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Optimal Capital Structure and Strategic Investment

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Abstract

This project drives the two firms' equity values which particularly considering their dynamic interactions between strategic investments in an asymmetric duopoly. The interactions are analyzed by a closed-loop feedback Nash equilibrium, which is a subgame perfect Nash equilibrium. This methodology can not only be employed to dynamically analyze the traditional duopoly game types of strategic substitutes and strategic complements, but also be utilized to investigate asymmetric competitive strategies in a duopoly game. Firms can therefore be divided into three groups: (1) the two firms are both strategic substitutes; (2) one firm is strategic substitute while the other is strategic complement; and (3) the two firms are both strategic complements. We are now using the above rule of firm classifications to empirically investigate how different relative competitive types affect the defaulted firm's credit risk.

Keywords: Credit Risk, Strategic Investment, Stochastic Differential Game, Closed-loop Feedback Nash Equilibrium

摘要

此計畫在考慮二家公司之間策略投資動態互動下，推導出二家公司之權益價值。此互動是利用 closed-loop feedback Nash equilibrium 來加以分析，此均衡是一種 subgame perfect Nash equilibrium。此架構不僅可以用來動態分析傳統雙佔賽局下之策略替代或策略互補的策略投資，且可以用來探討二公司不對稱策略投資之互動關係。公司可以因此被區分成三類：(1)二家公司都是策略替代；(2)一家公司是策略替代另一家公司是策略互補；(3)二家公司皆是策略互補。我們正在利用此種區分公司的方式來進行實證分析，探討此相對競爭型式如何影響破產公司之信用風險。

關鍵字：信用風險、策略投資、隨機微分賽局、Closed-loop Feedback Nash Equilibrium

I. Introduction

Since the pioneer works of Black and Scholes (1973) and Merton (1974), contingent claims analysis has been widely employed to investigate major issues of corporate finance, such as Black and Cox (1976), Fischer et al. (1989) and Leland (1994). In recent literature, some new structural models are further utilized to analyze special topics. For instance, Hennessy and Tserlukevich (2008) analyze debt choices in light of taxes and agency conflicts, while Morellec and Schurhoff (2009) investigate the effects of capital gains taxation on a firm's investment and financing strategies. Nevertheless, most of these studies are based on a single-firm setting and hence ignore the co-determined effects of the corresponding rivals' policies. This seems unsatisfactory because the product-market structure faced by firms is often neither monopoly nor perfect competition. In reality, a firm's sales and earnings normally depend on its rivals' actions, and their financing strategies would interact with each other. This paper attempts to investigate a firm's financing and investment strategies with consideration of its competitors' policies in a continuous-time stochastic game framework.

Recently, both empirical studies and theoretical models shed light on the links between corporate finance issues and firm's product-market structure. For example, the associated literature includes cash holdings and competition [Gabudean (2007); Morellec and Nikolov (2009)], a firm's risk and competition [Adam et al. (2007); Carlson et al. (2007)] and asset/stock returns and competition [Hoberg and Phillips (2009); Aguerrevere (2009)]. Therefore, the effects of competition on issues of corporate finance have attracted more and more attention.

The present paper is mainly connected to the studies of both industrial organization and structural corporate finance. For the related literature of industrial organization, Brander and Lewis (1986) pioneeringly examine the strategic commitment effect of issuing debts in Cournot product competition. Maksimovic (1988) analyzes the case of repeated Cournot quantity competition. He finds that higher debt levels lead to more aggressive product strategies (with higher quantities). Showlter (1995) and Dasgupta and Titman (1998) employ the frameworks of Bertrand price competition. Recently, Lyandres (2006) theoretically and empirically demonstrates a positive relationship between firms' optimal leverages and the extent of competitive interaction in their industries regardless of competition types in output markets. Some similar empirical studies have also been conducted by Phillips (1995) and Mackay and Phillips (2003). This line of research is often based on discrete-time two period models and usually does not accommodate such important aspects of debt as bankruptcy costs and tax shields.

As for the associated literature of structural models, Fries et al. (1997) analyze a competitive industry equilibrium assuming that upon default a firm exits the industry immediately. Miao (2005) examines the evolution of a competitive industry when firms face exogenous idiosyncratic technology shocks. Zhdanov (2007) builds a structural model to study strategic interactions among financing, entry and exit decisions of firms in a competitive industry. Yet there is little literature employing continuous-time stochastic frameworks to examine a firm's investment and financing strategies in an oligopoly market. Lanbrecht (2001) studies the effect of capital structure on the firms' investment and foreclosure policies in a duopoly market. However, his model takes the two firms leverages as exogenously given and thus could not be utilized to investigate determinants of debt issuance. Zhdanov (2008) develops a two-firm structural model to show that within a duopoly industry a firm's position (the leader or follower) has a crucial impact on its financing and investment policies. He indicates that the strategic effect of debts can result in a significant deviation from the optimal capital structure in the traditional single-firm structural model. In addition, he demonstrates the follower has a higher leverage ratio than the incumbent does and defaults first. Jou and Lee (2008) construct a structural model based on Leland (1994) to investigate a firm's debt level, investment timing, and investment scale choices. Employing a static symmetric Cournot Nash equilibrium, they show competition decreases the output price, which in turn stimulates a firm to defer its investment timing. Valta (2009) empirically examine the relationship between product market competition and the cost of debt. By utilizing loan contract data of U.S. listed manufacturing firms, he finds that firms in a product market with more competition would, on average, raise the cost of debt and lower the financial flexibility value of firms.

The above empirical and theoretical literature undoubtedly shows that a firm's decisions must be optimally determined with consideration of its rivals' strategies. However, the foregoing theoretical papers often rely on some exogenous assumptions to analyze the strategic behavior among firms in a duopoly, oligopoly or competitive industry. In the terminology of dynamic games, the so-called "open-loop" Nash equilibrium concept is employed where players simultaneously precommit to their entire path of strategy at the start of the game. Firms cannot alter their behavior in response to off-equilibrium actions by their opponents in the course of the game, even if it would be optimal for them to do so. In this sense, firms look like making decisions only at the outset, and hence it's nothing but a static interaction. Adam et al. (2007) is one exception. Based on a discrete-time two-stage dynamic game, they obtain subgame-perfect Nash equilibria (SPNE), which are dynamically consistent and result in the state-dependent optimal strategies. In this project, we would utilize the concept of "closed-loop" feedback Nash equilibrium (as detailed later), leading to a continuously dynamic subgame perfect equilibrium, to analyze a firm's optimal financing and investment decisions taking account of the feedback effects of rivals' responses in a dynamic system.

The remainder of this paper is organized as follows. Section II demonstrates the model and some numerical results are reported in Section III. Section IV concludes.

II. The Model

From the viewpoint of modeling, this project makes an attempt to extend Leland (1994) in a general oligopolistic competition market. Each firm's free cash flows are fully characterized by the possible feedback effect of its rivals' strategic operating actions. This is different from the setting of Goldstein et al. (2001), which assumes free cash flows are exogenously given.

The following first provides two reviews of the recent studies which initiate to employ the feedback Nash equilibrium (FNE) in a real option game framework. Back and Paulson (2009) indicate that the investment boundary of Grenadier (2002) is an open-loop but not closed-loop equilibrium in an oligopoly game. They further show that the perfectly competitive outcome is produced by closed-loop investment strategies that are mutually best responses in which the defer option is priceless and the traditional NPV investment rule is followed by all firms. Novy-Marx (2009) derives subgame-perfect equilibria for a dynamic infinite horizon capital accumulation game where the investment is irreversible and the demand is stochastic. He shows a Markov perfect strategy generates the same equilibrium as the open-loop Cournot equilibrium when the preemptive investment is both cheap and credible. To our knowledge, however, none existing papers employ the closed-loop feedback Nash equilibria concept to analyze a firm's optimal financing and investment strategies in a general oligopolistic competition framework.

For simplicity, we first assume only two competitive, risk-neutral firms exist, named as Firm 1 and Firm 2. The two firms continuously decide how much to spend their strategic investment flows (ϕ_1 and ϕ_2) on operating actions to build and maintain their competitiveness in this duopoly market. For example, operating strategies within an industry could be price competition, quantity competition, R&D strategic investment races, competitive advertising and so on.[1] Assume the operating revenues of Firm1 and Firm2, x_1 and x_2, are respectively given by

$$dx_1(t) = \left(v_1\phi_1(t)\sqrt{x_2(t)} - \xi_2\phi_2(t)\sqrt{x_1(t)}\right)dt + \sigma_1 dW_1(t),\ x_1(0) = x_1, \quad (1)$$

[1] According to Bulow et al (1985), all possible operating strategies could be generally divided into two types: strategic substitutes and strategic complements. Strategic substitutes (complements) mean that when the player's competitors turn to operate more aggressively, his optimal reaction is to become less (more) so. Therefore, quantity (price) competition is a typical example of strategic substitutes (complements).

$$dx_2(t) = \left(v_2\phi_2(t)\sqrt{x_1(t)} - \xi_1\phi_1(t)\sqrt{X_1(t)}\right)dt + \sigma_2 dW_2(t),\ x_2(0) = x_2, \tag{2}$$

where $W_1(t)$ and $W_2(t)$ are two well-defined correlated Wiener process demonstrating operation shocks faced by the two firms and $dW_1(t)dW_2(t) = \rho dt$. v_1 and v_2 respectively show the effectiveness of strategic operating decisions of Firm1 and Firm2 to raise the firms' revenues. The effectiveness is assumed to be positive since rational firms would make a strategic investment to benefit themselves. ξ_1 and ξ_2 stand for the impact of one firm's strategic investment on the other firm's revenues. For instance, ξ_2 is the effect of strategic operating action of Firm 2 on the revenues of Firm 1. If the effect is positive, the strategic action adopted by a firm is tough and aggressive to its competitor; otherwise, if the effect is negative, the strategic action is soft and accommodating. Different from the previous studies assuming the competition types (quantity or price competition) and then calculating a firm's revenues using the quantity multiplied price, the above setting directly model the firms' operating profits as two dynamic processes. In our framework, the two dynamics are not fully exogenously given, but would be endogenously updated by the optimal operating decisions of Firm 1 and Firm 2.

Let m_1 and m_2 denote the industry sales volume multiplied by the per-unit profit margin for Firm 1 and Firm 2, respectively. We formulate the following stochastic differential game faced by the two firms as

$$\underset{\phi_1(t)\geq 0}{\text{Max}} \left\{ V_1 = \mathrm{E}\left[\int_0^\infty e^{-rt} \left(m_1 x_1(t) - \frac{1}{2}\gamma_1(\phi_1(t))^2 \right) dt \right] \right\}, \tag{3}$$

$$\underset{\phi_2(t)\geq 0}{\text{Max}} \left\{ V_2 = \mathrm{E}\left[\int_0^\infty e^{-rt} \left(m_2 x_2(t) - \frac{1}{2}\gamma_2(\phi_1(t))^2 \right) dt \right] \right\}, \tag{4}$$

s.t. Equations (1) and (2) ,

where γ_1 and γ_2 are cost parameters of Firm 1 and Firm 2, and V_1 and V_2 are unlevered firm values of Firm 1 and Firm 2, respectively. Each firm is seeking to maximize its expected discounted profit streams subject to the two firms' revenue dynamics. Before summarizing our preliminary results of this stochastic differential game, we would highlight main differences between the traditional open-loop control and closed-loop control as in Figure 1.

Figure 1 explains the configurations of open-loop and closed-loop controls. First assume that the two firms would like to seek open-loop solutions. Employing open-loop controls requires the firms to determine their action trajectories at the outset, which results in the fact that the optimal controls and objective functions of two firms are only relevant to the exogenously given parameters, the initial state, and the time. Accordingly, open-loop strategies may be time-varying, but the major drawback is that the path cannot be changed once determined. This is realistic only if there are restrictive commitments concerning strategies. On the other hand, the closed-loop strategy would be updated by the dynamic system (including state dynamics), and in turn it would be not only time-dependent but also state-dependent. An operating manager would like not to put operating actions in such open-loop (automatic) controls. Instead, he/she would wish to monitor the market situation as it proceeds across time and modify operating actions if needed. As a result, closed-loop controls would be more appropriate than open-loop ones.

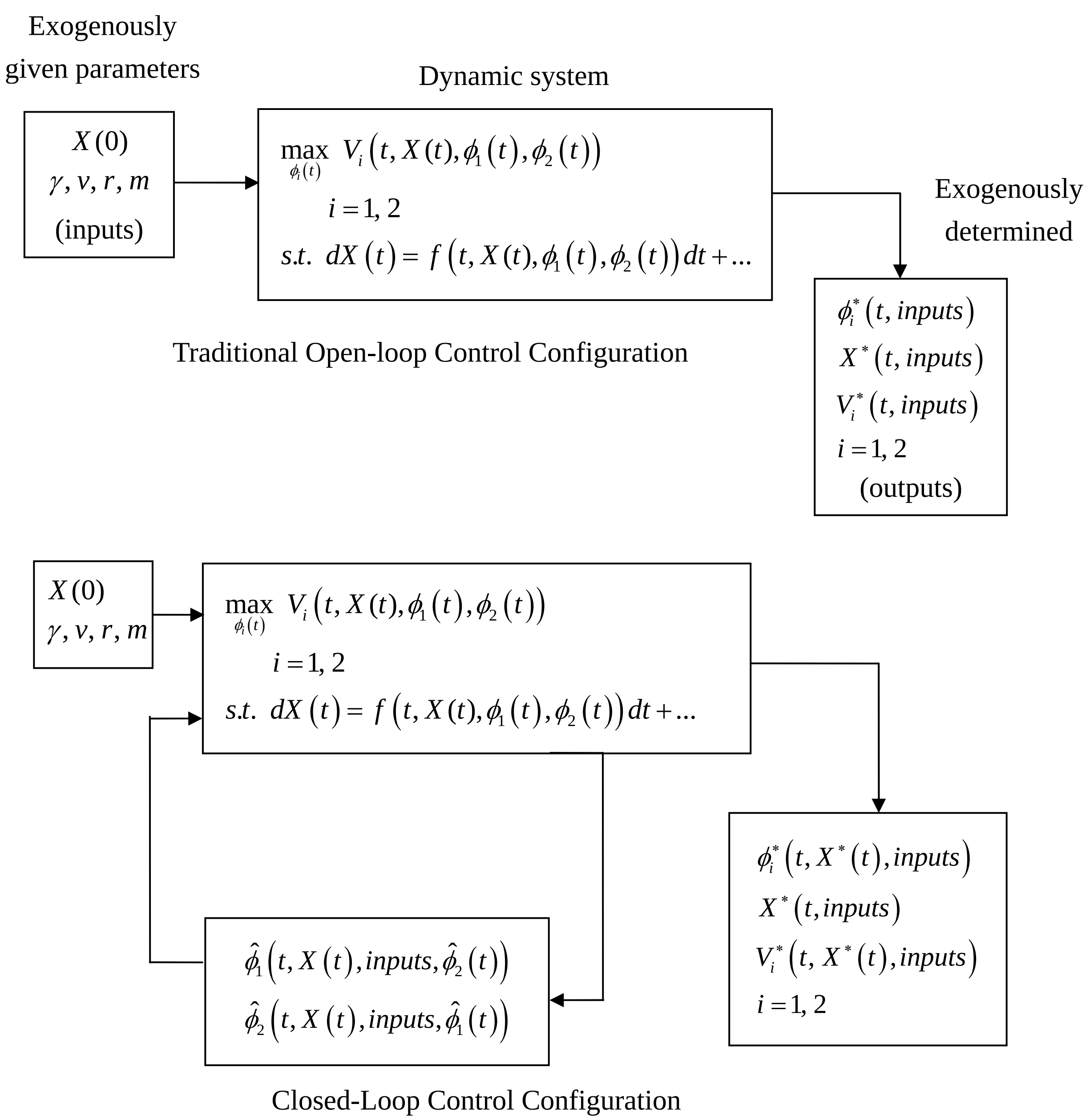

Figure 1   Configurations of Open-Loop and Closed-Loop Controls

Proposition 1 (Closed-loop feedback Nash equilibrium)

The unlevered firm values of Firm1 and Firm2 are then given by

$$V_1^*(t) = a_{11}x_1^*(t) + a_{12}x_2^*(t)\,, \tag{5}$$

$$V_2^*(t) = a_{21}x_1^*(t) + a_{22}x_2^*(t)\,, \tag{6}$$

where $a_{ij}, i, j = 1, 2$ can be solved by the following four equations:

$$ra_{11} = m_1 + \frac{1}{\gamma_2}\left(v_2 a_{12} - \xi_2 a_{11}\right)\left(v_2 a_{22} - \xi_2 a_{21}\right),$$

$$ra_{12} = \frac{1}{2\gamma_1}\left(v_1 a_{11} - \xi_1 a_{12}\right)^2,$$

$$ra_{22} = m_2 + \frac{1}{\gamma_1}\left(v_1 a_{21} - \xi_1 a_{22}\right)\left(v_1 a_{11} - \xi_1 a_{12}\right), \text{ and}$$

$$ra_{21} = \frac{1}{2\gamma_2}\left(v_2 a_{22} - \xi_2 a_{21}\right)^2.$$

$x_1^*(t)$ and $x_2^*(t)$ are the solutions of

$$dx_1^*(t) = \left(\frac{1}{\gamma_1}v_1(a_{11}v_1 - a_{12}\xi_1)x_2^*(t) - \frac{1}{\gamma_2}\xi_2(a_{22}v_2 - a_{21}\xi_2)x_1^*(t)\right)dt + \sigma_1 dW_1(t) \tag{7}$$

$$dx_2^*(t) = \left(\frac{1}{\gamma_2}v_2(a_{22}v_2 - a_{21}\xi_2)x_1^*(t) - \frac{1}{\gamma_1}\xi_1(a_{11}v_1 - a_{12}\xi_1)x_2^*(t)\right)dt + \sigma_2 dW_2(t)\,. \tag{8}$$

The optimal operating investments of Firm1 and Firm2 are given by

$$\phi_1^*(t) = \max\left(\frac{1}{\gamma_1}\left(a_{11}v_1 - a_{12}\xi_1\right)\sqrt{x_2^*(t)}, 0\right), \text{ and} \tag{9}$$

$$\phi_2^*(t) = \max\left(\frac{1}{\gamma_2}\left(a_{22}v_2 - a_{21}\xi_2\right)\sqrt{x_1^*(t)}, 0\right). \tag{10}$$

Comparing with eq. (1) and (2), eq. (7) and (8) particularly shows that the impact of one firm's strategic investment on the other firm's revenues gives the firm some feedback on its own revenue, and the effectiveness of the rival's strategic investment also affects the firm's revenue. The above two interactive results come from the closed-loop feedback Nash equilibrium.

Proposition 2 (Equilibrium Unlevered Firm Values)

According to Proposition 1, the equilibrium dynamics of unlevered firm values of Firm1 and Firm2 are given by

$$dV_1^*(t)=\left(\frac{1}{\gamma_1}(a_{11}v_1-a_{12}\xi_1)^2x_2^*(t)+\frac{1}{\gamma_2}(a_{22}v_2-a_{21}\xi_2)(a_{12}v_2-a_{11}\xi_2)x_1^*(t)\right)dt+a_{11}\sigma_1 dW_1(t)+a_{12}\sigma_2 dW_2(t) \tag{11}$$

$$dV_2^*(t)=\left(\frac{1}{\gamma_2}(a_{22}v_2-a_{21}\xi_2)^2x_1^*(t)+\frac{1}{\gamma_1}(a_{11}v_1-a_{12}\xi_1)(a_{21}v_1-a_{22}\xi_1)x_2^*(t)\right)dt+a_{21}\sigma_1 dW_1(t)+a_{22}\sigma_2 dW_2(t) \tag{12}$$

Eq. (11) and (12) not only demonstrate the similar characteristics of the drift terms as those in Eq. (7) and (8), but also show that the volatilities of the firm value are both related to the effectiveness of the two firms' strategic investments and the impacts of the firms' strategic investments on the other firm's revenues.

III. Numerical Results and New Findings

This section reports some interesting results of our model. The basic parameters are given as follows: $r=0.05$, $m_1=m_2=1$, $\gamma_1=\gamma_2=1$, $\sigma_1=\sigma_2=0.3$ and $\rho=0.5$. The comparative statistics for the two asymmetric firms are given in Table 1.

In view of Table 1, a comparison of exogenous and endogenous interactions shows the following features. First, for each scenario, there are some differentiations between the results of exogenous and endogenous interactions, showing that the closed-loop equilibrium generates different sensitivities between the two cases. Second, a change in the parameters of own SDE (v_i and ξ_j for firm i, $i\neq j$, $i,j=1,2$) has the same effect in the both cases. This is to be expected, since the first-order effects likely dominate the second-order effects, thereby leading to the same results. Third, the sensitivity of the firm's equity value to the own effectiveness of its rival's strategic investment, i.e., the sensitivity of V_i^* to v_j, $i\neq j$, $i,j=1,2$, plays a crucial role to uniquely identity the competitive type of strategic investments between the two firms. In particular, $\frac{\partial V_i^*}{\partial v_j}>(<)0$, where $i\neq j$, $i,j=1,2$, demonstrates that $\xi_i<(>)0$, $i=1,2$. If the firm's equity value is positively (negatively) correlated to the effectiveness of its rival's strategic investment, then the strategic investment of this firm are aggressive (accommodating).

Table 1. Comparative statics for two asymmetric firms

	Panel A: Exogenous interaction							
$\xi_1 > 0$ $\xi_2 > 0$	$\frac{\partial V_1^*}{\partial v_1} > 0$	$\frac{\partial V_1^*}{\partial \xi_1} < 0$	$\frac{\partial V_1^*}{\partial v_2} > 0$	$\frac{\partial V_1^*}{\partial \xi_2} < 0$	$\frac{\partial V_2^*}{\partial v_1} > 0$	$\frac{\partial V_2^*}{\partial \xi_1} < 0$	$\frac{\partial V_2^*}{\partial v_2} > 0$	$\frac{\partial V_2^*}{\partial \xi_2} < 0$
$\xi_1 > 0$ $\xi_2 < 0$	$\frac{\partial V_1^*}{\partial v_1} > 0$	$\frac{\partial V_1^*}{\partial \xi_1} < 0$	$\frac{\partial V_1^*}{\partial v_2} > 0$	$\frac{\partial V_1^*}{\partial \xi_2} < 0$	$\frac{\partial V_2^*}{\partial v_1} > 0$	$\frac{\partial V_2^*}{\partial \xi_1} < 0$	$\frac{\partial V_2^*}{\partial v_2} > 0$	$\frac{\partial V_2^*}{\partial \xi_2} < 0$
$\xi_1 < 0$ $\xi_2 > 0$	$\frac{\partial V_1^*}{\partial v_1} > 0$	$\frac{\partial V_1^*}{\partial \xi_1} < 0$	$\frac{\partial V_1^*}{\partial v_2} > 0$	$\frac{\partial V_1^*}{\partial \xi_2} < 0$	$\frac{\partial V_2^*}{\partial v_1} > 0$	$\frac{\partial V_2^*}{\partial \xi_1} < 0$	$\frac{\partial V_2^*}{\partial v_2} > 0$	$\frac{\partial V_2^*}{\partial \xi_2} < 0$
$\xi_1 < 0$ $\xi_2 < 0$	$\frac{\partial V_1^*}{\partial v_1} > 0$	$\frac{\partial V_1^*}{\partial \xi_1} < 0$	$\frac{\partial V_1^*}{\partial v_2} > 0$	$\frac{\partial V_1^*}{\partial \xi_2} < 0$	$\frac{\partial V_2^*}{\partial v_1} > 0$	$\frac{\partial V_2^*}{\partial \xi_1} < 0$	$\frac{\partial V_2^*}{\partial v_2} > 0$	$\frac{\partial V_2^*}{\partial \xi_2} < 0$
	Panel B: Endogenous interaction (closed-loop feedback equilibrium)							
$\xi_1 > 0$ $\xi_2 > 0$	$\frac{\partial V_1^*}{\partial v_1} > 0$	**$\frac{\partial V_1^*}{\partial \xi_1} > 0$**	**$\frac{\partial V_1^*}{\partial v_2} < 0$**	$\frac{\partial V_1^*}{\partial \xi_2} < 0$	**$\frac{\partial V_2^*}{\partial v_1} < 0$**	$\frac{\partial V_2^*}{\partial \xi_1} < 0$	$\frac{\partial V_2^*}{\partial v_2} > 0$	**$\frac{\partial V_2^*}{\partial \xi_2} > 0$**
$\xi_1 > 0$ $\xi_2 < 0$	$\frac{\partial V_1^*}{\partial v_1} > 0$	**$\frac{\partial V_1^*}{\partial \xi_1} \gtrless 0$**	$\frac{\partial V_1^*}{\partial v_2} > 0$	$\frac{\partial V_1^*}{\partial \xi_2} < 0$	**$\frac{\partial V_2^*}{\partial v_1} < 0$**	$\frac{\partial V_2^*}{\partial \xi_1} < 0$	$\frac{\partial V_2^*}{\partial v_2} > 0$	**$\frac{\partial V_2^*}{\partial \xi_2} \lessgtr 0$**
$\xi_1 < 0$ $\xi_2 > 0$	$\frac{\partial V_1^*}{\partial v_1} > 0$	**$\frac{\partial V_1^*}{\partial \xi_1} \lessgtr 0$**	**$\frac{\partial V_1^*}{\partial v_2} < 0$**	$\frac{\partial V_1^*}{\partial \xi_2} < 0$	$\frac{\partial V_2^*}{\partial v_1} > 0$	$\frac{\partial V_2^*}{\partial \xi_1} < 0$	$\frac{\partial V_2^*}{\partial v_2} > 0$	**$\frac{\partial V_2^*}{\partial \xi_2} \gtrless 0$**
$\xi_1 < 0$ $\xi_2 < 0$	$\frac{\partial V_1^*}{\partial v_1} > 0$	**$\frac{\partial V_1^*}{\partial \xi_1} \lessgtr 0$**	$\frac{\partial V_1^*}{\partial v_2} > 0$	$\frac{\partial V_1^*}{\partial \xi_2} < 0$	$\frac{\partial V_2^*}{\partial v_1} > 0$	$\frac{\partial V_2^*}{\partial \xi_1} < 0$	$\frac{\partial V_2^*}{\partial v_2} > 0$	**$\frac{\partial V_2^*}{\partial \xi_2} \lessgtr 0$**

IV. Conclusion and Self-Evaluation

This project drives the two firms' equity values which particularly considering their dynamic interactions of strategic investments in an asymmetric duopoly. The interactions between the two firms' strategic investments are analyzed by a closed-loop feedback Nash equilibrium, which is a subgame perfect Nash equilibrium. This methodology can not only be employed to dynamically analyze the traditional duopoly games of strategic substitutes (e.g., quantity competition) and strategic complements (e.g., price competition),[2] but also be utilized to investigate asymmetric competitive strategies in a duopoly game, i.e., one firm adopts a strategic substitute strategy while the other uses a strategic complement strategy.

Though the competition types between various counterparties may be different,

[2] Please refer to Lyandres (2006).

firms can be divided into three groups: (1) the two firms are strategic substitutes; (2) one firm is strategic substitute while the other is strategic complement; and (3) the two firms are strategic complements. We are now employing the above rule of classifications to empirically investigate how different relative competitive types affect the defaulted firm's credit risk. We expect to have some empirical results in the end of this year.

For the evaluation of the project, this project attends the first goal that we derive the closed-loop feedback Nash equilibrium in an asymmetric duopoly. However, we did not attend our second goal to analyze the optimal capital structure in this framework. The reason is that the game equilibrium is quite complicated so that the debt financing cannot be taken into consideration. We therefore turn into the empirical issue of credit risk by classifying defaulted firms into different relative competitive styles according the model's results and attempt to show that different competitive styles will lead to different credit risks.

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國科會補助計畫衍生研發成果推廣資料表

日期:2011/10/30

<table>
<tr><td rowspan="3">國科會補助計畫</td><td colspan="2">計畫名稱: 最適資本結構與策略投資</td></tr>
<tr><td colspan="2">計畫主持人: 黃星華</td></tr>
<tr><td>計畫編號: 99-2410-H-009-019-</td><td>學門領域: 財務</td></tr>
<tr><td colspan="3">無研發成果推廣資料</td></tr>
</table>

99 年度專題研究計畫研究成果彙整表

計畫主持人：黃星華	計畫編號：99-2410-H-009-019-
計畫名稱：最適資本結構與策略投資	

成果項目			量化：實際已達成數（被接受或已發表）	量化：預期總達成數(含實際已達成數)	量化：本計畫實際貢獻百分比	單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	1	1	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	0	1	80%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：□已發表 □未發表之文稿 ■撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

This project drives the two firms’ equity values which particularly considering their dynamic interactions between strategic investments in an asymmetric duopoly. The interactions are analyzed by a closed-loop feedback Nash equilibrium, which is a subgame perfect Nash equilibrium. This methodology can not only be employed to dynamically analyze the traditional duopoly game types of strategic substitutes and strategic complements, but also be utilized to investigate asymmetric competitive strategies in a duopoly game. Firms can therefore be divided into three groups: (1) the two firms are both strategic substitutes；(2) one firm is strategic substitute while the other is strategic complement； and (3) the two firms are both strategic complements. We are now using the above rule of firm classifications to empirically investigate how different relative competitive types affect the defaulted firm’s credit risk. We expect to have some empirical results in the end of this year.