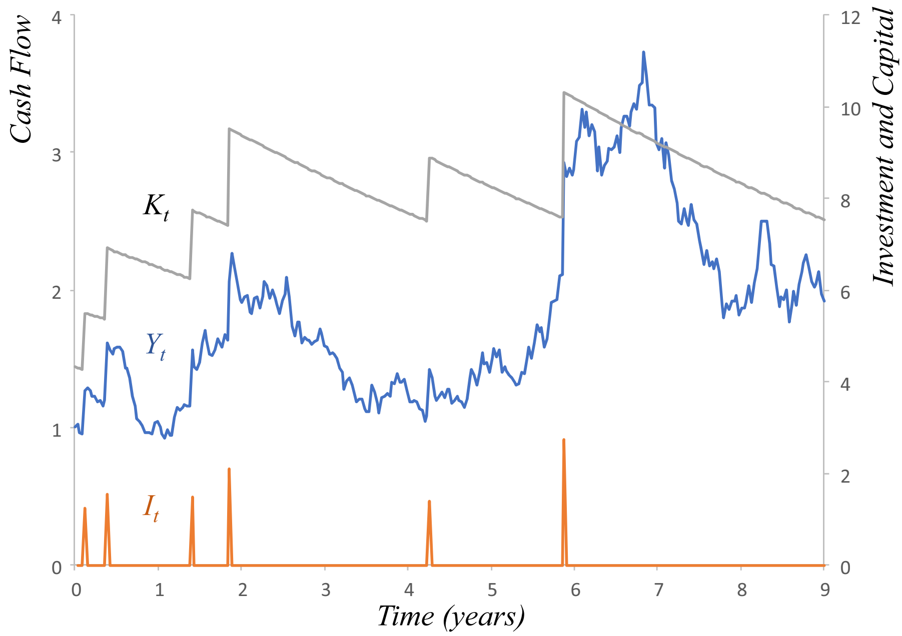

Figure 6. Investment, capital, and profitability process following (22) to (24).

where $\theta_t \equiv A_t a^{N_t} K_t^{N_t}/Y_{t-} = Y_t/Y_{t-} - 1$ is the jump in profitability due to the most recent investment. The firm accrues free cash flow over the time interval $[t, t + dt)$ at rate

$$Y_t dt - q_t \theta_t Y_{t-} dN_t, \tag{23}$$

where $q_t \equiv (A_t a^{N_t})^{-1}$ is the required investment per unit of incremental cash flow for the project launched on date t. The evolution of the firm's capital can thus be written as

$$dK_t = -\delta K_t dt + q_t \theta_t Y_{t-} dN_t. \tag{24}$$

See Figure 6 for an illustration of the investment, capital, and cash flow processes.

In the event of default at time τ, the liquidation value of the firm may depend on both its terminal profitability as well as its remaining capital stock. For simplicity, assume that the firm's liquidation value is linear in these components, so that[24]

$$L_\tau = \nu \left(\frac{Y_\tau}{r^* - \mu} \right) + \alpha K_\tau. \tag{25}$$

[24] The linear specification eases tractability, but is not crucial to the qualitative results.

Specifically, $\alpha \in [0, 1]$ is the fraction of the firm's capital that can be recovered in default, and $\nu \in [0, 1)$ represents the expected liquidation value associated with the firm's profitability as a fraction of its unlevered value. We can interpret

$$Y_t^\nu \equiv (1 - \nu) Y_t$$

as the incremental profitability that is specific to the firm and lost in default.

As before, the firm can issue (and repurchase) equity and unsecured debt at any time. In addition, assume that a fraction $\beta \in [0, 1]$ of the firm's capital can be appropriately ring-fenced and collateralized for the purpose of secured borrowing. Let S_t be the amount of secured debt outstanding on date t and normalize the coupon rate for secured debt to r. I impose the restriction

$$S_t \leq \alpha\beta K_t, \text{with amortization rate}\, m^s \geq \delta, \tag{26}$$

to assure that the value of the firm's underlying collateral always equals or exceeds the remaining principal of the loan. With these assumptions, all secured debt is risk free.[25] I now consider how the availability of collateral and secured financing affects the firm's optimal capital structure choice.

B. Project Finance

To illustrate the impact of collateral on the cost and method of financing, consider a firm that has already invested and has financing in place. Specifically, suppose the firm currently has profitability Y and capital K, with no future investment opportunities. How does the current value of equity depend on leverage as well as the mix of secured and unsecured financing? The following result answers this question using the valuation results from Section I.

PROPOSITION 7 (Adjusted valuation): *Consider a firm with profitability Y_t, capital K_t, unsecured debt F_t, and secured debt S_t. Suppose the firm will make no future investments and can issue (or repurchase) unsecured debt or equity at any time. Then, although the firm may issue unsecured debt gradually over time, shareholders do not gain from this incremental borrowing. If the debt amortization rate $m = m^s = \delta$, the value of equity and unsecured debt are given by*

$$V\left(Y_t^\nu, F_t^{K,S}\right) + L_t - S_t \quad \textit{and} \quad p\left(Y_t^\nu, F_t^{K,S}\right), \tag{27}$$

where V and p are the equilibrium equity value and debt price functions from Proposition 6, and the adjusted debt level is

[25] Restricting secured debt to be risk free simplifies the analysis and allows for a closed-form solution of the potential gains to shareholders. If the collateral value is itself risky, the expected recovery rate for secured debt would be less than one. There would then be an optimal tradeoff between the quantity of secured debt and the recovery rate. This case could be modeled as a simultaneous issuance of risk-free secured debt together with unsecured debt with the same combined expected recovery rate, and would have qualitatively similar results.

$$F_t^{K,S} \equiv F_t + \frac{\alpha K_t}{p(0)} - \rho \frac{S_t}{p(0)} \; with \; \rho = \frac{(\pi + \eta) r}{r^* + m} > 0.$$

PROOF: Let $F_t = e^{-mt} F_0$ be the debt level absent future borrowing and $\hat{r} = r(1 - \pi)$ be the after-tax coupon rate on secured debt. As discussed in Section I.C, shareholders' ability to dilute existing unsecured creditors allows them to capture any residual unsecured liquidation value of the firm in the event of default. The no-adjustment value of equity is therefore given by

$$\max_{\tau} E \left[\int_0^{\tau} e^{-r^* t} \left(Y_t - (c^* + m) F_t - (\hat{r} + m^s) S_t \right) dt + e^{-r^* \tau} (L_\tau - S_\tau) \right]. \quad (28)$$

Using

$$L_0 - S_0 = E \left[\int_0^{\tau} e^{-r^* t} \left(\nu Y_t + (r^* + \delta) \alpha K_t - (r^* + m^s) S_t \right) dt + e^{-r^* \tau} (L_\tau - S_\tau) \right],$$

we can rewrite (28) as

$$\max_{\tau} E \left[\int_0^{\tau} e^{-r^* t} \left(Y_t^{\nu} - (c^* + m) F_t - (r^* + \delta) \alpha K_t + (r^* - \hat{r}) S_t \right) dt \right] + L_0 - S_0. \quad (29)$$

Equation (29) implies that the firm will behave as though it had the modified cash flow process $\hat{Y}_t = Y_t^{\nu} - (r^* + \delta) \alpha K_t + (r^* - \hat{r}) S_t$. The general methodology in DH19 can then be applied to show that, as in Section I.B, with continuous trading opportunities the firm will issue unsecured debt gradually at a price equal to its marginal cost, with the same equity value as the no-adjustment value in (29). If we further assume $\delta = m = m^s$, then using $p(0) = (c^* + m)/(r^* + m)$ from (18),

$$(c^* + m) F_t + (r^* + \delta)(\alpha K_t) - (r^* - \hat{r}) S_t = (c^* + m) \left(F_t + \frac{\alpha K_t}{p(0)} - \rho \frac{S_t}{p(0)} \right).$$

Thus, (29) becomes $V(Y_0^{\nu}, F_0^{K,S}) + L_0 - S_0$. ∎

Equation (27) allows us to compute the value of the firm's equity in excess of its current liquidation value via an adjustment to the firm's leverage and profitability process. Note, however, that the firm does not actually increase its unsecured debt to the level $F_t^{K,S}$ on date t. It simply behaves *as though* it has additional leverage, with future debt pricing and dynamics as derived in Section I.[26]

Moreover, Proposition 7 implies that shareholders will gain by issuing secured debt whenever possible. Because it is fully collateralized with coupon rate r, secured debt can be issued at par. Thus, the net effect of an increase in S_t, after including the proceeds from debt issuance, would be a *reduction* in

[26] We can interpret the adjustment $\alpha K_t / p(0)$ as though the firm has leased the portion of the new investment that has resale value, with the lessor having priority over these assets in default. Because the lease is effectively senior to existing unsecured creditors, the effective debt price is $p(0)$—the debt price for an unlevered firm.

the effective leverage $F_t^{K,S}$ of the firm. This reduction reflects the fact that, in contrast to unsecured debt, shareholders will capture the funding advantage $(\pi + \eta)r$ associated with secured debt. Given this benefit, it is optimal for the firm to maximize its secured financing by setting $S_t = \alpha\beta K_t$ at all times.

Next, I apply this result to determine the impact of a new investment opportunity on the value of equity when a portion of the firm's capital can be used as collateral to issue secured debt.

PROPOSITION 8 (Investment with secured debt): *Suppose the firm currently has maximal secured debt, $S_t = \alpha\beta K_t$, and has a one-time opportunity to invest I and increase profitability by θ. Then the firm will borrow $\alpha\beta I$ using secured debt and fund the remainder of the investment with equity. If the debt amortization rate $m = \delta$, then the gain in the value of equity from the project is*

$$V\left(Y_t^{\nu}(1+\theta), F_t^{K,S} + (1-\beta\rho)\frac{\alpha I}{p(0)}\right) - V(Y_t^{\nu}, F_t^{K,S}) + \frac{\nu\theta Y_t}{r^* - \mu} - (1-\alpha)I. \quad (30)$$

PROOF: If the firm invests, it is optimal for the firm to maximize its secured debt, and so it will borrow an additional $\alpha\beta I$ immediately using the available collateral from the new investment. If $m^s > \delta$, the firm will also issue new secured debt at rate $(m^s - \delta)S_t$ to remain at the collateral constraint (26), and thus secured debt will evolve as though it has maturity $m^s = \delta$. Assuming $m = \delta$, from (27) the value of equity once the firm invests is

$$V\left(Y_t^{\nu}(1+\theta), F_t + \frac{\alpha(K_t + I)}{p(0)} - \rho\frac{(S_t + \alpha\beta I)}{p(0)}\right)$$
$$+ \frac{\nu(1+\theta)Y_t}{r^* - \mu} + \alpha(K_t + I) - (S_t + \alpha\beta I).$$

Given the secured debt financing of $\alpha\beta I$, the net equity investment required is $(1-\alpha\beta)I$. Deducting this amount, the value of equity just prior to investment is

$$V\left(Y_t^{\nu}(1+\theta), F_t^{K,S} + (1-\beta\rho)\frac{\alpha I}{p(0)}\right) + L_t + \frac{\nu\theta Y_t}{r^* - \mu} - S_t - (1-\alpha)I. \quad (31)$$

Comparing (27) and (31) gives the result. ■

Propositions 7 and 8 establish our main result regarding collateral. Secured debt allows the firm to exclude other creditors from the liquidation value associated with the firm's collateral. This commitment makes the value of the secured debt insensitive to the firm's total leverage. Hence, the firm will choose to issue secured debt immediately up to the value of its available collateral. Because secured debt is not devalued by future issuance, the firm is able to capture the full funding advantage from secured debt, increasing shareholder value. Equation (30) reflects this gain in terms of an equivalent "discount" ρ on the effective financing cost of the collateralizable portion of any new investment.

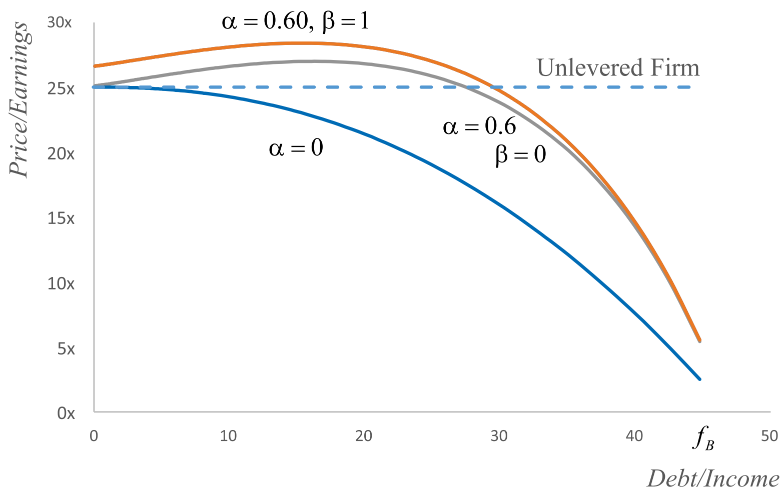

Figure 7. Investment cost threshold $\bar{q}(f)$ below which investment benefits shareholders. The debt overhang effect is diminished when assets are recoverable ($\alpha > 0$), and even more so when assets can serve as collateral ($\beta > 0$) and lower the firm's cost of capital. (Assumes 20% tax rate, 5% cost of capital for debt and equity, 1% growth rate, 35% cash flow volatility, 5% debt amortization, and 10% growth from investment.)

Now consider the optimal investment policy. If $I = q\theta Y$, an all-equity-financed firm would invest as long as $q < 1/(r^* - \mu)$. With leverage, this threshold will change. Let $\bar{q}(f)$ be the maximum investment cost per dollar of new earnings (i.e., the maximum price-earnings multiple) that shareholders of a firm with leverage f would be willing to pay to invest (i.e., such that (30) is positive). Figure 7 compares the investment threshold for the case in which all investment is nonrecoverable ($\alpha = 0$) versus the case in which investment can serve as collateral ($\alpha\beta > 0$). Note the increasing effect of debt overhang with leverage when investment is nonrecoverable. On the other hand, when investment provides additional collateral, the effect of debt overhang is offset by the lower funding cost of secured debt together with the firm's ability to dilute its existing unsecured creditors with new, higher priority claims.

Proposition 8 also explains the existence of a "pledgeability premium" associated with assets that can serve as collateral.[27] Consider, for example, a liquid asset ($\alpha = 1$) that is fully pledgeable as collateral ($\beta = 1$) versus one that is not pledgeable ($\beta = 0$). Then from (30), the firm would be willing to pay a premium ξ for the pledgeable asset equal to

$$\xi = \frac{1}{1-\rho} - 1 = \frac{(\pi + \eta)r}{r(1-\pi) + \delta}. \tag{32}$$

[27] See, for example, Chen et al. (2018) for recent evidence and estimation of such a pledgeability premium in Chinese corporate bond markets.

This premium reflects the lower cost of funds associated with the purchase of collateral.

C. Dynamic Investment

With continuous trading opportunities, the prior results demonstrate that when the firm invests:

- Shareholders gain by immediately issuing the maximal amount of secured debt possible given the firm's available collateral.
- Any additional funds needed for investment will be funded from equity, as there is no gain from the issuance of unsecured debt.[28]
- The pricing and dynamics of the firm's unsecured debt will follow the analytic results of Section I.B with a modified profitability process and debt level according to (27).

I conclude by briefly discussing how this characterization can be used to determine the value of equity, debt, and leverage dynamics when investment opportunities arise stochastically over time.

To simplify notation, set $\nu = 0$, so that the firm's liquidation value depends only on its remaining capital and set the maturity rate of all debt equal to the rate of depreciation.[29] Suppose new investment opportunities arrive at rate $\lambda \geq 0$. If the firm invests, its profitability will jump by θY given an up-front investment cost of $I = q\theta Y$.[30]

As demonstrated in Section II.B, it is optimal for the firm to issue secured debt to exhaust its available collateral. Additional capital that cannot be collateralized affects firm value as though it were financed with unsecured debt. From (30), let $\Gamma \equiv (1 - \beta\rho)\alpha/p(0)$ and define

$$\hat{F}_t = F_t + \Gamma K_t \tag{33}$$

to be the firm's effective debt level on date t after adjusting for these effects.

Using the general methodology developed in DH19, with continuous trade we can solve for the value of equity $V(Y, \hat{F})$ by assuming that the firm does not actively issue new debt. Thus, its effective debt level will change only as a result of debt maturity, capital investment, and depreciation. Once the equity value function is determined, the equilibrium price for unsecured debt is equal to the marginal cost of debt to equity holders, $p(Y, \hat{F}) = -V_F(Y, \hat{F})$, and the equilibrium debt issuance satisfies (11).

[28] Indeed, shareholders would suffer a strict loss if the firm issued a large block of unsecured debt.

[29] As shown in Section II.B, the only effect of $\nu > 0$ is a rescaling of the profitability process and hence can be immediately generalized. Setting $m = m^s = \delta$ allows us to track the firm's effective leverage as a single state variable, facilitating computation.

[30] We assume that the expected growth rate of the firm with investment, $\mu + \lambda\theta$, is less than r.

With stochastic investment, the no-adjustment equity value function satisfies the HJB equation

$$\begin{aligned} r^* V(Y, \hat{F}) &= Y - (c^* + m)\hat{F} - m\hat{F}V_F + \mu Y V_Y + \tfrac{1}{2}\sigma^2 Y^2 V_{YY} \\ &\quad + \lambda\Big[V\left(Y(1+\theta), \hat{F} + \Gamma q\theta Y\right) - V(Y, \hat{F}) - (1-\alpha)q\theta Y\Big]^+. \end{aligned} \tag{34}$$

That is, the required return r^* for shareholders must equal their total return from (i) cash flows net of after-tax debt payments, $Y - (c^* + m)\hat{F}$; (ii) expected capital gains from debt paydown and productivity shocks; and (iii) expected gains from the arrival of a new investment opportunity. Note that shareholders will only make investments that lead to positive gain in the share price; projects may sometimes be rejected depending on the degree of debt overhang at the time the opportunity arrives.[31]

As in Section I, I consider a Markov-perfect equilibrium in the state variable $\hat{f} = \hat{F}/Y$, the effective debt-income ratio of the firm. Then $V(Y, \hat{F}) = v(\hat{f})Y$, where v satisfies

$$\begin{aligned} (r^* - \mu)\, v(\hat{f}) = 1 - (c^* + m)\hat{f} - (\mu + m)\hat{f}\, v'(\hat{f}) + \tfrac{1}{2}\sigma^2 \hat{f}^2 v''(\hat{f}) \\ + \lambda\Big[v\left(\tfrac{\hat{f} + \Gamma q\theta}{1+\theta}\right)(1+\theta) - v(\hat{f}) - (1-\alpha)q\theta\Big]^+. \end{aligned} \tag{35}$$

The optimal default boundary $\hat{f}_b$ satisfies the usual value matching and smooth pasting conditions: $v(\hat{f}_B) = v'(\hat{f}_B) = 0$. Also, starting with zero effective leverage, shareholders earn the unlevered cash flows until the first investment is made, and hence

$$v(0) = \frac{1}{r^* - \mu + \lambda} + \frac{\lambda}{r^* - \mu + \lambda}\left[v\left(\frac{\Gamma q\theta}{1+\theta}\right)(1+\theta) - (1-\alpha)q\theta\right]^+. \tag{36}$$

Using this approach, it is relatively straightforward to calculate the value function $V(Y, \hat{F}) = v(\hat{f})Y$ numerically. Given any $(Y, K, F, S = \alpha\beta K)$, then analogous to (27) the equilibrium value of equity and the price of unsecured debt are equal to

$$E_t = v\left(\hat{f}_t\right) Y_t + \alpha(1-\beta)K_t \text{ and } p_t = p(\hat{f}_t) \tag{37}$$

with the expected issuance rate of unsecured debt again given by (11).

Figure 8 compares the equilibrium debt and investment policies when the firm's assets are pledgeable as collateral ($\beta = 1$) versus when they cannot be pledged ($\beta = 0$). When collateral is available, the firm can issue both secured and unsecured debt, with a total debt level that exceeds the level it could borrow using unsecured debt alone. When using unsecured debt only, the debt level

[31] Because secured debt reduces the effective debt burden of the firm, another benefit of collateral in a dynamic context is a reduction in the degree of underinvestment due to debt overhang. At the same time, debt overhang is an additional cost associated with unsecured debt. DH19 show that in a model with investment, the tax benefits from issuing unsecured debt are fully dissipated in equilibrium by the combined costs of default and debt overhang.

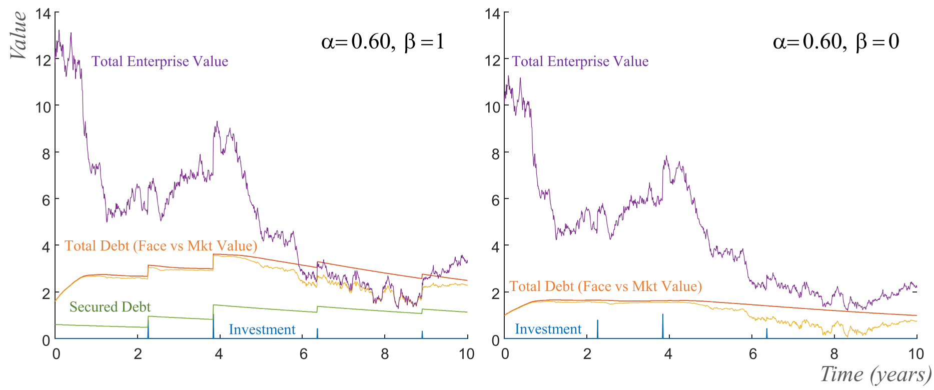

Figure 8. Total firm value, debt, and investment with and without collateral. In the left panel, $\beta = 1$ and all assets are pledgeable; in the right panel, $\beta = 0$ and only unsecured borrowing is possible. Although profitability and investment shocks are identical, note the higher firm value in the left panel, as well as its willingness to invest even after distress in year 8. In the right panel, even though total debt is lower, the firm does not invest after year 8 due to debt overhang.

responds gradually, and only to changes in profitability—there is no increase in debt associated with new investment. Finally, note that, despite having higher leverage, secured borrowing overcomes debt overhang, allowing the firm to continue to invest even in times of distress (see the investment after year 8 in the left panel).

Although the firm chooses to issue unsecured debt in the equilibria depicted in Figure 8, as discussed previously there is no net gain to shareholders from doing so. Thus, initial share prices would be unaffected if instead the firm chose to issue only secured debt (or no debt, if $\beta = 0$). These results confirm the claims in Figure 1 in the introduction.

III. Discussion and Conclusions

My goal in this address has been to demonstrate that when firms are free to adjust their capital structures over time, the leverage dynamics we observe, and their consequences for firm value, will depend largely on the commitment mechanisms that firms use to constrain their future behavior. With complete contracts, firms should adopt very high leverage, avoiding the costs of default or distress with a commitment to issue equity and deleverage aggressively when needed. Without commitment, firms will adjust debt gradually, but with no benefit to firm value and with otherwise similar firms potentially choosing very different target levels of leverage.

In this context, collateral emerges as a natural commitment device. By issuing secured debt against their available collateral, firms can capture the funding cost advantages from debt. This result helps explain the strong empirical correlation between asset tangibility and leverage. It also explains the existence of a pledgeability premium for assets that can serve as collateral, and why improvements in the availability of collateral, or the enforcement of collateral law, have a strong positive effect on lending activity (see, e.g., Haselmann, Pistor, and Vig (2009)) even when other sources of funding are available.

A. Alternative Commitment Mechanisms

Of course, collateral is not the only available commitment mechanism. Seniority provisions may play a similar role to secured debt—if senior creditors expect to receive a high recovery rate in default, the price of the most senior claims will be relatively insensitive to total leverage. In that case, the firm could issue a block of senior debt before gradually issuing more sensitive junior claims. That said, seniority provisions can be usurped, for example, by asset substitution, asset sales, or maturity shortening.[32] In addition, seniority provisions can exacerbate debt overhang concerns ex post. For example, in the dynamic model considered here, seniority is not an adequate substitute for secured debt, as the collateral associated with new investment would primarily benefit existing creditors, increasing debt overhang and reducing the funding cost benefits captured by shareholders.

Restrictive covenants are another widely used commitment mechanism. Covenants that limit the total debt of the firm would cap future debt issuance and allow the firm to capture funding benefits up front. That said, to the extent that these covenants are both imperfect and costly to renegotiate, they may restrict the firm's future investment and growth. Although the firm will optimally trade off these costs at the time the covenants are put in place, they will almost certainly be inefficient ex post.[33]

The value of commitment can help explain otherwise costly corporate behaviors such as reliance on a single lender (relationship banking) or establishing a reputation to maintain a target credit rating. Such commitments are likely to be fragile, as the temptation to renege may be overwhelming in difficult times. Reputations are easier to establish and maintain in the context of repeated interactions. Hence, private equity firms may be better able to capture the funding benefits associated with leverage because of the value they place on their reputation with creditors.[34]

Frictions may also play an important role. For example, a high fixed cost of borrowing will make debt issuance infrequent. By providing a commitment to periods of inaction, fixed costs allow the firm to capture some benefits from leverage that would otherwise be dissipated.[35] Time lags in the issuance process could also make debt issuance less frequent and thus more valuable. Even

[32] See, for example, Admati et al. (2018) and Brunnermeier and Oehmke (2013).

[33] See Matvos (2013) and Green (2018) for evidence regarding the cost and benefit of restrictive covenants, including the resulting path-dependence in refinancing decisions.

[34] Malenko and Malenko (2015) develop such a model and demonstrate that because private equity firms will compete away gains that are purely associated with financing benefits, only those firms that can provide additional value-added via operational improvements will be able to sustain their reputation with lenders.

[35] But as fixed costs approach zero, we would obtain a similar convergence result as in Section I.

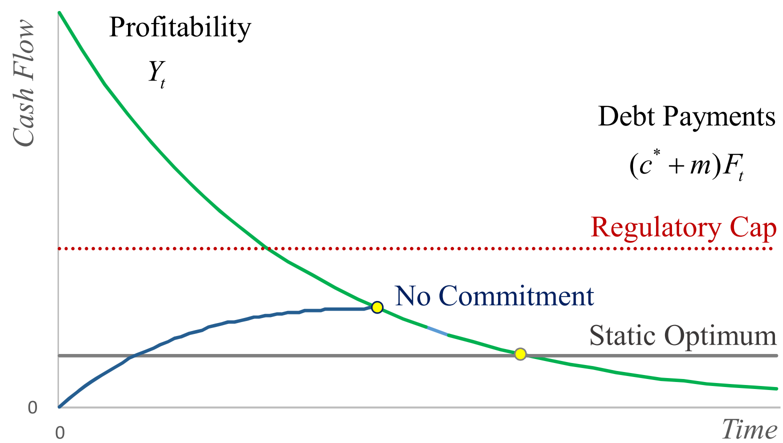

Figure 9. Firms may increase debt to a regulatory constraint, even if set inefficiently high, to benefit from external commitment.

governance frictions, which distort managerial leverage choices relative to shareholder preferences, could serve to increase the benefit from debt that the firm can capture.

B. Regulatory Constraints

Regulatory constraints that limit leverage or restrict interest deductibility also provide a commitment mechanism that can have a significant influence on equilibrium outcomes. As an example, consider again the simple deterministic model of Section I.A. Figure 9 shows an example of the path of debt payments in the no-commitment equilibrium as well as the static trade-off theory optimum in a setting with perpetual debt. Suppose a regulator were to impose a debt limit that prevents the firm from issuing debt with payments beyond a maximum level as shown in the figure. How would such a constraint affect equilibrium leverage choices?

Because the constraint does not bind in the no-commitment equilibrium, standard intuition might suggest that the equilibrium is unchanged. This intuition is incorrect, however, because the regulatory constraint itself provides a valuable external commitment technology to the firm. As long as the regulatory cap is not too high, once the cap is in place, the no-commitment equilibrium *disappears*. Instead, the firm would immediately issue debt up to the cap.[36] This new equilibrium dominates because the regulatory cap provides an external commitment device for the firm: The firm can issue a large amount of debt

[36] Specifically, this result holds for any debt cap below $f_0^0 Y_0$, where f_0^0 is the maximum leverage such that $v^0(f_0^0) = v^0(0)$ as illustrated in Figure 2. Note that the debt payment at this cap will always strictly exceed the debt payments in the no-commitment equilibrium, because the no-commitment equilibrium has the same equity value but with lower tax shields and therefore lower default costs.

immediately at a price above marginal cost because creditors know it will not issue again.

Of course, once at the cap, shareholders would like to have the cap relaxed so that they may issue more debt (Proposition 3), even though ex ante firm value would have been higher with a tighter cap (up to the point of the static optimum f_0^* in Figure 2).[37] Although this example is highly simplified, the following results can be shown more generally:

- Because it provides commitment, a regulatory cap on debt or leverage can induce firms to increase leverage up to the cap immediately.
- Once at the cap, shareholders will view the cap as costly and will prefer to have the cap relaxed. However, although the cap binds ex post, ex ante firm value (and total welfare) may be increased with a tighter cap.

C. Implications for Future Research

Reframing the question of capital structure and its dynamics in terms of commitment leads to several directions for future research. In terms of theoretical work, many existing models make assumptions for tractability that, as a side effect, obviate commitment effects. For example, restricting attention to one-period debt or risk-free debt, or requiring that existing debt mature or be repaid before new debt is issued, eliminates leverage ratchet effects in ways that are counterfactual. Similarly, imposing large fixed costs associated with issuance, or constraining the maximum amount the firm can borrow, introduces an exogenous commitment mechanism into the model. Instead, we need to develop richer dynamic models that allow for a better understanding of how firms may use a realistic set of contracting tools to trade off the benefits of commitment with the potential costs of financial inflexibility.[38]

Empirically, this framework implies that prior attempts to assess leverage simply as a "quantity" were doomed to fail. Instead, it must be evaluated as a path that firms navigate, at each point in time, making strategic trade-offs in terms of how much to constrain their future behavior. As such, the fine details of a firm's capital structure matter, including those related to maturity structure, covenant protections, ease of issuance, and even reputation. Most importantly, because prior commitments must sometimes bind to add value, we should expect significant hysteresis in firm behavior with broad (and lengthy) departures from what might be ex post optimal.

Finally, from a policy perspective, commitment effects can have a first-order impact on the policy responses we should expect. Tax code changes, regulatory constraints, or changes that affect market liquidity or frictions will have very different implications depending on both the constraints firms currently have in place and the implications of the changes for future commitment mechanisms.

[37] Here, I am evaluating only the direct effect on shareholders. If we view tax benefits as a transfer, then tightening the debt limit even further than f_0^* would increase total welfare.

[38] See, for example, Gamba and Saretto (2019) and Chaderina, Weiss, and Zechner (2018) for recent work exploring the implications of leverage ratchet effects for debt and equity pricing.

In particular, regulatory constraints designed to limit leverage may instead increase it, and tightening already-binding constraints may improve firm value (in addition to social welfare).

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