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不可回復之投資與風險的關係之實證研究
An Empirical Study of the Relationship between Irreversible Investment and Uncertainty

中文摘要

不確定性與投資決策之關係的文獻，早期在完全競爭市場、固定規模報酬與調整成本對稱等假設下，預測：未來不確定程度的增加將刺激投資。然而近年引起廣泛討論的「實質選擇權」(Real Options)理論則有相反的論述。其基本觀念是當投資成本具有不可回復性並且該投資計畫可延後執行時，廠商可選擇暫緩投資以等待更多資訊幫助正確的決策；該選擇延後決策的價值(option value)會隨風險程度的增加而提高，此隱含不確定性的高低與投資支出具有反向的變動關係。本研究乃提供兩種不同計量程序：二元 GARCH-M 模型與 Granger 因果檢定模型，以檢定不可回復的投資水準與風險高低之間的變動關係，以補充相關實證文獻之不足。結果發現，投資與風險間無一致的變動關係：Granger 因果檢定模型發現風險對投資有正向的落後影響；二元 GARCH-M 模型則提供負向影響的證據，符合實質選擇權的預測，但累計影響仍為正值。唯所有影響均不顯著。

關鍵詞：不可回復之投資，不確定性，二元 GARCH-M 模型，Granger 因果檢定

Abstract

Recent theoretical developments relating to investment under uncertainty have highlighted the importance of irreversibility of investment expenditure. Contrary to the considerable body of theoretical work, empirical investigation directly on the irreversible effect appears to be limited. This study provided much needed empirical evidence to test the underlying theory of irreversible investment. A bivariate GARCH-M approach and Granger causality process were implemented separately. Granger causality tests have found weak evidence that increased profit uncertainty raises fixed investment. The GARCH-M model, however, identified a negative impact between uncertainty and investment, but the cumulative impacts were positive. All the effects were not statistically significant. The empirical results appear not conclude the real option theory.

Key words: irreversible investment, uncertainty, bivariate GARCH-M model, Granger causality tests, empirical analysis

INTRODUCTION

The relationship between uncertainty and investment has been of interest to economists for a long time. The literature on the investment under uncertainty can generally be classified along two dimensions, based on the sign of investment-uncertainty relationship. One claims that under a composite assumption of perfect competition, a constant-returns-to-scale technology, and a symmetric adjustment cost of investment, the marginal value of capital is a convex function of the stochastic variable, which characterizes uncertainty. Simple Jensen's inequality then implies that an increase in uncertainty increases the value of investment and, hence, investment expenditure. This is the familiar positive effect of uncertainty on investment (Cabaliero 1991; Leahy and Whited 1996; Carruth et al. 2000). Harman's study (1972), later extended by Abel (1983), represents the early work.

The other dimension starts with the notion of irreversibility, which has attracted much attention recently. Pioneered by Pindyck's (1991), and Dixit and Pindyck's influential work (1994), the investment opportunity is viewed as an (American) option to invest. The basic intuition is that when investment is irreversible and can be postponed, the option value of waiting for more information to arrive before committing resources becomes an additional cost of current investment. Compared to the net present value approach, the firm will defer the investment when it takes the option value (benefit of waiting) into account. That is, the irreversibility may lead to a postponement of investment decisions. Since this option value increases in uncertainty, there is a negative effect of uncertainty on investment. Clearly, the irreversibility of capital expenditures will be a key determinant of the investment-uncertainty link. Recent theoretical literature includes Dixit (1995), Ostbye (1996), Lee and Shin (2000), Rose (2000), Sarkar (2000), and Doraszelski (2001).

It is worthy of notice, however, that despite the growing theoretical literature on uncertainty and investment, empirical investigation directly on the irreversible effect appears to be limited (exception are Ghosal and Loungani, 1996, 2000; Sing and Patel, 2001). Possible reasons for the contradiction are the difficulty in defining irreversibility and in measuring uncertainty in an empirical context. I therefore believe that there is a room to explore the subject further. This project does not attempt to discriminate between alternative theories of investment, but to provide much needed empirical evidence supporting the underlying theory of irreversible investment.

Different from previous studies, two testing methodologies were considered. First, a bivariate GARCH-in-mean (GARCH-M) model will be specified, which simultaneously estimated the effects of uncertainty on the variables of interests and is generally believed to be efficient in estimation. Second, a univariate-GARCH approach was implemented to capture the uncertainty faced by a firm. Then through the Granger causality test investigated the effects of the uncertainty on the investment. Details of the econometric modeling will be discussed in the following section.

RESEARCH METHODOLOGY

A variety of uncertainty measurement concerning investment behavior has been proposed by various authors. Some econometric applications are discussed in Carruth et al. (2000). Following a number of studies (e.g., Huizinaga 1993; Episopos 1995; Price 1995), a GARCH approach was implemented to estimate the uncertainty in the underlying research. I defined the uncertainty as the conditional variances of the corporate profits (π_t), employed by Ghosal and Loungani (2000). Two testing methodologies are discussed bellowed.

I. Simultaneous Models – A univariate GARCH-in-Mean Model

This section presents an estimate of the conditional variance of corporate profit (π_t) and fixed investment (I_t) using the bivariate GARCH-M estimator. The model, explicitly incorporating variance measures in the equation describing π_t, facilitates estimation and statistical inferences about the effects of variances on the mean value of I_t, is specified as:

$$\pi_t = \gamma + \varepsilon_{1t}, \quad \varepsilon_{1t} \mid \Omega_{t-1} \sim N(0, h_t) \tag{1}$$

$$I_t = \alpha_0 + \alpha_1 I_{t-1} + \alpha_2 I_{t-2} + \textstyle\sum_{i=1}^{3} \beta_i h_{t-i} + \varepsilon_{2t} \tag{2}$$

$$\varepsilon_t \mid \Omega_{t-1} = \left(\begin{matrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{matrix} \middle| \Omega_{t-1} \right) \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, H_t \right) \tag{3}$$

where $N(\cdot)$ denotes a bivariate normal distribution, and

$$H_t = \begin{bmatrix} Var(\varepsilon_{1t} \mid \Omega_{t-1}) & Cov(\varepsilon_{1t}, \varepsilon_{2t} \mid \Omega_{t-1}) \\ Cov(\varepsilon_{1t}, \varepsilon_{2t} \mid \Omega_{t-1}) & Var(\varepsilon_{2t} \mid \Omega_{t-1}) \end{bmatrix} = \begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} \tag{4}$$

or

$$Vech(H_t) = W + \textstyle\sum_{i=1}^{p} A_i \; Vech(\varepsilon_{t-i}\varepsilon'_{t-i}) + \sum_{i=1}^{q} B_i \; Vech(H_{t-i}) \tag{5}$$

$h_{11,t}$ and $h_{22,t}$ denote the conditional variances of corporate profits and the fixed investment, respectively, and $h_{12,t}$ is their conditional covariance. $Vech(\cdot)$ is an operator to stack a given symmetric matrix into a vector. W is a 3 by 1 matrix, and A and B are both 3 by 3 diagonal matrices, all consisting of the parameters being estimated. Equation (5) can also be expressed explicitly as:

$$Vech(H_t) = \begin{bmatrix} h_{11,t} \\ h_{12,t} \\ h_{22,t} \end{bmatrix} = \begin{bmatrix} w_1 \\ w_2 \\ w_3 \end{bmatrix} + \begin{bmatrix} a_1 & 0 & 0 \\ 0 & a_2 & 0 \\ 0 & 0 & a_3 \end{bmatrix} \begin{bmatrix} \varepsilon_{1,t-1}^2 \\ \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}^2 \end{bmatrix}$$

$$+ \begin{bmatrix} b_1 & 0 & 0 \\ 0 & b_2 & 0 \\ 0 & 0 & b_3 \end{bmatrix} \begin{bmatrix} h_{11,t-1} \\ h_{12,t-1} \\ h_{22,t-1} \end{bmatrix}. \tag{6}$$

The likelihood function is

$$L(\theta) = \textstyle\sum_{t=1}^{T} l_t(\theta) = \displaystyle\sum_{t=1}^{T} \left[-\frac{1}{2}\log\left|H_t(\theta)\right| - \frac{1}{2}\varepsilon_t(\theta)'\, H_t^{-1}(\theta)\, \varepsilon_t(\theta) \right] \tag{7}$$

where θ is the set of parameters being estimated and T is the number of observation. The model will be estimated by the maximum-likelihood-estimation (MLE) technique.

Further to avoid the sensitivity by the assumption on the simplified diagonal matrix, we also considered a constant covariance coefficient (ρ) model. That is,

$$h_{11,t} = w_1 + a_1\varepsilon_{1,t-1}^2 + b_1 h_{11,t-1} \tag{8}$$

$$h_{22,t} = w_3 + a_3\varepsilon_{2,t-1}^2 + b_3 h_{22,t-1} \tag{9}$$

$$h_{12,t} = \rho\sqrt{h_{11,t}}\,\sqrt{h_{22,t}}\,. \tag{10}$$

II. Two-Stage Models

The central hypothesis needs to be tested is whether increases in uncertainty imply decreases in irreversible investment. The first step hence is to define the factor of the risky environment and measure its uncertainty, and then construct an investment model to characterize the relationship between uncertainty and investment, based on which to undertake the hypothesis test.

A univariate GARCH model following equation (1) and (8) was first estimated, and from the conditional variance equation constructed a time series in uncertainty through recursive calculation. We proceeded to perform Granger causality tests to examine the directional causal relationships between the fixed investment and the computed conditional variances, $\hat{h}_t$, a proxy for the corporate profit uncertainty. The Granger causality approach is chosen in literature (e.g., Fountas, Karanasos, and Kim, 2002) over the simultaneous-estimation approach since the granger causality approach minimizes the number of estimated parameters. Hsio's (1981) sequential procedure for causality, which combines Akaike's criterion and the definition of Granger causality, is adopted. Consider the models in levels:

$$I_t = \alpha_0 + \sum_{i=1}^{s} \alpha_i I_{t-i} + \sum_{j=1}^{k} \beta_j \pi_{t-j} + u_{x,t} \qquad (11)$$

where I and π are stationary variables. The Granger causality method of testing for the null that π does not cause I is equivalent to test $H_0 : \beta_1 = \ldots = \beta_k = 0$ against H_1 : at least one $\beta_j \neq 0$, using the standard test which has the standard F distribution with (s, T-s-k-1) degree of freedom.

The statistic depends on s and k and various information criteria have been used to choose the optimal value of lag lengths. Hsio's (1981) sequential procedure for causality, which combines Akaike's final prediction error criterion (AIC)[1] and the definition of Granger causality, has discussion for the advantages of using this method over other testing procedures. There are several steps involved in applying the sequential procedure (Silvapulle and Choi 1999).

1. Treat I as a one-dimensional process as in equation (11) with all $\beta_j = 0$ and compute its AIC with s varying from one to L, which is chosen arbitrarily. Choose the s which gives the smallest AIC and let the corresponding AIC denoted as AIC(s,0).
2. Treat I as a controlled variable with s lag length determined in step 1 and π as a manipulated variable as in equation (11). Compute again the AICs of equation (11) by varying the order of lags of π from 1 to L and determine k which give the minimum AIC, denoted as AIC(s,k).
3. Compare AIC(s,0) with AIC(s,k). If the former is greater than the latter, then it can be concluded that π causes I.

ESTIMATION RESTULS

In our empirical analysis we used the fixed private investment and corporate profits[2] for the Unite State documented by the U.S. Department of Commerce, downloadable from the Federal Reserve Bank at St. Louise. The rationale for employing fixed investment as a proxy for irreversible expenses is that it presumably has higher sunk costs whereas for corporate profits is that firm decisions are subjective to the potential profits and therefore the uncertainty of the profits.

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[1] Akaike's final prediction error criterion is defined as:

$$\text{AIC} = T \ln(\text{residual sum of squares}) + 2n$$

where n is the number of parameters estimated; T is the number of usable observations.

[2] The data are net values from with inventory valuation adjustment and capital consumption adjustment.

The data have quarterly frequency and range from 1970:1 till 2003:1. Both are seasonally adjusted. Investment growth and corporate profit growth are quarterly difference of the log of the respective levels. Allowing for differencing implies 132 usable observations. Preliminary diagnostic tests were conducted to check for unit roots and time trends in the variables, using the Augmented Dickey-Fuller tests. Neither fixed investment nor corporate profits exhibited a time trend and both reject the null hypothesis of a unit root.

The estimation results are presented in Table 1. We report the results of Granger causality tests in the fist column to provide some statistical evidence on the nature of the relationship between fixed investment and profit uncertainty. The lag structure of the model was specified following the procedure discussed above. Weak evidence was found that increased uncertainty raises fixed investment, which is against the real option theory. Only 3-period-lagged uncertainty has significant effects under 10% significant levels.

The GARCH-M model was specified with the aid of the likelihood ratio tests. Since our concern is the effect of the variance of profits on the investment, we allowed the lagged terms of the conditional variance to enter the investment equation. Also the lag structure was specified to be consistent with the results of the Granger-causality equation. To avoid the sensitivity of the specification on the conditional variance, diagonal variance-covariance matrix and constant correlation coefficient models were both estimated and reported in the second and third columns, respectively, in table 1. The results are consistent that no significant effect has been found between uncertainty and investment. However, that 1-period-lagged uncertainty has a weakly negative impact on the investment across the models, which concludes the real option theory, while the cumulative effects of the lags, though insignificant, are negative.

CONCLUSION (including self evaluation)

To provide much needed empirical evidence to test the underlying theory of irreversible investment on uncertainty, two testing methodologies were considered. The bivariate GARCH-in-mean (GARCH-M) model, which simultaneously estimated the effects of uncertainty on the fixed investment, found no strong evidence that an increase in uncertainty raises the investment expenses. A weak positive impact of 1-peirod-lagged uncertainty was identified, while the cumulative effects were prevailed. The results are consistent across different setting of the variance-covariance matrix of the bivariate models. Granger causality also concluded that no significant effect between uncertainty and investment.

The study did not follow the proposal we first proposed in the way that instead of dividing the sample industries into groups based on the defined sunk cost proxies and conducting the tests across the groups, we used the macro data thus our sample may include industries with different degrees of price flexibility and that the competitive models with price uncertainty alone imply an ambiguous effect of uncertainty on capital input. The main reason is that the industry data available from the US Annual Survey of Manufacturers and Census of Manufacturers are only annually documented and with limited years. The low frequent data appear not fit the time-series model we specified in the study well. Future study will be suggested to focus on the measurements of the uncertainty with different or more facets, which will be a better approximation to the risky environment firms are encountered when their investment decisions are made.

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TABLE 1 Estimation Results

	Granger Causality	Diagonal GARCH-M	Constant GARCH-M
α_0	-0.2841	-0.3184	-0.2644
	(0.4760)	(0.9916)	(0.9218)
α_1	0.4345*	0.4163*	0.4135*
	(0.0900)	(0.0909)	(0.0900)
α_2	0.1710**	0.2522*	0.2497*
	(0.0912)	(0.0954)	(0.0921)
β_1	0.0054	-0.0219	-0.0216
	(0.0308)	(0.0539)	(0.0525)
β_2	0.0047	0.0047	0.0033
	(0.0308)	(0.0451)	(0.0440)
β_3	0.0530**	0.0801	0.0753
	(0.0291)	(0.1164)	(0.1081)
w_1		8.9941*	9.0453*
		(3.8894)	(3.9719)
w_2		0.1667	
		(0.3636)	
w_3		0.0221	0.0186
		(0.0283)	(0.0257)
a_1		0.0934	0.0946
		(0.1211)	(0.1188)
a_2		0.0256	
		(0.0883)	
a_3		0.0708*	0.0720*
		(0.0354)	(0.0334)
b_1		-0.1308	-0.1375
		(0.3716)	(0.3797)
b_2		0.2331	
		(1.4583)	
b_3		0.8951*	0.9000*
		(0.0534)	(0.0497)
ρ			0.1334
			(0.0880)

Single asterisks denote the coefficient is significant at the 5% significant level.
Double asterisks denote the coefficient is significant at the 10% significant level.
The values in parentheses are standard deviations.