数理解析研究所講究録
第 1675 巻 2010 年 49-59

Reversibility, Operating Flexibility, and Asset Returns in Competitive Equilibrium *

千葉工業大学・社会システム科学部 高嶋 隆太 (Ryuta Takashima) †
Faculty of Social Science,
Chiba Institute of Technology

東京大学・大学院工学系研究科 中田 翔治 (Shoji Nakada)
Graduate School of Engineering,
The University of Tokyo

東京大学・大学院工学系研究科 大畑 翔柄 (Shohei Ohata)
Graduate School of Engineering,
The University of Tokyo

1 Introduction

A firm has several investment projects, and must make decisions such as investment, disinvestment, abandonment, and capacity choice in these projects. The firm's value and its exposure to systematic risk, which are affected by uncertainty over the state of the economy and market structure, are dependent on these decisions.

The previous works that analyze the relation between firms' investment decision and their asset return dynamics include Berk, Green, and Naik (1999), Gomes, Kogan, and Zhang (2003), Kogan (2004), Carlson, Fisher, and Giammarino (2004), and Cooper (2006). The closest work on the interaction among firms' investment decisions and their asset return dynamics in a oligopolistic market to this paper is Aguerrevere (2009). Aguerrevere (2009) shows that the link between the degree of competition and the firms' asset return dynamics varies with the market demand. Specifically, Aguerrevere (2009) considers the firm that has an investment option and a option to reduce capacity utilization when demand fall, that is, operating flexibility, and obtains the result that is consistent with the empirical findings as Hou and Robinson (2006).

The firm's decisions include not only investment and capacity change but also disinvestment and exit. Especially, the disinvestment decision is one of the reasons for a change in the firm's capital stock. The firm can sell off capital stock to recover part of investment. There exist several works with respect to the link between the firm's disinvestment or exit decisions and its asset return dynamics. Carlson et al. (2009) investigate risk dynamics in a duopolistic market with asymmetric cost structure of firms. They find that for both investment and disinvestment the increase in competition leads to risk reduction. Siyahhan (2009) analyzes the link between firms' exit decisions and risk dynamics in a duopolistic market, and finds that firm risk decreases as the demand level approaches the exit threshold.

As shown in these previous works, firm's decisions such as investment, disinvestment, and capacity change affect their asset return. Therefore, it is necessary to examine the effect of risk dynamics on the firm, which has these options, in competitive market. In this paper, we investigate how the strategic behaviors of firms such as investment, disinvestment, operating

*This paper is an abbreviated version of Takashima, Nakada, and Ohata (2010). The authors would like to thank the participants of FMA2009: RIMS Workshop on Finacial Modeling and Analysis in Kyoto, Japan (25-27 November 2009) for their helpful comments and suggestions. This research was supported in part by the Grant-in-Aid for Scientific Research (No. 20241037) of the Japan Society for the Promotion of Science in 2008–2012.

†2-7-1 Tsudanuma, Narashino-shi, Chiba 275-0016, Japan, E-mail: takashima@sun.it-chiba.ac.jp

flexibility affect their asset returns dynamics. Specifically, we use the model of the equilibrium investment strategies of firms such as Baldursson (1998), Grenadier (2002), and Aguerrevere (2003) to analyze firms' decisions in competitive industries.

We first examine the case in which each firm has no disinvestment decision to compare our approach with that of Aguerrevere (2009). We find that firms in more competitive industries have a higher beta when demand is low, whereas firms in more concentrated industries have a higher beta when demand is high. Hence, our results is similar to the result of Aguerrevere (2009) that is derived by a different approach.

Then, we investigate the effect of competitive interaction among firms on asset returns dynamics. We find that unlike Aguerrevere (2009), there are three regions as follows: a region of low demand level in which increase in competition leads to lower risk, a region of middle demand level in which increase in competition leads to higher risk, and a region of high demand level in which increase in competition leads to lower risk. For the region of low demand level, specifically, due to disinvestment option, increasing competition leads to reduce risk. This results is consistent with that in Carlson et al. (2009).

Finally, we examine how uncertainty affects firms' asset return dynamics. We find that the region of middle demand level becomes small as uncertainty increases. This is because that the effect of investment and disinvestment options becomes large due to increasing uncertainty.

The remainder of this paper is organized as follows. The next section presents the setup of model and derives the firm value and the expected returns. We then develop the model taking into account the disinvestment and the operating flexibility. Section 3 provides some numerical results with respect to the effect of competition in the market on the relation between firm's decisions and asset returns. Section 4 concludes.

2 The Model

2.1 Model Setup

This paper extends the model of Grenadier (2002), who derives the equilibrium investment strategies, and examines the effect of competition in the market on the relation between firms' decisions such as investment and disinvestment, and their asset return.

Consider an industry composed of n identical firms producing a single homogeneous good. At time t, firm i produces q_t^i units of output. We assume that the output price is given by the inverse demand function as follows:

$$P_t = X_t Q_t^{-\frac{1}{\gamma}}, \tag{1}$$

where X_t is an exogenous shock to demand, $Q_t = \sum_i q_t^i$ is the industry output, and $\gamma > 1$ is the elasticity of demand. The evolution of the demand shock follows a geometric Brownian motion:

$$dX_t = \mu X_t dt + \sigma X_t dW_t, \quad X_0 = x, \tag{2}$$

where μ is the instantaneous expected growth rate of X_t, σ is the associated volatility, and W_t is a standard Brownian motion. Since all firms are identical, a symmetric equilibrium is considered as follows:

$$q_t^i = \frac{Q_t}{n}, \qquad q_t^{-i} = \frac{(n-1)Q_t}{n}, \tag{3}$$

where q_t^{-i} is the output of all firms except firm i, that is, $q_t^{-i} = \sum_{j=1,j\neq i}^{n} q_t^j$.

Following Carlson, Fisher, and Giammarino (2004) we assume that there exist traded assets that can be used to hedge demand uncertainty in order to derive the firm value. Let B_t denote the price of a riskless asset with dynamics,

$$dB_t = rB_t dt, \tag{4}$$

where r is the constant risk-free rate of interest. We suppose that the price dynamics of the risky asset is given by a geometric Brownian motion:

$$dS_t = \eta S_t dt + \sigma S_t dW_t. \tag{5}$$

The risky asset S_t and the demand shock X_t are perfectly correlated. We can use B_t and S_t to construct a portfolio with B_t and S_t that exactly replicates the demand shock X_t and derive its risk neutral measure. Thus, the evolution of the demand shock under risk neutral measure is given as follows:

$$dX_t = (r - \delta)X_t dt + \sigma X_t d\hat{W}_t, \tag{6}$$

where $\delta = \eta - \mu$, and $\hat{W}_t = W_t + \frac{\eta - r}{\sigma}t$.

Let $\pi^i(X_t, q_t^i; Q_t)$ denote the profit flow at time t for firm i. The profit flow can be represented by the following equation:

$$\pi^i(X_t, q_t^i; Q_t) = (P_t - c)q_t^i = X_t Q_t^{-\frac{1}{\gamma}} q_t^i - cq_t^i, \tag{7}$$

where c is a constant cost flow. Furthermore, as in Aguerrevere (2009), the profit flow with operating flexibility is given by

$$\pi^i(X_t, q_t^i; Q_t) = \max_{0 \le q_t^i \le \frac{Q_t}{n}} \left[X_t Q_t^{-\frac{1}{\gamma}} q_t^i - cq_t^i \right] \tag{8}$$

The solution for the symmetric equilibrium assumption can be obtained by solving Eq. (8):

$$\pi(x, Q) = \begin{cases} \left(\dfrac{c}{n(n\gamma - 1)}\right)\left(\dfrac{n\gamma - 1}{n\gamma c}x\right)^{\gamma}, & \text{for } x < \dfrac{n\gamma c Q^{\frac{1}{\gamma}}}{n\gamma - 1}, \\ \dfrac{Q^{\frac{\gamma - 1}{\gamma}}}{n}x - \dfrac{cQ}{n}, & \text{for } x > \dfrac{n\gamma c Q^{\frac{1}{\gamma}}}{n\gamma - 1}. \end{cases} \tag{9}$$

2.2 Firm Value in Competitive Equilibrium

At any time t, each firm can invest in additional capacity to increase its output by an infinitesimal increment dq^i, and increases a output by incurring a cost of I per unit of output. Firm's investment decisions affect the output price in Eq. (1), which is a function of the industry output. Thus each firm can not ignore other firm's investment decisions and is determined as part of a Nash-Cournot equilibrium. Each firm chooses its discrete investment times τ_ℓ^i at which to increase its capacity $q_{\tau_\ell^i}^i$ for $\ell = 1, 2, \cdots, \infty$ to maximize the expected discounted value. The value function for firm i can then be represented by the following equation:

$$V^i(x, q_0^i, q_0^{-i}; q_t^i, q_t^{-i}) = \sup_{\{\tau_\ell^i, q_{\tau_\ell^i}^i\}_{\ell=1}^{\infty}} \mathbb{E}\left[\int_0^\infty e^{-rt}\left[\pi^i(X_t, q_t^i, q_t^{-i})\right] dt - \int_0^\infty e^{-rt} I dq_t^i\right] \tag{10}$$

Following Grenadier (2002), we consider the symmetric Nash-Cournot equilibrium investment strategy as that of a myopic firm, which ignores competitive behavior. Although the determination of a Nash-Cournot equilibrium in investment strategies becomes a complex problem, due to this setting, the solution can be obtained by the standard framework. When the marginal value of the symmetric Nash-Cournot equilibrium investment strategy for firm is $m(x, Q)$, using the standard argument as in Dixit and Pindyck (1994), the following ordinary differential equation, which is satisfied by the marginal value, can be derived:

$$\frac{1}{2}\sigma^2 x^2 m'' + (r - \delta)xm' - rm + \frac{\partial \pi}{\partial q^i} = 0, \tag{11}$$

where

$$\frac{\partial \pi}{\partial q^i}(x,Q) = \frac{n\gamma - 1}{n\gamma} Q^{-\frac{1}{\gamma}} x - c. \tag{12}$$

The general solutions of Eq. (11) are given as follows:

$$m(x,Q) = a_1 x^{\beta_1} + a_2 x^{\beta_2} + \frac{n\gamma - 1}{n\gamma} Q^{-\frac{1}{\gamma}} \frac{x}{\delta} - \frac{c}{r}, \tag{13}$$

where a_1 and a_2 are unknown constants, and β_1 and β_2 are the positive and the negative roots, respectively, of the characteristic equation $\frac{1}{2}\beta(\beta-1) + (r-\delta)\beta - r = 0$. The marginal value must satisfy the following boundary conditions:

$$m(0,Q) = -\frac{c}{r}, \tag{14}$$

$$m(X^*(Q),Q) = I, \tag{15}$$

$$\frac{\partial m(X^*(Q),Q)}{\partial x} = 0, \tag{16}$$

where $X^*(Q)$ is the optimal investment threshold. Condition (14) requires that the option value becomes zero if the demand is close to zero. Therefore, from this condition, we have $a_2 = 0$. Conditions (15) and (16) are the value-matching and smooth-pasting conditions, respectively. From conditions (14-16), we can obtain the equilibrium value of a firm's marginal investment as follows:

$$m(x,Q) = -\frac{n\gamma - 1}{n\gamma} \frac{v_n^{1-\beta_1}}{\beta_1 \delta} Q^{-\frac{\beta_1}{\gamma}} x^{\beta_1} + \frac{n\gamma - 1}{n\gamma} \frac{Q^{-\frac{1}{\gamma}}}{\delta} x - \frac{c}{r}, \tag{17}$$

where

$$v_n = \frac{\beta_1}{\beta_1 - 1} \frac{n\gamma}{n\gamma - 1} \delta \left(I + \frac{c}{r} \right). \tag{18}$$

The equilibrium investment threshold is given by

$$X^*(Q) = v_n Q^{\frac{1}{\gamma}}. \tag{19}$$

Furthermore, following Grenadier (2002), we derive the value of each firm in equilibrium. When the value of each firm in equilibrium is $V(x,Q)$, the ordinary differential equation, which is satisfied by the firm value, is derived as follows:

$$\frac{1}{2}\sigma^2 x^2 V'' + (r-\delta) x V' - rV + \pi(x,Q) = 0. \tag{20}$$

The boundary condition for the firm value is given by

$$\frac{\partial V(X^*(Q),Q)}{\partial Q} = \frac{I}{n} \tag{21}$$

This condition (21) ensures that when the demand rises above the threshold $X^*(Q)$, Q increases by the infinitesimal increment dQ, and the firm incurs a investment cost $\frac{I}{n}dQ$. By solving the differential equation (20) subject to the boundary condition (21), the value of each firm in equilibrium can be obtained as follows:

$$V(x,Q) = A(Q) x^{\beta_1} + \frac{x}{n\delta} Q^{\frac{\gamma-1}{\gamma}} - \frac{cQ}{nr}, \tag{22}$$

where

$$A(Q) = \frac{v_n^{-\beta_1}}{n} \frac{\gamma}{\gamma - \beta_1} \left(I + \frac{c}{r} - \frac{v_n}{\delta} \frac{\gamma - 1}{\gamma} \right) Q^{\frac{\gamma - \beta_1}{\gamma}}. \tag{23}$$

A specific case with $c = 0$ is the model of Grenadier (2002).

2.3 Expected Returns

In this section, likewise Aguerrevere (2009), following Carlson, Fisher, and Giammarino (2004), we derive the beta of firm i.

From Itô's lemma and the evolution of the demand shock in Eq. (2), the instantaneous change in V is given by

$$dV_t = \left[\mu X_t \frac{dV_t}{dX_t} + \frac{1}{2}\sigma^2 X_t^2 \frac{d^2V_t}{dX_t^2}\right] dt + \sigma X_t \frac{dV_t}{dX_t} dW_t, \tag{24}$$

where

$$\sigma_V \equiv \frac{\sigma X_t}{V_t}\frac{dV_t}{dX_t}, \tag{25}$$

is the volatility of the firm value V. When the expected return on the firm is μ_V, and the covariance between the expected return on the firm and the market portfolio (risky assets) is σ_{VM}, by the CAPM, the expected return on the firm is represented by

$$\mu_V = r + (\mu - r)\frac{\sigma_{VM}}{\sigma^2}, \tag{26}$$

where

$$\beta \equiv \frac{\sigma_{VM}}{\sigma^2}, \tag{27}$$

is the beta of the firm. Let ρ_{VM} denote the the coefficient of correlation between the firm and the market portfolio. σ_{VM} can be rewritten as

$$\sigma_{VM} = \rho_{VM}\sigma_V\sigma. \tag{28}$$

Substituting Eqs. (25) and (28)into Eq. (27), the beta of the firm can be rewritten as follows:

$$\beta = \rho_{VM}\frac{X_t}{V_t}\frac{dV_t}{dX_t} \tag{29}$$

Since, as described above, the demand of the state variable and the market portfolio are perfectly correlated, $\rho_{VM} = 1$. Therefore, the beta of firm can be represented as the elasticity of its market value with respect to the demand:

$$\beta = \frac{X_t}{V_t}\frac{dV_t}{dX_t}. \tag{30}$$

By substituting (22) into (30), the beta of the firm, which consider the investment option to increase its production capacity, can be obtained as follows:

$$\beta(x, Q) = \frac{\beta_1 A(Q)x^{\beta_1} + \frac{x}{n\delta}Q^{\frac{\gamma-1}{\gamma}}}{A(Q)x^{\beta_1} + \frac{x}{n\delta}Q^{\frac{\gamma-1}{\gamma}} - \frac{cQ}{nr}}. \tag{31}$$

2.4 Investment, Disinvestment, and Operating Flexibility

In the previous section, the model for analyzing the beta of the firm that has the investment option is presented. In this section, we consider the firm that has not only the investment decision, but also disinvestment decision and operating flexibility.

The value function for firm i taking into account investment and disinvestment decisions, and operating flexibility is given by

$$\begin{aligned} V^i(x, q_0^i, q_0^{-i}; q_t^i, q_t^{-i}) = \sup_{\{\tau_\ell^i, q_{\tau_\ell^i}^i\}_{\ell=1}^{\infty}} \mathbb{E}\Bigg[& \int_0^\infty e^{-rt} \max_{0 \le q_t^i \le \frac{Q_t}{n}} \left\{X_t Q_t^{-1/\gamma} q_t^i - c q_t^i\right\} dt \\ & - \int_0^\infty e^{-rt} I dq_t^i + \int_0^\infty e^{-rt} A dq_t^i, \Bigg] \end{aligned} \tag{32}$$

where A is a salvage value per unit capacity. Likewise the previous section, we consider the marginal value of the symmetric Nash-Cournot equilibrium investment strategy. From Eq. (9) the marginal profit flows is given by

$$\frac{\partial \pi}{\partial q^i}(x,Q) = \begin{cases} 0, & \text{for } x < \hat{X}, \\ \dfrac{n\gamma - 1}{n\gamma} Q^{-\frac{1}{\gamma}} x - c, & \text{for } x > \hat{X}, \end{cases} \tag{33}$$

where $\hat{X} = \frac{n\gamma c Q^{\frac{1}{\gamma}}}{n\gamma - 1}$. In the region where $x < \hat{X}$, the ordinary differential equation, which is satisfied by the marginal value, is derived as follows:

$$\frac{1}{2}\sigma^2 x^2 m_0'' + (r - \delta) x m_0' - r m_0 = 0. \tag{34}$$

The general solutions of Eq. (34) are given as follows:

$$m_0(x,Q) = B_1 x^{\beta_1} + B_2 x^{\beta_2}, \tag{35}$$

B_1 and B_2 are unknown constants. In the region where $x > \hat{X}$, the ordinary differential equation, which is satisfied by the marginal value, is derived as follows:

$$\frac{1}{2}\sigma^2 x^2 m_1'' + (r - \delta) x m_1' - r m_1 + \frac{n\gamma - 1}{n\gamma} Q^{-\frac{1}{\gamma}} x - c = 0 \tag{36}$$

The general solutions of Eq. (36) are given as follows:

$$m_1(X,Q) = B_3 x^{\beta_1} + B_4 x^{\beta_2} + \frac{n\gamma - 1}{n\gamma} \frac{Q^{-\frac{1}{\gamma}}}{\delta} x - \frac{c}{r} \tag{37}$$

B_3 and B_4 are unknown constants. The marginal value must satisfy the following boundary conditions:

$$\begin{aligned} m_1(\overline{X},Q) &= I, && (38) \\ \frac{\partial m_1}{\partial x}(\overline{X}(Q),Q) &= 0, && (39) \\ m_1(\hat{X},Q) &= m_0(\hat{X},Q), && (40) \\ \frac{\partial m_1}{\partial x}\left(\hat{X},Q\right) &= \frac{\partial m_0}{\partial x}\left(\hat{X},Q\right), && (41) \\ m_0(\underline{X},Q) &= A, && (42) \\ \frac{\partial m_0}{\partial x}(\underline{X}(Q),Q) &= 0, && (43) \end{aligned}$$

where $\overline{X}(Q)$ and $\underline{X}(Q)$ is the optimal investment and disinvestment thresholds, respectively. Conditions (38) and (39) are, respectively, the value-matching and smooth-pasting conditions that the marginal value must satisfy when the investment option is exercised. (40) and (41) are boundary conditions in which $m_0(X,Q)$ and $m_1(X,Q)$ should have equal values and derivatives because the function must be continuously differentiable across it. Conditions (42) and (43) are, respectively, the value-matching and smooth-pasting conditions for the disinvestment option. These six equations provide a simultaneous nonlinear equation system, which can be solved for $B_1, B_2, B_3, B_4, \overline{X}$, and $\underline{X}$ by means of a numerical calculation method. From these calculations, the marginal value for each region, and the thresholds for investment and disinvestment can be shown.

Likewise, we derive the value of each firm in equilibrium. In the region where $x < \hat{X}$, the ordinary differential equation, which is satisfied by the firm value, is derived as follows:

$$\frac{1}{2}\sigma^2 x^2 V_0'' + (r-\delta)xV_0' - rV_0 + \left(\frac{c}{n(n\gamma-1)}\right)\left(\frac{n\gamma-1}{n\gamma c}x\right)^{\gamma} = 0 \tag{44}$$

The general solutions of Eq. (44) are given as follows:

$$V_0(x,Q) = C_1(Q)x^{\beta_1} + C_2(Q)x^{\beta_2} + \frac{\left(\frac{c}{n(n\gamma-1)}\right)\left(\frac{n\gamma-1}{n\gamma c}x\right)^{\gamma}}{r-\gamma(r-\delta)-\gamma(\gamma-1)\frac{\sigma^2}{2}}, \tag{45}$$

where C_1 and C_2 are unknown constants. In the region where $x > \hat{X}$, the ordinary differential equation, which is satisfied by the firm value, is derived as follows:

$$\frac{1}{2}\sigma^2 x^2 V_1'' + (r-\delta)xV_1' - rV_1 + \frac{Q^{\frac{\gamma-1}{\gamma}}}{n}x - \frac{cQ}{n} = 0 \tag{46}$$

The general solutions of Eq. (46) are given as follows:

$$V_1(x,Q) = C_3(Q)x^{\beta_1} + C_4(Q)x^{\beta_2} + \frac{Q^{\frac{\gamma-1}{\gamma}}}{n\delta}x - \frac{cQ}{nr}, \tag{47}$$

where C_3 and C_4 are unknown constants. The boundary condition for the firm value is given by

$$\begin{aligned} \frac{\partial V_1}{\partial Q}\left(\overline{X}(Q),Q\right) &= \frac{I}{n}, &(48)\\ V_1(\hat{X},Q) &= V_0(\hat{X},Q), &(49)\\ \frac{\partial V_1}{\partial x}\left(\hat{X},Q\right) &= \frac{\partial V_0}{\partial x}\left(\hat{X},Q\right), &(50)\\ \frac{\partial V_0}{\partial Q}\left(\underline{X}(Q),Q\right) &= \frac{A}{n}. &(51)\end{aligned}$$

We can obtain $C_1(Q), C_2(Q), C_3(Q)$, and $C_4(Q)$ by solving numerically. The beta of firm that has investment and disinvestment options, and operating flexibility can then be obtained as follows:

$$\beta(x,Q) = \begin{cases} \dfrac{x}{V_0(x,Q)}\dfrac{\partial V_0(x,Q)}{\partial x}, & \text{for } \underline{X} \le x < \hat{X}, \\ \dfrac{x}{V_1(x,Q)}\dfrac{\partial V_1(x,Q)}{\partial x}, & \text{for } \hat{X} < x \le \overline{X}. \end{cases} \tag{52}$$

3 Numerical Analysis

In the previous section, we presented a model that enables the analysis of the asset return dynamics of firm with investment and disinvestment options and operating flexibility in competitive market. In the following section, we present the calculation results of asset return dynamics and the effect of competition and uncertainty.

In Tab. 1, the base case parameters, which are used in the following analyses, are shown. These base case parameter values are same values as in Aguerrevere (2009) except the salvage value per unit of output, A, to compare results in each model. Furthermore, likewise Aguerrevere (2009), investment and disinvestment thresholds are independent of the number of firms in the market. Thus the industry capacity Q^m for m of more than two is determined so that for each number of firms investment and disinvestment thresholds are same values.

Table 1: Base case parameters

Volatility of demand shock	σ	0.2
Risk-free rate	r	0.06
Difference in each drift	δ	0.05
Elasticity of demand	γ	1.6
Initial industry capacity	Q^1	100
Investment cost per unit of output	I	1.0
Operating cost	c	0.06
Salvage value per unit of output	A	0.1

In order to compare our approach with that of Aguerrevere (2009) that employs the firm's incremental investment approach as Pindyck (1988) and He and Pindyck (1992), we show the result of a specific case in which the firm has no disinvestment option in Fig. 1. Fig. 1 shows the effect of competition on the beta of the firm that has no disinvestment option for a monopoly, a duopoly, a 5-firms oligopoly, a 10-firms oligopoly, and a 1000-firms oligopoly (perfect competition). Firms in more competitive industries have a higher beta when demand is low, while firms in more concentrated industries have a higher beta when demand is high. Therefore, this results is similar to the result of Aguerrevere (2009) that is derived by a different approach, and is also is consistent with the empirical findings as Hou and Robinson (2006).

Fig. 2 shows the effect of competition on the beta of the firm for each number of firms. It can be seen from Fig. 2 that there are three regions that compose of a region of low demand level in which increase in competition leads to lower risk, a region of middle demand level in which increase in competition leads to higher risk, and a region of high demand level in which increase in competition leads to lower risk. A difference between our model and the model of Aguerrevere (2009) lies in the existence of disinvestment decision. For the region of low demand level, due to disinvestment option, increasing competition leads to reduce risk. This results is

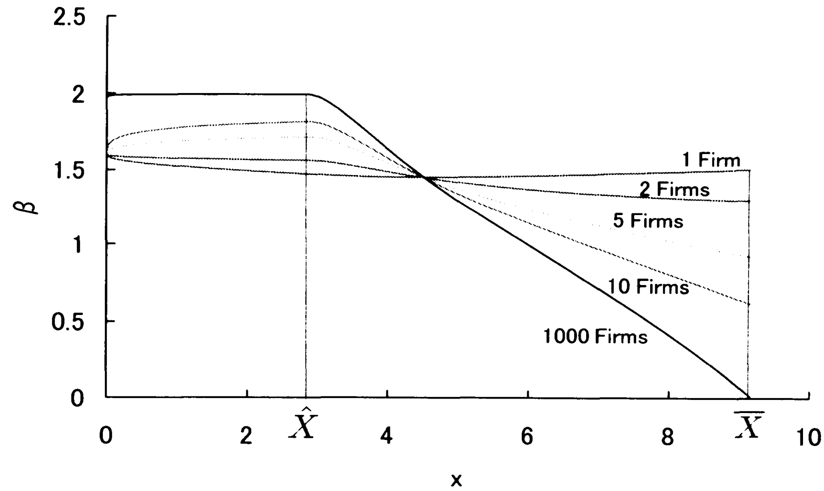

Figure 1: Beta of the firm as a function of demand level for each number of firms. This case is a specific case in which the firm has no disinvestment option.

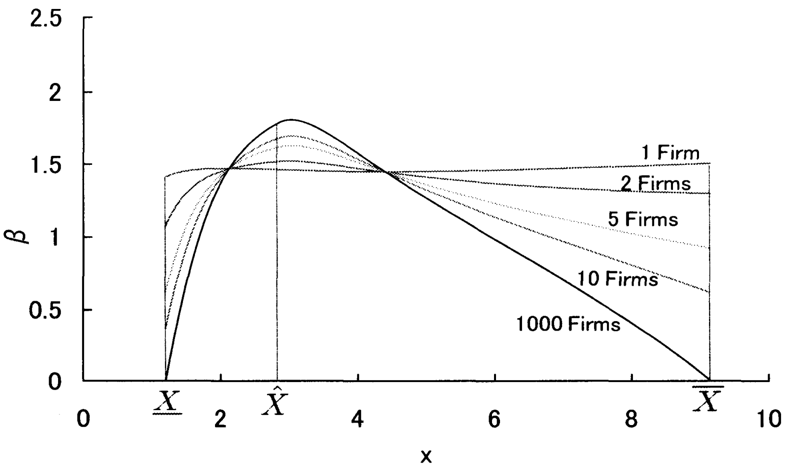

Figure 2: Beta of the firm as a function of demand level for each number of firms. Each firm has investment, disinvestment, operating flexibility.

consistent with that in Carlson et al. (2009) that for both investment and disinvestment the increase in competition leads to risk reduction.

Figs. 3 and 4 show the effect of competition on the beta of the firm for $\sigma = 0.1$ and 0.2, respectively. As the volatility becomes large, the investment threshold increases and the disinvestment threshold decreases. This result is that of standard real options model as McDonald and Siegel (1986) implies that investment and disinvestment decisions are deferred under uncertainty. In addition, as shown in this figure, the region of middle demand level becomes small as uncertainty increases. This is because that the effect of investment and disinvestment options becomes large due to increasing uncertainty.

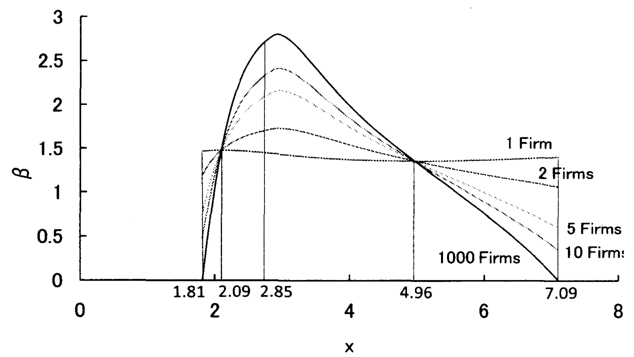

Figure 3: Beta of the firm as a function of demand level for $\sigma = 0.1$.

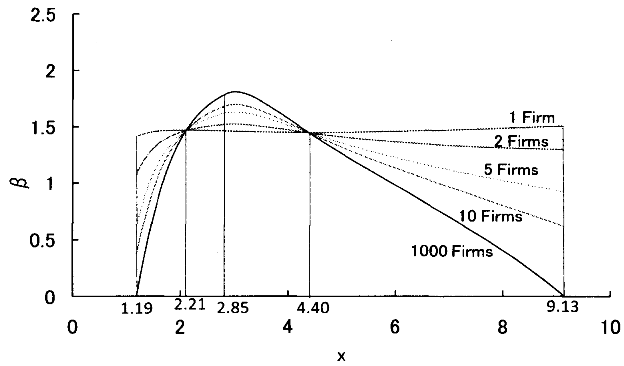

Figure 4: Beta of the firm as a function of demand level for $\sigma = 0.2$.

4 Concluding Remarks

In this paper, we have developed a model to analyze the effect of competition in the market on the relation between firms' decisions such as investment, disinvestment, and capacity change and their asset return dynamics. We note first that although a model used in this study is different from that of Aguerrevere (2009), our results is similar to the result of the previous work. Second, for the relation between firm's beta and demand level, there are a region of low demand level in which increase in competition leads to lower risk, a region of middle demand level in which increase in competition leads to higher risk, and a region of high demand level in which increase in competition leads to lower risk. Finally, since the effect of investment and disinvestment options becomes large due to increasing uncertainty, the region of middle demand level becomes small as uncertainty increases.

The firm's value and asset return would be dependent not only on its investment decisions, but also its financing and capital structure. Therefore, extension of this study towards the asset return of the firm with debt and equity financing would be warranted. Other directions for future work in this area include the setting of competitive market with asymmetric firms, and the inclusion of entry and exit decisions.

References

Aguerrevere, F.L. (2003), "Equilibrium investment strategies and output price behavior: A real-options approach," *Review of Financial Studies*, **16**, 1239–1272.

Aguerrevere, F.L. (2009), "Real options, product market competition, and asset returns," *Journal of Finance*, **64**, 957–983.

Baldursson, F.M. (1998), "Irreversible investment under uncertainty in oligopoly," *Journal of Economic Dynamics & Control*, **22**, 627–644.

Berk, J.B., Green, R.C. and Naik, V. (1999), "Optimal investment, growth options, and security returns," *Journal of Finance*, **54**, 1153–1607.

Carlson, M., Fisher, A. and Giammarino, R. (2004), "Corporate investment and asset price dynamics: Implications for the cross-section of returns," *Journal of Finance*, **59**, 2577–2603.

Carlson, M., Dockner, E., Fisher, A. and Giammarino, R. (2009), "Leaders, followers, and risk dynamics in industry equilibrium," Working paper, University of British Columbia.

Cooper, I. (2006), "Asset pricing implications of non-convex adjustment costs and irreversibility of investment," *Journal of Finance*, **61**, 139–170.

Dixit, A.K. and Pindyck, R.S. (1994), *Investment under Uncertainty*, Princeton University Press, Princeton, NJ.

Gomes, J., Kogan, L. and Zhang, L. (2003), "Equilibrium cross section of returns," *Journal of Political Economy*, **111**, 693–732.

Grenadier, S.R. (2002), "Option exercise games: An application to the equilibrium investment strategies of firms," *Review of Financial Studies*, **15**, 691–721.

He, H. and Pindyck, R.S. (1992), "Investments in flexible production capacity," *Journal of Economic Dynamics & Control*, **16**, 575–599.

Hou, K. and Robinson, D. (2006), "Industry concentration and average stock returns," *Journal of Finance*, **61**, 1927–1956.

Kogan, L. (2004), "Asset prices and real investment," *Journal of Financial Economic*, **73**, 411–431.

McDonald, R. and Siegel, D. (1986), "The value of waiting to invest," *Quarterly Journal of Economics*, **101**, 707–727.

Pindyck, R.S. (1988), "Irreversible investment, capacity choice, and the value of the firm," *American Economic Review*, **79**, 969–985.

Siyahhan, B. (2009), "Efficiency, leverage and exit: The role of information asymmetry in concentrated industries," Working paper, e-FERN.

Takashima, R., Nakada, S. and Ohata, S. (2010), "Reversibility, operating flexibility, and asset returns in oligopoly," in preparation.