TWIN-RATE UNCERTAINTY, DEBT AND INVESTMENT DECISIONS– EVIDENCE FROM DOW JONES PANEL DATA

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ABSTRACT

This article modifies the intertemporal optimization model proposed by Bo and Sterken (2002) by considering firm debt composition to derive a more suitable physical investment function and evaluates how twin-rate(i.e., interest rate and exchange rate) uncertainty, derived from the issuance of domestic and foreign debts, influences firms' investment decisions. The new model focuses on the effects of financial leverage—the use of debt and its role in the financial structure of a company—on firm decisions under uncertainty. Empirical results reveal that from the viewpoint of market standing, companies in Dow Jones Indexes decrease their investment as uncertainty increases. Moreover, when the foreign interest rates are lower along with lower exchange rate volatility, companies in the Dow Jones Indexes are inclined to increase the issuance of overseas firm debt in order to finance their planned investments.

JEL: G10; G32

KEYWORDS: Twin-rate uncertainty, debt, investment decisions

INTRODUCTION

The relationship between firm investment and uncertainty continues to fascinate economic researchers, because the effects of these uncertainties on firm investment present an impression of chaos and ambiguity. Huizinga (1993) documented that sources of uncertainty are found to be significant factors that influence the sign of the investment-uncertainty relationship. It is apparent that to analyze the investment-uncertainty relationship, we must think more carefully about the source of uncertainty.

A firm's investment decisions can be divided into two types: financial investment and physical investment. For physical investment, many studies have focused on adopting the cash flow model to derive investment functions. Nickell (1978) utilized the intertemporal optimization model to derive a firm's investment function under uncertain cash flows. The benefits of Nickell's dynamic objective function include the fact that it considers the dynamics of cash flow as well as the uncertainty factors inherited in this function. Bo and Sterken (2002) extended the dynamic objective function (i.e., the discounted cash flow function) used by Nickell (1978) to formalize a new investment function to analyze the relationship between interest rate uncertainty and firm investment. However, in deriving the investment function, Bo and Sterken assumed the firm maximizes discounted cash flow, which is affected only by firm debt and interest rate uncertainty. Meanwhile, debt in the model is generally called firm debt and cannot be further divided into sub-debts, which would be useful in judging the investment-uncertainty relationship. Due to the continuing process of internationalization and the prospering development of financial markets, many firms in developed countries utilize foreign capital to finance physical investment at lower costs. For example, by floating overseas debt in Europe (i.e., European Convertible Bonds, ECB), many U.S. firms obtain much less costly capital to finance their investment. In other words, considering only the effects of a firm's domestic debt and interest rate uncertainty on investment is incomplete, especially for firms in developed countries.

The objective of this paper is to modify the structural model of Bo and Sterken and derive a more complete firm investment equation and evaluate the effect of uncertainty and debt on firms' investment decisions. For this, we divide firm debt into non-overseas debt and overseas debt. Since issuing debt overseas involves foreign interest rate uncertainty and exchange rate uncertainty (i.e., twin-rate uncertainty), we must add these two uncertainties and overseas firm debt to the cash flow function to derive the new investment function.

In this study, firms considered in the panel data include U.S. Dow Jones Component Stock (DJCS) companies for the period Q1 1995 to Q2 2007. After the global financial crisis started in Q3 2007, systematic risks and uncertainties in markets became fiercely volatile. Therefore, in order to maintain the stability of sampled data, we have chosen Q1 1995 to Q2 2007 as the sample period for estimation. The empirical results demonstrate that the cross-effects of exchange rate volatility, foreign interest rate, and overseas firm debts on firm investment are positive. Therefore, when the foreign interest rate and the volatility of the exchange rate is low, companies listed in the Dow Jones Indexes are inclined to increase the issuance of overseas firm debt in order to finance their planned investments.

The remainder of this paper is structured as follows. Section II reviews the related literature. Section III sets up a new intertemporal optimization model by considering the issue of overseas firm debt and derives a firm investment function, which depends on firm debt, twin-rate uncertainty and their cross terms. Sections IV and V provide data description and empirical results. Section VI presents the conclusions.

LITERATURE REVIEW

Earlier literature on the investment-uncertainty relationship mainly focused on the presence of symmetric convex costs of adjustment. Hartman (1972) and Abel (1983, 1984 and 1985) found that the mean-preserving spread (MPS) increases in price uncertainty and thereby raises investments of a competitive firm. This indicates a positive investment-uncertainty relationship. However, some studies have considered irreversibility and found that increased uncertainty lowers investment (Pindyck, 1988; Bertola, 1988), thus implying a negative relationship.

Caballero (1991) suggested that the different results are due to the asymmetric nature of adjustment costs. For this reason, Caballero developed a simple model with a cost-of-adjustment mechanism to take into account both symmetric convexity and irreversibility. He found that a combination of different degrees of imperfect competition and asymmetric adjustment costs probably reverses the positive correlation between uncertainty and investment to a negative correlation. Abel et al. (1996) developed a more general options model of irreversibility, including "call" and "put" options. Their empirical results revealed that the symmetric treatment of these two options still leads to ambiguous predictions for the effects of uncertainty on investment.

Recently, Lee and Shin (2000) argued that the "option value" of waiting for new information should be considered as an additional cost of investment. After this consideration, the investment is irreversible and can be postponed by the investors. Since the option value increases in uncertainty, this reveals a negative effect of uncertainty on investment. Lee, Makhija and Paik (2008) also supported the notion that real-options investments provide value under abnormal uncertainty because the effects of uncertainty on firm investment present an impression of ambiguity.

Twin-rate uncertainty indicates an uncertain environment comprising interest rate uncertainty and exchange rate uncertainty. Bo and Sterken (2002) analyzed the joint impact of interest rate volatility and debt on investment. They found the cross-effects of these two variables on investment are positive; this result is more important for highly indebted firms than for less indebted ones.

With respect to the relationship between investment and exchange rate volatility, most studies have focused on the devaluation argument. (Paganetto, 1995; Buffie and Won, 2001; Benavente, Johnson and Morande, 2003; Pratap and Urrutia, 2004). In earlier studies, many discussions were conducted by using data at the industry level. For instance, Campa and Goldberg (1995) used U.S. industry data (two-digit SIC manufacturing sectors) to investigate the linkage between exchange rates and investment, emphasizing the external exposure through both export sales and imported inputs. They found depreciation of the U.S. Dollar is associated with investment contraction rather than expansion. This is probably because industries with low markups (price over cost) cannot absorb a large proportion of the movements in exchange rates. This investment is significantly influenced by the appreciation and depreciation of the U.S. Dollar.

Later studies on investment behavior evolved to emphasize a shift from industry-level considerations to individual firm aspects. Nucci and Pozzolo (2001) used panel data on Italian firms to develop a more precise assessment of how an individual firm's investment responds to specific shocks of currency devaluation. Atella et al. (2003) also argued that exchange rate volatility depresses investment, with sensitivity decreasing among Italian firms with greater market power. Henceforth, in this study we try to use panel data to process blue chip companies in DJCS to prevent probable aggregate biases in industry data and estimate how the individual company's investment responds to the volatility of twin rates.

THEORETICAL FRAMEWORK

Modeling Interest Rate Uncertainty in an Investment Equation

We extend the empirical research on the effects of uncertainty on firm investment. That is, we link the uncertainty factors — interest rate volatility and exchange rate volatility — with firm investment in a structural way. In this section, we first discuss interest rate uncertainty based on Nickell's (1978) dynamic objective function for firms under uncertainty, which takes the form of Eq.(1).

$$\max V_j(0) = \int_0^{\infty} e^{-rt}[E_0(CF_{jt}) - \theta Var(CF_{jt})]d_t \tag{1}$$

where $V(0)$ is the discounted present value of the firm at time $t=0$, E_0 is the expectation value based on the information available at time $t=0$, r is the constant discount rate faced by the firm and is measured in real terms, CF_{jt} is the cash flow generated by firm j at time t, $Var(CF_{jt})$ is the variance of cash flow, which is the measure of the amount of the risk associated with the future income stream, θ is the market price of risk. We assume that θ is positive, which is equivalent to assuming a risk-averse attitude of the owners of the firm. Eq.(1) states that the value of the firm is equal to the expected present value of the future cash flow generated by the firm less the total cost of the risk associated with that particular cash flow.

In order to derive the investment equation, the firm is assumed to maximize Eq.(1), subject to the capital accumulation process Eq.(2), and the cash flow identity Eq.(3). Most studies define cash flow as operating profits minus interest payments, plus the depreciation of capital stock, as shown in Eq.(3).

$$\text{s.t. } K_t = I_t - \delta K_{t-1} \tag{2}$$

$$CF_t \equiv P_t F(K_t, L_t) - \omega_t L_t - P_t A(K_t, I_t) - P_t I_t - i_t B_t(I_t, IW_t) + \delta K_{t-1} \tag{3}$$

where $F(K_t, L_t)$ is the production function; K_t, L_t, and I_t are the capital stock, the labor input, and the gross investment of the firm at time t, respectively; δ is the constant rate of depreciation of capital; and ω_t and P_t are the nominal wage rate and the output price respectively. For the sake of convenient analysis, we assume that the price of capital goods is equal to that of output. $A(K_t, I_t)$ represents the adjusted capital stock. $B_t(I_t, IW_t)$ is the net borrowing of the firm and is a function of the current investment I_t and a vector IW_t, which represents the internal source of investment financing available at time t. Finally, i_t is the interest rate at time t.

Assuming that the firm is operating in competitive markets, then the only source of uncertainty is the interest rate. By using the conventional quadratic adjustment cost function and a linear borrowing function, we can obtain the following investment equation (4).

$$\frac{I_t}{K_t} = \beta_0 + \beta_1 i_t + \beta_2 Var(i_t) \times B_t + \varepsilon_t \tag{4}$$

where ε_t is the error term, the βj $(j = 0,1,2)$ are parameters, and $Var(i_t)$ is the variance of the interest rate at time t.

Eq.(4) provides a theoretical relationship between investment and interest rate volatility. Since we are interested in how the interaction between interest rate uncertainty and debt affects firm investment, the individual effect of interest rate volatility and the individual effect of debt should be isolated from the cross-effect of the two. Therefore, the empirical specification of the investment equation is as shown in Eq.(5).

$$\frac{I_t}{K_t} = f_j + \beta_1 i_t + \beta_2 Var(i_t) \times B_t + \beta_3 Var(i_t) + \beta_4 B_t + \varepsilon_t \tag{5}$$

where f_j are firm effects (or fixed effects, which describe the characteristics of an individual firm); β_3 and β_4 represent the marginal effects of the interest rate volatility and debt on the investment-to-capital ratio; β_2 gives the sensitivity of the investment-to-capital ratio to the joint effect of interest rate volatility and debt. In estimation, B_t is scaled by the capital stock in order to eliminate the size effects.

<u>Modeling Twin-Rate Uncertainty in an Investment Equation</u>

Since the U.S. capital market is more mature and most DJCS companies are financed mainly through direct financing rather than indirect financing, the financing tool may issue overseas firm debts in other countries (such as the U.K.) in order to reduce enterprise costs. Thus, excluding twin-rate uncertainty and the issuance of overseas firm debt seems incomplete. For this reason, on the basis of the dynamic function adopted by Nickell (1978) and revised by Bo and Sterken (2002), we modify the cash flow equation Eq.(3) to Eq.(7) and derive an investment equation as Eq.(9). For the proof and derivation of the modified investment function for modeling twin-rate uncertainty in an investment equation, can be referred to Appendix A of this paper.

According to the derivation processes of the investment model mentioned in Eq.(2) to Eq.(5), we derive an extended investment model to describe the correlation between the volatility of the twin rate and firm investment in Eq.(7).

$$\text{s.t. } K_t = I_t - \delta K_{t-1} \tag{6}$$

$$\begin{aligned} CF_t &\equiv P_t F(K_t, L_t) - \omega_t L_t - P_t A(K_t, I_t) - P_t I_t - i_t B_t(I_t, IW_t) \\ &- \overset{*}{i}_t\, e\, \overset{*}{B}_t(I_t, IW_t) + \delta K_{t-1} \end{aligned} \tag{7}$$

where $\overset{*}{i}_t$ is the foreign interest rate represented by the U.K. bank rate, e indicates the exchange rate of the Pound Sterling in terms of U.S. Dollars, and $\overset{*}{B}_t$ indicates the issuance of overseas firm debts. Therefore, the investment equation Eq.(4) can be rewritten as Eq.(8).

$$\frac{I_t}{K_t} = \beta_0 + \beta_1 i_t + \beta_2 Var(i_t) \times B_t + \beta_3 e_t + \beta_4 \overset{*}{i}_t\, Var(e_t) \times \overset{*}{B}_t + \mu_t \tag{8}$$

where μ_t is the error term; βj $(j = 0,1,2,3,4)$ are parameters; e_t is the exchange rate at time t; $\overset{*}{i}_t\, Var(e_t) \times \overset{*}{B}_t$ represents the cross-effects of foreign interest rate, exchange rate volatility and overseas firm debts. Since we are also interested in the interaction between exchange rate uncertainty in affecting firm investment, the own effect of exchange rate volatility should be isolated from the cross-effect and Eq.(8) can be rewritten as follows.

$$\begin{aligned} \frac{I_t}{K_t} &= f_j + \beta_1 i_t + \beta_2 Var(i_t) \times B_t + \beta_3 Var(i_t) + \beta_4 B_t + \beta_5 e_t \\ &+ \beta_6 \overset{*}{i}_t\, Var(e_t) \times \overset{*}{B}_t + \beta_7 Var(e_t) + \mu_t \end{aligned} \tag{9}$$

DATA AND ESTIMATION

We chose the sample firms for empirical study based on the DJCS, which consists of 30 blue chip stocks in the U.S. capital market. After deletion of incomplete data, 21 companies remained in the sample group. The data were sourced from the COMPUSTAT and AREMOS databases. Table 1 presents the data description and measurement. We determined Q1 1995 to Q2 2007 as the sample period to achieve data stability because the global financial crisis started in Q3 2007. For the estimation, we adopt the Fixed Effects Model to investigate time-series and cross-sectional data. There are 1,050 observations in the DJCS profile. All series are quarterly data, processed in the standardized form.

Measurements of Interest Rate Volatility and Exchange Rate Volatility

We discuss two kinds of interest rates: firm interest rate (to represent the standing of the firm) and market interest rate (to represent the standing of the government). In order to measure their volatilities, we utilize two methods: the 12-month moving-average standard deviation (12MASD), to measure predicted historical data, and the ARMA deviation, to measure the unpredicted variance of the stochastic process. Considering the time dependence of the variance, the GARCH (generalized autoregressive conditional heteroskedasticity) type of volatility is applied (Huizinga, 1993). For the ARMA deviation, the firm interest rate is assumed to follow a first-order autoregressive process (AR(1)). We separately estimate the

AR(1) interest rate for each firm and save the estimated residuals. Then the variance of the residuals is computed as the measure of uncertainty. Table 1 presents data description and measurements for the sample firms. Because the sample firms' data are DJCS specific, we report the empirical results of the Fixed-Effects Model in this paper.

Table 1: Data Description and Measurement

Notation	Measurement	Data Source
$\frac{I}{K}$	Capital Expenditure Divided by Total Fixed Assets	COMPUSTAT
i	(1) The Levels of Firm Interest Rate = Firm Interest Expense Divided by Total Debt	COMPUSTAT
	(2)The Levels of Market Interest Rate = Federal Fund Rate	
B	Total Debt Divided by Total Fixed Assets	COMPUSTAT
	(Total Debt = Total Long-Term Debt Plus Total Current Liabilities)	
$Var(i)$	The Variance of Firm Interest Rate or Market Interest Rate	COMPUSTAT
$Var(i) \times B$	The Cross-Effect of Interest Rate Volatility and Firm Debt	COMPUSTAT
e	The Levels of Exchange Rate (i.e. Pound Sterling per US Dollar)	COMPUSTAT
$Var(e)$	The Variance of Exchange Rate	COMPUSTAT
i^*	Foreign Interest Rate = UK Bank Rate	AREMOS
B^*	Overseas Firm Debt = Assuming a Percentage of the Quantity of Total Firm Debt	COMPUSTAT
$i^* Var(e) \times B^*$	The Cross-Effect of Foreign Interest Rate, Exchange Rate Volatility	COMPUSTAT
	and Overseas Firm Debt	& AREMOS

This table shows the data description and measurements of U.S. DJCS companies. The data are sourced from COMPUSTAT and AREMOS.

EMPIRICAL RESULTS

This paper extends the original model proposed by Nickell (1978) to cover three additional variables—foreign interest rates, exchange rate volatility, and overseas firm debts—and their cross-effect terms to understand the correlations. Empirical results are shown in Tables 2 and 3, and explained as follows:

Both firm interest rate and market interest rate exert significant positive influences on firm investment. In contrast to Bo and Sterken (2002), this paper contends that an increase in the interest rate (either firm rate or market rate) raises firm investment in DJCS. The likely reason is that the financing methods of DJCS companies (U.S. blue chip companies) are based not only on bank loans (indirect financing) but also on the company's internal capital, overseas firm debt, and equity (direct financing). During the empirical period, Q1 1995 to Q2 2007, the U.S. economy was booming, so a large proportion of listed companies increased their capital by issuing overseas firm debts, especially in Europe, in order to decrease financing costs. When domestic interest rates are high, companies will raise finance by issuing overseas debts to reduce costs. This will increase firm investment. Therefore, interest rates are positively correlated with firm investment for DJCS companies.

Table 2: The Correlation between Twin-Rate Uncertainty and Firm Investment

	Firm interest rate		*Market interest rate*	
	Measure 1 (12MASD)	***Measure 2 (ARMA)***	***Measure3 (12MASD)***	***Measure 4 (ARMA)***
$Const.$	0.1369	0.1293	0.1575	0.1756
	(8.2988)***	(7.8724)***	(10.2577)	(10.5511)***
i	0.5360	0.8916	0.0038	0.0055
	(3.2836)***	(5.4789)***	(5.4636)***	(8.5405)***
$Var(i)$	1.4615	2.9477	-0.0076	-0.0201
	(0.6364)**	(1.7349)**	(-0.8936)**	(-1.3905)
$Var(i)\times B$	-1.1508	-4.7326	-0.0124	-0.0174
	(-0.3782)***	(-2.0835)**	(-1.0923)*	(-0.9463)
B	0.0215	0.0560	0.0517	0.0672
	(1.7882)***	(4.9669)	(3.9194)***	(5.8002)
e	-0.0267	-0.0539	-0.0514	-0.0841
	(-3.4928)***	(-7.7305)***	(-6.4196)***	(-11.1723)***
$Var(e)$	-1.5869	-0.7825	-1.0388	-0.3666
	(-13.7790)	(-8.9997)***	(-6.9839)	(-3.6168)***
$i^{*}Var(e)\times B^{*}$	0.2994	0.1986	0.1791	0.1069
	(12.5971)***	(11.3742)***	(5.7186)***	(5.2205)***
$R-squared$	0.7323	0.7480	0.7561	0.7497
$R-squared$				
$F-statistic$	115.0164***	106.3190***	121.4534***	17.3960***
SE	0.0288	0.0297	0.0283	0.0286
DW	0.2151	0.2373	0.2141	0.2342
$Nobs$	1,050	1,050	1,050	1,050

Data Source: COMPUSTAT and AREMOS
This table shows the Fixed-Effects estimation results of the equation:

$$\frac{I_t}{K_t} = f_j + \beta_1 i_t + \beta_2 Var(i_t)\times B_t + \beta_3 Var(i_t) + \beta_4 B_t + \beta_5 e_t + \beta_6 \overset{*}{i_t} Var(e_t)\times \overset{*}{B_t} + \beta_7 Var(e_t) + \mu_t$$

The number of firms in the sample is 21; the sample period is Q1 1995 – Q2 2007.
White heteroskedasticity-consistent t-statistics are shown in parentheses.
12MASD measure: The variance of the predictable part of the interest rate and exchange rate. ARMA measure: The variance of the unpredictable part of the interest rate and exchange rate based on the ARCH (1) model estimation.
**Significant at the 10% level.*
*** Significant at the 5% level.*
**** Significant at the 1% level.*

Debt exhibits a significant positive influence on firm investment. Since most DJCS companies are low-debt firms, the debt-financing cost is lower. Furthermore, the return on investment derived from debt-financing in DJCS companies is higher as compared to other companies. It is, therefore, not necessary for DJCS companies to be concerned about the interest rate burden or the debt-revaluation effect. Based upon the reversible point of view, DJCS companies will increase their investment expenditures in spite of an increase in debt,

Table 3: Fixed Effects for Dow Jones Component Stock Companies with Correlation between Twin-Rate Uncertainty and Firm Investment

Fixed Effects				
Company	**Firm Interest Rate** **Measure 1** **(12MASD)**	**Measure 2** **(ARMA)**	**Market Interest Rate** **Measure 3** **(12MASD)**	**Measure 4** **(ARMA)**
Wal-Mart	0.0270	0.0244	0.0288	0.02828
3M	0.0299	0.0334	0.0244	0.0245
Alcoa	-0.0062	-0.0062	-0.0031	-0.0026
AT&T	0.0216	0.0187	0.0280	0.02824
Boeing	-0.0780	-0.0787	-0.0787	-0.0791
Caterpillar	-0.0673	-0.0746	-0.0589	-0.0595
Coca-Cola	-0.0322	-0.0322	-0.0317	-0.0319
Du Pont	-0.0176	-0.0202	-0.0097	-0.0095
Eastman K.	-0.0077	-0.0060	-0.0084	-0.0085
Exxon	0.0286	0.0320	0.0275	0.0283
Home Depot	0.1211	0.1279	0.1141	0.1147
Honeywell	-0.0441	-0.0454	-0.0403	-0.0400
Intel	0.1695	0.1796	0.1580	0.1584
IBM	-0.0153	-0.0141	-0.0214	-0.0221
Intl Paper	-0.0543	-0.0607	-0.0431	-0.0429
Johnson & J	0.0124	0.0153	0.0094	0.0095
McDonald	0.0065	0.0035	0.0142	0.0147
Merck	-0.0079	-0.0042	-0.0095	-0.0090
Procter & G	-0.0199	-0.0222	-0.0181	-0.0183
Hewlett-Packard	-0.0137	-0.0149	-0.0259	-0.0267
United Tech	0.0556	-0.0581	-0.0552	-0.0561

This table shows the empirical results of the Fixed-Effects model for DJCS.

From the empirical results, we can also see that an increase in interest rate volatility raises firm investment. This also suggests that since the U.S. economy was booming during the sample period, from Q1 1995 to Q2 2007, it might be possible that firms with dissimilar debt patterns responded to the cross-effect differently because the debt-revaluation effect differs between high- and low-debt firms. When low-debt firms such as DJCS companies, face higher interest rate volatility, they will probably respond by investing more in the market.

Since the sample consists of low-debt firms, the cross-effect of debt and interest rate volatility on investment shows a significant negative reaction. The notably negative cross-effect for DJCS suggests that the positive debt effect on firm investment is offset by the negative effect of higher borrowing costs due to highly volatile interest rates for low-debt firms. This leads DJCS (low-debt) firms to cut investment. As regards exchange rate, two measurements show a significant negative influence on firm investment. This result supports the devaluation argument advanced by Atella et al. (2003) that the more the US Dollar depreciates (in other words, foreign currency appreciates), the more investment DJCS firms will undertake.

The volatility of the exchange rate exerts a significant negative influence when the ARMA deviation is used to estimate the investment equation. We can see that at this time the unpredicted part (ARMA measure) is much more significant than the predicted part (12MASD). The likely explanation is that unlike the interest rate variable, which is a domestic financial indicator, the exchange rate variable cannot be decided individually. Usually, volatile exchange rates of the past cannot fully help predict a volatile situation in the future. Meanwhile, the decision-making process concerning exchange rates is more complicated than the mechanism for interest rates. In this paper, we use Pound Sterling corresponding to the U.S. Dollar as the exchange rate to measure volatility because the U.K. is the main European country where U.S. companies issue debt instruments. Also, we can see that not only the U.S. but also the U.K. has a say in determining the exchange rate. Therefore, for the exchange rate, its unpredicted part (ARMA deviation) is much more significant than its predicted part (12MASD).

In addition, the empirical results suggest that exchange rate volatility reduces investment, as noted by Atella et al. (2003) as well. A stable exchange rate is an incentive for firms to increase investment. In other words, to some extent, any economic system may prefer and benefit from a stable exchange rate in terms of firm investment as well as profits.

The cross-effects of the three variables, foreign interest rates (measured by quarterly data of the U.K. bank rate), exchange rate volatility and overseas firm debts, exhibit a significant positive influence on firm investment. In this section, for simplicity, we assume the quantity of overseas firm debt is some proportion of the quantity of total firm debts for each DJCS company. The results show that according to the theory of uncovered interest rate parity, on the assumption that domestic bonds and foreign bonds are imperfect substitutes, when foreign interest rates as well as exchange rate volatility are lower, DJCS companies are more inclined to issue overseas debts in Europe (comparatively lower costs) rather than borrowing capital from U.S. domestic banks or issuing equity (comparatively higher costs). This phenomenon will create an opportunity to issue a greater amount of overseas debts to increase the firm's capital. Therefore, the cross-effects of the three variables—foreign interest rate, exchange rate volatility, and the quantity of overseas debts—will exert a significantly positive effect on firm investment.

CONCLUSION

The contributions of this paper are summarized as follows. First, this paper derives an investment function originally proposed by Nickell (1978) and revised by Bo and Sterken (2002) and extends it to cover three additional variables—foreign interest rate, exchange rate volatility, and overseas firm debts—and their cross-effect term to study the correlations between twin-rate uncertainty and firm investment. Second, in contrast to traditional methodologies, we use Dow Jones Panel Data—a mixed time-series and cross-sectional estimation approach—under a micro-structural framework to explore the investment-uncertainty relationship. Third, in order to estimate the volatility of financial indicators, we use two kinds of methods: 12MASD and ARMA deviation. The evidence shows that most economic agents are inclined to be rationally expectant. Fourth, most results of past studies reviewed, including aggregate and disaggregate studies of the investment-uncertainty relationship (see Carruth et al., 2000), are inclined toward a negative effect. Consistent with the traditional specification, our empirical results on DJCS also exhibit a negative investment-uncertainty relationship from the viewpoint of marketing standing. This shows that in most circumstances, economic agents will be inclined to decrease their investment expenditures with higher uncertainty. Finally, in this paper, we obtain further proof that when foreign interest rates are lower along with lower exchange rate volatility, DJCS firms are inclined to issue overseas firm debts to decrease their financing costs.

This research highlights the effect of financial structure uncertainty on a firm's physical investment. If the firm's debt composition is segmented into domestic and foreign debts, this will introduce volatilities of exchange and interest rates. Empirical evidence indicates that these financial uncertainties have a significant impact on physical investment, which implies more channels in financial markets that influence a firm's physical investment than are proposed in the existing literature.

In sum, the volatilities of financial variables, especially the twin rate, play a major role in a firm's investment decision. Each volatility type exerts a unique influence, including scale, direction and policy implications. No investor or decision maker can neglect the volatility derived from financial markets. As mentioned by Lensink, Bo and Sterken (2000), researchers should rely on more empirical investigations to test the relationship between uncertainty and investment. For more effective results, topics such as the source of uncertainty, the technique used to quantify uncertainty and cross-sectional differences, could be engaged in future studies.

APPENDIX

Appendix A: Proof and Derivation of the Investment Equation for Modeling Twin-Rate Uncertainty

According to the dynamic objective function for the firm under uncertainty of Nickell (1978) which takes form as Eq.(A1).

$$MaxV_j(0) = \int_0^{\infty} e^{-rt}\,[E_0(CF_{jt}) - \theta \mathrm{Var}(CF_{jt})]\,d_t \tag{A1}$$

$$\text{s.t. } \dot{K}_t = I_t - \delta K_{t-1} \tag{A2}$$

$$\begin{aligned} CF_t \equiv\ & p_t F(K_t, L_t) - \omega_t L_t - p_t A(K_t, I_t) - p_t I_t - i_t B_t(I_t, IW_t) - \\ & i_t^* e_t B_t^*(I_t, IW_t) + \delta K_{t-1} \end{aligned} \tag{A3}$$

Inserting (A3) into (A1), that is, inserting the expected value and the variance of cash flow in Eq.(A1) and utilizing Eq.(A2), then we set up the Hamiltonian function for the problem:

$$\begin{aligned} H = \{[& p_t F(K_t, L_t) - w_t L_t - p_t A(K_t, I_t) - p_t I_t - E(i_t) B_t(I_t, IW_t) + \delta K_{t-1} \\ & - \theta Var(i_t) B_t^2(I_t, IW_t)] + \mu(I_t - \delta K_{t-1}) - E(i_t^*)(e_t) B_t^*(I_t, IW_t) \\ & - \theta Var(i_t^*)^2 (e_t)(B_t^*)^2 (I_t, IW_t) + \mu(I_t - \delta K_{t-1})\} e^{-rt} \end{aligned} \tag{A4}$$

where $Var(i_t)$ is the variance of the interest rate. We assume that the adjustment cost function takes the conventional quadratic form given by:

$$A(K_t, I_t) = \alpha_1 I_t + \alpha_2 \frac{I_t^2}{K_t} \tag{A5}$$

where α_1, α_2 are constants and $\alpha_2 > 0$.

We further assume that the net borrowing of the firm is linear in the current period investment. Consequently, the specification of the borrowing function, we have:

$$\frac{\partial B_t(I_t, IW_t)}{\partial I_t} = \lambda \tag{A6}$$

Also let $\frac{\partial i_t^*}{\partial I_t} = \gamma$,where $-1 < \gamma < 0$, B_t^* is some percentage of B_t.

Inserting Eq.(A5) into Eq.(A4). Using Eq.(A6) and utilizing the realizations of the interest rate as a proxy for its expected value $E(i_t) = i_t$, also utilizing the realizations of the exchange rate as a proxy for its expected value $E(e_t) = e_t$, we obtain the first-order condition of the problem:

$$\frac{I_t}{K_t} = \frac{-(1+\alpha_1)+\dfrac{\mu}{p_t}}{2\alpha_2} - \frac{\lambda}{2\alpha_2 p_t} i_t - \frac{\theta\lambda}{\alpha_2 p_t} Var(i_t) \times B_t - \frac{\lambda\gamma}{2\alpha_2 p_t} e_t - \frac{2\theta(\lambda)\gamma}{\alpha_2 p_t}(i_t^*) Var(e_t) \times B_t^* \quad \text{(A7)}$$

Normalizing the price of goods and redefining the parameters, Eq.(A7) becomes:

$$\frac{I_t}{K_t} = \beta_0 + \beta_1 i_t + \beta_2 Var(i_t) \times B_t + \beta_3 e_t + \beta_4 (i_t^*) Var(e_t) \times B_t^* + \varepsilon_t \quad \text{(A8)}$$

where ε_t is error term. β_0 contains both the Q-effect and an intercept. The sign of β_0 is unknown. $\beta_1 < 0$ since $\alpha_2 > 0$ and $\lambda < 0$. $\beta_2 < 0$ since $\alpha_2 > 0$, $\lambda > 0$ and $\theta > 0$. $\beta_3 > 0$ since $\alpha_2 > 0$, $\lambda > 0$ and $\gamma < 0$. $\beta_4 < 0$ since $\alpha_2 > 0$, $\theta > 0$, $\lambda > 0$ and $\gamma < 0$.

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