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**The Effects of Long-Term Debt
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in Duopolistic Markets**

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Abstract

While many marketing models ignore the influence of financial variables on a firm's marketing strategy, this paper explores the effect of debt on the profit maximizing price for a new product. We assume a duopolistic market structure in which two firms produce a heterogeneous new consumer durable that is sold over two different periods. Firms know market demand in the first period with certainty, while demand in the second period is uncertain. Moreover, firms have free access to the capital market and finance part of their operating costs by issuing long-term debt. In this setting, we study the influence of long-term debt on firms' pricing policies. It turns out that leveraged firms compared to unleveraged ones have different pricing strategies. In particular, first-period prices are lower and second-period prices are higher in case of long-term debt than in case of no leverage. Finally we find that prices for firms that take on debt are less volatile than prices for purely equity-financed firms.

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Introduction

There seems to be a consensus among marketing scientists that the success of a new product critically depends on the pricing policy adopted by the firm. Marketing theory tells us that new products can be launched either by selling at a high initial price or at a low introductory price (e.g., Dean, 1951, 1976; Kotler, 1997). That is, management can follow a skimming strategy which requires setting a high price initially and then gradually decreasing the price, or pursue a penetration strategy which implies that new products are introduced at a low price which eventually is increased. Penetration pricing will be adequate if markets are large and consumers are price-sensitive, while skimming strategies are proposed for small markets consisting of consumers who are willing to pay higher prices.

The two contrasting pricing policies offer a lot of guidance for price management when firms sell a new consumer durable. Marketing theory suggests different approaches within the framework of diffusion models of new product acceptance. They provide a rationale for these pricing policies as optimal strategies over a product's life cycle (Robinson and Lakhani, 1975; Bass, 1980; Dolan and Jeuland, 1981; Kalish, 1983; Dockner and Jørgensen, 1988; Simon, 1989; Rao, 1993). While many of these studies address a variety of interesting questions from the marketing point of view (e.g., what are optimal pricing policies over the product life cycle when costs are subject to the learning curve, what is the influence of actual and potential competition in new product markets, and what are optimal marketing mix strategies), there has been no attention to the question of how firms' financing decisions influence their pricing policies. The reason why this problem has not received much attention is rooted in finance theory, which predicts that under a large variety of circumstances the choice of a firm's capital structure (i.e., its financing decision) is irrelevant for its value. This irrelevance proposition, first stated by Modigliani and Miller (1958) in their seminal paper, implies that there are no interrelations between a firm's financial and output related variables. While this proposition is very appealing in perfectly competitive markets, it does not necessarily hold for product markets where firms face market power. In fact, financial economists recently have started to explore the role of debt in models in which firms operate in an oligopolistic market (Brander and Lewis, 1986; Glazer, 1994; Dasgupta and Titman, 1994; Dockner, Elsingher, and Gaunersdorfer, 1997). It is shown that in an imperfectly competitive output market there can be a strategic influence from the amount of debt a firm issues on its output market behavior.

In this paper we study the effect of long-term debt on the pricing policy a firm adopts for a new consumer durable (e.g., washing machine) over two consecutive periods. In particular, we take a standard diffusion model in which saturation effects are the driving dynamics on the demand side, assume a duopolistic market structure, and allow firms to compete on prices over two periods.

First, we examine optimal pricing policies when demand is certain and firms are fully equity-financed. We use standard game theory techniques and derive two sets of equilibria, one in which firms use naive (open-loop) pricing strategies, and one in which they employ sophisticated sequentially rational (closed-loop) strategies. If the firms use open-loop strategies, they set their prices as a time path and ignore strategic interactions with their counterparts. If they use closed-loop strategies, they consider the reactions of their competitors and set their

optimal prices accordingly. Hence, we can argue that the closed-loop game is more appropriate to capture competition (for further details on the distinction between open and closed-loop equilibria see Erickson, 1991). In the case of fully equity-financed firms we find that profit maximizing prices are decreasing over time in both cases, and closed-loop prices are always below open-loop ones. These results are an immediate consequence of the diffusion dynamics on the demand side and the rival's market power. Since we concentrate on the sales of a new consumer durable with dominating saturation effects, the optimal pricing policy turns out to be a skimming strategy. Firms that have market power gradually lower the price in order to exhaust the entire market potential.

Next, we introduce demand uncertainty in the second period and suppose that firms are partly debt-financed. In this setting, firms face the risk of bankruptcy if demand is lower than expected. Since managers are aware of this possibility, they choose a different pricing strategy in case of debt-financing compared to no debt-financing. In particular, prices in the second period are increasing with the level of debt, while those in the first period are decreasing. This implies that debt-financing changes firms' pricing policies and causes prices to be less volatile in case of debt than without it.

The Model

We consider a market in which two firms sell a new consumer durable. Following the literature on the diffusion of innovations (for a literature review see Mahajan, Muller, and Bass, 1993), we assume that demand in this market is primarily governed by external forces (i.e., innovation sales) and not by communication between early adopters and non-adopters. Hence, we use the Fourt and Woodlock (1960) model to capture these dynamics. Let us assume that M^i is the number of potential buyers of firm i 's product and that Q_t^i is the number of consumers that already have adopted firm i 's product until the beginning of period t . Then, sales of firm i during period t , q_t^i , are proportional to the remaining market potential:

$$q_t^i = \omega[M^i - Q_t^i] ,$$

with $0 \leq \omega \leq 1$. Hence, accumulated sales evolve according to the state equation:

$$Q_{t+1}^i = q_t^i + Q_t^i .$$

The initial level of adopters of firm i 's product are given by $Q_0^i \geq 0$. The diffusion equation as stated here does not consider any marketing influences on sales. To relax this, we assume that firms are able to influence the number of potential buyers in every single period by choosing an appropriate pricing policy. This leads to replacing the constant market potential M^i by $M^i(p_t^i, p_t^j)$. Since firms are competing in a heterogeneous duopolistic market, firm i 's demand is influenced not only by its price, but also by the price of the rival firm j . To keep the analytical structure of the model as simple as possible, we assume a linear relationship between prices and the level of potential adopters. The linearity assumption is not crucial for the derivation of the main conclusions in this paper. However, it simplifies the algebra considerably. The market potential is therefore modeled as:

$$M^i(p_t^i, p_t^j) = \alpha + \beta p_t^i + \gamma(p_t^j - p_t^i), \quad i \neq j ,$$

where $\alpha > 0$, $\beta < 0$, $\gamma > 0$, and $|\beta| > \gamma$. The parameter β measures the influence of the firm's own price on the level of demand; and γ measures the influence arising from the price difference between the two competitors. With this specification, the sales of firm i in period t are given by:

$$q_t^i = \omega[M^i(p_t^i, p_t^j) - Q_t^i] = \omega[\alpha + \beta p_t^i + \gamma(p_t^j - p_t^i) - Q_t^i] , \quad (1)$$

and the sales dynamics, again, evolve according to $Q_{t+1}^i = q_t^i + Q_t^i$. Firms are assumed to face constant cost of production, c , and maximize the discounted profits over a given planning period T . Hence, the objective function of firm i becomes:

$$\pi^i = \sum_{t=0}^T \rho^t \pi_t^i(p_t^i, p_t^j) = \sum_{t=0}^T \rho^t [p_t^i - c] q_t^i ,$$

where $\rho \geq 0$ is the constant discount rate.

With the specification of the sales dynamics and the objective functions, our model becomes a structurally-linked, dynamic game with two players. As the solution concept to this game we choose the Nash equilibrium (Friedman, 1986). To derive the Nash equilibrium prices for this game, we need to specify the strategy spaces that are employed by the firms. There are two contrasting concepts available. Firms can either choose their pricing policies as simple time paths ignoring the current level of sales, or they can choose pricing decision rules in which the current level of price depends on the current level of accumulated sales. As mentioned before, the first class of strategies is called open-loop and the second one closed-loop strategies.

Optimal Prices in Case of No Debt-Financing

To derive optimal pricing strategies for both firms, we make the simplifying assumption that the firms' planning horizon is only two periods, i.e., $T = 1$. We first look at the case when firms choose prices as simple time paths. We can state the following proposition:

Proposition 1: *If firms choose prices as simple time paths and hence ignore dynamic strategic interactions, optimal prices are above static levels and decrease over time.*

Proof of Proposition 1: The pricing problem in case of no debt and a planning horizon of two periods implies the following decision problem:

$$\begin{aligned} & \max_{p_0^i, p_1^i} \{ \pi^i(p_0^i, p_0^j, p_1^i, p_1^j) = \pi_0^i + \pi_1^i = \\ & = (p_0^i - c)\omega[\alpha + \beta p_0^i + \gamma(p_0^j - p_0^i) - Q_0^i] + \rho(p_1^i - c)\omega[\alpha + \beta p_1^i + \gamma(p_1^j - p_1^i) - Q_1^i] \} , \quad (2) \end{aligned}$$

where we assume that the initial level of accumulated sales is equal to zero, so that $Q_0^i = 0$ and $Q_1^i = q_0^i$ hold. Since the pricing game is linear quadratic and symmetric, a unique symmetric open-loop equilibrium exists that is given by the first-order conditions of the maximization problem (2):

$$\frac{\partial \pi^i}{\partial p_0^i} = 0 \quad \frac{\partial \pi^i}{\partial p_1^i} = 0 . \quad (3)$$

The first order conditions (3) in case of symmetry result in

$$\begin{aligned}(2\beta - \gamma)p_0 &= -\alpha + c(\beta - \gamma) + \rho(p_1 - c)(\beta - \gamma) \\ (2\beta - \gamma)p_1 &= c(\beta - \gamma) + \beta p_0 .\end{aligned}\tag{4}$$

A solution of this system shows that prices in both periods are higher than in the corresponding static model. Subtracting the second equation (4) from the first leads to

$$(2\beta - \gamma)(p_0 - p_1) = -(\alpha + \beta p_0) + \rho(p_1 - c)(\beta - \gamma) < 0 .$$

This implies that $p_0 > p_1$. \square

The result of proposition 1 confirms our intuition. Since demand is governed only by external effects, and sales today cause the remaining market potential to decrease (saturation effects dominate), firms find it optimal to choose a skimming pricing policy. As innovators dominate the market, firms set high initial prices and then gradually decrease them. This result corresponds to many existing findings in the literature (cf., Feichtinger, 1982; Dockner, 1985; Rao, 1993).

The choice of open-loop strategies suffers from the disadvantage that firms are required to precommit themselves. They announce their pricing policies at the beginning of the planning period and then stick to these policies, i.e., it is not feasible for them to revise their pricing strategies over the course of time. Therefore, the more interesting equilibrium concept is the one in which firms choose closed-loop strategies. Here they design their current prices as decision rules that depend on the level of accumulated sales, or, to put it differently, firms really behave strategically in the following sense. They design their optimal price in each period by anticipating the rival's reaction to any change in the firm's price and by taking this anticipated reaction into account. Hence, with closed-loop strategies firms really interact strategically, leading to proposition 2:

Proposition 2: *When firms choose closed-loop strategies, optimal prices in each period are lower than open-loop prices and decrease over time.*

Proof of Proposition 2: We again start with the maximization problem (2):

$$\max_{\tilde{p}_0^i, \tilde{p}_1^i} \{ \pi^i = (\tilde{p}_0^i - c)\omega[\alpha + \beta\tilde{p}_0^i + \gamma(\tilde{p}_0^j - \tilde{p}_0^i) - Q_0^i] + \rho(\tilde{p}_1^i - c)\omega[\alpha + \beta\tilde{p}_1^i + \gamma(\tilde{p}_1^j - \tilde{p}_1^i) - Q_1^i] \} .$$

When firms use closed-loop strategies, they take into account that the prices in period one depend on the prices chosen in period zero. Therefore, we need to apply backward induction and the first-order conditions are given by

$$\begin{aligned}\frac{\partial \pi_1^i}{\partial \tilde{p}_1^i} &= 0 \\ \frac{\partial \pi^i}{\partial \tilde{p}_0^i} &= \frac{\partial \pi_0^i}{\partial \tilde{p}_0^i} + \rho \left[\frac{\partial \pi_1^i}{\partial \tilde{p}_0^i} + \underbrace{\frac{\partial \pi_1^i}{\partial \tilde{p}_1^i} \frac{\partial \tilde{p}_1^i}{\partial \tilde{p}_0^i}}_0 + \frac{\partial \pi_1^i}{\partial \tilde{p}_1^i} \frac{\partial \tilde{p}_1^j}{\partial \tilde{p}_0^i} \right] = 0 .\end{aligned}\tag{5}$$

The first two terms in (5) arise because of the dynamics of the model. The third term arises because the price \tilde{p}_1^i depends on the price \tilde{p}_0^i , but it vanishes (by applying the envelope theorem); the fourth term captures the strategic interaction (i.e., it takes into account that the price \tilde{p}_1^j changes whenever the price \tilde{p}_0^i is changed). With symmetry the first-order conditions result in

$$\begin{aligned} (2\beta - \gamma)\tilde{p}_1 &= c(\beta - \gamma) + \beta\tilde{p}_0 \\ (2\beta - \gamma)\tilde{p}_0 &= -\alpha + c(\beta - \gamma) + \rho(\tilde{p}_1 - c)(\beta - \gamma) \left[1 - \frac{\gamma^2}{\Delta} \right], \end{aligned} \quad (6)$$

where $\Delta \equiv 4(\beta - \gamma)^2 - \gamma^2 > 0$. Note that the dependence of the second-period price of firm j on the first-period price of firm i for the symmetric equilibrium is given by $\frac{\partial \tilde{p}_1^j}{\partial \tilde{p}_0^i} = (1/\Delta)\gamma(\beta - \gamma) < 0$. Subtracting the first equation (6) from the second gives

$$(2\beta - \gamma)(\tilde{p}_0 - \tilde{p}_1) = -(\alpha + \beta\tilde{p}_0) + \rho(\tilde{p}_1 - c)(\beta - \gamma) \left[1 - \frac{\gamma^2}{\Delta} \right] < 0.$$

This shows that prices are decreasing. For the rest of the proof see the appendix. \square

The interesting result of proposition 2 implies that strategic competition results in lower prices. The reason for this finding has a simple intuitive explanation. Since firms compete for customers, strategic interactions cause them to be more aggressive in the product market. Although prices in case of closed-loop strategies are lower than open-loop prices, dynamic prices are again higher than corresponding static ones. This is again the consequence of the skimming pricing strategy adopted by the firms.

Optimal Prices When Firms are Debt-Financed

In the preceding section we have studied the case where firms choose optimal prices when they are fully equity-financed. We find that, given our demand dynamics, optimal pricing strategies follow a skimming profile where closed-loop prices are more competitive than open-loop ones. In this section we now turn our attention to the question whether or not the choice of a firm's capital structure has an influence on its pricing policy. To study the implications of debt on optimal prices we generalize our model slightly. Until now we have assumed that the market potential in both periods is known with certainty. Here we extend this assumption by allowing random disturbances in the following way. We suppose that the firm's market potential in period zero is known with certainty. However, the market potential in period one still depends on the prices, but is subject to random disturbances given by the random variable ϵ . Hence, demand in periods zero and one looks as follows:

$$\begin{aligned} q_0^i &= \omega[M^i(p_0^i, p_0^j) - Q_0^i] \\ q_1^i &= \omega[M^i(p_1^i, p_1^j) + \epsilon - Q_1^i]. \end{aligned}$$

ϵ is a random variable with density function $f(\epsilon)$ defined over the interval $[\underline{\epsilon}, \bar{\epsilon}]$ and an expected value given by $E(\epsilon) = 0$. From now on we set $\omega \equiv 1$.

Since demand in period one is uncertain, we need to rewrite the firm's objective function, which is now given by:

$$\pi^i = q_0^i(p_0^i - c) + \rho \int_{\underline{\epsilon}}^{\bar{\epsilon}} (M^i(p_1^i, p_1^j) + \epsilon - q_0^i)(p_1^i - c) f(\epsilon) d\epsilon , \quad (7)$$

where we made use of the fact that $Q_1^i = q_0^i$ which holds when the initial cumulated sales are equal to zero. The objective function (7) implies that in the case of $E(\epsilon) = 0$ the problem becomes identical to that solved in the previous section. This, however, holds only in case of no debt. If we introduce debt the situation will change, since firms face the risk of bankruptcy. In particular, if the demand realization turns out to be lower than expected, profits are not sufficient to pay back the outstanding debt and, hence, bankruptcy occurs. We assume that the level of debt in period zero is $D^i > 0$. Then the outstanding debt in period one is given by $\tilde{D}^i = D^i - (p_0^i - c)q_0^i$, which we assume to be strictly greater than zero because debt is long-term. Therefore, the firm's objective function in period one becomes:

$$\pi_1^i = \int_{\hat{\epsilon}}^{\bar{\epsilon}} [(M^i(p_1^i, p_1^j) + \epsilon - q_0^i)(p_1^i - c) - \tilde{D}^i] f(\epsilon) d\epsilon , \quad (8)$$

where $\hat{\epsilon}$ is that level of demand for which the firm is able to pay back its outstanding debt in the second period:

$$(M^i(p_1^i, p_1^j) + \hat{\epsilon} - q_0^i)(p_1^i - c) = \tilde{D}^i .$$

The objective function (8) states that management is maximizing the expected equity value and not the total value of the firm. Since in case of bankruptcy the debt holders are the residual claimants, equity maximizing managers care only for those states of demand for which $\epsilon \in [\hat{\epsilon}, \bar{\epsilon}]$ holds and the firm continues to exist. Taking both periods together, the firm's objective function becomes:

$$\pi^i = q_0^i(p_0^i - c) + \rho \int_{\hat{\epsilon}}^{\bar{\epsilon}} [(M^i(p_1^i, p_1^j) + \epsilon - q_0^i)(p_1^i - c) - \tilde{D}^i] f(\epsilon) d\epsilon . \quad (9)$$

To solve this dynamic maximization problem, we make use of dynamic programming. This requires to choose the period one prices in such a way as to maximize the function

$$\max_{p_1^i} \int_{\hat{\epsilon}}^{\bar{\epsilon}} [(M^i(p_1^i, p_1^j) + \epsilon - q_0^i)(p_1^i - c) - \tilde{D}^i] f(\epsilon) d\epsilon ,$$

where we need to take into account that the critical demand level $\hat{\epsilon}$ depends on the prices in period one (p_1^i, p_1^j) . Hence, we get as first-order conditions

$$\frac{\partial \pi_1^i}{\partial p_1^i} = \int_{\hat{\epsilon}}^{\bar{\epsilon}} \left[\frac{\partial M^i(p_1^i, p_1^j)}{\partial p_1^i} (p_1^i - c) + (M^i(p_1^i, p_1^j) + \epsilon - q_0^i) \right] f(\epsilon) d\epsilon = 0 .$$

Given the linearity, we can easily solve this integral equation and check that the sufficient conditions are satisfied. From the first-order condition of the period one prices, we get that

$$p_1^i = p_1^i(p_0^i, p_0^j, \tilde{D}^i, \tilde{D}^j) .$$

This is what we need to take into account when solving for period zero prices. Note that the optimal prices in period one depend on the debt level. The optimality conditions for the optimal prices at $t = 0$ then become $\frac{\partial \pi^i}{\partial p_0^i} = \frac{\partial \pi_0^i}{\partial p_0^i} + \frac{\partial \pi_1^i}{\partial p_0^i} + \frac{\partial \pi_1^i}{\partial p_1^j} \frac{\partial p_1^j}{\partial p_0^i} = 0$ (cf., equation (5)).

Deriving a closed-form solution of this game requires the solution of a fourth-degree algebraic equation. While this is in principle possible, an analytic solution does not admit any insights from which managerial implications can be drawn. Therefore, we focus on a numerical analysis. For that matter we specify the parameters of the model as follows: $\alpha = 1$, $\beta = -0.1$, $\gamma = 0.01$, $\bar{\tau} = 0.5$, $c = 0$, and $\rho = 1$. Further we assume an uniform distribution of ϵ .

Simulations

The results of the simulations are depicted in Figures 1 and 2. They show a very interesting pattern. We see that the level of debt influences the firms' pricing policies. The influence, however, is different in period zero and in period one.

 Insert Figure 1
 about here

 Insert Figure 2
 about here

Proposition 3: *Increasing levels of debt cause the optimal price in case of a symmetric equilibrium to increase in period one and decrease in period zero.*

This is quite a striking result which has the following interpretation. Given the objective of the firms' managers (i.e., equity value maximization), they only care about those demand realizations for which debt can be repaid. This implies that they are only interested in large realizations of demand when debt is high. But large demand realizations cause the managers to set higher prices. Hence, the effect of debt on prices is driven by the managers' objective. What needs to be realized, however, is that with debt the firm's profits in period one are lower than in case of no debt. So firms are worse off with debt than without debt even though they have the incentive to increase the price. But, as shown in Figures 1 and 2, firms still employ a skimming price policy (prices in period one are lower than in period zero). Hence, firms still intertemporally price discriminate. The skimming price strategy is an immediate consequence of the dynamics on the demand side (i.e., new consumer durable with saturation effects). With high prices, initially sales are low and the remaining market potential for future periods is high. Hence, a firm can exhaust a market by gradually decreasing the price. In case of debt, however, the following mechanism is at work. Since

debt increases the price of the product in period one, sales in that period will be lower. Therefore, in order to skim the market, firms have an incentive to set lower prices in period one. Although this behavior exhausts the market potential more rapidly, it does not create any problem for the firms, since period one sales will be low given the higher price.

There is also a second explanation of the decreasing prices in period zero that relates to the firm's profits. Since larger debt in period one causes firms' profits to decrease, they have an incentive to carry over as little debt as possible into the second period. To be able to do this requires that firms set the prices in period zero accordingly (i.e., to set the prices in such a way as to increase period zero profits; see Table 1). This behavior introduces the incentive to lower the price given the fact that the firms operate on the elastic part of the demand curve. As a consequence, we can conclude that debt does not only influence the pricing behavior of firms, it also smoothes out the price differences over the period. Prices with debt become less volatile and the skimming effect less pronounced.

The last results refer to the symmetric equilibrium. Therefore, in Figure 2 we also present the results for the asymmetric case. Here, we can conclude that in principle the effects are identical to those in the symmetric case, with the only difference being that the price change of firm i due to an increase in the level of debt of firm j is very modest.

Although we derived our results only numerically with special functional forms (linear demand), the continuity properties of our equilibrium conditions ensure that they hold for large sets of different parameter specifications and nonlinear demand.

Table 1: Profits in Period Zero

No Debt	With Debt	
Profit	Debt Level	Profit
2.3204	2.5	2.4775
	2.6	2.4778
	2.7	2.4784
	2.8	2.4792
	2.9	2.4802
	3.0	2.4813
	3.1	2.4826
	3.2	2.4839
	3.3	2.4854

Conclusions

This paper studies the influence of financial variables on the pricing policy of a firm selling a new consumer durable in a duopolistic market. In particular, we addressed the issue of whether or not firms have an incentive to change their pricing strategies of a product over a time horizon of two consecutive periods when the firms partly use debt-financing. Since the output market is assumed

to be imperfectly competitive, it is to be expected that the choice of the capital structure has an influence on firms' marketing activities. It turns out that when managers choose their pricing policies so as to maximize the firms' equity value, long-term debt has a significant impact on firms' dynamic pricing strategies. Period-one prices increase, while period-zero prices decrease relative to their levels when firms use no debt-financing.

When managers choose a pricing policy in order to maximize the firm's equity value, and demand is uncertain, they concentrate only on those states of nature in which there will be no bankruptcy. Since bankruptcy depends on the level of debt (it is more likely the higher the level of debt is), high levels of demand are required so that the second-period profits are sufficiently high to repay the debt. Hence, equity maximizing managers have a bias towards those states where demand and, therefore, marginal revenues are high, which implies that optimal prices are high, too. This explains why second-period prices increase with the level of debt. To understand the decrease of first-period prices, we need to use the skimming price argument that holds for consumer durables with strong saturation effects. In that case, firms find it optimal to continuously decrease the price in order to skim the market. Since, in case of debt, prices in the second period are increasing with the level of debt and, hence, sales are lower, the firms can set lower prices in the first period to increase sales, i.e., the saturation effect in case of debt is not that severe than in case of no debt.

Our results have several important implications. First, we find that second-period debt causes firms to increase prices, thereby being less aggressive in the product market, i.e., product market competition becomes "softer" with an increase in leverage. This theoretical finding is consistent with empirical facts as pointed out in a recent paper by Chevalier (1995). Second, we show that debt has the effect that prices become less volatile over the planning horizon. In terms of our model this implies that managers of leveraged firms should adopt a less pronounced skimming strategy. Third, it turns out that increased competition in the market place causes firms to lower their prices. While we prove this result only for the case of fully equity-financed firms, it corresponds well with our intuition that the selected price level is linked to the nature of competition.

Finally, we want to point out some open questions that are worth to be looked at in future research: One of the crucial assumptions in this paper is the managers' equity value maximizing behavior. While there are some rational justifications for this assumption, it would be interesting to allow for an objective function that maximizes a combination of equity and debt value. Furthermore, the demand side of the market in this paper is kept very simple. It would be challenging to see how additional dynamics on the demand side, like word-of-mouth communication, would change the general conclusions derived. Additionally, as the sequencing of several products at different stages in their life-cycles is ignored, we believe that studying the effects of financial variables on the firms' corresponding marketing decisions would add value to the existing knowledge.

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Technical Appendix

The relationship between open-loop and closed-loop strategies in the case of no debt-financing

From (4) and (6) we get that

$$p_1 \lesssim \tilde{p}_1 \iff p_0 \lesssim \tilde{p}_0 .$$

Simple manipulations show that $(\tilde{p}_1 - p_1) \left[\frac{(2\beta - \gamma)^2}{\beta} - \rho(\beta - \gamma) \right] = -(\beta - \gamma)\rho\frac{\gamma^2}{\Delta}(\tilde{p}_1 - c)$ holds. Since $-(\beta - \gamma)\rho\frac{\gamma^2}{\Delta}(\tilde{p}_1 - c) > 0$ and $\left[\frac{(2\beta - \gamma)^2}{\beta} - \rho(\beta - \gamma) \right] < 0$, it follows that

$$\tilde{p}_1 - p_1 < 0 .$$

Hence we get $\tilde{p}_1 < p_1$ and $\tilde{p}_0 < p_0$. □

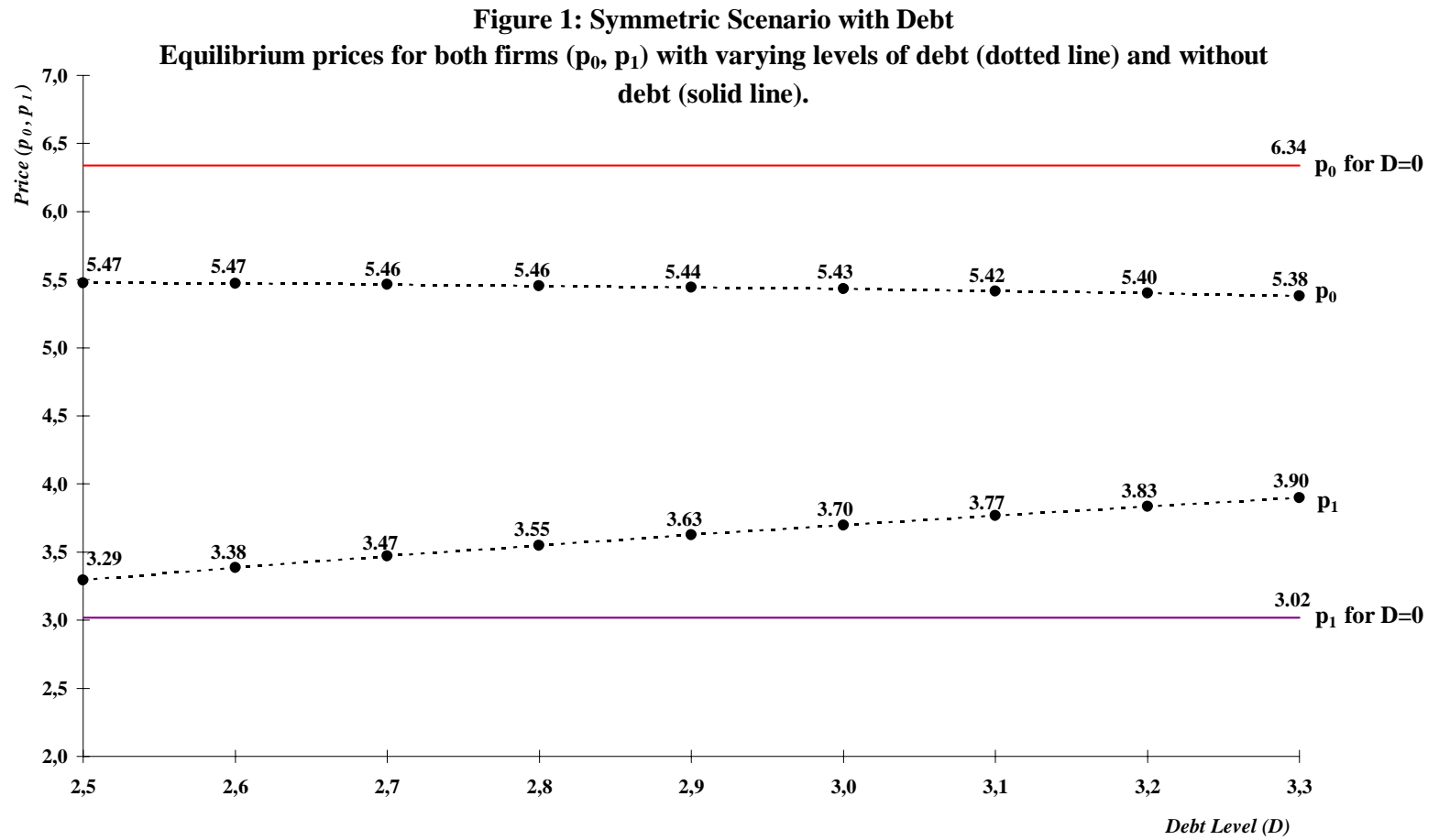


Figure 2: Asymmetric Scenario for $D^i = 2.5$
 Equilibrium prices for both firms ($p_0^i, p_0^j, p_1^i, p_1^j$) with asymmetric levels of debt.

