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ABSTRACT

Corporate Leverage and Product Differentiation Strategy*

We explore the joint determination of product differentiation strategy and corporate leverage in a setting where (i) product differentiation is valued by customers; (ii) debt is necessary to discipline managers; and (iii) liquidation is costly for customers, in particular, when products are highly differentiated from competitors' products. We show that when managerial incentive problems call for high leverage, firms position their products closer to competitors to reduce deadweight costs customers incur in liquidation. We discuss our findings in light of case study evidence.

JEL Classification: G3, L1 and L2
Keywords: customer lock-in strategies, innovation, leverage, liquidation costs and product differentiation

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1 Introduction

During the mid 1990s, Apple Computer Inc. experienced severe financial and operating difficulties.[1] It piled up record losses, suffered internal turmoil, and had its debt ratings dramatically downgraded.[2] These developments raised concerns among financial market observers about Apple's long–term viability. Software makers began to worry about Apple's survival prospects, too. Quoting from Apple's 1998 10–K filing: *"To the extent the company's financial losses in prior years and declining demand for the company's products [...] have caused software developers to question the company's prospects [...], developers could be less inclined to develop new application software [...] and more inclined to devote their resources to developing and upgrading software for the larger Windows market."* This suggests that the exit of Apple from the computer market would have imposed substantial costs on its customers. First, software makers most likely would have refrained from developing new software for the Mac. Second, customers would have lost the opportunity to repurchase a Mac in the future. As a result, quasirents from current investments in software and learning would have evaporated. Not surprisingly, therefore, Apple's crisis led soon to a crisis of confidence among Apple's potential customers. Despite aggressive price cuts, Apple saw its market share dramatically shrink.[3] A quote from *Business Week* (February 2, 1996) illustrates a potential customer's perception of the crisis: *"[...] after Apple announced a $69 million quarterly loss [...] she crossed Apple off her list. 'I can see future directions for the PC, but I can't see it for the Mac.' "*

The example of Apple points to some more general considerations. First, a vendor's financial troubles can make potential customers reluctant to purchase from the vendor. This feature is particularly relevant for manufacturers of durable equipment for which customers require service, upgrades, and spare parts. To the extent that these services are most efficiently provided by the original manufacturer, liquidation can undermine the availability of after–sales services or make them more costly. It may also reduce the possibility of purchasing upgrades or of repurchasing the same product. When the original vendor goes bankrupt, and creditors take control over the firm's assets, the latter cannot be compelled to fulfill the implicit (or explicit, e.g. warranty coverage) contracts regarding the provision of future services or add–on products. As a result, consumers should be reluctant to purchase durable, service–intensive products from highly leveraged firms.

Second, sales drops should be more pronounced the more a firm's product differs from competitors' products. When a product is highly differentiated from com-

[1] See Business Week, January 29, 1996, and February 5, 1996.

[2] From February 1996 to February 1997 Moody's downgraded Apple's long–term and subordinated debt ratings four times to B3 and Caa, respectively (San Jose Mercury News, February 26, 1997).

[3] For instance, from 1995 to 1996 gross margins decreased from 29% to 15% while Apple's market share of the world computer market dropped from 8.2% during last quarter of 1995 to 7.1% during first quarter of 1996. From 1996 to 1997 Mac unit sales declined by 27%. See Business Week, January 29, 1996, and Apple's 1998 10–K filing.

petitors' products, customers typically rely on the original manufacturer to obtain product–specific aftersales services. In contrast, when the product is similar to those of competitors, customers should be able to get service, spare parts, upgrades, and complementary products even if the firm is no longer in the market. Likewise, when customers have to incur product–specific learning costs, switching to an alternative product should not be too costly, provided that the alternative product is similar to the previously purchased one. Going back the case of Apple, potential customers presumably would have been much less reluctant to purchase a Mac if the Mac did not differ so much from the PC (in particular, if customers could have used PC software on their Macs).

These considerations are consistent with the empirical findings of Opler and Titman (1994). They observe that highly leveraged firms lose market share to their less leveraged competitors in industry downturns. They also find that sales drops tend to be more pronounced in service intensive industries and when products are highly specialized and differentiated. Opler and Titman (1994) interpret this as evidence that sales drops are at least partially driven by customers' fears to be left without maintenance service. In an earlier contribution, Opler and Titman (1993) report that firms initiating leveraged buy outs (LBOs) have lower R&D ratios and are less likely to sell durable, service intensive goods, such as equipment and machinery. This is consistent with the view put forward in the present paper that LBOs are costly when customers rely on a vendor's long term viability.

Conversely, empirical studies indicate that R&D expenditures decline after LBOs. For example, in a sample considered by Kaplan (1989), LBO firms reduce capital expenditures by 33% in relation to their industry peers in the two years following the buyout. Likewise, Hall (1990) reports that increases in leverage were followed immediately by substantial reductions in R&D investment in a large panel of US manufacturing firms during the 1980s.[4] These findings can be interpreted as LBO firms being less tempted to waste free cash flow (as in our paper). Another interpretation put forward in our paper is that highly leveraged firms deliberately engage in less drastic innovation and product differentiation strategies in order to reduce the deadweight costs that customers incur in liquidation. Yet, positioning products too closely to competitors comes at a cost: it toughens price competition and reduces the product's perceived value added over competitors' products.

The aim of this paper is to address the interaction between these two forces, and to derive implications for optimal product positioning strategies and corporate leverage. Our contribution is to relate the firm's equilibrium financial structure to the characteristics of its product choice, and vice versa. How should companies adjust capital structure when liquidation is costly for customers? What, in turn, is the optimal product differentiation strategy when a company is highly leveraged and faces high bankruptcy risk?

[4] Smith (1990) reports similar patterns. See also Hall (2002) for an excellent survey of empirical studies on the financing of R&D.

We provide answers to these questions by considering the *joint* determination of product differentiation strategy and corporate leverage in a setting where (i) product differentiation is valued by customers; (ii) debt is necessary to discipline managers; and (iii) liquidation is costly for customers, in particular, when products are differentiated from competitors' products. The trade off between strengthening managerial incentives and reducing liquidation deadweight costs leads to the prediction that the equilibrium degree of product differentiation is limited by the severity of agency problems. In particular, we show that when managerial incentive problems call for high leverage, firms position their products closer to competitors in order to reduce liquidation deadweight costs imposed on customers and thus to increase their willingness to pay.

Our approach requires that consumers can observe leverage. If leverage were unobservable, it could not possibly influence consumers, and, consequently, there would be no gain to commit to low leverage. Unobservability of leverage thus results in high leverage, low customer confidence, and suppressed operating profits. This suggests that firms may have incentives to make voluntary public announcements about their financial structure to influence not only financial market players but also potential customers. We believe that this is of particular importance after adverse economic shocks. For instance, during the Asian financial crisis in 1998, public announcements made by companies listed on the South Korean stock exchange soared by 80% (see Korea Times, January 15, 1999). Concerning the demand side of the market, we argue that consumers indeed have incentives to gather information about the financial soundness of a firm they plan to purchase from. The reason is that rational consumers will take into consideration the "life-cycle", total cost of ownership of a product they consider purchasing.[5]

Our research complements a growing literature on how corporate financial structure is influenced by various product market considerations, and vice versa (see, among others, Bolton and Scharfstein 1990, Brander and Lewis 1986, Maksimovic 1988, Maksimovic and Titman 1991, Titman 1984). Closest to our analysis are Titman (1984) and Maksimovic and Titman (1991). Titman (1984) explores how financial structure is affected by potential customers' concerns about a firm's long term viability. He shows that in situations where a value–maximizing liquidation policy cannot be contracted upon directly, financial structure can serve as a commitment mechanism to liquidate only when liquidation is efficient for all stakeholders, including customers. We draw on Titman's argument, but take the analysis one step further. In particular, Titman fixes product characteristics and shows that firms producing durable, service–intensive products will have relatively low leverage. We argue that firms should also use channels other than reducing their leverage in order to increase potential customers' valuation for their products. In particular, when managerial incentive problems (or, alternatively, tax considerations) call for

[5]See, for example, Shapiro (1995) for an account of how companies take into consideration the total cost of ownership of high–volume copy machines before committing to a purchase.

high leverage, firms should alter the very characteristics of their products, in particular, reduce their uniqueness. We thus emphasize the importance of examining the joint determinacy of product differentiation and corporate financing decisions. The relevance of this consideration is illustrated by the previously discussed industry examples (see also the discussion in section 5) and empirical findings indicating that firms cut down innovation efforts following increases in leverage.

Maksimovic and Titman (1991) consider how financial structure alters a firm's incentives to maintain a reputation for producing high quality products. They show that debt may reduce value by undermining a firm's incentives to invest in reputation. This is because a reduction in quality increases current but decreases future cash flows, which in their model comes at the expense of debt holders.[6] Reputation building concerns play no role in our setting. Rather, our model builds on the premise that product differentiation (e.g. quality) increases a customer's valuation when the firm is not liquidated, but also increases deadweight costs that the customer incurs in liquidation. Thus, in situations where debt is needed to discipline managers (and, consequently, liquidation in bad states of the world cannot be avoided) firms will deliberately refrain from adopting overly drastic product differentiation choices.

This paper is also related to industrial organization literature on second sourcing. Farrell and Gallini (1988) consider a monopolist's temptation to exploit customers once they have incurred product–specific investments. They demonstrate that the monopolist can solve the hold up problem by licensing its product to competitors. Thus, as in our model, the supplier guarantees customers that a "second source" will be available in the future from which customers can purchase at low cost. However, the mechanism behind their model is rather different from ours. In their model, long–term contracts would eliminate the hold–up problem and the corresponding ex ante efficiency losses. Likewise, in our setting, potential hold–up problems could be addressed with long–term warranty contracts. Yet, to restore the disciplinary power of liquidation threats imposed on management, creditors must not be liable for customers' warranty claims. As such, warranty protection will fail in bad states of the world. Efficiency losses thus stem from the firm's assets being seized by creditors in default, as a result of which the most efficient after sales service provider, namely the firm itself, is no longer able to provide such service. "Second sourcing" — in our setting, reducing the cost of third party after sales service — is targeted to limit these efficiency losses.

The present paper is organized as follows. The next section outlines the model. Section 3 explores the interplay between the firm's capital structure choice and product differentiation strategy within a *vertical* product differentiation setting. Section 4 considers the case of *horizontal* product differentiation. Section 5 provides a discussion of our findings in light of case study evidence from the computer and software industries. Section 6 concludes. Proofs are relegated to the appendix.

[6] Yet, they also demonstrate that substituting equity for debt may commit a firm not to liquidate despite liquidation being efficient for financial stakeholders (the reason being that equity holdes are junior in liquidation). This latter effect can increase a firm's ability to offer high–quality products.

2 The Model

The formal framework elaborates on the interaction between a firm's capital structure choice and product differentiation strategy. The firm is run by a management team, produces a durable product, and provides after sales service. The following features of the contracting and product market environment are central to our analysis: (i) the relationship between the firm's initial owners/outside creditors and the management team is subject to moral hazard. Debt is needed to discipline management, but may drive the firm into bankruptcy and liquidation; (ii) liquidation imposes deadweight costs on the firm's customers as they have to switch to less efficient third party providers of after sales service once the firm is liquidated; (iii) while customers value variety, product differentiation increases potential deadweight costs in liquidation.

Formally, we consider a two–period model with three dates, $T = 0, 1, 2$. All agents are risk neutral and the risk free interest rate is normalized to zero. The timing of events is illustrated in figure 1.

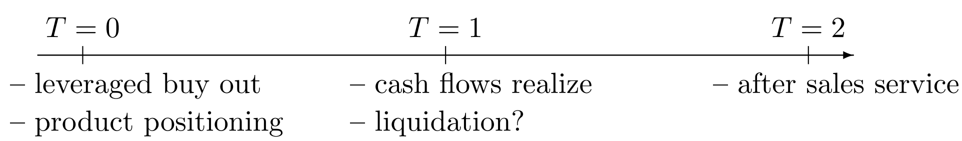

Figure 1: Timing

At $T = 0$, the firm's initial owners *sell* the firm to the management team through a *leveraged buy out* (to be explained in detail below). The firm (respectively, management) subsequently decides about its product differentiation strategy, quotes a price for its product, and potential customers decide whether to purchase from the firm (after having observed the firm's leverage, product design, and prices). At $T = 1$, cash flows realize. From an ex ante perspective, these are uncertain. For simplicity, we suppose that the firm either generates income equal to its product market revenues or no income at all (in the latter case, the firm is subject to a severe cost shock). Let θ denote the probability that the firm is not subject to the cost shock. We refer to $1 - \theta$ as the firm's *default risk*. At this stage, the firm's creditors may liquidate the firm and seize its assets. If the firm is not liquidated, after sales service is provided by the firm during the second period.

The relationship between the firm's initial owners/creditors and the management team needed to run the firm is subject to moral hazard. We consider the unverifiable cash flows framework along the lines of Bolton and Scharfstein (1996) and Hart and Moore (1998). Income is unverifiable (but observable) and management can divert it. There are several alternatives how the firm's initial owners could address the agency problem. As will be discussed in more detail below, in our setting, the most convenient way for the owners to benefit from their claims is to sell the firm's assets to management via a leveraged buy out. Management thus issues debt on a competitive credit market, transfers the proceeds of the debt issue to the initial owners, and takes ownership of the firm's assets. The liquidation threat associated with debt disciplines management to pay out free cash flow as long as liquidation is costly for management (Jensen 1986). These costs can stem from losses of reputation, of control benefits, and of other private benefits. Gilson (1989) provides empirical evidence that these losses can be quite substantial. He finds that about more than half of the managers of financially distressed firms are replaced and not hired by comparable, exchange–listed firms for at least three years. We capture these costs by assuming that management loses an amount $B > 0$ if the firm is liquidated and creditors seize its assets.[7]

The $T = 1$ liquidation value of the firm's assets is given by L. To make the analysis interesting, we assume that liquidation is inefficient, $L < B$. We allow for partial liquidation. For simplicity, there are constant returns to scale: if creditors seize a fraction $\beta \in [0, 1]$ of the firm's assets, the firm survives subsequent asset restructuring with probability $1 - \beta$ and fails with probability β (in which case assets become worthless and the firm exits). Expected liquidation proceeds and management's continuation control benefit are thus given by βL and $(1 - \beta)B$, respectively. A credit contract specifies a repayment R to be made at $T = 1$. If management pays out R, the firm is not liquidated.[8] If management does not pay out R, creditors are entitled to seize a fraction $\beta > 0$ of the firm's assets and collect the liquidation proceeds. As we shall argue below, β is closely related to the firm's leverage (the value of debt claims over the total value of the firm).

We now turn to the description of the product market characteristics. Until section 4, we consider a representative consumer with preference for variety. The firm is *innovative* in that it can differentiate its product from the product offering of a competitive fringe. A product with design $t \in [0, \infty)$ gives the consumer a payoff of $V(t)$ (over the two periods), where $V(t)$ is twice continuously differentiable, $V(0) = 0$, $V'(t) > 0$, $V''(t) < 0$, and $\lim_{t\to\infty} V'(t) = 0$. The competitive fringe produces a product with design $t' = 0$ at zero marginal cost. We normalize the payoff from consuming the competitive fringe's product to zero. Thus, in the absence of liquidation deadweight costs, the representative consumer's willingness to pay would be given by $V(t)$.

The consumer relies on after sales service during the second period. It is inessential for our argument whether the consumer pays for after sales service up front or when the service is provided. We thus consider long term "warranty" contracts: if the firm is not liquidated, it provides after sales service (for simplicity, at zero marginal cost). In contrast, if creditors seize the firm's assets, after sales service can no longer

[7]More precisely, we suppose that management *gains* a control benefit B if the firm is not liquidated. See Dyck and Zingales (2001) for a comparative empirical analysis of private benefits of control. Most generally, the parameter B can be thought of being inversely related to the severity of managerial incentive problems. This allows to relate B to variables that are typically employed in empirical analysis to proxy the severity of agency problems (see e.g. La Porta et al. 1997, 1998).

[8]This is without loss of generality as long as the assets' liquidation value is sufficiently low relative to the liquidation deadweight costs imposed on customers, which we will assume throughout the text. See the appendix for a full characterization of the optimal financial contracts.

be provided by the firm. In this case the consumer has to turn to one of many third party service providers. These service providers compete à la Bertrand and their cost of providing service (and thus the price charged for it) depends on the degree of product differentiation. The more the product is differentiated from the competitive fringe's product offering, the larger is the service provider's cost of supplying service (reflecting the higher costs of providing service for such a product). Formally, the cost of providing service by a third party is given by $C(t) = \alpha c(t)$, where $c(t)$ is twice continuously differentiable, $\alpha > 0$, $c(0) = 0$, $c'(t) > 0$, and $c''(t) > 0$. We refer to α as the product's *service intensity*.

Consistent with most bankruptcy codes (Appelbaum 1992), we assume that creditors' claims are senior to customers' warranty claims. Thus, creditors cannot be held liable for customers' claims. In contrast, the initial owners would be liable for customers' claims if they did not sell the firm's assets to management via a leveraged buy out and instead employed a managerial incentive scheme. This implies that a termination threat by the initial owners on management would lack credibility as they would internalize the deadweight costs imposed on customers when firing management and liquidating the firm (management is essential for efficiently providing after sales service). As such, the initial owners would be reluctant to indeed stick to termination. In contrast, creditors can impose a credible threat of liquidation on management as they do not internalize the deadweight costs liquidation imposes on customers. This explains why a leveraged buy out is preferable in our setting.[9]

Under an incentive compatible and feasible contract, management pays out R in the high cash flow state, the firm is continued, and customers are provided with after sales service at zero cost. In the low cash flow state, management has to default and is liquidated at scale β. The firm's remaining assets enable management to provide after sales service with probability $1 - \beta$. If management is unable to provide after sales service, customers must approach the less efficient third party service provider and are charged $C(t)$. The representative consumer's willingness to pay for the firm's product is thus given by $V(t) - (1 - \theta)\beta C(t)$.

It is important to stress that the inefficiencies in our setting do not per se stem from creditors not being liable for customers' warranty claims. Neither does it matter whether customers pay for service up front or when it is provided. If customers were to pay for service ex post, the total surplus captured by the initial owners would not be altered. This is because the service revenues would be offset by a proportionate reduction in the initial price. Rather, inefficiencies stem from the firm's assets being seized by creditors in default, as a result of which the most efficient service provider, namely the firm itself, is no longer able to provide service.[10] The associated efficiency

[9] The importance of hard claims (debt) as a means of constraining management is by now well accepted in the literature. See, for example, Dewatripont and Tirole (1994) and Hart and Moore (1997).

[10] We do not allow for ex post renegotiation between creditors and customers. This can be justified with the potentially large number of customers. It thus would be prohibitively costly for creditors and customers to enter renegotiation.

losses are born ex ante by the firm's initial owners, who thus face a trade off between strengthening managerial incentives to pay out free cash flow and reducing liquidation deadweight costs.

3 Corporate Leverage and Product Differentiation

This section explores the interplay between the firm's choice of capital structure and product differentiation strategy. In practice, management will pick the level of product differentiation after having taken over the firm (i.e. once capital structure has been fixed) in order to maximize its payoff. The level of product differentiation that is optimal for management at this stage may not be ex ante optimal for the firm's initial owners, i.e. maximize the proceeds of the debt issue. Yet, as will be discussed in more detail below, there is no conflict of interest between management and financial stakeholders about the choice of product differentiation. If the latter were not contractible, management would stick to the level of product differentiation that maximizes the proceeds of the debt issue. The analysis thus proceeds as follows. We first derive the firm's optimal capital structure, taking the level of product differentiation as given. We subsequently characterize the ex ante optimal level of product differentiation. We complete the argument by showing that management would not deviate from this level of product differentiation.

Consider a credit contract (R, β) and suppose the firm generates revenues Π. If management pays out R at $T = 1$, the firm is continued and management captures its control benefit B. If it defaults strategically (suppose for a moment that management can pay out R in the high cash flow state), creditors are entitled to liquidate a fraction β of the firm's assets and collect the liquidation proceeds. Yet, liquidation is inefficient and management has cash reserves Π which it can use to buy back assets from creditors. We assume for simplicity that creditors make a take–it–or–leave–it renegotiation offer to management. Creditors offer management to liquidate a fraction $\beta' < \beta$ of the firm's assets in exchange for management making a cash transfer R'. The renegotiation offer maximizes creditors' payoff $R' + \beta' L$ subject to three relevant constraints, (i) management's acceptance constraint, $\Pi - R' + (1 - \beta')B \geq \Pi + (1 - \beta)B$, (ii) the cash constraint, $R' \leq \Pi$, and (iii) $\beta' \geq 0$. Supposing that $\beta B \leq \Pi$, this problem is solved for $\beta' = 0$ and $R' = \beta B$. Management thus has incentives to pay out R in the high cash flow state (rather than defaulting strategically and triggering renegotiation) if and only if $R \leq \beta B$.

Next, suppose the firm is subject to the cost shock, i.e. does not generate any income. Management has to default for liquidity reasons and creditors liquidate a fraction β of the firm's assets. There is no room for renegotiation since management has nothing to offer in exchange for creditors waiving their liquidation rights.

It is worthwhile to contrast these outcomes with a situation where shareholders do not initiate a leveraged buy out but instead impose a managerial incentive scheme. In our setting, a managerial incentive contract stipulates that shareholders have the right to fire management (in which case the firm is liquidated) with probability

β if and only if management does not pay out a dividend R. Consider then the renegotiation stage after strategic default. If shareholders exercised the liquidation option, their expected payoff would amount to $\beta(L-C(t))$. Thus, as long as $C(t) > L$ (which we assume), shareholders' payoff from proceeding with liquidation would be negative (recall that shareholders, in contrast to creditors, are liable for customers' warranty claims). This implies that shareholders would not stick to liquidation if renegotiation after strategic default broke down. Termination threats imposed by shareholders thus lack credibility, as a result of which shareholders are unable to extract free cash flow from management. Initiating a leveraged buy out and allocating liquidation rights to creditors allows to restore the disciplinary power of liquidation threats (but comes at the expense of inefficient liquidation in the low cash flow state).

An optimal financial contract maximizes the proceeds of the debt issue (which are captured by the initial owners) subject to the contract being feasible, incentive compatible, and accepted by management (its reservation utility is normalized to zero). Let $\Pi(\beta, t)$ denote the firm's product market income in the high cash flow state as a function of leverage β and the level of product differentiation t. Assuming that the firm extracts the representative consumer's willingness to pay, we have $\Pi(\beta, t) = V(t) - (1-\theta)\beta C(t)$. The initial owners' problem is thus to

$$\max_{R,\beta\in[0,1]} \quad \theta R + (1-\theta)\beta L \tag{1}$$

s.t.

$$\theta(\Pi(\beta, t) - R + B) + (1-\theta)(1-\beta)B \geq 0 \tag{2}$$

$$R \leq \beta B \tag{3}$$

$$R \leq \Pi(\beta, t) = V(t) - (1-\theta)\beta C(t) \tag{4}$$

The optimal financial contract is easily derived. Note first that management's participation constrained (2) is not binding as it is implied by the cash constraint (4). We are thus left with the managerial incentive constraint (3) and the cash constraint (4). By inspection, a *tougher* financial structure (β high) relaxes the incentive constraint but tightens the cash constraint. This leads to the following proposition:

Proposition 1 *Suppose liquidation is sufficiently costly for customers: $C(t) \geq L/\theta$. Then, the optimal financial contract is given by*

$$\tilde{\beta} = \min\left[\frac{V(t)}{B + (1-\theta)C(t)}, 1\right] \tag{5}$$

$$R = \begin{cases} \tilde{\beta}B = \Pi(\tilde{\beta}, t) < B & \text{for } B > V(t) - (1-\theta)C(t) \\ B & \text{for } B \leq V(t) - (1-\theta)C(t). \blacksquare \end{cases} \tag{6}$$

When management's control benefit B is very low, creditors cannot extract much from management and the cash constraint is not binding. It thus optimal to punish strategic default with full liquidation and to give absolute priority to creditors. In contrast, absolute priority is violated at the optimum as soon as management's loss from liquidation is sufficiently large (formally, for $B > V(t) - (1-\theta)C(t)$, we have $R = \tilde{\beta}B > \tilde{\beta}L$ but $\tilde{\beta} < 1$, hence, absolute priority is violated). In this case, creditors can extract a lot from management. Yet, a tough financial structure is costly since it impedes the firm's survival prospects in the low cash flow state and as such undermines customers' willingness to pay. Creditors thus commit not to liquidate the firm at full scale if management defaults on outstanding debt claims. It is worthwhile to note that this contract will not be renegotiated after customers made their purchasing decisions. This is because the contract is constrained efficient for management and creditors and hence renegotiation proof.[11]

If financial structure were unobservable, creditors would not give up absolute priority. Here, the only reason to give up absolute priority is to increase customers' willingness to pay. However, given customers' purchasing decisions, it is a best response for creditors to fully liquidate after default in order to maximize proceeds from liquidation. This is of course anticipated by customers and hence suppresses their willingness to pay. As a result, both creditors (respectively, the initial owners) and management would be worse off if financial structure were unobservable (see the appendix for a characterization of the optimal contract when contracts are unobservable). This argument suggests that firms have strong incentives to make financial structure public to not only influence financial market participants but also other stakeholders, such as customers. One way to do so is to go public, as financial disclosure laws require public firms to disclose financial structure.[12] Our conclusions are also in line with empirical evidence indicating that firms increase public announcements about financial restructuring in periods of economic or financial distress. This latter point, as was discussed earlier, is well illustrated by the disclosure strategies of South–Korean firms during the East–Asian financial crisis.

Consider the next case, $C(t) < L/\theta$. We show in the appendix that in this case liquidation can occur even if management does pay out.[13] Furthermore, the firm is fully liquidated after liquidity default. As we would like to highlight the effects of liquidation deadweight costs on financial structure and product positioning, we assume that these costs are large relative to the asset liquidation value. We thus restrict attention to the first case, $C(t) \geq L/\theta$. Specifically, we simplify the model by setting the liquidation value equal to zero and by assuming that $B > V(t)-(1-\theta)C(t)$ holds at the optimum.

How is creditors' liquidation right $\tilde{\beta}$ related to the leverage of the firm? Define leverage as the value of debt (the proceeds of the debt issue) over the value of debt and the value of inside equity (i.e. what inside equity holders, namely management,

[11] See Dewatripont (1988) and Caillaud et al. (1995) for more on the role of renegotiation–proofness constraints in models of strategic contract design in order to influence third parties.

[12] See Pagano et al. (1998) for an empirical study of the determinants of initial public offerings. Consistent with our intepretation, they find that IPOs are followed by lower cost of credit.

[13] To see why suppose creditors are entitled to liquidate some assets even if management satisfies its payment obligations. As long as the cash constraint is not binding this cannot be optimal since the marginal expected gain is θL while the marginal expected loss is $\theta B > \theta L$. Creditors are thus better off extracting a higher repayment and foregoing the liquidation proceeds. However, if the cash constraint is binding, the marginal expected loss of liquidation in the high cash flow state is given by $\theta(\theta C)$. Thus, for $\theta C < L$ liquidation in the high cash flow state could be optimal.

would be willing to pay for their control rights, if they could). The value of debt is given by $\theta\tilde{\beta}B$, whereas the value of inside equity is given by $\theta B + (1-\theta)(1-\tilde{\beta})B$. Thus, leverage is given by

$$\frac{\theta\tilde{\beta}}{1-(1-2\theta)\tilde{\beta}} \tag{7}$$

It is easily verified that (7) has the same comparative statics as creditors' liquidation right $\tilde{\beta} = V(t)/(B + (1-\theta)C(t))$. We can state the following

Corollary 1 *Leverage decreases as agency problems between creditors and management become less severe, default risk increases, and/or customers incur higher deadweight costs in liquidation.* ■

These predictions are consistent with the empirical findings of Titman and Wessels (1988). They find that one of the most important predictors of corporate leverage is the ratio of R&D expenditures to sales, with the relation being negative. This is in line with our findings in that firms with high R&D expenditures tend to produce highly differentiated goods for which original manufacturer support is likely to be a significant feature.

We now turn to the firm's problem of positioning its product. The initial owners' aim is to maximize the proceeds from the debt issue. Therefore, the ex ante optimal degree of product differentiation t^* solves

$$\max_{t\in[0,\infty)} \quad R = \tilde{\beta}(t)B = \frac{V(t)}{B+(1-\theta)C(t)}B \tag{8}$$

s.t.

$$\tilde{\beta}(t) \in [0,1] \tag{9}$$

By concavity and assuming that $\tilde{\beta}(t) \leq 1$ is not binding, the optimal degree of product differentiation t^* is unique and characterized by the first–order condition

$$V'(t^*)B + (1-\theta)\alpha\Big(V'(t^*)c(t^*) - V(t^*)c'(t^*)\Big) = 0 \tag{10}$$

Using the implicit–function theorem, we can state the following comparative statics,

$$\text{sign } \frac{dt^*}{dB} = \text{sign } V'(t^*) > 0 \tag{11}$$

$$\text{sign } \frac{dt^*}{d\theta} = \text{sign } -[V'(t^*)c(t^*) - V(t^*)c'(t^*)] > 0 \tag{12}$$

$$\text{sign } \frac{dt^*}{d\alpha} = \text{sign } V'(t^*)c(t^*) - V(t^*)c'(t^*) < 0 \tag{13}$$

where (12) and (13) follow from the first–order condition (10). As the first term is positive, $V'(t^*)c(t^*) - V(t^*)c'(t^*)$ must be negative. We thus have the following result:

Proposition 2 *The optimal degree of product differentiation t^* is unique and characterized by the first order condition (10). Product differentiation is strictly decreasing in the severity of managerial incentive problems, in the default risk $1-\theta$, and in the product's service intensity α.* ■

When managerial incentive problems are severe, creditors should be given tough liquidation rights to restore the disciplinary power of liquidation threats. Yet, tough liquidation rights suppress customers' willingness to pay. To counterbalance this latter effect, the firm positions its product closer to competitors. Similarly, an increase in the default risk and/or in the product's service intensity tend to raise expected liquidation deadweight costs. These costs are born ex ante by the firm's initial owners. In response, the firm reduces its leverage *and* moves its product closer to competitors' product offerings.

In principle, the level of product differentiation that maximizes the proceeds of the debt issue (and the payoff of the initial owners) may not be optimal for management once capital structure has been determined. If product differentiation were unverifiable and up to the discretion of management, the initial owners would have to contemplate how capital structure would affect management's choice of product differentiation. We shall now argue that management would stick to the ex ante optimal level of product differentiation. To see why note that maximizing the proceeds of the debt issue, $\tilde{\beta}(t)B$, where $\tilde{\beta}(t) = V(t)/(B + (1-\theta)C(t))$, is equivalent to maximizing product market revenues $\Pi(\tilde{\beta}(t^*), t)$ with respect to t, when taking capital structure as given. Intuitively, product differentiation is targeted to relax the cash constraint for a *given* capital structure. Yet, the best way to relax the cash constraint is to maximize product market revenues. Next, note that the cash constraint is binding at t^*. Henceforth, if management deviated from t^*, it would have to default for liquidity reasons. After renegotiation, management would not only transfer the entire product market income to creditors, the firm would also be partially liquidated. This shows that management would stick to the ex ante optimal level of product market differentiation, even if its choice were unverifiable and up to the discretion of management.

4 Horizontal Product Differentiation

In the previous section, we considered a representative agent with taste for variety. The firm's product differentiation choice thus corresponds to a problem of vertical product differentiation. Yet, in practice, firms are often faced with situations where they have to make product differentiation choices not only along the vertical but also the horizontal dimension of the product space. In this section, we provide a brief discussion of how our analysis extends to the case of *horizontal* product differentiation.

Suppose there is a unit mass of consumers who differ in their "taste" $x \in [0, 1]$ for a specific design $t \in [0, 1]$. A consumer with taste x has a one–period valuation of $v-(t-x)^2$ when purchasing a product with design t (we take v to be sufficiently large to have the market always covered). Consumers are uniformly distributed over $[0, 1]$. As before, there is a competitive fringe producing a product with design $t' = 0$ at zero marginal cost.[14] Note that while a monopolistic firm would position its product at 1/2 in order to match the taste of the median consumer, here the firm picks a higher degree of product differentiation in order to relieve competitive pressure from the fringe. The optimal product position in the absence of default risk or liquidation costs would be given by 2/3, as is easily verified. In what follows, we show that the firm will position its product closer to competitors when liquidation imposes deadweight costs on customers.

Since the competitive fringe firms compete à la Bertrand and produce at zero cost, they charge a price of zero for their product offering. When purchasing the fringe product, a consumer with taste x thus derives a payoff of $2(v-x)^2$. Conversely, when purchasing the innovative firm's product, the consumer derives a net utility of $v-(x-t)^2-p$ during the first period, where p denotes the price charged for the product. With probability $\theta+(1-\theta)(1-\beta)$, the firm is not liquidated at date $T=1$ and after sales service is provided by the firm. With probability $(1-\theta)\beta$, the firm is liquidated and after sales service has to provided by the less efficient third party at cost $C(t)$. The location $\hat{x}$ of the *indifferent* consumer is thus defined by:

$$2(v-(\hat{x}-t))^2-p-(1-\theta)\beta C(t)=2(v-\hat{x}^2) \tag{14}$$

The right hand side is the payoff from purchasing the competitive fringe's product offering, while the left hand side is the payoff from consuming the firm's product.[15] It is easily verified that (14) reduces to

$$\hat{x}(p)=\frac{p+2t^2+(1-\theta)\beta C(t)}{4t} \tag{15}$$

At the pricing stage, the firm's problem is to

$$\max_p \Big(1-\hat{x}(p)\Big)p \tag{16}$$

This problem is solved for

$$p=\frac{2t(2-t)-(1-\theta)\beta C(t)}{2} \tag{17}$$

Substituting (17) into the profit function, reduced form profits amount to

$$\Pi(\beta,t)=\frac{1}{16t}[2t(2-t)-(1-\theta)\beta C(t)]^2 \tag{18}$$

To obtain closed form solutions, we give an explicit functional form to the cost function. For convenience, let $C(t)=\alpha t^2$. From the previous analysis, the firm's leverage $\tilde{\beta}(t)$ (as a function of the level of product differentiation) is given by the

[14] Alternatively, one could consider a duopoly setting where the competitor chooses its location strategically. This would not yield significantly different insights.

[15] We should stress that the subgame in which consumers decide whether to purchase a product after having observed prices and leverage may have multiple equilibria. In this case, consumers may fail to coordinate on the pareto–efficient equilibrium that minimizes the firm's failure probability and maximizes gains from trade. We restrict attention to the pareto–efficient equilibrium.

solution of $\beta B = \Pi(\beta, t)$. The optimal degree of product–differentiation maximizes the proceeds of the debt issue. The initial owners' problem is to

$$\max_{t\in[0,1]} \quad \tilde{\beta}(t)B \tag{19}$$

s.t.

$$\tilde{\beta}(t) \in [0,1] \tag{20}$$

As long as the constraint $\tilde{\beta}(t) \leq 1$ is non–binding, one can show that this problem is solved for

$$t^* = \frac{\sqrt{3B[16\alpha(1-\theta)+27B]} - 9B}{4\alpha(1-\theta)} \in \left(0, \frac{2}{3}\right) \tag{21}$$

Let $\hat{B} \equiv 16/(27(2+\alpha(1-\theta)))$. It is easily verified that $\tilde{\beta}(t^*) < 1$ if and only if $B > \hat{B}$. We can state the following

Proposition 3 *Suppose $B > \hat{B}$. Then, the firm positions its product at $t^* \in (0, 2/3)$ and moves closer to competitors when managerial incentive problems become more severe, the firm faces higher default risk, and/or the product becomes more service–intensive.* ■

This corresponds to the previously derived intuition: to restore customer confidence the firm moves closer to competitors when managerial incentive problems call for high leverage. The equilibrium price, profits, and leverage are given by $p = 4/3\ \ t^*$, $\Pi = 4/9\ \ t^*$, and $\tilde{\beta} = 4/(9B)\ \ t^*$, respectively. Prices and profits thus display the same comparative statics as the optimal level of product differentiation. They are decreasing in the default risk, in the service intensity, and in the severity of managerial incentive problems. Leverage is decreasing in the default risk and the service intensity, but increasing in the severity of managerial incentive problems.

5 Discussion: Differentiation versus TCO

The trade off between differentiation and total cost of ownership (TCO) allows to shed light on some critical issues companies are facing when deciding about financing and product differentiation strategies. Industrial organization theory (Tirole 1990) and the strategic management literature (Porter 1985) suggest a number of ways how companies can differentiate themselves from competitors in order to sustain superior product market rents. We discussed the possibility of vertical product differentiation (e.g. innovation) and horizontal product differentiation. Yet another strategy to capture product market rents is to lock in customers to a certain product. For example, Padilla (1995) demonstrates within a switching cost setting that customer lock–in unambiguously leads to higher profits through its softening effects on price competition.[16] In light of Padilla's findings, one would expect that companies

[16] In standard switching cost settings the presence of switching costs gives rise to efficiency losses only insofar higher prices may deter some consumers from consuming the product. In contrast, consumers do not incur switching costs in equilibrium. This is different in our setting, where consumers actually incur switching costs in equilibrium, namely when the firm is liquidated. Endogenously reducing switching costs and slashing leverage would allow firms to soften these efficiency losses.

endogenously design lock–in situations. Anecdotical evidence suggests that these considerations are particularly relevant in the technology industries. For instance, customer lock–in through firm–specific software standards is commonly regarded to be a key driver for companies in the storage networking industry to capture superior product market rents (see Merrill Lynch research report, March 27, 2002).

This paper's findings suggest that differentiation (vertical, horizontal, lock–in/endogenous switching costs) has a downside in that it can increase a potential customer's total cost of ownership. When customers rely on a supplier's continued support and the supplier has poor financial prospects, potential customers' willingness to pay for a highly differentiated product may be suppressed. This suggests that in situations where leverage is needed to discipline managers, firms may deliberately refrain from choosing overly drastic product differentiation strategies. Conversely, one would expect the most innovative firms to be subject to disciplinary devices other than arm's length debt. Our analysis thus provides a novel explanation for why innovative firms pick monitoring intensive venture capital financing, rather than relying on arm's length financing or unmonitored bank financing (Hellmann and Puri 2000, Kortum and Lerner 2001).

In light of our findings, one would expect that companies facing deteriorating balance sheets "move closer" to competitors in order to address customers' concerns about total cost of ownership. Coming back to the example of Apple, we will discuss in the sequel of this section how Apple reacted to its deteriorating financial conditions during the mid 1990s and how our theory allows to shed light on Apple's strategy. We shall argue that Apple addressed customer concerns about total cost of ownership with the introduction of PC–compatible Macs and with giving software makers additional incentives to develop software for the Mac. We subsequently provide a discussion of how Baan, a Dutch enterprise resource planning software maker, reacted to its worsening financial conditions in 1997/98 by altering its customer lock–in strategy.

In 1996, Apple introduced PC–compatible Macs which were equipped with two processors, a PowerPC processor running Mac software, and a Pentium processor running Windows software. Previously, Mac users could emulate a PC, either using hardware devices or software. However, hardware devices were expensive, while cheap software solutions resulted in low speed. In 1998, Apple removed the dual–platform machines from its product line with the introduction of the PowerPC G3 processor. The speed of this processor made it possible to entirely rely on emulation software. One explanation for Apple's strategy is that it widens the range of software Mac–users can choose from and thus increases the valuation consumers attach to the Mac. On the one hand, this increases demand and allows Apple to charge higher prices. On the other hand, it may also increase competitive pressures as users which are typically attached to the Mac begin to discover the whole range of PC–software and the PC itself.

We suggest a complementary explanation for Apple's strategy. As was discussed in the introduction, Apple faced deteriorating financial conditions during the mid

1990s. Many observers expressed concerns about Apple's long term viability. Most likely, an exit of Apple from the computer market would have imposed substantial costs on Mac users as software makers would have refrained from developing software for the Mac. Achieving PC–compatibility with the introduction of the dual–platform solution in 1996 and the development of the PowerPC G3 processor in 1998 reduced the degree to which Mac users must rely on Mac specific software. As a result, reluctance of consumers to purchase a Mac should have decreased. This is consistent with the evolution of Apple's sales figures and profits during those years.[17]

Apple also tried to restore customer confidence through addressing software developers' reluctance to develop software for the Mac (see the quote from Apple's 1998 10–K filing mentioned in the introduction). At a developer conference in May 1997, top executives of Apple announced that the development platform for its future operating system would allow developers to generate and deploy applications not only for the Mac operating system but also for Microsoft's Windows 95 and Windows NT (Java World, June 1997). The upside of this strategy is that it expands the market for software developers and as such makes it more attractive for software makers to develop software for the Mac. One possible downside is that the PC becomes an attractive alternative for Apple's traditional turf, i.e. the publishing and advertising industry, if there is a wide range of PC–compatible graphics and publishing software available.

A second example that illustrates our findings comes from the market for enterprise resource planning (ERP) software. In 1997/98, Dutch ERP software maker Baan started to face financial difficulties. At that time, Baan launched a joint venture with JDA (another small player in the ERP market), integrating Baan's enterprise software with JDA's retail management software.[18] Baan also implemented several compatibility arrangements, including the launch of more than 200 interfaces allowing customers to easily connect to third–party software, including *competing ERP applications*.[19] This latter strategy is hard to reconcile with the notion that software companies should design customer lock–in situations in order to capture superior product market rents. Our findings suggest that Baan deliberately reduced customer lock–in to ensure customers not to be left stranded with a specific software suite, should Baan fail to continue servicing its customers.

There is a complementary explanation for why Apple faced deteriorating sales performance after having been hit by losses: the presence of network externalities. When current sales performance is a signal for current and future network size (and network size is important for customers), customers may be unwilling to purchase from a vendor after having observed poor sales performance. Our analysis suggests that this consideration is even more relevant when the vendor is highly leveraged.

[17]From 1996 to 1997, Mac unit sales declined by 27%. From 1997 to 1998, Mac unit sales declined only by 4%. During 1996 and 1997 Apple made net losses of $816m and $1045m, respectively, while in 1998 net income was $309m.

[18]See PC Week, August 26, 1998.

[19]See Baan press release, October 12, 1998.

Companies may refrain from adopting overly drastic differentiation strategies for reasons different from the ones considered in this paper. For example, vertical product differentiation through quality or innovation is typically subject to additional production or R&D costs. These observations could be easily captured within our formal setting considered in section 3 by noting that the value function $V(t)$ may well have an interior maximum. In this case, firms would face a trade–off between too much and too little differentiation even in the absence of deadweight liquidation costs. Our findings suggest that the presence of liquidation costs shifts the balance between the costs and benefits of differentiation towards the cost side. The relevance of this consideration is demonstrated by the observation that Apple and Baan reduced customer lock–in in reaction to their worsening financial difficulties. These financial difficulties made potential customers wonder about the firms' long term viability. Apple and Baan reacted to these concerns by reducing the uniqueness of their products.

6 Conclusions

This paper puts forward a theory of the interplay between corporate leverage and product differentiation strategy. While existing studies elaborate on the impact of a firm's product characteristics on its financial structure, the novelty of our analysis stems from the observation that product design and differentiation choices are equally important choice variables. Building on the premise that debt allows to discipline managers, our framework thus elaborates on the joint determinacy of corporate leverage and product differentiation strategy. Specifically, we considered a setting where (i) product differentiation is valued by customers; (ii) debt is necessary to discipline managers; and (iii) liquidation is costly for customers, in particular, when products are highly differentiated from competitors' products.

We demonstrate that when managerial incentive problems call for high leverage, firms position their products closer to competitors to reduce deadweight costs imposed on customers in liquidation and thus to increase their willingness to pay. Likewise, firms that are subject to high exogenous insolvency risk should choose relatively less differentiated and innovative products, while at the same time slashing leverage. The former strategy reduces deadweight costs imposed on customers in liquidation, the latter directly addresses customer concerns about the supplier's long term viability.

Our findings suggest several novel insights into the interdependency of financing decisions and product market strategies, such as differentiation, innovation, and customer lock–in strategies. While drastic product differentiation strategies allow firms with healthy balance sheets to sustain superior product market rents, firms with high leverage and poor balance sheets should be deterred from adopting overly drastic differentiation choices. Customers purchasing such products from firms in poor financial condition may face a too high total cost of ownership. As was discussed in the previous section, these considerations suggest that the most innovative firms should choose monitoring intensive financing sources, such as venture capital financing, rather than relying on unmonitored bank financing or market disciplinary devices, such as arm's length debt.

The present paper's analysis suggests a number of interesting avenues for future research. One issue we abstracted from in this paper are demand complementarities. When a firm is highly leveraged and potential customers rely on the firm's long term viability, one can envision situations where pessimistic perceptions about the firm's viability quickly become self–fulfilling. Potential customers refrain from purchasing as they expect the vendor to fail, thereby driving the vendor into bankruptcy and liquidation. This consideration is relevant whenever potential customers are too dispersed to coordinate their purchasing decisions. In such kind of situations, *customer confidence* can be restored through steep price cuts and debt holders publicly accepting concessions. We address these issues in ongoing research (Arping and Loranth 2002).

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Appendix

Characterization of the optimal observable financial contract:
Without loss of generality, consider financial contracts $(\underline{\beta}, \underline{R}, \bar{\beta}, \bar{R})$ such that the firm pays out $\bar{R}$ $(\underline{R})$ and is liquidated at scale $\bar{\beta}$ $(\underline{\beta})$ in the high (low) cash flow state. It is easily verified that $\underline{R} < 0$ is not optimal. Thus, from limited liability $\underline{R} = 0$. To simplify notation let $\bar{R} = R$ and suppress t. The optimal financial contract solves the following program:

$$\max_{R,\underline{\beta}\in[0,1],\bar{\beta}\in[0,1]} \quad \theta(R + \bar{\beta}L) + (1-\theta)\underline{\beta}L \tag{22}$$

s.t.

$$\theta\left(\Pi\left(\underline{\beta}, \bar{\beta}\right) - R + (1-\bar{\beta})B\right) + (1-\theta)(1-\underline{\beta})B \geq 0 \tag{23}$$

$$R \leq \left(\underline{\beta} - \bar{\beta}\right) B \tag{24}$$

$$R \leq \Pi\left(\underline{\beta}, \bar{\beta}\right) \tag{25}$$

where $\Pi\left(\underline{\beta}, \bar{\beta}\right) = V - \theta\bar{\beta}C - (1-\theta)\underline{\beta}C$. Note first that

$$R = \min\left[V - \left(\theta\bar{\beta} + (1-\theta)\underline{\beta}\right)C, (\underline{\beta} - \bar{\beta})B\right] \tag{26}$$

To see why note that either (24) or (25) must be binding. Otherwise, one could slightly increase R without affecting neither constraint and increasing the objective function (22). Note further that (23) is not binding because of (25) and $(\underline{\beta}, \bar{\beta}) \in [0,1]^2$.

Substituting (26) into (22) and rearranging terms, we can simplify the problem:

$$\max_{(\bar{\beta}\in[0,1],\underline{\beta}\in[0,1])} \quad \min\Big[\theta\Big(V - \left(\theta\bar{\beta} + (1-\theta)\underline{\beta}\right)C + \bar{\beta}L\Big) + (1-\theta)\underline{\beta}L, \tag{27}$$
$$\theta\Big((\underline{\beta} - \bar{\beta})B + \bar{\beta}L\Big) + (1-\theta)\underline{\beta}L\Big]$$

The second expression inside the minimum operator is increasing in $\underline{\beta}$ and decreasing in $\bar{\beta}$. The effect on the first expression is ambiguous. It is easily verified that the first expression is decreasing in $\underline{\beta}$ and $\bar{\beta}$ if and only if $\theta C \geq L$.

Consider $\theta C \geq L$ (proposition 1): As both expressions inside the minimum operator are decreasing in $\bar{\beta}$, we have $\bar{\beta} = 0$. Suppose $\underline{\beta}$ is interior. Then, the optimal $\underline{\beta}$ solves $\underline{\beta}B = V - (1-\theta)\underline{\beta}C$. Thus,

$$\underline{\beta} = \frac{V}{B + (1-\theta)C} \tag{28}$$

and $R = \underline{\beta}B$. For $B < V - (1-\theta)C$, $\underline{\beta} \leq 1$ is binding such that $\underline{\beta} = 1$ and $R = B$. This gives proposition 1.

Next, consider $\theta C < L$. The first expression inside the minimum operator is increasing in $\underline{\beta}$ and $\bar{\beta}$. As both expressions inside the minimum operator are increasing in $\underline{\beta}$ we have $\underline{\beta} = 1$. Suppose that $\bar{\beta}$ is interior. The optimal $\bar{\beta}$ solves $V - (\theta\bar{\beta} + (1-\theta)C) = (1-\bar{\beta})B$. Thus,

$$\bar{\beta} = \frac{B - (V - (1-\theta)C)}{B - \theta C} \geq 0 \tag{29}$$

for $B \geq V - (1-\theta)C$ and $\bar{\beta} \leq 1$ as long as $V \geq C$. For $B < V - (1-\theta)C$, we have $\underline{\beta} = 1$, $\bar{\beta} = 0$, and $R = B$. ■

Characterization of the optimal unobservable financial contract:
The optimal unobservable contract solves the following program:

$$\max_{(\bar{\beta}\in[0,1],\underline{\beta}\in[0,1],R)} \quad \theta(R + \bar{\beta}L) + (1-\theta)\underline{\beta}L$$

$$R \leq (\underline{\beta} - \bar{\beta})B \tag{30}$$

$$R \leq \Pi = V - (\theta\bar{\beta}^* + (1-\theta)\underline{\beta}^*)C \tag{31}$$

where $\bar{\beta}^*$ and $\underline{\beta}^*$ are the representative consumer's (rational) beliefs about the exit probabilities in the high and low cash–flow states, respectively.

Obviously, $\underline{\beta} = 1$. Then, $R = \min[(1-\bar{\beta})B, \Pi]$ such that the maximization problem reduces to

$$\max_{\bar{\beta}\in[0,1]} \min\left[(1-\bar{\beta}B) + \bar{\beta}L, \Pi + \bar{\beta}L\right] \tag{32}$$

This is solved for $\bar{\beta} = 1 - \frac{\Pi}{B}$. In equilibrium, $\underline{\beta} = \underline{\beta}^*$ and $\bar{\beta} = \bar{\beta}^*$. Hence,

$$\bar{\beta} = \frac{B - (V - (1-\theta)C)}{B - \theta C} \geq 0 \tag{33}$$

for $B \geq V - (1-\theta)C$, and $R = (1-\bar{\beta})B$. For $B < V - (1-\theta)C$, we have $\underline{\beta} = 1$, $\bar{\beta} = 0$, and $R = B$. ■

Proof of proposition 2:
Suppose $\tilde{\beta}(t) \leq 1$ is not binding. We will show that

$$\max_{t\in[0,\infty)} \tilde{\beta}(t) = \frac{V(t)}{B + (1-\theta)C(t)} \tag{34}$$

has a unique, interior solution which is characterized by the first order condition

$$\psi(t) = V'(t)(B + (1-\theta)C(t)) - V(t)(1-\theta)C'(t) = 0 \tag{35}$$

First, note that for the case $\lim_{t\to\infty} V(t)$ finite, we have

$$\lim_{t\to\infty} \tilde{\beta}(t) = \lim_{t\to\infty} \frac{V(t)}{B + (1-\theta)C(t)} = 0 \tag{36}$$

since $C'(t) > 0$. For the case $\lim_{t\to\infty} V(t) \to \infty$, we have

$$\lim_{t\to\infty} \tilde{\beta}(t) = \lim_{t\to\infty} \frac{V'(t)}{(1-\theta)C'(t)} = 0 \tag{37}$$

from L'Hôpital's rule, since $\lim_{t\to\infty} V'(t) = 0$ and $C''(t) > 0$. Thus, $\lim_{t\to\infty} \tilde{\beta}(t) = 0$. Next, $\tilde{\beta}(t)$ is continuously differentiable, $\tilde{\beta}(0) = 0$, and $\tilde{\beta}'(0) > 0$. Hence, a maximum t^* exists, is interior, and satisfies the first order condition $\tilde{\beta}'(t^*) = \psi(t^*)/(B + (1-\theta)C(t^*))^2 = 0$. Next, because a maximum exists $\psi(t) = 0$ must have a solution. Finally, note that the solution is unique since $\psi'(t) < 0$. ■

Proof of proposition 3:
One can easily verify that

$$\Pi(\beta, t) = \frac{1}{16t}[2t(2-t) - (1-\theta)\beta\alpha t^2]^2 \tag{38}$$

is strictly decreasing in β until it obtains a minimum of 0 at $\hat{\beta} = 2(2-t)/((1-\theta)\alpha t)$. For $\beta > \hat{\beta}$ prices and profits are zero. Our solution $\tilde{\beta}(t)$ is therefore the unique positive root of

$$\Pi(\beta, t) = \beta B \tag{39}$$

subject to $\beta \leq \hat{\beta}$. This is solved for

$$\tilde{\beta}(t) = \frac{2t}{((1-\theta)\alpha t^2)^2}\left(\sqrt{2B + (2-t)(1-\theta)\alpha t^2} - \sqrt{2B}\right)^2 \tag{40}$$

One can show that $\max_t \tilde{\beta}(t)$ s.t. $\tilde{\beta}(t) \leq 1$ is solved for

$$t^* = \frac{\sqrt{3B[16\alpha(1-\theta) + 27B]} - 9B}{4\alpha(1-\theta)} \tag{41}$$

as long as $B \geq \hat{B} = 16/(27(2 + \alpha(1-\theta)))$. By inspection, t^* is strictly positive, strictly decreasing in $\alpha(1-\theta)$, and strictly increasing in B. From L'Hôpital's rule,

$$\lim_{\alpha(1-\theta)\to 0} t^* = \lim_{\alpha(1-\theta)\to 0} \frac{6B}{\sqrt{3B(16\alpha(1-\theta) + 27B)}} = \frac{6B}{9B} = \frac{2}{3} \tag{42}$$

Moreover, again from L'Hôpital's rule,

$$\lim_{B\to\infty} t^* = \lim_{B\to\infty} \frac{\sqrt{\frac{48\alpha(1-\theta)}{B} + 81} - 9}{\frac{4\alpha(1-\theta)}{B}} = \lim_{B\to\infty} \frac{6}{\sqrt{\frac{48\alpha(1-\theta)}{B} + 81}} = \frac{2}{3} \tag{43}$$

Thus, t^* is bounded above by 2/3. ■