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Negative uncertainty sensitivity of investment and market structure

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ABSTRACT

This paper examines how industry competition changes the sensitivity of investment to uncertainty using Japanese firm data. A switching regression model is employed to test the predictions of the real options theory regarding the uncertainty–investment relationship under different industry competition attributes. We find that the negative uncertainty sensitivity of investment is increased by industry concentration, but decreased by market share. The latter finding supports the view of strategic investment behavior of rival firms under uncertainty, rather than the erosion of option values by competition.

1. Introduction

Several studies have examined how uncertainty affects firms' investment decisions using micro data (e.g., Leahy and Whited, 1996; Guiso and Parigi, 1999). Most studies find a negative sensitivity of investment to uncertainty. Theoretically, uncertainty can affect investment in two opposing ways. Hartman (1972) and Abel (1983) argue that higher uncertainty can increase investment if the marginal value of capital is a convex function of uncertainty. On the other hand, McDonald and Siegel (1986) and Dixit and Pindyck (1994) demonstrate that uncertainty can decrease investment based on the real options theory. The early literature on real options analyzes optimal investment for a firm in isolation. Firms' investment decisions under uncertainty can be affected by industry competition. Recent developments include models that allow for strategic interaction between firms. Grenadier (2002) examines the impact of strategic competition on real options. He derives an expression for the option premium to delay investment and shows that the premium is a decreasing function of the number of competitors. Industry competition erodes the value of waiting and increased competition lowers the investment trigger, and thus accelerates investment. Meanwhile, Novy-Marx (2007) analyzes the investment behavior of competitive firms with heterogeneous existing capacity. He shows that competition does not erode the option premium. Focusing on the strategic rivalry between duopoly firms, Kulatilaka and Perotti (1998) examine the investment threshold of a leader firm and show that high volatility may lower the threshold and increase the firm's strategic investment.

A few studies have attempted to test these predictions using micro data. Bulan (2005) examines the effect of industry competition on investment using US firm data. She splits the sample by industry concentration ratios and regresses investment on uncertainty variables. She finds the negative sensitivity of investment to uncertainty only for less competitive firms. Guiso and Parigi (1999) and Drakos and Goulas (2006) use firm-level data and split the sample by firms' market power. They find that the negative uncertainty sensitivity becomes stronger for firms with higher market power.

This paper investigates how industry competition changes the sensitivity of investment to uncertainty, using Japanese firm data. A switching regression model is employed to test predictions of the real options theory regarding a potential role for market structure variables to influence firms' investment decisions under uncertainty. Contrary to previous studies, we find that firms with larger market shares are less cautious to invest.

2. Methodology

We follow Abel and Eberly (1997) and Eberly (1997) in defining an optimal investment that maximizes the value of investment less the cost of investing. The value of investment is expressed as a product of I and marginal q. The value of q is the present value of expected marginal revenue products of capital. If the marginal capital revenue evolves according to a geometric Brownian motion

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with drift g and volatility s, q is an increasing function of s^2 (e.g., Hartman, 1972; Abel, 1983). This property is in accordance with the empirical results of Leahy and Whited (1996), indicating that an increase in uncertainty decreases investment, primarily through its effect on q.

The adjustment cost of investing, for firm i at time t, is expressed by

$$c\left(I_{it}, K_{it}, b_{it}\right) = b_{it} I_{it} + v \frac{\beta}{1+\beta} \left(\frac{I_{it}}{K_{it}}\right)^{\frac{1+\beta}{\beta}} K_{it}, \tag{1}$$

where K_{it} represents the capital stock and b represents linear costs. The optimal investment is given by $I_{it}^{*} = \arg\max[q_{it} I_{it} - c(I_{it}, K_{it}, b_{it})]$. I_{it}^{*} represents a first-best investment under uncertainty, which firms decide in isolation without considering industry competition.

We then test an investment equation of the following log form:

$$\ln \frac{I_{it}^{*}}{K_{it}} = \beta \ln\left[q_{it} - b_{it}\right] - \beta \ln v + \theta_d g_{it} + \theta_v s_{it}, \tag{2}$$

where g_{it} is the expected growth rate of the marginal revenue product of capital and s_{it} the standard deviation of the growth rate. If we follow Abel and Eberly (1997) and the empirical results of Leahy and Whited (1996), $\theta_d = \theta_v = 0$ holds. Theoretical studies such as Grenadier (2002) and Novy-Marx (2007) predict that industry competition changes the sensitivity of investment to uncertainty. If q does not fully capture the competition effect on the uncertainty–investment relationship, θ_d and θ_v can deviate from zero. Thus, we approximate the empirical investment equation by Eq. (2).

Bulan (2005) and other studies split their samples by industry concentration, or by firms' market power, to examine the competition effect. These methods may contain selection issues. Firms with small market shares can behave differently depending on whether they are in concentrated or competitive industries. To mitigate the issues, we employ the switching regression model of Goldfeld and Quandt (1976) to test the predictions of the real options theory regarding the uncertainty–investment relationship under different industry competition. The switching function is defined by

$$z_{ijt} = \gamma_0 + \gamma_1 MS_{it} + \gamma_2 H_{jt} + \epsilon_{it}, \tag{3}$$

where MS_{it} is firm i's market share, H_{jt} is the Herfindahl–Hirschman index, and j indexes industry. We examine how these market structure variables change the degree of the effect of uncertainty on investment (θ_d, θ_v) using a two-regime switching model. We assume that the adjustment cost of investing does not change between regimes. The empirical model to be estimated is given as follows:

$$\ln \frac{I_{it}}{K_{it}} = \begin{cases} \beta \ln\left[q_{it} - \alpha p_{jt}\right] - \delta + \theta_{d1} g_{it} & \\ \quad + \theta_{v1} s_{it} + u_{1it}, & z_{ijt} < 0 \\ \beta \ln\left[q_{it} - \alpha p_{jt}\right] - \delta + \theta_{d2} g_{it} & \\ \quad + \theta_{v2} s_{it} + u_{2it}, & z_{ijt} \geq 0, \end{cases} \tag{4}$$

where estimating the coefficient α allows the acquisition price of capital b_{it}, to be proportional to the measured price p_{jt}. We follow Eberly (1997) to calculate p_{jt}.

The parameters in the investment equations and the switching function are estimated by the maximum likelihood method. We assume that u_{1it}, u_{2it}, and ϵ_{it} are jointly and normally distributed with zero means and covariance matrix $\mathbf{\Omega}$, where

$$\mathbf{\Omega} = \begin{pmatrix} \sigma_1^2 & \sigma_{12} & \rho_1 \sigma_1 \\ \cdot & \sigma_2^2 & \rho_2 \sigma_2 \\ \cdot & \cdot & 1 \end{pmatrix}$$

and σ_ϵ^2 is normalized to unity. ρ_* denotes the correlation between u_{*it} and ϵ_{it}. The likelihood function for each observation is given by

$$\begin{aligned} l_{it} = & \frac{1}{\sigma_1} \phi\left(w_{it}\left(\alpha, \beta, \delta, \theta_{d1}, \theta_{v1}, \sigma_1\right)\right) \\ & \cdot \Phi\left(\frac{-\gamma_0 - \gamma_1 MS_{it} - \gamma_2 H_{jt} - \rho_1 w_{it}\left(\alpha, \beta, \delta, \theta_{d1}, \theta_{v1}, \sigma_1\right)}{\sqrt{1-\rho_1^2}}\right) \\ & + \frac{1}{\sigma_2} \phi\left(w_{it}\left(\alpha, \beta, \delta, \theta_{d2}, \theta_{v2}, \sigma_2\right)\right) \\ & \cdot \left[1 - \Phi\left(\frac{-\gamma_0 - \gamma_1 MS_{it} - \gamma_2 H_{jt} - \rho_2 w_{it}\left(\alpha, \beta, \delta, \theta_{d2}, \theta_{v2}, \sigma_2\right)}{\sqrt{1-\rho_2^2}}\right)\right], \end{aligned}$$

where $\phi(\bullet)$ is the normal density, $\Phi(\bullet)$ is the cumulative distribution function, and $w_{it}(\bullet) = \left(\ln I_{it}/K_{it} - \beta \ln\left[q_{it} - \alpha p_{jt}\right] + \delta - \theta_{d*} g_{it} - \theta_{v*} s_{it}\right)/\sigma_*$.

3. Data

We use Japanese firm data from the Development Bank of Japan's Corporate Financial Databank. We construct our data set of Japanese listed firms in manufacturing industries over the period 1980–2010. The firm-level variables are as follows. I_{it} is installed capital expenditures. K_{it} is beginning-of-period net fixed assets. We proxy q_{it} by the beginning-of-period market-to-book ratio. p_{jt} is the tax-adjusted relative price of capital (see Appendix of Eberly, 1997 for details). We proxy the uncertainty variable by real sales growth (e.g., Comin and Philippon, 2005). g_{it} is calculated as the average growth rate of real sales (deflated by GDP deflator) over the past five years. s_{it} is calculated as the standard deviation of the real sales growth over the past five years.

The market structure variables are constructed at the four-digit industry level. Market share is calculated as $MS_{it} = y_{it}/\sum_{i\in j} y_{it}$, where y_{it} is firm i's sales. The Herfindahl–Hirschman index is calculated as $H_{jt} = \sum_{i\in j} MS_{it}^2$. Beginning-of-period values of market structure variables are used in the estimation of Eq. (3). We consider only positive investment rates in the estimation. Any observations more than five standard deviations away from the means of $\ln I_{it}/K_{it}$, $\ln q_{it}$, and real sales growth are excluded as outliers. The remaining sample consists of 35,891 firm-year observations.

4. Results

The results are summarized in Table 1. Column (1) shows the estimation results of the single investment Eq. (2). Two-digit industry dummies are included in the estimations (not shown in Table 1). The estimated θ_d and θ_v are both significant at the 1% level. Unlike Leahy and Whited (1996), this indicates that an increase in uncertainty is likely to decrease investment other than through its effect on q.

Column (2) reports the switching model estimates. The uncertainty sensitivity of investment changes between the regimes. The real sales growth volatility reduces investment more when firms belong to regime 2. The negative volatility sensitivity of investment in regime 2 (high-sensitivity) is twice larger than that in regime 1 (low-sensitivity). Using $\Delta\theta_d = \theta_{d2} - \theta_{d1}$ and $\Delta\theta_v = \theta_{v2} - \theta_{v1}$ in the estimation, we obtain estimates (standard errors) of −0.128 (0.206) and −1.45 (0.155) for $\Delta\theta_d$ and $\Delta\theta_v$, respectively. The difference between θ_{v1} and θ_{v2} is significant at the 1% level, whereas the difference between θ_{d1} and θ_{d2} is insignificant.

Table 1
Estimation results.

	(1)	(2)
β	0.364*** (0.015)	0.391*** (0.017)
α	0.407*** (0.034)	0.367*** (0.049)
δ	1.76*** (0.023)	1.72*** (0.027)
θ_d	2.62*** (0.078)	
θ_{d1}		2.58*** (0.077)
θ_{d2}		2.45*** (0.173)
θ_v	−1.87*** (0.067)	
θ_{v1}		−1.25*** (0.063)
θ_{v2}		−2.70*** (0.133)
γ_0		−0.657*** (0.030)
γ_1		−2.69*** (0.127)
γ_2		2.22*** (0.132)
σ_1		0.544*** (0.001)
σ_2		1.36*** (0.012)
ρ_1		0.121** (0.060)
ρ_2		−0.038** (0.019)
L.L.	−46 868.9	−44 256.8
Obs.	35 891	35 891

Notes: Standard errors are in parentheses.
** Indicate statistical significance at 5% level.
*** Indicate statistical significance at 1% level.

In the switching function, the coefficient on industry concentration is significantly positive, indicating that higher concentration raises the probability of firms belonging to the high sensitivity regime. Meanwhile, the coefficient on market share is significantly negative, indicating that large share firms are likely to belong to the low sensitivity regime. The estimated effect of industry concentration on choosing the investment regime indicates that firms in more competitive industries have a weaker negative sensitivity of investment to uncertainty. This finding is consistent with Grenadier (2002) which suggests that increases in industry competition erode the option value to delay investment and mitigate the negative effect of uncertainty on investment. On the other hand, the finding that a large market share reduces the negative uncertainty sensitivity of investment suggests the negative relationship between the option value and market share. If firms with large market shares tend to exhibit monopoly behavior, we can expect a positive relationship between the option value and market share. Contrary to the standard interpretation and the previous findings by Guiso and Parigi (1999) and Drakos and Goulas (2006), our results indicate that large share firms have a weaker negative sensitivity of investment to uncertainty. Our finding is rather consistent with Kulatilaka and Perotti (1998), who argue that higher volatility may lead firms with dominant market positions to increase strategic investment.

5. Conclusion

Previous empirical studies, using sample-split methods, support the views that competition erodes the value of waiting and accelerates investment and that the option value of a firm with dominant market power is less reduced by competition. We utilize a switching regression model to examine the sensitivity of investment to uncertainty under different market structure characteristics. By analyzing Japanese firm data, we find that the negative uncertainty sensitivity of investment is increased by industry concentration, but decreased by market share. The latter result supports the view of strategic investment behavior of firms in rivalry under uncertainty, rather than the erosion of option values by competition.

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