Financial Structure and Oligopoly: The R&D Effect

(Preliminary and Incomplete)

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Abstract

Financial structure is an important decision variable for firms, and varies significantly across industries. Capital intensive industries such as manufacturing or utilities, which have substantial physical assets and typically generate stable cash flows, tend to have relatively high debt-equity ratios. In contrast, research intensive industries, such as those in the "high tech" sector, issue much less debt. Conventional wisdom is that financial distress costs are the most important explanatory factor for this variation in financial structure. That is, firms with more uncertain prospects might seek to minimize the chance of financial distress and the associated costs by keeping debt levels low. However, the high tech giants with very low debt to equity ratios such as Apple, Google, Microsoft, Amazon, Facebook, and others do not seem vulnerable to financial distress risk. In this paper, we offer a alternative

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theory to explain why financial structure varies across industries. We focus on the relationship between financial structure and R&D in an oligopoly context. There are two distinct types of R&D – process R&D, which lowers the cost of producing a given product, and product R&D, which changes product characteristics and/or improves product quality. Our key insight is that process R&D is complementary with the strategic use of debt to improve a firm's market position under oligopoly. As in Brander and Lewis (1986), firms have an incentive to use debt to commit themselves to a more aggressive position in the output market. Process R&D strengthens this effect. Product R&D, on the other hand, increases product differentiation, weakens head-to-head competition between oligopolistic rivals, and reduces the incentive to use debt for strategic purposes. As manufacturing industries and utilities make relatively more use of process R&D, while high-tech industries undertake relatively more product R&D, we can explain why the high-tech industries make relatively less use of debt and have much lower debt to equity ratios.

1 Introduction

Financial structure (or "capital structure") varies systematically and dramatically across industries, as some industries exhibit much higher debt and leverage levels than others. There is also substantial within-industry variation in financial leverage. The most traditional explanation for such variation is based on a trade-off between the tax benefits of debt and the possibility of financial distress costs. Firms with stable cash flows that face little risk of financial distress have an incentive to take on debt to reduce tax liabilities. Firms facing more cash flow uncertainty use more equity and less debt so as to reduce the likelihood of financial distress and any associated costs. Other well-established theories of financial structure are based on agency considerations, on signalling under potential adverse selection, and on strategic effects of financial structure in oligopoly output markets.

While these theories have significant explanatory power, important empirical puzzles remain. For example, such theories cannot readily explain why high-tech giants such as Facebook and Google have very low debt to equity and debt to asset ratios. These firms do not seem vulnerable to financial distress risk, nor are they subject in any obvious way to other traditional explanations for low leverage. More systematically, Frank and Goyal (2009) undertake a careful empirical analysis of a large set of factors that have been proposed as explanatory variables for market leverage and state (p. 3) that "a set of six factors account for more than 27% of the variation in leverage, while the remaining factors only add a further 2%." But this means that about 70% of the variation was unexplained by the large set of variables considered.

Our primary objective in this paper is to offer a new contributing explanation for variation in financial structure across firms and across industries. This explanation is based on R&D in an oligopoly context. R&D intensity (often measured by the ratio of R&D expense to revenues or something similar) has previously been suggested as a determinant of financial leverage. It is, for example, one of the factors included by Frank and Goyal (2009), but did not make their "top six" in explanatory power. Our innovation is to focus not on the amount or intensity of R&D, but on the type of R&D. Specifically we compare the effects of cost-reducing R&D – also called "process R&D" with those of "product R&D" – R&D focused on changing product characteristics.

Our primary finding is that process R&D is complementary with the use of strategic debt financing and therefore tends to increase the use of debt. In contrast, product R&D increases product differentiation and reduces the strategic motive for debt finance. Therefore, our analysis suggests that industries that rely more on process R&D should exhibit higher leverage (more debt) than industries that rely on product R&D.

We consider a sequential decision structure and compare the equilibrium obtained using process R&D with that arising from product R&D. In each case, firms initially decide simultaneously on the amount of R&D to undertake, then decide how much debt to take on, and finally decide on the output level to produce. The final stage is a Cournot stage and the overall equilibrium is the sequentially rational Nash equilibrium in the three stage game.

Our paper contributes to three literatures. First, the paper adds a significant consideration to the long-standing literature on financial structure within the firm. Second, we contribute to the economic literature on R&D by providing a new partial explanation of the nature and magnitude of R&D investments. In addition, we contribute to the theory of oligopoly by showing how the interaction of R&D and financial structure decisions affects product market interaction in Cournot oligopoly.

Section 2 of the paper provides a literature review. Section 3 presents the basic model and Section 4 compares process and product R&D. Section 5 contains concluding remarks.

2 Literature Review

The literature on the determinants of financial structure is very large. A highly-cited review of the major traditional theories of financial structure is provided by Harris and Raviv (1991), and an empirical survey that also reviews more recent theoretical contributions is Parsons and Titman (2009). Frank and Goyal (2009) provides a valuable reassessment of the empirical evidence regarding the major theories.

Within this literature, some attention has been paid to the role of R&D in influencing financial structure. At a theoretical level, the amount of R&D might be related to agency problems or to other informational asymmetries that form the basis of some traditional theories of financial leverage. R&D might even affect tax liabilities and/or financial distress costs and therefore be relevant to the original tax shield vs. financial distress cost theory of financial structure. In empirical work, R&D intensity frequently appears as one of a battery of explanatory variables for financial leverage, although it is usually not the primary focus of attention. In most such papers, R&D intensity is negatively associated with leverage – higher R&D intensity is associated with lower leverage. R&D is the primary focus in Aghion et al. (2004) who find a nonlinear relationship. For firms that report R&D, Aghion et al. (2004) find the usual negative relationship, but find that firms that report low but positive R&D use more debt finance than firms that report no R&D.

In considering the empirical work on R&D and leverage, it is difficult to be confident of causal interpretations. After all, R&D and financial structure are both endogenous variables in some larger managerial decision problem, so regressing one variable on the other does not necessarily identify underlying causation. Along these lines, Nam et al. (2003) find that both leverage and R&D are influenced by underlying managerial attitudes toward risk – inducing a correlation between leverage and R&D that is not causal. We suggest that in order to attempt causal interpretation it may be helpful provide a formal model in which the relationship between debt and R&D is clearly specified. This paper provides such a model.

Our analysis is most closely related to the line of research focussing on the strategic motives for debt finance under oligopoly, including Brander and Lewis (1986, 1988), Maksimovic (1988), Dasgupta and Titman (1998), Showalter (1999), Wanzenried (2003), and others. This line of research focuses on the use of debt to influence product market interactions between oligopoly firms. Our analysis fits into that category but adds a prior stage of decision-making in which firms decide on R&D, anticipating the effect of R&D decisions on subsequent financial and product market outcomes.

3 Model Fundamentals

3.1 Market Structure and Timing

We consider a duopoly model with three stages. The two firms, denoted 1 and 2 or i and j, act simultaneously in each stage. They first choose R&D levels simultaneously, then choose debt levels, then choose output levels. The equilibrium concept is the sequentially rational Nash equilibrium in the three stage game, incorporating a Cournot game in the final stage. The two products may be either perfect or imperfect substitutes.

We consider two versions of the model. In one version, firms undertake process R&D in the first stage. Increases in process (cost-reducing) R&D in stage 1 lead to lower marginal production costs in the output stage, while the degree of product differentiation is fixed. In a second version of the model, firms undertake product R&D in the first stage. In this case, the marginal production cost is fixed, but the degree of product differentiation between the products varies depending on the amount of R&D undertaken by the firms. Comparison of these two versions of the model shows that whether R&D is process R&D or product R&D has significant implications for the effect of R&D on financial structure. More specifically, the two types of R&D have essentially opposite effects.

3.1.1 Demand

We assume a symmetric quadratic utility function with an additive numeraire term, giving rise to symmetric linear inverse demand functions in output levels $q_i$and q_j. In addition, demand is subject to uncertainty. The firms are subject to independent random demand shocks denoted z_i and z_j. The inverse demand functions can be written as follows:

$$p_i = a - q_i - sq_j + z_i \tag{1}$$

The demand intercept is a, and higher values of a reflect higher demand. The slope of the inverse demand function (the derivative of a firm's price with respect to the firm's own output) is assumed, without loss of generality, to be 1.[1] The degree of product substitutability is s. Thus lower levels of s imply less product substitutability (more product differentiation). As the slope of demand is one and the products are substitutes, parameter s must lie between 0 and 1. If s = 1, the products are perfect substitutes and if s < 1 the products are imperfect substitutes. We do not consider the case of unrelated goods (s = 0) as we wish to avoid proliferation of special cases.

We assume that all market participants are risk neutral. To keep the algebra as simple as possible, we use a uniform distribution with mean zero for z_i. Using f to represent this probability density function and allowing the range of $z_i$to be $[\underline{z}, \bar{z}]$ and $\underline{z}$= $\bar{z}$ yields:

$$f(z_i) = 1/2\bar{z} \tag{2}$$

[1] If we start with an arbitrary slope b for the inverse demand function, then units can be redefined and other parameters adjusted accordingly to specify inverse demand functions with a slope of 1.

3.1.2 Cost

In terms of production cost, we assume there is no fixed cost, and a constant and symmetric marginal cost, c, which has to be lower than a to guarantee production to take place.

For the case of process R&D investment, we assume each firm incurs a quadratic R&D cost, $\frac{1}{2}k_{ci}^2$, where k_{ci} is the R&D intensity on cost reduction and for simplicity we also assume one firm's effort on cost reduction has no spill over effect on the other. The firm's (constant) marginal cost will become $c-\ k_{ci}$ where k_{ci} is determined by the amount of cost-reducing R&D undertaken.

For the case of process R&D investment, each firm contributes k_{si} to differentiate their products by incurring a quadratic R&D cost, $\frac{1}{2}k_{si}^2$, meaning that the joint contribution is:

$$k_s = k_{si} + k_{sj} \tag{3}$$

Considering the R&D effect, the degree of differentiation is modelled as:

$$s = 1 - \beta k_s \tag{4}$$

where β is the differentiation impact factor and the product of βk_s is assumed to be between zero and one to guarantee s is between zero and one and if k_s is zero, then the products are homogenous.

3.1.3 Debt

The following break-even condition defines a critical demand shock level for each firm: Random shocks z_i and z_j are not realized until after quantity decisions are made. These random shocks affect prices and profits. Low levels of z_i lead to a low price for product i and might cause firm i to make operating losses. Even if firm i covers its operating cost, it might still be unable to pay its previously incurred debt Di if the operating revenue is too small. For each firm i, there is a critical value of z_i, denoted $\hat{z}_i$, below which the firm cannot pays its debt and goes bankrupt. If $z_i < \hat{z}_i$, the equity value of the firm drops to zero and the firm's debtholders become the firm's owners and residual claimants. If $z_i \geq \hat{z}_i$, the firm is able to meets it financial obligations and is solvent. The critical or breakeven value $\hat{z}_i$ is therefore implicitly defined by :

$$(a - q_i - q_j + \hat{z}_i)q_i - D_i = 0 \tag{5}$$

If $z_i > \hat{z}_i$ firm i can fully pay back debt to debtholders; otherwise the firm goes bankrupt as debt is greater than its earnings for any $z_i < \hat{z}_i$ Notice that $\hat{z}_i$ is strictly increasing D_i: Taking on more debt implies that the critical value of z_i that separates bankrupt from solvent values of z_i increases, implying that the firm will go bankrupt over a wider range of states of nature. Given the relation between

$\hat{z}_i$ and D_i, we assume $\hat{z}_i$ is a linear function of D_i :

$$\hat{z}_i = \alpha D_i \tag{6}$$

3.2 Game Solution

We investigate how different types of R&D results in different capital structures across industries by comparing the process and product R&Ds' effects on firm's financial structure in Cournot product market competition. Backward induction is employed to solve this game. As is standard for multi-stage games, we analyze the final stage first, then work backwards, ending with the first stage.

We first analyze the process R&D case.

3.2.1 Stage 3: Output Market Equilibrium

In the third (and final) stage, the two firms choose quantity levels q_i and q_j simultaneously, conditional on debt levels D_i and D_j, determined in the second stage, and on process (cost-reducing) R&D expenditure levels k_{ci} and k_{cj}, determined in the first stage. This third stage is very similar to the final (i.e. second) stage in Wanzenried (2003), which is a special case of Brander and Lewis (1986), with the specific functional forms for demand and the distribution of uncertainty used here. The innovation in the current paper is to introduce a first stage R&D decision that affects output stage marginal cost. That R&D is sunk by the time the third stage is reached.

Given the debt level in the last stage, each firm chooses output level to maximize its expected shareholder value:

$$\max_{q_i} \pi_i = \int_{\hat{z}_i}^{\bar{z}} [(a - q_i - sq_j + z_i)q_i - (c - k_{ci})q_i - D_i - \frac{1}{2}k_{ci}^2] \frac{1}{2\bar{z}} dz_i \tag{7}$$

According to Equation (7), the first order condition to solve q_i is

$$\frac{\partial}{\partial q_i} \int_{\hat{z}_i}^{\bar{z}} [(a - q_i - sq_j + z_i)q_i - (c - k_{ci})q_i - D_i - \frac{1}{2}k_{ci}^2] \frac{1}{2\bar{z}} dz_i \tag{8}$$

$$= \int_{\hat{z}_i}^{\bar{z}} \frac{\partial(a - q_i - sq_j - c + k_{ci} + z_i)q_i}{\partial q_i} \frac{1}{2\bar{z}} dz_i \tag{9}$$

$$-\frac{\partial \hat{z}_i}{\partial q_i}[(a - q_i - sq_j - c + k_{ci} + z_i)q_i - D_i - \frac{1}{2}k_{ci}^2] \tag{10}$$

Solving the partial derivative and setting Equation (8) equal to zero and assuming s is equal to 1, we have the best response function on quantity for both firms at the equilibrium:

$$q_i = \frac{1}{4}(2a - 2q_j - (c - k_{ci}) + \bar{z} + \alpha D_i) \tag{11}$$

$$q_i = \frac{1}{6}(2a + \bar{z} + 2\alpha D_i - \alpha D_j) \tag{12}$$

$$\frac{\partial q_i}{\partial D_i} > 0 \tag{13}$$

$$\frac{\partial q_i}{\partial D_j} < 0 \tag{14}$$

As $\hat{z}_i$and $\hat{z}_j$ are functions of debt levels $D_i$and D_j, Equation (11) shows the dependence of output levels on the debt undertaken in Stage 2. The effect of debt on the Cournot output equilibrium has been well-established in the strategic debt literature, starting with Brander and Lewis (1986), and is reported here as Proposition 1.

Proposition 1 *i) An increase in its own debt level makes a firm more aggressive in that its output rises for any given output of its rival (i.e. its quantity best response curve shifts out). ii) A unilateral increase in the debt of firm i increases q_i and reduces q_j.*

The intuition underlying Proposition 1 is that an increase in the debt of firm i increases the critical value of $z_i$required for the firm to be solvent – the firm needs a better state of nature if it is pay off a larger debt obligation. Therefore, shareholders confine their attention to these better states of natures. In these better states, the marginal revenue of output is higher at any given output level, leading the firm (which is controlled by shareholders) to prefer a higher output level given any output chosen by the rival.

An implication of Proposition 1 is that, starting from the standard Cournot equilibrium with no debt, the firm gains a strategic advantage from more debt – committing it to a more aggressive output market strategy and gaining an advantage relative to its rival. Both firms face this incentive, leading to higher output levels than in the no-debt case.

Our innovation in this paper is to include cost-reducing R&D, implying that k_{ci} is positive. Equation (7) shows that cost-reducing R&D has an effect of output levels.

3.2.2 Stage 2: Determination of Debt Levels

Firms take on debt in stage 2, after R&D is undertaken but before output is produced. The debt taken on by Firm i is denoted Di, which is the amount that the firm promises to repay lenders (debtholders) at the end of stage 3, after the product is sold and revenue is realized.

In effect, shareholders can sell financial claims over future earnings to debtholders for their actuarially fair value. The amount D is the amount the firm agrees to pay to debtholders. This amount will exceed the amount actually received by the firm from debtholders, which is amount B. The difference between B and D includes any interest payments and a required risk premium reflecting the possibility of bankruptcy and the resulting incomplete payment of the debt.

We do not rule out the possibility that firms may take on debt in stage 1. However, stage 2 is the last opportunity to take on (or retire) debt. In this situation, the debt decision is properly modelled as a stage 2 decision as whatever is chosen in stage 1 can always be adjusted in stage 2.

In considering the debt decision, we abstract from both bankruptcy costs and any tax advantages of debt. Therefore, in our model, the only determinant of a unique debt level is the strategic effect of debt, which is the effect of debt on output levels as described in Proposition 1. In the absence of such a strategic effect, firms would be indifferent regarding their debt levels (i.e. regarding their financial structure) as in the classic model of Modigliani and Miller (1958).

To obtain the highest combined value from sales and bonds and residual profit, shareholders would seek to maximize the combined value of debt and equity in their stage 2 maximization. This implies simply maximizing the value of the firm over the full range of possible states of nature. Therefore, each firm chooses its debt level to maximize its expected firm value and the firm's objective function is shown as:

$$\max_{Di} \pi_i = \int_{\underline{z}}^{\bar{z}} [(a - q_i(\hat{z}_i, \hat{z}_j) - sq_j(\hat{z}_i, \hat{z}_j) - (c - k_{ci}) + z_i)q_i(\hat{z}_i, \hat{z}_j) - \frac{1}{2}k_{ci}^2] \frac{1}{2\bar{z}} dz_i \quad (15)$$

Solving the partial derivative and setting Equation (15) equal to zero (i.e. $\frac{\partial \pi_i}{\partial D_i} = 0$), we have the best response function on optimal debt for both firms at the equilibrium:

$$D_i^* = \frac{2a + 16k_{ci} - 4k_{cj} - 5\bar{z}}{5\alpha} \quad (16)$$

From this result, we can find that firm i's debt financing increases with its own process R&D but decreases by its rival's.

$$\frac{\partial^2 \pi_i}{\partial D_i \partial k_{ci}} = \frac{\partial D_i^*}{\partial k_{ci}} > 0 \tag{17}$$

$$\frac{\partial^2 \pi_i}{\partial D_i^* \partial k_{cj}} = \frac{\partial D_i^*}{\partial k_{cj}} < 0 \tag{18}$$

3.3 Stage 1: Process R&D investment: Sequential Strategic Complement for Debt

Under process R&D, the firm's objective function is shown as:

$$\max_{k_{ci}} \pi_i = \int_{\underline{z}}^{\bar{z}} [(a - q_i - sq_j + z_i)q_i - (c - k_{ci})q_i - \frac{1}{2}k_{ci}^2] \frac{1}{2\bar{z}} dz_i \tag{19}$$

The best response function on optimal debt for both firms at the equilibrium is shown as:

$$\frac{\partial \pi_i}{\partial k_{ci}} = \frac{1}{25}(12a + 11k_{ci} - 24k_{cj}) = 0 \tag{20}$$

In the first stage, each firm invests in process R&D to reduce their marginal cost and becomes more competitive in the product market. Hence, the process R&D investment intensifies the competition between firms and also increases their fully-equity financed profits before each of them issues debt. Brander and Lewis

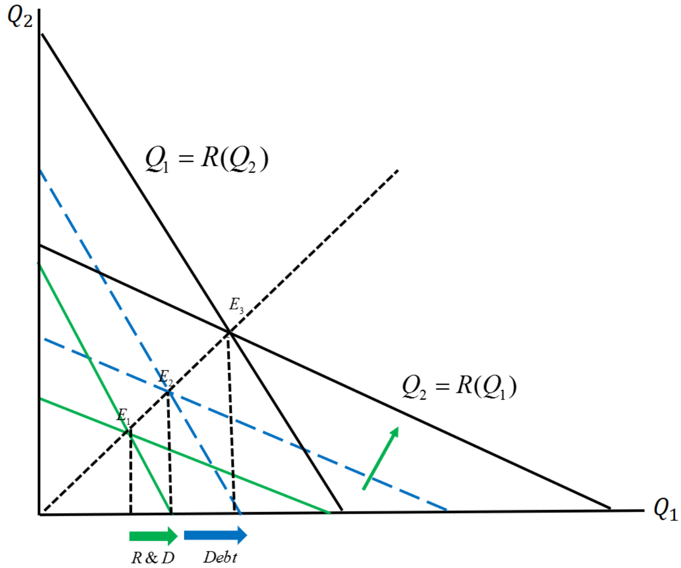
(1986) show debt financing strategically makes each rival more aggressive in product market competition due to limited liability. Since the process R&D investment increases the fully-equity financed profits, it also increases the marginal benefit of debt financing for the current debt level to maximize the debt-equity financed profits. As a result, each firm issues more debt to fully utilize its strategic effect compared to that if there is no process R&D, meaning that process R&D strengthens the strategic effect of debt financing and the relation between process R&D and debt are sequential strategic complements. As prior to debt financing the process R&D from each firm increases its own profits but decreases the others', we find the debt level of each firm increases with its own process R&D but decreases with the other's R&D, meaning that the strategic effect of debt depends on both rivals' R&D investment.

Proposition 2 *The debt level, the critical demand shock level and the probability of bankruptcy increases as the process R&D investment increases.*

Now we turn to the product R&D case.

3.3.1 Stage 3: Output Market Equilibrium

Similar to the process R&D case, in the third (and final) stage, the two firms choose quantity levels q_i and q_j simultaneously, conditional on debt levels D_i and D_j, determined in the second stage, and on process (cost-reducing) R&D expenditure levels k_{si} and k_{sj}, determined in the first stage. The innovation in the current



paper is to introduce a first stage R&D decision that affects output stage marginal cost. That R&D is sunk by the time the third stage is reached.

Given the debt level in the last stage and assuming c is zero for simplicity, each firm chooses output level to maximize its expected shareholder value:

$$\max_{q_i} \pi_i = \int_{\hat{z}_i}^{\bar{z}} [(a - q_i - sq_j + z_i)q_i - D_i - \frac{1}{2}k_{si}^2]\frac{1}{2\bar{z}}dz_i \tag{21}$$

Solving the partial derivative and setting Equation (21) equal to zero, we have the best response function on quantity for both firms at the equilibrium:

$$q_i = \frac{1}{4}(2a - 2sq_j + \alpha D_i + \bar{z}) \tag{22}$$

$$q_i = \frac{(2a + \bar{z})(2 - s) + 2\alpha D_i - s\alpha D_j)}{2(4 - s^2)} \tag{23}$$

$$\frac{\partial q_i}{\partial D_i} > 0 \tag{24}$$

$$\frac{\partial q_i}{\partial D_j} < 0 \tag{25}$$

Our another innovation in this paper is to include product R&D, implying that s is endogenized by product R&D investment $\frac{1}{2}k_{si}^2$.

3.3.2 Stage 2: Determination of Debt Levels

Firms take on debt in stage 2, after R&D is undertaken but before output is produced. As $\hat{z}_i$and $\hat{z}_j$ are functions of debt levels $D_i$and D_j, Equation (26) shows the dependence of output levels on the debt undertaken in Stage 2.

Therefore, each firm chooses its debt level to maximize its expected firm value and the firm's objective function is shown as:

$$\max_{Di} \pi_i = \int_{\underline{z}}^{\bar{z}} [(a - q_i(\hat{z}_i, \hat{z}_j) - sq_j(\hat{z}_i, \hat{z}_j) + z_i)q_i(\hat{z}_i, \hat{z}_j)q_i - \frac{1}{2}k_{si}^2]\frac{1}{2\bar{z}}dz_i \tag{26}$$

Solving the partial derivative and setting Equation (26) equal to zero, we have the best response function on optimal debt for both firms at the equilibrium:

$$\frac{\partial \pi_i}{\partial D_i} = 0 \Longrightarrow D_i^* = \frac{(2as - (2 - s)\bar{z})s - 4\bar{z}}{\alpha(4 + (2 - s))} \tag{27}$$

From Equation (27), we can find that when the degree of differentiation decreases or the degree of substitution increases, the optimal debt level decreases and the result is shown in Equation (28).

$$\frac{\partial D_i^*}{\partial s} = \frac{4as(4+s)}{\alpha(4+(2-s)s)^2} > 0 \tag{28}$$

3.4 Stage 1: Product R&D: Sequential Strategic Substitute for Debt

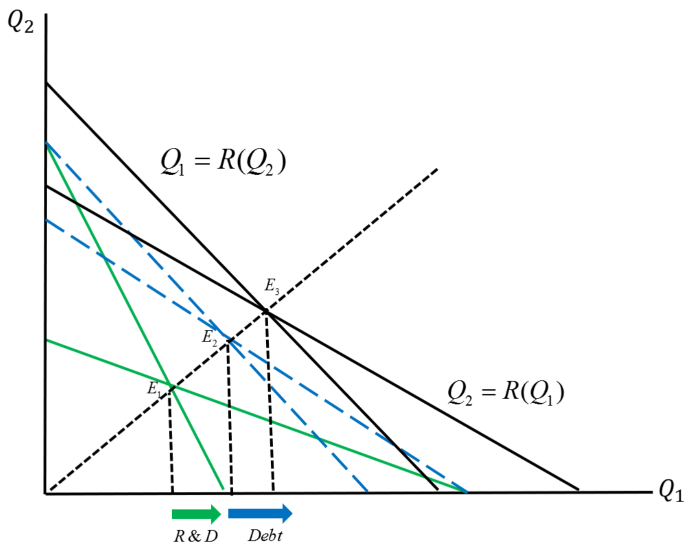
Under product R&D, the firm's objective function is shown as:

$$\max_{k_{si}} \pi_i = \int_{\underline{z}}^{\bar{z}} [(a - q_i - sq_j + z_i)q_i - \frac{1}{2}k_{si}^2] \frac{1}{2\bar{z}} dz_i \tag{29}$$

Given the function form, it is hard to find an explicit solution for the optimal level of product R&D, but we can prove that the optimal debt level decreases as the product R&D increases. This is because the degree of substitution is negatively associated with the product R&D (i.e. $s = 1 - \beta k_s$) and the product R&D is the joint contribution from two firms' (i.e. $k_s = k_{si} + k_{sj}$) so that each firm's product R&D in stage 1 decreases their optimal debt level in stage 2, which is shown in Equation (30)

$$\frac{\partial^2 \pi_i}{\partial D_i \partial k_{si}} = \underset{+}{\frac{\partial D_i^*}{\partial s}} \underset{-}{\frac{\partial s}{\partial k_s}} \underset{+}{\frac{\partial k_s}{\partial k_{si}}} < 0 \tag{30}$$

In oligopolistic competition, in addition to lowering marginal cost to raise profits, each firm can alternatively increase the degree of product differentiation by investing product R&D. On the one hand product R&D increases firms' equity-financed profits; on the other hand, it effectively softens competition between firms before their financial structure decision. Contrast to process R&D, product R&D lowers the marginal benefit of debt financing even each firm's profits are higher driven by such investment. This is because when it makes the products more differentiated, the head-to-head competition between firms is weakened. Each firm will cut their sales to raise profits since their own elasticity of demand becomes more elastic driven by product R&D (i.e. moving from homogenous duopoly to monopoly). However, the strategic effect of debt financing is to make each rival more aggressive to gain a larger market share, which contradicts with product R&D effect. As a result, given the less effective debt financing under product R&D, each firm issues less debt. We argue that product R&D mitigates the strategic effect of debt financing and the relation between them are sequential strategic substitutes. Further, product R&D may be superior to debt financing as to increases the degree of differentiation does not raise the possibility of default. Alternatively we can think if debt financing for each firm in the second stage were not be always



available, the restriction of debt use may facilitate firms' innovation motivation.

Proposition 3 *The optimal debt level, critical demand shock level, and the probability of bankruptcy decrease as the product R&D increases.*

Process R&D increases firms' profits by reducing marginal cost and product R&D also increases firms' profits by enhancing consumers' willingness to pay. However, they have totally opposite effects on firms' financial structure: the former one strengthens the strategic effect of debt financing, inducing each firm to issue more debt but the latter one weakens this effect and makes each firm issue less debt. The nature of product for each industry determines their R&D focus, which in turn, affects its capital structure.

4 Conclusion

Financial structure is an important decision variable for firms, and varies significantly across industries. Capital intensive industries such as manufacturing or utilities, which have substantial physical assets and typically generate stable cash flows, tend to have relatively high debt-equity ratios. In contrast, research intensive industries, such as those in the "high tech" sector, issue much less debt. By focusing on the relationship between financial structure and R&D in an oligopoly context, we show that process R&D is complementary with the strategic use of debt to improve a firm's market position under oligopoly. As in Brander and Lewis (1986), firms have an incentive to use debt to commit themselves to a more aggressive position in the output market. Process R&D strengthens this effect. Product R&D, on the other hand, increases product differentiation, weakens head-to-head competition between oligopolistic rivals, and reduces the incentive to use debt for strategic purposes. As manufacturing industries and utilities make relatively more use of process R&D, while high-tech industries undertake relatively more product R&D, we explain why the high-tech industries make relatively less use of debt and have much lower debt to equity ratios.

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