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DEBT FINANCING IN A DUOPOLY WITH ASYMMETRIC COSTS

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Abstract. This paper examines the strategic use of debt financing in a quantity-setting duopoly with asymmetric costs. Before output competition (Cournot or Stackelberg) with demand uncertainty takes place, both firms can strategically choose to issue debt to commit to an aggressive output stance. We find that the strategic use of debt, serving as a commitment device, can help the disadvantaged firm (*i.e.*, the high-cost firm in Cournot competition or the follower firm in Stackelberg competition) to leapfrog its superior rival in product market competition. Moreover, in light of the substitution between first-mover advantage and the commitment advantage of debt financing, when the order of firms' moves in output is endogenously determined, in a sizable parameter region, there exists a Pareto-dominant equilibrium that the high-cost firm acts as the Stackelberg leader.

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1. Introduction

The famous Modigliani–Miller theorem shows that in a perfect market environment, the value of a firm is independent of its financial structure (Modigliani and Miller [29]). For a long period time, the two major fields of financial structure and oligopoly theory place little emphasis on the strategic relationship with each other. However, in a seminal contribution, Brander and Lewis [5] proposed for the first time that in a Cournot duopoly, a firm's capital structure affects its and its opponent's decisions in product market competition, thereby affecting the profits of both parties. Due to the limited liability effect, once the debt contract is determined, the owner-manager of the firm would not consider the interests of the debtholders when making output decisions, but only aims at maximizing the shareholder value. In this sense, the owner-manager would only focus on the good states of the world. In contrast, the bad states are irrelevant because, at that point in case of bankruptcy, the debtholders become the residual claimants. Therefore, an indebted firm would produce higher output than when it has no debt. Specifically, if the distortion of the firm's product market strategy, caused by strategic commitment of risky debt, affects its competitors' product market choices in a beneficial way for the firm, debt can help firms to obtain a strategic advantage.

In the real business world, leverage is a common-adopted tool for many firms to expand production and market share. As the largest telecom giant in the United States, AT&T is also the most indebted company in the world (Ventura [38]). Owing to acquisitions from its business partners, including Volvo, the London Taxi

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Company, and the Proton Malaysia Holdings Ltd, etc., Geely Holding Group has become the world's top ten auto companies (Duff [13]). Behind Geely's rapid expansion and acquisitions, its debt levels have also seen a sharp rise. It is these large amounts of debt financing that help Geely expand its product line and reap a larger market share, making it an outstanding firm in the auto industry. Growing by borrowing, Belgian brewer Anheuser-Busch InBev has become an enormous beer empire. In the past 20 years, it has initiated a series of acquisitions and developed hundreds of brands to consolidate its product portfolio, proving it the undisputed leader in the beer industry. Today, Anheuser-Busch InBev controls approximately 25% of the world beer market. In the supply chain environment, external financing helps firms consolidate their relationship with upstream and downstream partners, and avoid being isolated or squeezed out of the market by other supply chain members (Yang *et al.* [41]).

In addition to the strategic use of debt to gain a competitive advantage, companies are also working to take the lead in other aspects, such as engaging in cost-reduced process innovation, or actively participating in market research activities to obtain the first-mover advantage over their competitors. Lieberman and Montgomery [26] proposed that there may be differences in technology, resources, foresight, or even luckiness, among the competitive firms in the real commercial world. Therefore, to better understand the value of strategic debt, it is necessary to allow for the asymmetry among firms when investigating the impact of capital structure on product market competition. However, the existing literature has not yet considered the interaction between debt issuance and inter-firm asymmetries (such as cost difference and the order of moves among competing firms).

On the one hand, for oligopoly firms with different production technologies, their motivations for the use of strategic debt may be different. Are those cost-efficient firms more likely to pursue debt leverage, or those inefficient ones? Moreover, traditional wisdom believes that debt will intensify output competition, leading to lower industry profits (*e.g.*, Lieberman and Montgomery [26], Wanzenried [40], Franck and Le Pape [16], Haan and Toolsema [18]). However, in the case of cost asymmetry, if strategic debt enables those efficient firms to occupy a higher market share, the efficiency and profitability of the industry may be improved [42].

On the other hand, the abilities to obtain market information and make production plans are often different across firms, which determines whether they can seize the opportunity of announcing their production quantities before their competitors. It is well-known that there is a first-mover advantage in quantity competition, and the leader obtains higher profits with higher output than the follower (Gal-Or [17]). Firms are committed to moving first in the real business competition and achieving better market performance (Lieberman and Montgomery [26]). However, in the presence of debt issuance options, can the first-mover advantage be sustained? Are the first-mover advantage and strategic use of debt financing substitutes or complements? If they are substitutes, can the Stackelberg follower gain a competitive advantage through pre-competitive strategic debt and thus leapfrog the leader? And under what conditions? For competing firms with asymmetric costs, if they can non-cooperatively determine their production decision orders, is there a Pareto-dominant equilibrium strategy?

To address the above questions, in this paper, we establish a stylized model to investigate the effect of debt financing in a duopoly with asymmetric costs. We allow for three possible competition modes: the simultaneous mode (Cournot), and the sequential modes where the cost-efficient firm and the inefficient firm act as the Stackelberg leader, respectively. Compared with the previous literature on debt financing and output market competition, the novelty of this paper is that we incorporate the asymmetry between competing firms (*i.e.*, cost difference, first- and second-moves in production decisions). Before output competition (Cournot or Stackelberg) with demand uncertainty takes place, we assume that both the two asymmetric firms can strategically choose to issue debt to commit to an aggressive output stance.

The rest of this paper is organized as follows. Section 2 provides a brief summary of the relevant literature. Section 3 describes the model setup, including the demand system, cost asymmetry, modes of output competition, debt contract, etc. We derive the equilibrium outcomes under three competition modes in Sections 4.1, 4.2, and 4.3, respectively. Section 4.4 compares three competition modes under some parameter conditions and

obtains the Pareto-dominant equilibrium strategy of output decision orders. Section 5 concludes this paper and identifies several directions for future research.

2. Literature review

Motivated by Brander and Lewis [5], many subsequent contributions further studied the strategic role of debt financing in output market competition. By introducing the cost of bankruptcy, Brander and Lewis [6] further studied the impact of the debt levels on firms' competitive behavior in the product market. Wanzenried [40] modeled a differentiated duopoly and studied how firms' optimal debt levels depend on specific market characteristics, such as the degree of product substitutability and demand volatility. Haan and Toolsema [18] and Franck and Le Pape [16] clarified a technical issue in Wanzenried [40] and they showed that the equilibrium debt levels decrease monotonously with the degree of demand volatility. Clayton [8] extended the model of Brander and Lewis [5] and found that, when companies also have an investment choice, the effect of limited liability will lead to weaker product market competition. Boubaker *et al.* [3] examined how competitive pressure from the product market affects firms' choice between bank debt and public debt, and they found that it makes firms rely less on bank debt financing. Finally, Brander and Song [4] investigated the relationship between debt leverage and R&D decisions in a duopoly context. In their model, there are two types of R&D, namely cost-reducing process R&D and differentiation-increasing product R&D. They found that while process R&D is complementary to the strategic use of debt, product R&D reduces firms' incentive to issue debt.

In addition to the above literature that studies the strategic effect of debt financing in the output competition situation, there are some contributions investigated the strategic debt in other scenarios by incorporating the issues of information sharing (Hughes *et al.* [19]), entry deterrence (McAndrews and Nakamura [27], Showalter [33]), patent race (Jensen and Showalter [21]), capacity positioning (Leach *et al.* [25]), and so on.[2]

This theoretical literature provides us with a comprehensive understanding of the strategic role of debt. However, to the best of our knowledge, the above literature restricts duopoly firms to be symmetrical and ignores the possible asymmetries across firms, which is the main focus and novelty of this paper.

From the perspective of strategic commitment, this paper also contributes to the managerial delegation literature. Under oligopolistic competition, firm owners may strategically hire third-party managers and set a compensation scheme that deviates from pure profit maximization. This idea was first introduced to the industrial economics in pathbreaking papers by Vickers [39], Fershtman and Judd [15] and Sklivas [35]. Serving as two types of credible commitment devices, both debt financing and managerial delegation can be used strategically to improve the firm's competitive advantage. Specially, both of them would induce firms to produce more aggressively in a Cournot framework. Debt financing corresponds to a firm's capital structure and managerial delegation corresponds to its organization structure. The common managerial contracts are based on sales revenue (Fershtman and Judd [15], Sklivas [35]), cost reduction (Balasubramanian and Bhardwaj [2], Veldman and Gaalman [37]), product/process improvement (Veldman and Gaalman [36]), market share (Jansen *et al.* [20], Ritz [31]), relative performance (Aggarwal and Samwick [1], Miller and Pazgal [28]), etc. However, strategic debt only works in an environment with uncertainties. The distortion in the decision marking of an indebted firm results from the "over-optimism" about risk due to the limited liability. In the context of managerial delegation, however, firm owners directly set compensation contracts to induce their managers to act in a way that deviates from profits. The presence or absence of market risk usually does not affect the decision-making and the uncertainty is generally not modeled in the literature of managerial delegation. We refer interested readers to Kopel and Pezzino [23] for state-of-the-art reviews of the relevant strategic commitment literature.

Our paper contributes to the literature on strategic delegation (commitment) in an asymmetric duopoly setting. Assuming each firm can offer its manager one of the two compensation contacts, namely profit incentive or revenue incentive, Sen and Stamatopoulos [32] showed that there exist Nash equilibria where the inefficient (*i.e.*, high-cost) firm can earn greater profits than its efficient (*i.e.*, low-cost) rival. When allowing for the

[2]Driven by the limited liability, some papers have studied the impact of other forms of financing, such as trade credit, in a horizontally competitive environment (easing or intensifying the competition). For example, see [30] and [12].

continuous range of incentive parameters, Delbono *et al.* [11] argued that the efficient firm always earns higher profits than its inefficient rival. Moreover, strategic delegation always leads to a Prisoner's Dilemma. Colombo [9] revisited the admissible parameter set as studied in Delbono *et al.* [11], and he showed that the efficient firm can be better off when both firms delegate production. Fang and Zhao [14] examined the impact of product differentiation in an asymmetric duopoly under strategic delegation, and they found that when products become closer substitutes, the efficient firm always makes its manager more aggressive, while the inefficient firm may make its manager less aggressive. This paper examines the strategic use of debt financing in a duopoly with asymmetric costs. We show that the presence of debt financing may allow the less efficient firm to earn greater profits than the more efficient one. Moreover, it is shown that the first-mover advantage and the commitment benefit generated by debt financing are strategic substitutes. As a result, our analysis suggests that the more efficient firm may be willing to give up the first-mover advantage in product market competition.

3. Model setting

3.1. Demand structure

There are two firms (indexed by firm 1 and firm 2) in the market and they produce outputs q_1 and q_2, respectively. The inverse demand function can be expressed as

$$p = 1 - q_1 - q_2 + \epsilon, \tag{1}$$

where the random variable ϵ denotes the market uncertainty (risk). For analytical tractability, we assume that $\epsilon \in \{\epsilon_g, \epsilon_b\}$, *i.e.*, a good or bad market status of the realizations, measured by $\epsilon_g = +z$ or $\epsilon_b = -z$ with equal probabilities, where $z \in (0, 1)$. Here we assume that both firms face the same random shocks in demand, which is consistent with previous literature (*e.g.*, Brander and Lewis [5], Wanzenried [40], Brander and Song [4]). It's easy to see that $\mathrm{E}[\epsilon] = 0$, $\mathrm{Var}[\epsilon] = z^2$. Therefore, we can use the parameter z to capture the degree of market uncertainty, where the larger the z, the stronger the demand volatility.[3]

3.2. Cost asymmetry

There exists a cost difference between the two firms, and we assume that firm 1 (resp., firm 2) is the more (resp., less) efficient one, *i.e.*, $c_1 < c_2$. Without loss of generality, we normalize $c_1 = 0$, and $c_2 = c$, where $0 < c < 1$. There is no agency problem, and the owner-manager of each firm maximizes the firm value which equals the expected profit. To focus on duopoly competition, we assume that c cannot be too great to ensure positive quantities (and expected profits) for each subgame. For example, in the standard Cournot case where neither firm issues debt, equilibrium quantities for the two firms are $q_1^* = (1 + c)/3$ and $q_2^* = (1 - 2c)/3$ respectively, then $c < 1/2$ is required to ensure $q_2^* > 0$ (and $\pi_2^* > 0$).

3.3. Modes of competition

In addition to cost difference, we also allow the two firms to make quantity decisions simultaneously or sequentially. We consider three modes of output competition, the simultaneous mode of Cournot competition (mode C), and the sequential modes where firm 1 (mode $S1$) and firm 2 (mode $S2$) act as the Stackelberg leader, respectively.

[3]Franck and Le Pape [16] and Haan and Toolsema [18] clarified a technical issue in Wanzenried [40] and they stated that, considering the strategic interaction of endogenous bankruptcy thresholds of the two debt-burdened firms, equilibrium debt obligations and quantities cannot be derived explicitly under the uniform distribution assumption. Moreover, an implicit limitation of continuous distribution of uncertainty is that, for any small amount of debt, there are always states of the world in which a firm would go bankrupt. Therefore, the symmetric choices that both firms issue debt must occur in equilibrium. In our two-state uncertainty model, we are able to derive a richer set of symmetric and asymmetric equilibria and it is more realistic. See McAndrews and Nakamura [27] for more detailed explanations.

3.4. The option of debt issuance

Before output competition (Cournot or Stackelberg) takes place, the two firms have an option to issue debt for strategic purposes, which is to be repaid out of revenues from sales. The decisions of whether or not to issue debt are made simultaneously by the two firms. Both firms are limited liability companies. If the sales profit (revenue minus cost) cannot repay the debt obligation in case of the bad demand state, the firm becomes insolvent and all the earnings are paid to the debtholders. Once the firm has made its capital structure decision, the debt level will be known to its rival before the output competition stage. The capital structure disclosed by the firm is true and credible, because the financial fraud will face severe penalties from the regulatory authorities.

Following the debt contract literature, we assume that capital investment is made before the financing mix decision and the loan borrowed by the firm is used to retire the owner's equity. The capital market is competitive and the creditor (usually the bank) can only earn a risk-free rate in equilibrium. Without loss of generality, to focus on the strategic effect of debt issuance, we set the risk-free rate equal to zero as in the previous literature (*e.g.*, Brander and Lewis [5], McAndrews and Nakamura [27], Wanzenried [40], Kouvelis and Zhao [24], Brander and Song [4], etc.).

3.5. Output strategy and firm objectives

Given the rival's output strategy, if firm i has no debt, it maximizes the expected profit

$$\pi_i = \mathrm{E}[(1 - q_i - q_{3-i} + \epsilon)q_i - c_i q_i] = (1 - q_i - q_{3-i} - c_i)q_i, \tag{2}$$

and the output strategy (reaction function) is

$$q_i(q_{3-i}) = \frac{1 - q_{3-i} - c_i}{2}, \quad i = 1, 2. \tag{3}$$

If the firm issues debt that makes it bankrupt in case of the bad state, as described above, then only the good state is relevant. Given the debt contract, the owner-manager of firm i maximizes the equity value, which is the expected profit net of debt obligation in the good state,

$$V_i(q_i|D_i) = \frac{1}{2}[(1 - q_i - q_{3-i} + \epsilon_g - c_i)q_i - D_i] + L_i, \tag{4}$$

where L_i and D_i represent the actual loan received and the debt to be repaid, respectively.[4] Thus, according to (4), the output strategy of firm i with risky debt is given by

$$q_i(q_{3-i}) = \frac{1 + \epsilon_g - q_{3-i} - c_i}{2}, \quad i = 1, 2. \tag{5}$$

It's readily to see that when firm i is indebted, its output strategy in the market competition is more aggressive than when there is no debt. We call the output strategy (reaction function) expressed by (3) the *conservative* strategy which corresponds to the case with no debt (N), and the reaction function in (5) the *aggressive* strategy which corresponds to the case with risky debt (D). There are four pairs of debt choices (and corresponding output strategies) of the two firms: (N, N) where neither firm issues debt, (D, N) where the cost-efficient firm (firm 1) issues debt while firm 2 does not, (N, D) where firm 2 issues debt while firm 1 does not, and (D, D) where both firms pursue debt financing.

Since the creditors are foresighted to take into account the possibility of potential bankruptcy, the owners of the firms can only borrow money that promises to repay D_i for its true value L_i. That is, given the promised debt obligation D_i, the actual amount of the loan is provided as

$$L_i = \frac{1}{2}D_i + \frac{1}{2}[(1 + \epsilon_b - q_{iD} - q_{3-i} - c_i)q_{iD}], \tag{6}$$

[4]Henceforth, if there is no special indication, the term "debt" refers to the promised repayment of debt (*i.e.*, debt obligation).

where q_{iD} denotes the aggressive output strategy of firm i with debt, and the rivals output strategy q_{3-i} can be the aggressive (if it is indebted) or conservative (if it is debt-free). Thus, the reduced form of the expected equity value in (4) can be written as

$$\begin{aligned} V_i &= \frac{1}{2}[(1+\epsilon_g - q_{iD} - q_{3-i} - c_i)q_{iD} - D_i] + \frac{1}{2}D_i + \frac{1}{2}[(1+\epsilon_b - q_{iD} - q_{3-i} - c_i)q_{iD} \\ &= (1 - q_{iD} - q_{3-i} - c_i)q_{iD}. \end{aligned} \tag{7}$$

In fact, debt issuance itself has no direct effect on the firm value (expected profit), but has a strategic effect by changing the performance of the firm and its rival in output market competition, thereby affecting the (expected) profits of both the two firms.

3.6. Definition of the debt level

Following McAndrews and Nakamura [27], we define the debt level issued by the firm is the minimal amount that induces it to adopt the aggressive strategy as expressed in (5).

Given the rival's output strategy q_{3-i} (conservative or aggressive), if the debt level of firm i is D_i, then the expected payoff of firm i by adopting the aggressive and conservative output strategies are expressed respectively as

$$\begin{aligned} \text{Payoff}_{\text{aggressive}} =& \frac{1}{2}[(1+\epsilon_g - q_{iD} - q_{-i} - c_i)q_{iD} - D_i]^+ \\ &+ \frac{1}{2}[(1+\epsilon_b - q_{iD} - q_{-i} - c_i)q_{iD} - D_i]^+ + L_i, \end{aligned} \tag{8}$$

$$\begin{aligned} \text{Payoff}_{\text{conversative}} =& \frac{1}{2}[(1+\epsilon_g - q_{iN} - q_{-i} - c_i)q_{iN} - D_i]^+ \\ &+ \frac{1}{2}[(1+\epsilon_b - q_{iN} - q_{-i} - c_i)q_{iN} - D_i]^+ + L_i, \end{aligned} \tag{9}$$

where $[\cdot]^+ = \max\{\cdot, 0\}$. With a slight abuse of notation, let

$$\begin{aligned} R_{Dg} &= (1+\epsilon_g - q_{iD} - q_{-i} - c_i)q_{iD}, \quad R_{Db} = (1+\epsilon_b - q_{iD} - q_{-i} - c_i)q_{iD}, \\ R_{Ng} &= (1+\epsilon_g - q_{iN} - q_{-i} - c_i)q_{iN}, \quad R_{Nb} = (1+\epsilon_b - q_{iN} - q_{-i} - c_i)q_{iN}. \end{aligned}$$

It is readily to verify that $R_{Dg} > R_{Ng} > R_{Nb} > R_{Db}$ and $R_{Ng} + R_{Nb} > R_{Dg} + R_{Db}$ (because q_{iN} is the best response to maximize the expected profit). Assuming that $R_{Db} \le D_i \le R_{Nb}$. As described above, the debt level D_i of firm i is supposed to make the expected payoff expressed in (8) greater than that in (9), *i.e.*, $\frac{1}{2}(R_{Dg} - D_i) \ge \frac{1}{2}(R_{Ng} - D_i) + \frac{1}{2}(R_{Nb} - D_i)$, that is, $D_i \ge R_{Ng} + R_{Nb} - R_{Dg}$ is required. Therefore, we define $R_{Ng} + R_{Nb} - R_{Dg}$ as the minimum credible debt level issued by the firm that commits to adopting the aggressive output strategy.

3.7. Timeline of events

The sequence of events can be summarized as follows. First, in the debt contract stage, both firms simultaneously determine whether to issue debt. For the firm that chooses to issue debt to commit to an aggressive output strategy, its debt level is defined as in the above subsection. Second, in the market competition stage, after observing each other's debt choices, the two firms make their quantity decisions simultaneously or sequentially, which depends on the specific exogenous mode of competition. Finally, after the quantity decisions made by the two firms, market uncertainty is realized (a good or bad state). The indebted firm goes bankrupt if it cannot repay the promised debt to the debtholder in case of the bad market state. Both firms are risk-neutral. We use backward induction approach to solve the subgame perfect equilibrium (SPE) and we focus on the pure-strategy equilibria.

TABLE 1. Equilibrium results in different subgames under *Cournot* competition.

Firm 1 \ Firm 2	N	D
(a) Quantities		
N	$\frac{1}{3}(1+c)$; $\frac{1}{3}(1-2c)$	$\frac{1}{3}(1+c-z)$; $\frac{1}{3}(1-2c+2z)$
D	$\frac{1}{3}(1+c+2z)$; $\frac{1}{3}(1-2c-z)$	$\frac{1}{3}(1+c+z)$; $\frac{1}{3}(1-2c+z)$
(b) Expected profits		
N	$\frac{1}{9}(1+c)^2$; $\frac{1}{9}(1-2c)^2$	$\frac{1}{9}(1+c-z)^2$; $\frac{1}{9}(1-2c+2z)(1-2c-z)$
D	$\frac{1}{9}(1+c-z)(1+c+2z)$; $\frac{1}{9}(1-2c-z)^2$	$\frac{1}{9}(1+c-2z)(1+c+z)$; $\frac{1}{9}(1-2c+z)(1-2c-2z)$

4. EQUILIBRIUM ANALYSIS

4.1. Cournot competition

In this subsection, we examine the mode that the two firms make output decisions simultaneously to engage in Cournot competition. Given the debt choices of two firms, the equilibrium results (quantities and expected profits) in different subgames, *i.e.*, (N,N), (N,D), (D,N) and (D,D), are summarized in Table 1. We assume that both firms are active in all subgames, that is, the equilibrium quantities (and expected profits) of the two firms are positive for each subgame.

From Table 1a it's easy to see that, as the cost gap between the two firms widens, firm 1's equilibrium quantity increases, while firm 2's output decreases. Moreover, when one firm issues debt and the other does not (subgame (D,N) or (N,D)), for the debt-burdened firm, a higher degree of uncertainty induces it to behave more aggressively with higher outputs. Since quantities are strategic substitutes, the debt-free rival has to reduce its output. Ignoring cost difference ($c=0$), when $z>1/4$, the debt-burdened firm even produces more than when it acts as a Stackelberg leader. Comparing the equilibrium profits in different subgames from Table 1b, we can obtain the following results.

Proposition 4.1. *(i)* $\pi_1(N,N)>\pi_1(N,D)$, $\pi_2(N,N)>\pi_2(D,N)$. *(ii)* $\pi_1(D,N)>\pi_1(D,D)$, $\pi_2(N,D)>\pi_2(D,D)$. *(iii) Define* $\Pi(i,j)=\pi_1(i,j)+\pi_2(i,j)$, $i,j\in\{N,D\}$, *then we have*

$$\Pi(N,N)>\max\{\Pi(N,D),\Pi(D,D)\}, \tag{10}$$

$$\Pi(D,N)>\max\{\Pi(N,D),\Pi(D,D)\}, \tag{11}$$

$$\Pi(N,N)-\Pi(D,N)\begin{cases}\geq 0, & 0\leq c\leq \frac{z+1}{5},\\ <0, & \frac{z+1}{5}<c<\frac{1-z}{2}.\end{cases} \tag{12}$$

Propositions 4.1-(i) and 4.1-(ii) show that, for each firm, regardless of whether the firm has debt or not, it always hopes that its rival chooses not to issue debt, because the aggressive output strategy of the rival reduces the firm's residual demand. This property is consistent with McAndrews and Nakamura [27].

In a setting without cost asymmetry, McAndrews and Nakamura [27] showed that industry profits reach the highest in subgame (N,N), where neither firm issues debt. This is because the aggressive output strategy of any firm will lower the market price, thereby reducing the overall industry profits. However, in a Cournot duopoly with asymmetric costs, Proposition 4.1-(iii) shows that, when the degree of cost asymmetry is relatively large, the asymmetric pair of debt choices (D,N), where the efficient firm issues debt while the inefficient one does not, may reach the highest industry profits. This indicates that the efficient firm makes better use of strategic debt to gain a competitive advantage than the inefficient firm. In the asymmetric debt choice scenario (D,N), given a wide cost gap between the two firms, strategic debt entails a larger (resp., less) market share for the more (resp., less) efficient firm, thus leading to lower industry average costs and higher industry profits (Zanchettin [42]).

Next, we examine equilibrium debt choices for the two firms. Consider a pair (i, j) where $i, j \in \{N, D\}$, with i and j indicating the debt choices (also the corresponding output strategy) of firm 1 and firm 2, respectively. For subgame (i, j) to be an equilibrium, in addition to ensuring positive quantities and expected profits for both firms (*i.e.*, $q_i^* > 0$ and $\pi_i^* > 0$ for $i = 1, 2$), we also require the following incentive compatible constraints to hold:

$$\begin{cases} \pi_1(i, j) > \pi_1(-i, j), \\ \pi_2(i, j) > \pi_2(i, -j), \end{cases} \tag{13}$$

where $-i \neq i, -j \neq j$. That is, (i, j) is an equilibrium if and only if a unilateral deviation by either firm does not yield higher profits to that firm. By comparing the expected profits in different subgames as shown in Table 1b, we derive the following subgame equilibria of debt choices and the corresponding parameter conditions for each equilibrium.

Proposition 4.2. *There are four debt choice equilibria under the mode of Cournot competition, and the conditions for each equilibrium are summarized as follows:*

$$(N, N) : \left(\frac{1}{2} < z \leq \frac{3}{4} \wedge 0 < c < 2z - 1\right) \vee \left(\frac{3}{4} < z < 1 \wedge 0 < c < \frac{1}{2}\right), \tag{14}$$

$$(N, D) : \left(\frac{1}{3} < z \leq \frac{3}{8} \wedge 0 < c < 3z - 1\right) \vee \left(\frac{3}{8} < z < \frac{1}{2} \wedge 0 < c < \frac{1}{2}(1 - 2z)\right), \tag{15}$$

$$\begin{aligned} (D, N) : \left(0 < z \leq \frac{1}{3} \wedge \frac{1}{2}(1 - 3z) < c < \frac{1 - z}{2}\right) \vee \left(\frac{1}{3} < z \leq \frac{1}{2} \wedge 0 < c < \frac{1 - z}{2}\right) \\ \vee \left(\frac{1}{2} < z < \frac{3}{5} \wedge 2z - 1 < c < \frac{1 - z}{2}\right), \end{aligned} \tag{16}$$

$$(D, D) : 0 < z < \frac{1}{3} \wedge 0 < c < \frac{1}{2}(1 - 3z), \tag{17}$$

and the relevant parameter regions are illustrated in Figure 1.

Ignoring cost difference, *i.e.*, $c = 0$, in equilibrium, when the degree of market uncertainty is low ($z < 1/3$), moderate ($1/3 < z < 1/2$), and high ($z > 1/2$), there are two, one and zero firms choosing to issue debt, respectively. Figure 1 confirms this negative relationship between debt and risk (see De Bettignies and Duchêne [10] and references therein for more detailed explanations). Taking cost asymmetry into account, the equilibrium results would change to some extent. When the degree of market risk is sufficiently low ($0 < z < 1/3$), the efficient firm definitely chooses to issue debt, while the inefficient firm chooses to issue only when its cost is low enough (*i.e.*, $c < (1 - 3z)/2$). As the market risk increases within a certain range ($1/3 < z < 1/2$), there may be two asymmetric equilibria, (D, N) and (N, D). Notice that the parameter range in condition (15) is a subset of that in (16), then equivalently in Figure 1, the region (N, D) is included by the region (D, N). This indicates that given the same level of market risk, the cost-inefficient firm is less willing to issue debt than its efficient rival. When market uncertainty is relatively large ($1/2 < z < 3/5$), the inefficient firm must not choose to issue debt, but the efficient firm may choose to do if and only if the cost advantage over its rival is sufficiently great. The efficient firm can withstand risk better in product market competition than the inefficient firm. Therefore, except for the degree of market volatility, cost disadvantage is also a resistance for the inefficient firm to issue debt for the strategic purpose. The intuition is that the higher marginal costs make the firm more sensitive to price reduction caused by the aggressive output strategy. In addition, the higher marginal cost of the rival increases the risk tolerance of the efficient firm. Finally, when the degree of market risk is sufficiently great (*i.e.*, $z > 3/5$), neither firm chooses to issue debt in equilibrium, because in this situation, the cost of distorted incentives outweighs the benefit of strategic advantage.

According to the equilibrium conditions in Proposition 4.2, we can write the following result.

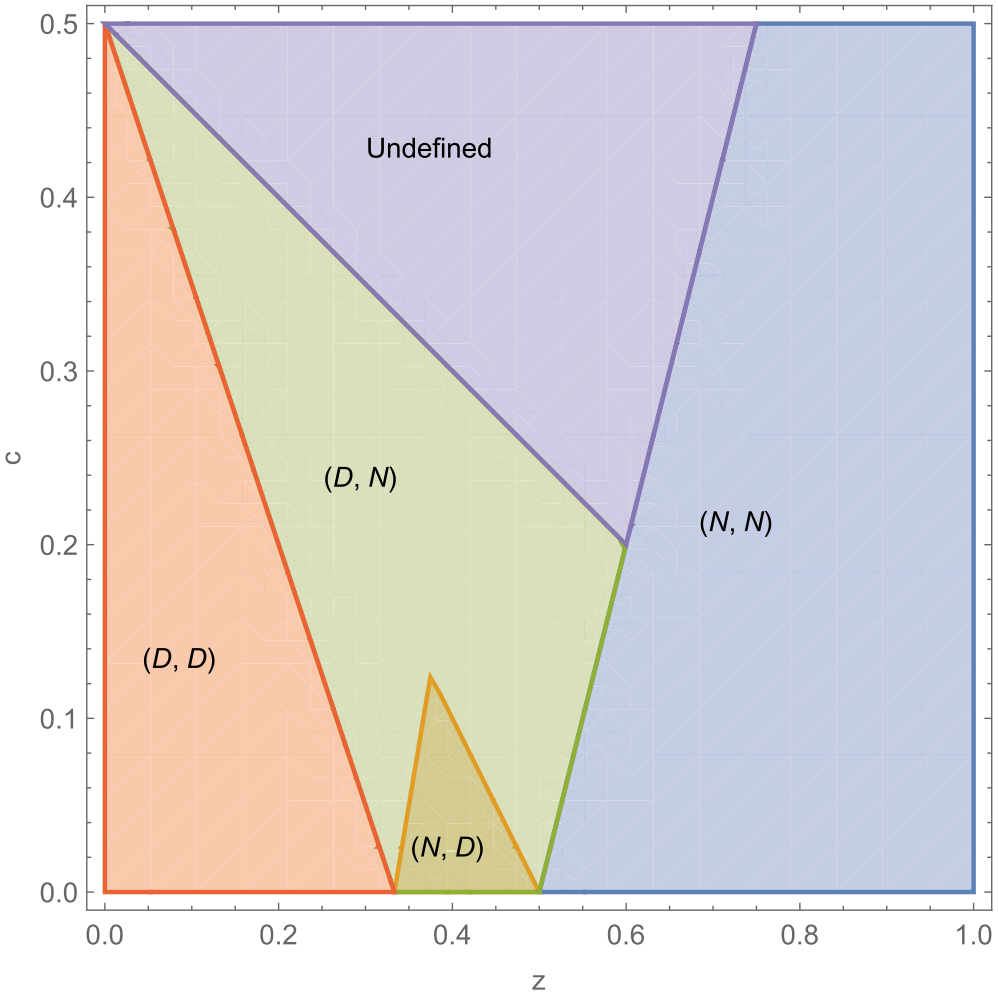

FIGURE 1. Equilibrium outcomes under Cournot competition.

Corollary 4.3. *Supposing the market uncertainty is moderate (i.e.,* $\frac{1}{3} < z < \frac{1}{2}$*), then* (N, D) *is an equilibrium only when the cost asymmetry is not too large, i.e.,* $0 < c < \min\{3z - 1, \frac{1}{2}(1 - 2z)\}$.

As illustrated in Figure 1, to make ND an equilibrium, where the high-cost firm issues debt and the low-cost one does not, the following conditions must be satisfied: (1) the degree of market uncertainty is neither too high nor too low, and (2) cost asymmetry between the two firms is sufficiently small. In fact, a larger cost gap reduces the incentive for the less efficient firm to use strategic debt. Since the high-cost firm is more sensitive to price reduction than its rival, when the cost asymmetry between the two firms is sufficiently great, the positive effect of higher quantity induced by debt commitment is dominated by the negative effect of price reduction. In this situation, it is better for the inefficient firm to take a conservative output strategy of not deviating from the profit incentive.

The following corollary characterizes the equilibrium amounts of debt of the two firms in each subgame, which is defined in Section 3.6.

Corollary 4.4. *The (minimal) credible levels of debt issued to commit to an aggressive output strategy in different subgames are expressed as follows:*

$$D_1(D,N) = \frac{1}{9}\left((1+c)^2 - 3z(1+c) - 2z^2\right), \tag{18}$$

$$D_2(N,D) = \frac{1}{9}\left(1 + 4c^2 - 4c(1-2z) - 4z(1+z)\right), \tag{19}$$

$$D_1(D,D) = \frac{1}{9}\left((1+c)^2 - 6z(1+c) + z^2\right), \tag{20}$$

$$D_2(D,D) = \frac{1}{9}\left((1-2c)^2 - 6z(1-2c) + z^2\right). \tag{21}$$

Moreover, $D_1(D,N) > D_2(N,D)$, $D_1(D,D) > D_2(D,D)$.

Notice that in the presence of cost difference, given the same market state to be realized, the efficient firm is less likely to go bankrupt than the inefficient firm. Therefore, to make debt a credible commitment mechanism, the cost-efficient firm needs to issue a larger amount of debt than its inefficient rival to commit to an aggressive output strategy.

Proposition 4.5. *In the relevant parameter space as shown in Figure 1, in regions* (N,N), (D,D) *and* (D,N), $\pi_1 > \pi_2$; *in region* (N,D), $\pi_2 > \pi_1$.

Under symmetric debt choices (N,N) and (D,D), firm 1 earns a higher profit than its rival due to the cost advantage. In asymmetric equilibria (D,N) and (N,D), the game resembles the Battle of the Sexes game, where both firms prefer to be the one that issues debt. Under asymmetric pair (D,N), firm 1 makes use of strategic debt to commit to an aggressive output stance, further expanding its competitive advantage. When market risk is moderate and the cost disadvantage of firm 2 is not too large (*i.e.*, in the parameter region (D,N) as shown in Fig. 1), two pairs of asymmetric debt choices, (D,N) and (N,D) coexist. In the region (N,D) where firm 2 issues debt while firm 1 does not, the strategic benefit obtained by firm 2 through debt commitment can make up for its cost disadvantage, thereby delivering it a higher profit than its efficient rival. This is somewhat similar to the result of Sen and Stamatopoulos [32]. That is, in the context of strategic delegation with asymmetric costs, there also exist Nash equilibria in which the high-cost firm chooses to delegate while the low-cost firm does not, making higher profits than its more efficient rival. In the real business world, the strategic use of debt financing may provide those inefficient firms an opportunity to defeat their efficient competitors. The success of Geely Holding Group is such an example. Geely's technology may not be top-notch in the auto industry, but it has achieved substantial expansion through multiple rounds of debt financing, defeating many powerful competitors.[5]

4.2. Sequential mode where the cost-efficient firm acts as the Stackelberg leader

In this subsection, we examine the mode of Stackelberg competition where the efficient firm acts as the leader. Given the debt choices of both firms, equilibrium quantities and expected profits are shown in Table 2 for different subgames. According to the equilibrium conditions defined by (13), we can characterize equilibrium debt choices of the two firms under different parameter conditions.

Proposition 4.6. *Under the mode of Stackelberg competition where firm 1 acts as the leader, there are two possible equilibria,* (N,N) *and* (N,D), *and the conditions for each equilibrium are summarized as follows:*

$$(N,N): \left(0 < z \le \frac{2}{3} \wedge \frac{1}{6}(2-3z) < c < \frac{1}{3}\right) \vee \left(\frac{2}{3} < z < 1 \wedge 0 < c < \frac{1}{3}\right), \tag{22}$$

[5]The local government urges the banks to provide low-interest or even interest-free loans for the debt financing required by Geely to acquire Volvo (https://www.reuters.com/article/us-geely-china-sales-idUSTRE5BU0AO20091231), which makes our assumption of risk-free interest rate more reasonable.

TABLE 2. Equilibrium results in different subgames under Stackelberg competition where *firm 1* acts as the leader.

Firm 1 \ Firm 2	N	D
(a) Quantities		
N	$\frac{1}{2}(1+c)$; $\frac{1}{4}(1-3c)$	$\frac{1}{2}(1+c-z)$; $\frac{1}{4}(1-3c+3z)$
D	$\frac{1}{2}(1+c+2z)$; $\frac{1}{4}(1-3c-2z)$	$\frac{1}{2}(1+c+z)$; $\frac{1}{4}(1-3c+z)$
(b) Expected profits		
N	$\frac{1}{8}(1+c)^2$;$\frac{1}{16}(1-3c)^2$	$\frac{1}{8}(1+c-z)^2$;$\frac{1}{16}(1-3c+3z)(1-3c-z)$
D	$\frac{1}{8}(1+c-2z)(1+c+2z)$;$\frac{1}{16}(1-3c-2z)^2$	$\frac{1}{8}(1+c-3z)(1+c+z)$; $\frac{1}{16}(1-3c+z)(1-3c-3z)$

$$(N,D): 0<z<\frac{2}{3}\wedge 0<c<\frac{1}{6}(2-3z), \tag{23}$$

and the relevant parameter regions are illustrated in Figure 2.

Proposition 4.6 shows that, regardless of whether the follower issues debt or not, the Stackelberg leader is always unwilling to issue debt for any degree of market uncertainty and cost asymmetry. For the Stackelberg leader, the first-mover advantage allows it to choose the most favorable output level when making the production decision. Therefore, the leader has no incentive or need to issue debt to commit to an aggressive output stance that may lead to potential bankruptcy. For the follower, however, this is not the case. Because the product market competition follows the capital structure decisions, the follower has an incentive to commit to a more aggressive strategy by issuing risky debt, forcing the leader to reduce output and thus narrowing the gap with the leader. When there is no cost difference ($c = 0$), as long as the degree of market uncertainty is not too large ($z < 2/3$), the follower will definitely choose to issue debt. When there exists cost asymmetry, the follower becomes more conservative in deciding whether to issue debt. The more significant the cost disadvantage, the more stringent condition for market risk. That is, if the cost gap is huge, then the inefficient follower issues debt only when the degree of market volatility is sufficiently low.

Next, we explore that under the mode of Stackelberg competition where the efficient firm acts as the leader, whether the inefficient follower can leapfrog the efficient leader, through the strategic use of debt.

Proposition 4.7. *In the relevant parameter space as shown in Figure 2, in region (N,N), $\pi_1 > \pi_2$; In region (N,D), $\pi_2 > (<)\pi_1$ if $c < (>)\tilde{c}(z)$, where $\tilde{c}(z) = \frac{z+5}{7} - \frac{2}{7}\sqrt{9z^2-8z+8}$ and $\tilde{c}(z)$ is increasing in z.*

Proposition 4.7 reinforces our main result that the inefficient firm can earn a higher profit than its efficient rival in a Cournot setting (*i.e.*, Prop. 4.5). Under Stackelberg competition where the efficient firm acts as the leader, the inefficient firm is at a disadvantage in terms of both production cost and order of movement. Traditional wisdom holds that the first mover earns higher profits than the second mover under quantity competition (Gal-Or [17]). In region (N,D) of Figure 2, the inefficient follower commits to an aggressive output strategy by strategically issuing risky debt, narrowing the gap with its superior rival, the Stackelberg leader. According to Table 2a, in subgame (N,D), the output of the debt-burdened firm 2 (resp., debt-free firm 1) increases (resp., decreases) with the degree of market uncertainty. When the degree of market uncertainty is greater than a certain threshold and the cost disadvantage is not remarkable, the inefficient follower even produces higher output (and makes a higher profit in equilibrium) than the efficient leader. Moreover, within a reasonable range of market fluctuations, a more aggressive output strategy resulting from greater volatility can make up for the follower's disadvantage in marginal cost to a larger extent ($\tilde{c}(z)$ increases with z).

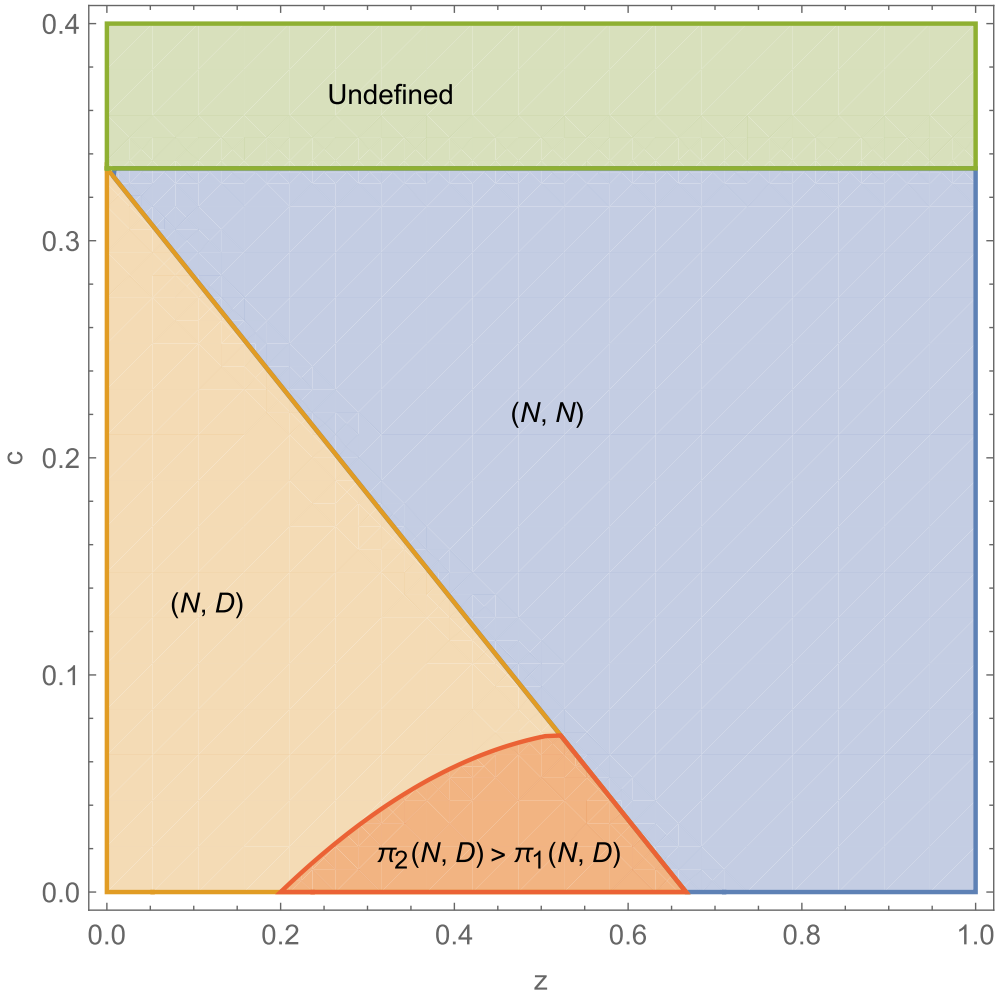

FIGURE 2. Equilibrium outcomes under Stackelberg competition where the cost-efficient firm is the leader.

4.3. Sequential mode where the cost-inefficient firm acts as the Stackelberg leader

In this subsection, we examine the mode of Stackelberg competition where the *inefficient* firm acts as the leader. Given the debt choices of both firms, equilibrium quantities and expected profits are summarized in Table 3 for different subgames. According to the equilibrium conditions in (13), we can derive equilibrium debt strategies of the two firms and the corresponding parameter conditions.

Proposition 4.8. *There are two equilibria under Stackelberg competition where firm 2 acts as the leader,* (N, N) *and* (D, N)*, and the conditions for each equilibrium are summarized as follows:*

$$(N,N): \frac{2}{3} < z < 1 \wedge 0 < c < \frac{1}{4}(3z-2), \tag{24}$$

$$(D,N): \left(0 < z \leq \frac{2}{3} \wedge 0 < c < \frac{1-z}{2}\right) \vee \left(\frac{2}{3} < z < \frac{4}{5} \wedge \frac{1}{4}(3z-2) < c < \frac{1-z}{2}\right), \tag{25}$$

TABLE 3. Equilibrium results in different subgames under Stackelberg competition where *firm 2* acts as the leader.

Firm 1 \ Firm 2	N	D
(a) Quantities		
N	$\frac{1}{4}(1+2c)$; $\frac{1}{2}(1-2c)$	$\frac{1}{4}(1+2c-2z)$; $\frac{1}{2}(1-2c+2z)$
D	$\frac{1}{4}(1+2c+3z)$; $\frac{1}{2}(1-2c-z)$	$\frac{1}{4}(1+2c+z)$; $\frac{1}{2}(1-2c+z)$
(b) Expected profits		
N	$\frac{1}{16}(1+2c)^2$;$\frac{1}{8}(1-2c)^2$	$\frac{1}{16}(1+2c-2z)^2$;$\frac{1}{8}(1-2c+2z)(1-2c-2z)$
D	$\frac{1}{16}(1+2c-z)(1+2c+3z)$;$\frac{1}{8}(1-2c-z)^2$	$\frac{1}{16}(1+2c-3z)(1+2c+z)$; $\frac{1}{8}(1-2c+z)(1-2c-3z)$

and the relevant parameter regions are illustrated in Figure 3.

As explained above, similarly, when the inefficient firm acts as the Stackelberg leader, in equilibrium it must not issue debt for any degree of cost asymmetry and market uncertainty. Interestingly, when the degree of market uncertainty satisfies that $2/3 < z < 4/5$, when the efficient firm acts as the leader, there must be the (N, N) equilibrium where neither firm issues debt as shown in Figure 2. However, when the inefficient firm acts as the leader, the efficient firm is likely to issue debt as long as the inefficient firm's marginal cost is relatively high ($c > (3z-2)/4$). It further validates what we have stated above that, a higher cost of the competitor raises the threshold of the maximum degree of risk that a firm can bear when choosing to issue debt. Comparing the two sequential competition modes, the region (N, D) in Figure 2 is contained by the region (D, N) in Figure 3. Based on this observation, we can put forward a hypothesis to be tested empirically, that is, the average debt level in the industry is higher in the scenario where those inefficient firms move first in market competition than that in the scenario where those efficient firms make the first move.

Proposition 4.9. *In the relevant parameter space as shown in Figure 3, in region* (N, N), $\pi_1 > \pi_2$*; in region* (D, N), $\pi_2 > (<)\pi_1$ *if* $c < (>)\hat{c}(z)$*, where* $\hat{c}(z) = \frac{3-z}{2} - \sqrt{2-z^2}$ *and* $\hat{c}(z)$ *is decreasing in* z*.*

As long as the level of market risk is not too low ($z > 1/5$), the efficient follower can always earn a higher profit than the inefficient leader. Only in a market with little volatility (the strategic benefit of debt is weak) and the cost gap is sufficiently narrow, the inefficient leader can make higher profits than the efficient follower. Comparing the two sequential modes, it is more difficult for the inefficient firm to leapfrog the rival when it acts as the Stackelberg leader. This raises a question: If the competition mode can be endogenously determined, is there an equilibrium strategy that is beneficial to both of the two firms?

4.4. Pareto-dominant mode of competition

In this subsection, we focus on cases where demand volatility and cost asymmetry are both sufficiently small, such that both firms will choose to issue debt under Cournot competition (*i.e.*, (D, D) region in Fig. 1), and the Stackelberg follower will issue debt under sequential modes (*i.e.*, (N, D) region in Fig. 2 and (D, N) region in Fig. 3). As we have observed above, the efficient firm makes better use of strategic debt than its inefficient rival. Then, when the two firms can freely preannounce their quantity decision timings, with the option of debt issuance, is there a Pareto-dominant strategy among these three modes of quantity competition?

First, we compare equilibrium profits under the two sequential modes where firm 1 (mode $S1$) and firm 2 (mode $S2$) act as the Stackelberg leader, respectively. Under mode $S1$, the parameter condition for (N, D) equilibrium is characterized by (23). Under mode $S2$, the corresponding condition for (D, N) equilibrium is characterized by (25). Notice that the set represented by condition (23) is a subset of the set represented by

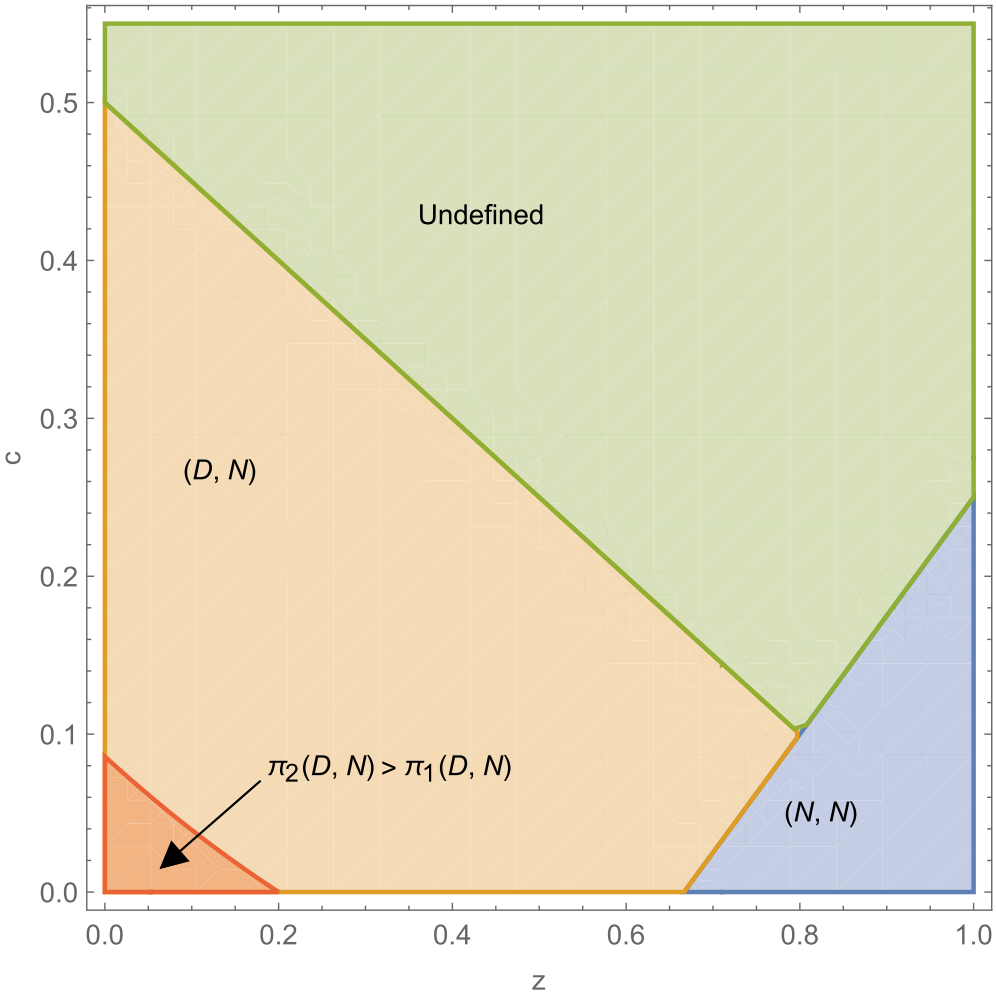

FIGURE 3. Equilibrium outcomes under Stackelberg competition where the cost-inefficient firm is the leader.

(25). Therefore, regardless of the mode $S1$ or $S2$, the Stackelberg follower will issue debt under the parameter conditions in (23), which is illustrated by the region AOB in Figure 4.

Comparing the equilibrium profits of firm 1 under the two modes, we have

$$\pi_1^{S2}(D,N) > (<)\pi_1^{S1}(N,D) \Leftrightarrow 2c^2 + 8z \cdot c + z(6-5z) - 1 > (<)0. \tag{26}$$

That is, in region CDB (resp., $AODC$) in Figure 4, mode $S2$ (resp., $S1$) is more favorable for firm 1. Similarly, comparing the equilibrium profits of firm 2 under the two modes, we have

$$\pi_2^{S2}(D,N) > (<)\pi_2^{S1}(N,D) \Leftrightarrow c^2 - 2\,(7z-1)\,c + 6z - 5z^2 - 1 < (>)0. \tag{27}$$

That is, in region $AODE$ (resp., DEB) in Figure 4, mode $S2$ (resp., $S1$) is better for firm 2. Therefore, in the common part of regions CDB and $AODE$, *i.e.*, region CDE, mode $S2$ Pareto-dominates mode $S1$. Since there is no intersection between the regions $AODC$ and DEB, mode $S1$ cannot Pareto dominate $S2$.

Next, we incorporate mode C, Cournot competition, to compare the two modes $S2$ and C in region CDE where mode $S2$ has been proved to Pareto-dominate mode $S1$. Under mode C, the parameter conditions for

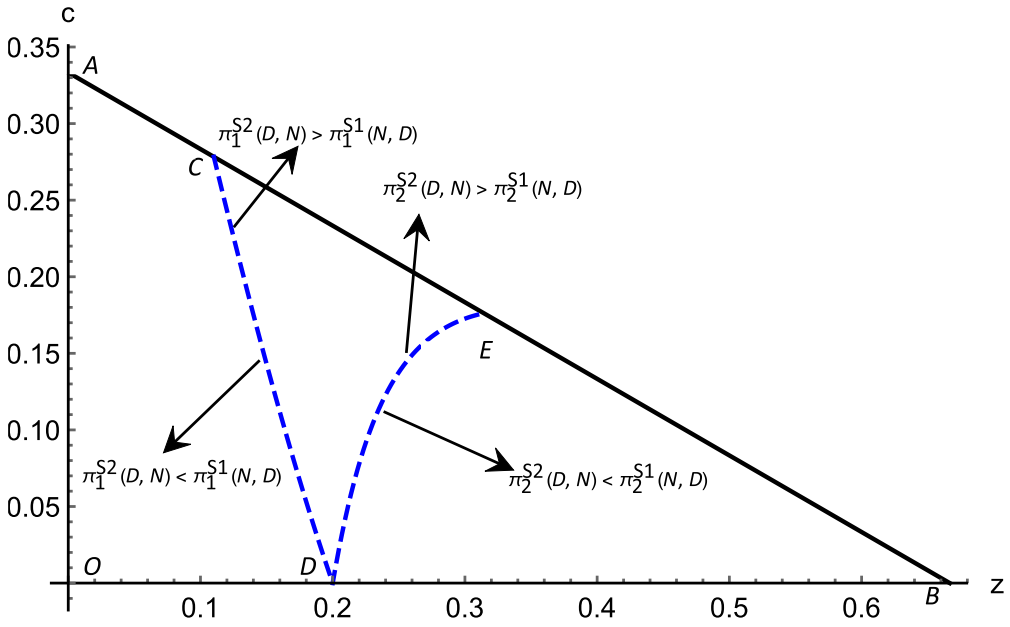

FIGURE 4. Comparison of equilibrium profits under mode $S1$ and mode $S2$.

equilibrium (D, D) are characterized by (17). We can draw the common part of the region CDE and the corresponding parameter space represented by condition (17), which is the region $CDGF$ in Figure 5.

It can be verified that under the conditions as drawn by the region $CDGF$ in Figure 5, $\pi_i^{S2}(D,N) > \pi_i^{C}(D,D)$ holds for firm $i = 1, 2$. That is, mode $S2$ also Pareto-dominates mode C. Then, we can obtain the following proposition.

Proposition 4.10. *When the degree of market uncertainty (z) and cost asymmetry (c) satisfy the conditions as shown in the $CDGF$ region in Figure 5, the competition mode that the cost-inefficient firm moves first is the Pareto-dominant strategy, i.e., for firm $i = 1, 2$, $\pi_i^{S2}(D,N) \geq \max\{\pi_i^{S1}(N,D), \pi_i^{C}(D,D)\}$.*

When the degree of cost asymmetry c and market uncertainty z satisfy the conditions drawn by the region $CDGF$ in Figure 5, even if the efficient firm has a chance to move first in making quantity decisions, it is more willing to invite its rival to move first, and firm 2 is also willing to give up the use of strategic debt in exchange for the first-mover advantage. This is because the efficient firm can make better use of strategic debt than the inefficient firm. In region $CDGF$, for the efficient firm, the strategic benefit of debt commitment exceeds the gain from the first-mover advantage, while the opposite is true for the inefficient firm. Therefore, mode $S2$ is more profitable for both firms rather than mode $S1$. On the other hand, too many quantities would be produced under mode C where both firms issue debt to commit to aggressive output strategies, which would definitely intensify the market competition and hurt both firms.

5. Concluding remarks

In this paper, we investigate firms' debt issuance choices and output decisions in a duopoly with asymmetric costs. We find that with the option of debt issuance, the cost-inefficient firm may make higher profits than its efficient rival through the strategic use of debt. In addition to the negative relationship between market risk and debt financing, higher marginal costs also reduce the incentive for the firm to use strategic debt. This is because the firm with a high cost is sensitive to price reduction caused by an aggressive output stance. However,

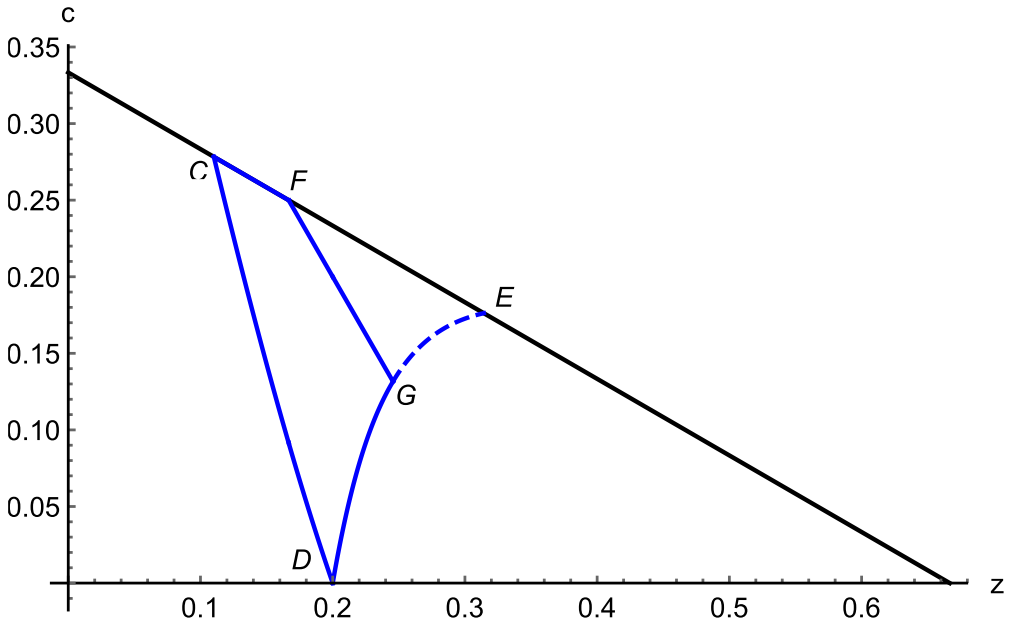

FIGURE 5. Parameter space where mode $S2$ is the Pareto-dominant strategy.

the cost disadvantage of the firm will increase its rival's tolerance for market volatility, which is manifested in the increase of the market risk threshold only below which the firm is willing to issue debt. Therefore, the cost-efficient firm can make better use of strategic debt than the inefficient firm.

In addition to the standard Cournot competition as in the previous strategic debt and product market competition literature, we also consider two sequential modes where the cost-efficient firm and the inefficient firm act as the Stackelberg leader, respectively. Under the sequential mode, the Stackelberg leader never chooses to issue debt. Within a reasonable range of the degree of market risk and cost asymmetry, the follower will choose to issue debt, committing to an aggressive output strategy to narrow the gap with the first mover (and even overleaps the leader). The Stackelberg leader always does not want any fluctuations in the demand market so that it can maintain its leadership in quantity and profit, while the follower may benefit from moderate market uncertainty.

Since the debt commitment advantage and first-mover advantage are substitutes, when firms can freely choose their production timings, we find that the sequential mode where the inefficient firm moves first in quantity competition may be a Pareto-dominant strategy. Under admissible parameter conditions, for the efficient firm, the strategic benefit of debt commitment exceeds the gain from the first-mover advantage, but for the inefficient firm, the opposite is true.

From the perspective of strategic device of debt commitment, this study provides one appreciable explanation for why those inefficient firms can defeat their efficient competitors in the real business environment. Our model can be extended in the following aspects. First, we assume a homogeneous duopoly, thus future research can further model a differentiated duopoly to investigate the impact of product differentiation on capital structure decisions of the two asymmetric firms. Zanchettin [42] found that product differentiation may have opposite effects on the two asymmetric firms when the cost gap is sufficiently wide. For example, the efficient firm may have a local incentive to reduce the degree of product differentiation. Moreover, Fang and Zhao [14] confirmed that this effect would be strengthened in the context of managerial delegation. Although Wanzenried [40] studied the impact of product substitutability on the optimal financial structure, the author did not consider the issue of cost asymmetry. In addition, one can examine debt financing in a context of horizontal/vertical product

differentiation duopoly, where the degree of product differentiation is endogenously determined. Second, it is meaningful to study the effect of debt financing in a price-setting oligopoly with cost asymmetry in a sequential move game. Due to bankruptcy risks and/or financing costs, price competition between horizontal firms will be eased (*e.g.*, Showalter [34], Peura *et al.* [30]). Finally, incorporating firms' other strategic decisions such as process R&D (Brander and Spencer [7], Kopel and Löffler [22], Brander and Song [4]) into an asymmetric duopoly with debt financing may be a potentially fruitful direction for future research.

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