An Empirical Examination of the Relationship Between Real Options Values and the Rate of Investment

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Paper prepared for presentation at the 1st International European Forum on Innovation and System Dynamics in Food Networks
Officially endorsed by the European Association of Agricultural Economists (EAAE), Innsbruck-Igls, Austria
February 15-17, 2007

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Abstract

This paper examines the relationship between uncertainty and investment decisions by food and non-food firms. Using hysteresis and the real options paradigm, we review why uncertainty might cause firms to delay investment. In particular, our model looks for a negative relationship between capital invested and uncertainty. In the alternative, if the relationship is positive, this may be consistent with the exercise of growth options or competitive markets. Empirical results are mixed. In one of the four models we present there is clear evidence of hysteresis, that is a negative relationship between year over year investment and uncertainty. The remaining 3 models indicate the opposite, a positive relationship between investment and risk. Although the models differ, the first model is the stronger of the three. Nonetheless, the results are ambiguous. Although we use a large cross sectional, time series panel set of data, we find nothing remarkable about the food industry per se, except that across industries, their level of investment is about in the middle.

Introduction

The relationship between risk, profitability and capital investment has until recently been cast in a framework based on the expected utility hypothesis in which an investment is made if its net present value (NPV) is non-negative and the return on equity from the investment is consistent with expected returns to equity for similar risk projects. Until recently, this model has been the mainstay of capital investment under uncertainty in corporate finance text books and by extension adapted to corporate decision making. However, a relatively newer paradigm, based on the concept of real options[1] has been popularized in a number of books including Dixit and Pyndick, Trigeorgis, and Kulatilaka. Real options not only provide an explanation for observed economic behaviour, such as hysteresis (e.g. Dixit and Pyndick), but also provide what is purportedly a new paradigm for making strategic capital decisions under conditions of risk. On the one hand, models of hysteresis argue that it is optimal in some instances for a firm to postpone making positive NPV capital investments if the underlying cash flows are uncertain. Under this proposition, an option to wait would suggest that capital investments under conditions of increasing risk will decrease, but under conditions of increasing returns, will increase[2]. An alternative proposition is that increasing uncertainty can lead to increased investment because

1. A real option is an option on a real rather than financial asset and has the property that it provides management with the right, without obligation, to take some action, or receive some benefit, at a future date

of growth options. Under this theory, firms facing increasing uncertainty in cash flow face an increased probability of a large payoff. By postponing the decision, shareholders do not benefit from increased future earnings, which if realized will increase the value of the investment. The option value arises from investing immediately, with a positive probability of gaining from uncertain growth, or not investing with a zero probability of gaining from growth opportunities. If firms were taking advantage of growth options then empirically, one would expect to observe a positive correlation between increasing capital investment and uncertainty.

The real options propositions contrast with the conventional NPV approach to investment analyses. The competing paradigms now raise significant questions about how investment decisions are actually made by firms. From an academic point of view we care about such questions to ensure that our teaching of investment analyses is consistent with practice, and from a practitioner's point of view determining and understanding the prevalence of one investment paradigm over another has implications for maximizing shareholder value. The purpose of this paper is to examine this issue. In particular, the purpose of this paper is to determine whether there is any empirical evidence to either support or refute the real options paradigm vis a vis the NPV rule. Treating the three possibilities as hypotheses we have:

1) If capital investment decreases with increasing uncertainty, while cash flows either increase or decrease, then this would be consistent with an option to wait.
2) If capital investment increases with increasing uncertainty, then this would be consistent with firms taking advantage of growth options, and
3) If capital investment decreases with increasing uncertainty and increases with cash flow then this would indicate consistency with the expected utility hypothesis.

From an empirical point of view the only conflict occurs with (1) and (3) when cash flows are positive. If uncertainty is increasing and cash flows are positive then an ambiguity would arise that would not permit a distinction between a reduction in investment due to hysteresis under the real options framework, or risk aversion under the expected utility hypothesis.

The outline of the paper is as follows. The next section briefly reviews the relationship between the NPV rule and the real options framework. In order to focus on the more salient issues related to specific hypotheses, mathematical detail is left to the references. The next section introduces methods and data. This is followed by a number of econometric models which are used to test the hypothesis. The paper is then concluded.

The Real Options Approach to Capital Investment

Traditional investment valuation uses the future expected cash flow discounted at a rate that reflects the project's risk to calculate the net present value, V. In contrast, the real option approach can be viewed as a stream of cash flows plus a set of options.

$$(1)\quad V^*(p(T),s,T) = V(p(t),t) + F(p(T),s,T)$$

where V^* is the value of the project; V is the net present value of a project or investment; and F(p(T),s,T) is the real option value. The option value is determined by three components. First,

2. The caveat to the option to wait is that it only applies to oligopolies or monopolists. Under increasing competition, the option to wait evaporates very quickly as posturing for competitive position outweighs the benefits of postponement.

p(T) represents the level of expected (but uncertain) cash flow at some period of time TŠt; second, s represents the underlying (intertemporal) risk of the investment, and third, T represents a moment in time at which it is optimal to invest. Because cash flows evolve randomly over time, the optimum time to invest can be at the initial decision period, t, or some future time period T>t. Consider first, the NPV rule which implicitly assumes that s=0 and T=t. When s=0 and T=t F(p(T),s,T)=0 and V^* = VŠ0. That is, in the absence of uncertainty, there is no option to postpone the investment. Now consider the case where s>0 and T>t. Under these conditions the firm has a positive option to postpone making the investment. The rationale for postponing the investment is that in time, there is a positive probability that uncertainty will be resolved or new information will emerge to reduce ambiguity. Dixit and Pyndick have shown that it may be optimal to postpone an investment until some time period T>t, with expected cash flows p(T) > p(t)[1]. The value of T will generally increase with uncertainty as measured by s. The incremental value to the firm (shareholders) is given by the value of F(), the option to wait. The option to wait also provides a key element of strategy when at time t, V(t)<0; that is the initial project NPV valuation is negative. Rather than dismissing the project in its entirety under the NPV rule, the real options paradigm provides a mechanism to justify keeping a project alive rather than killing it[2].

A growth option has characteristics that differ from the option to wait. In general, a growth opportunity arises from leveraging increased probabilities of gain when volatility increases. The option value is F(p(t),s,t)>0, which states that it is optimal to invest immediately in order to capture future growth opportunities. The value of the growth option increases with increasing s, and can also occur if the NPV, V(t)<0. In contrast to the option to wait, the growth opportunities and high potential for future capital gains signal an immediate investment regardless of fundamental value.

1. The quantitative origins of real options derive from the work of Black and Scholes, and Merton (1973) in pricing financial options. Their solution focuses on factors that change the value of the option over time. The Merton-Black-Scholes breakthrough used a log-normal diffusion process (geometric Brownian motion) to model the stochastic evolution of stock prices. The Black-Scholes model was the beginning of many papers that priced various types of options and empirically tested their predictions. A particular framework characterized the earlier real option models, in which a fixed sunset clause or a specific expiration date was set and the value of the option with such expiry date was calculated. In this framework, also called time domain, time plays a crucial role. In this case options are characterized by a fixed price or value which triggers a project. If the present value of a project exceeds the predetermined trigger at or before the expiration date, than the project or investment will be undertaken. Otherwise it will not. This is the framework developed by Constantinides, and McDonald and Siegel.

2. The focus of a more recent literature on real options moved from considering options in the time domain to evaluating options in the value domain; that is, in contrast to traditional options that provide a right without obligation at or before some future date, a real options framework in the value domain does not revolve around a specific time frame. Projects can be postponed until certain economic conditions are reached, no matter when. In this case the trigger condition may or may not arise at some unknown time in the future rather than at a fixed future date. The trigger condition is not a fixed value as in the time dependent model but rather an economic condition that causes a project acceptance or rejection to be triggered. This is the basic framework of Dixit and Pindyck. When real options are defined in the time domain, a model framework similar to Balck and Scholes has been suggested (see Constantinides and McDonald and Siegal).

Empirical Studies in Real Options

Despite the economic importance of real options there is a dearth of studies that actually attempt to measure whether the options paradigm is real, or whether it is economically significant. Ferderer (1993) investigates whether increased uncertainty increases or decreases aggregate investment spending, and how the explanatory power of uncertainty explain aggregate investment relative to other financial measures such as the cost of capital or Tobin's q. Part of his concern was findings by Hartman (1972) and Abel (1983, 1984, and 1985) that showed that increased price uncertainty lead competitive risk-neutral firms to increase investment, perhaps due to the marginal revenue product of capital being convex in price. Ferderer finds that there is a negative and significant correlation between uncertainty and durable equipment expenditures and orders for new plant and equipment, and that the risk premium (measured by forward looking bond spreads) has a larger impact on investment than either the cost of capital or Tobin's q. His results appear to confirm, at least at the aggregate level, the significance between investment and uncertainty. Bulan (2001) examines the relationship between firm expenditures and risk for a panel of 2,467 U.S. firms and finds evidence of real options to delay investment. Increased firm specific risk delays investment because of option value and not simply a tradeoff between risk and return. He also finds a greater delay in investment when industry wide uncertainty increases.

Quigg (1993) examined the option value of urban land and found that there was a 6% option premium above the lands intrinsic value which she attributed to a waiting option to develop land. Cunningham (2004) also provides evidence for Seattle Washington that if land prices become more uncertain, development declines and land price increases. Plantinga, Lubowski and Stavins (2002) provide evidence that options values associated with irreversible and uncertain land development are capitalized into farmland prices (a result which supports conjectures by Cappozza and Sick 1994) and Turvey (2003) suggests that options derived from future, but uncertain growth in agricultural cash flow, can explain the agricultural land price puzzle in which farmland, even in low growth districts with limited development options, tend to transact for a price higher than fundamental value.

Harchaoui and Lasserre (2001) investigate whether or not real options can explain capacity investment behavior in Canadian copper mines and estimate econometrically the magnitude and timing of irreversible investments. Their analysis supports the real option framework which, they remark, is an improvement over traditional NPV approaches based on output price and cost of capital that have a relatively poor record of explaining observed investment behavior. Moel and Tufano investigate some of the propositions in Brennan and Schwartz's (1985) model of closing and reopening mines. Their empirical results based upon observations from 285 gold mines in the U.S. largely confirm the Brennan-Schwartz model. For example, mines with high fixed costs or high reserves tended to stay open longer under conditions of market risk, and increases in gold price volatility is positively correlated with an open mine remaining open, and a closed mine remaining closed. They conclude that recent paradigms based on managerial flexibility driven by real options are a material corporate event. They further show that managerial flexibility is also affected by portfolio driven spillover effects. Diversified mining companies for example are less likely to shut a mine down, versus a single-mine firm, all other things being equal.

But not all research indicates that real options are either understood or create value. Howell and Jägle (1997) provide laboratory evidence that shows that managers' Intuition regarding options values is not very precise, and that the value of real options can be significantly over or underestimated.

An Empirical Analysis of Investment Under Uncertainty

The objective of this paper is to estimate empirically, for a group of food industry firms and a control group outside of the food industry, the relationship between capital investment and uncertainty. In a manner similar to Bulan (2001), this objective is intended to examine the null hypothesis that uncertainty is unrelated with the investment policy. Rejection will support the hypothesis of the presence of economic hysteresis. Furthermore, this paper aims at showing that the industry structure influences, in the presence of uncertainty, the rate of capital invested. With different industries characterized by different structures, uncertainty will be translated into investment in a different way for the different industries.

The data used in the analysis are from the 2004 Stern Stewart Performance Russell 3000. After deleting missing value we obtained a sample that runs from 1985 to 2003 and contains 2685 firms. Twenty-three industries are represented in the sample: Energy, Materials, Capital Goods, Commercial Services and Suppliers, Transportation, Autos & Components, Consumer Durables and Apparel, Hotels, Restaurants and Leisure, Media, Retailing, Food and Staples Retailing, Food, Beverage and Tobacco, Household and Personal Products, Health and Equipment & Services, Pharmaceuticals and Biotechnology, Banks, Diversified Financials, Insurance, Software & Services, Technology, Hardware and Equipment, Semiconductors & Semiconductor Equipment, Telecommunication Services, and Utilities.

To measure investments we use the *operating capital*, the amount of investment employed in operations. In our analysis we look at the capital invested by each firm, each year. The difference between the operating capital at time t and operating capital at time t minus 1 is used as a proxy for the invested capital in year t ($K_t - K_{t-1}=I_t$). In the following analysis we examine the yearly invested capital in $ terms as well as the annual investment rate (I_t/ K_{t-1}) and at the annual percentage changes in investments (I_t/ I_{t-1}).

Measuring uncertainty is a more difficult task, since uncertainty can take many forms. Moreover, uncertainty concerns not what actually happens but what might occur and managers may view the future differently. For example some managers may view future risk in terms of recent variability in operating income, while others may take a longer term view. We cannot address this question specifically except to run a variety of possibilities and make a determination as to whether the results are materially different in consequence and statistic. We obtain a general measure of uncertainty from the standard deviation of the firms' yearly *Net Operating Profit After-Tax (NOPAT)*. Net Operating Profits After-Tax is an operating income, which has been cleaned of the results of financial (e.g., the financing component of operating leases) and accounting distortions. For our purpose, the NOPAT is an acceptable proxy for what in the theory presented before has been called cash flow. Also, we run the model introducing uncertainty and expected profits in different ways.

Results

We proceed first by discussing the correlations between the base variables and then the estimation of regression equations. Correlations reveal that higher levels of profitability tend to be weakly correlated with higher levels of investments with a Pearson correlation coefficient of 0.313. Nevertheless, there is a significant negative correlation between the annual variation in NOPAT ($NOPAT_{t-1}$-$NOPAT_{t-2}$) and annual variation in capital investments ($I_t - I_{t-1}$). This suggests that even though higher profitability is associated with higher investments, wider increases in profitability are less important than small increases in stimulating investments. But, when considering percentage annual changes in profitability and investments, no statistical significant correlation can be found (.003). We find a positive, but weak, association between investments and standard deviation of the profitability. The capital invested at time t was also compared with the standard deviation of the NOPAT calculated with the values of the NOPAT at time t-1 back to time t-9. The 11,905 observations show a weak association between the two variables. To investigate the relationship between NOPAT, risk, and investments we ran several different regression models, four of which are discussed below. Collectively however, the correlation results do not suggest a strong behavioural response as might be expected from mean-variance analysis or expected utility. If utility played a significant roll one would expect much stronger negative correlations between profitability and risk and investment and risk. This we do not see, suggesting that the investment strategy is guided by a different economic influence, which we conjecture is the influence of real options.

The first regression (a) is a non-linear regression that examines the relationship between changes in NOPAT ($) and risk ($) on the change in investments ($). The rationale behind this model is to investigate, under the null, whether the adjustment relationship is based on a simple one-year change in expectations. The regression is developed as follows with the D variables representing industry and time dummy variables.

(a)

$$\alpha_I = \beta_1 + \beta_2\alpha_N + \beta_3\sigma_N + \beta_4\sigma_N\sigma_N + \beta_5\alpha_N\sigma_N + \beta_6 D_1 + \ldots + \beta_{29}D_{23} + \beta_{30}T_{2003} + \ldots + \beta_{40}T_{1994} + \varepsilon$$

where $\alpha_I = E(I_t - I_{t-1})$ represents the drift parameter of the variable "investments," $\alpha_N = E(NOPAT_t - NOPAT_{t-1})$ represents the growth parameter of the variable NOPAT, $\sigma_N = \sqrt{E\left[(NOPAT_t - NOPAT_{t-1}) - \left(E(NOPAT_t - NOPAT_{t-1})\right)\right]^2}$ represents the variance parameter for the NOPAT, $D_1 + \ldots + D_{23}$ are dummy variables for different industries, and $T_{2003} + \ldots + T_{1994}$ are dummy variables for the year.

The second regression model (b) investigates whether or not there is a relationship between current year's investment and a weighted average (0.4, 0.3, 0.2, 0.2) of NOPAT. In contrast to model (a), this model examines the level of investments committed against a weighted average measure of NOPAT:

(b)

$$- \beta_2 \overline{X}_{NOPAT,t-1} + \beta_3\sigma_{NOPAT,t-1} + \beta_4\sigma_{NOPAT,t-1}\sigma_{NOPAT,t-1} + \beta_5\overline{X}_{NOPAT,t-1}\cdot\sigma_{NOPAT,t-1} + \beta_6 D_1 + \ldots + \beta_{29}D_{23} + \beta_{30}T_{2003} + \ldots + \beta_{46}T_{1988} + \upsilon$$

where I_t represents the capital investments committed in year t, $\overline{X}_{NOPAT,t-1}$ is a weighted average of the most recent years net operating profits (from year t-1 backwards), $\sigma_{NOPAT,t-1}$ represents the variability of the net operating profits, $\sigma_{NOPAT,t-1}\sigma_{NOPAT,t-1}$ represents the square of variability of the net operating profits, $\overline{X}_{NOPAT,t-1}\cdot\sigma_{NOPAT,t-1}$ represents the interaction between the previous two variables, $D_1+...+D_{23}$ and $T_{2003}+...+T_{1988}$ are respectively the dummy variables for different industries and time. Regression models (a) and (b) consider changes in the variables of interest between two following years expressed in absolute terms. Regression model (c) considers instead percentage changes.

The third regression model relates the percentage change in investment to the percentage change in NOPAT and the percentage change in the standard deviation. In regression (c) the year over year percentage change in investments is regressed against the year over year percentage change in NOPAT and standard deviation. In (c) the inference is that changes in investment are highly related to most recent changes in NOPAT. The regression (c) is as follows:

(c) $$\alpha_{I\%} = \beta_1 + \beta_2\alpha_{N\%} + \beta_3\sigma_{N\%} + \beta_4\sigma_{N\%}\sigma_{N\%} + \beta_5\alpha_{N\%}\sigma_{N\%} + \beta_6 D_1 + ... + \beta_{26}D_{23} + \varepsilon$$

where $\alpha_{I\%} = E\left[\left(\frac{I_t - I_{t-1}}{I_{t-1}}\right)\right]$ represents the expected value of the percentage changes of investments, $\alpha_{N\%} = E\left[\left(\frac{NOPAT_t - NOPAT_{t-1}}{NOPAT_{t-1}}\right)\right]$ represent the expected percentage change of the NOPAT, and $\sigma_N = \sqrt{E\left[\left(\frac{NOPAT_t - NOPAT_{t-1}}{NOPAT_{t-1}}\right) - \left(E\left(\frac{NOPAT_t - NOPAT_{t-1}}{NOPAT_{t-1}}\right)\right)\right]^2}$ represents the standard deviation of the percentage changes in the NOPAT .

The fourth regression is a naive approach, in which investment is regressed against lagged NOPAT. The inferences are that investment is heavily influenced by NOPAT in the previous year and that there is a lag between the profit and risk signals and the time that investment is made.

(d)

$$I_t = \beta_1 + \beta_2 NOPAT_{t-1} + \beta_3\sigma_{NOPAT,t-1} + \beta_4\sigma_{NOPAT,t-1}\sigma_{NOPAT,t-1} + \beta_5 NOPAT_{t-1}\cdot\sigma_{NOPAT,t-1} + \beta_6 D_1 + ... + \beta_{29}D_{23} + \beta_{30}T_{2003} + ... + \beta_{48}T_{1986} + \varsigma$$

where I_t is the capital investment in time t, $NOPAT_{t-1}$ represents the NOPAT lagged one period, and $\sigma_{NOPATt-1}$ represents the standard deviation of the NOPAT.

In all regressions, D_1 to D_{23} represent dummy variables for the twenty-three industries in the database. Dummy variables are defined as follows: D_i = {1 if the observation belongs to industry i_{th}, or 0 otherwise}. Utilities is used as control group. The time dummy variables are defined as follows: T_i = {1 if the observation belongs to year i_{th}, 0 otherwise}. We exclude the dummy for year 2003, which is used as the control.

Regression results are summarized in Table 1. As indicated previously, if hysteresis exists there will be a negative relationship between the risk variable and the level of investment. If investment increases with NOPAT and decreases with risk, then this would signify correspondence with the expected utility hypothesis, but there is no way to empirically distinguish between option values and risk aversion in this case. As discussed above the weak correlations between the variables may be indicating that the expected utility model is not as strong as perhaps the influence of real options. If, however, there is a positive relationship between risk and investment, regardless of the sign on NOPAT, then this could signify one of two alternatives. First, as variance increases, probabilities are dispersed from the centre of the probability distribution to its tails, which means that there exists an increasing probability of higher future cash flows. This possibility is more consistent with a growth option rather than the option to postpone, which has been the main focus of the discussions and theoretical development. In the alternative, Dixit and Pindyck also argue that in the presence of increased competition the options to postpone rapidly evaporate. Firms invest to protect turf and market share even in the presence of increased risk. A finding of no relationship between risk and investment would also support this argument. The main findings are found in Table 1.

Table 1. OLS estimates for models (a), (b), (c) and (d)

	Model (a)	Model (b)	Model (c)	Model (d)
Dependent Variable	I	I_t	I%	I_t
$_1$ (Constant)	13.618	6.480	-0.029	-2.162
	(155.488)	(81.436)	(.055)	(91.417)
$_2$ (Growth)	7.599	.373	$2.506*10^{-3}$	.670
	(.235)	(.034)	$(3.036*10^{-4})$	(.047)
$_3$ (Standard Dev.)	-2.642	1.645	$1.065*10^{-3}$	2.011
	(.358)	(.109)	$(2.954*10^{-4})$	(.207)
$_4$ (Variance Sq.)	$2.811*10^{-4}$	$-2.161*10^{-4}$	$-2.994*10^{-7}$	$-5.162*10^{-4}$
	$(1.373*10^{-4})$	$(1.670*10^{-5})$	$(1.197*10^{-7})$	$(5.348*10^{-5})$
$_5$ (Interaction)	$-1.237*10^{-3}$	$2.596*10^{-4}$	$-8.350*10^{-7}$	$-5.038*10^{-5}$
	$(1.131*10^{-4})$	$(1.131*10^{-5})$	$(1.190*10^{-7})$	$(1.953*10^{-5})$
Adjusted R^2	.137	.128	.076	.053
D.W.	2.820	2.026	1.958	1.994
N. Observations	11922	26510	21169	23827

*0.05 level of confidence

In regression model (a), $_2$, which refers to the expected growth of the profits, is positive. For an increase in one \$ of $_N$, invested capital increases by \$7.599 thousand. $_3$, which refers to the volatility of the profits, is negative suggesting that an increase in profit's uncertainty is related to a decrease in investments, while $_4$ is positive indicating that an increase in the square of profit's uncertainty is related to an increase in investments. The interaction variable between and is significant, and the sign is negative. Theory predicts that . In model $\frac{\partial \alpha_I}{\partial \sigma_N} < 0$ (a) the total variation of $_I$ with respect to $_N$, is equal to:

$$\frac{\partial \alpha_I}{\partial \sigma_N} = \beta_3 + \beta_4 \sigma_N + \beta_5 \alpha_N = -2.642 + 2.811 * 10^{-4} \sigma_N - 1.237 * 10^{-4} \alpha_N$$

Therefore, $\frac{\partial \alpha_I}{\partial \sigma_N}$ using average $_N$ and σ_N in the sample \$20.851 thousand and \$89.936 thousand, respectively, we find uncertainty and investments show a negative relationship. This is indicative of an hysteresis effect. According to the real options paradigm, the greater the uncertainty the smaller will be the level of investment as investment will be delayed. In other words, we interepret the observation that investment with increasing risk as being the same as a slower turnover in capital in the presence of risk due to postponement. With a Chi Squared-statistic equal to 1,919.01, we reject the null hypothesis that all estimated parameters are equal to zero at a 0.05 level of confidence. The t-test on individual coefficients shows the significance of particular coefficients (standard errors are in brackets in table 1). The joint significance of the following sets of regression coefficients were tested with a Wald test under the following null hypotheses:

a. H_0: $_2$=$_5$=0, H_1= at least one of them is nonzero,

b. H_0: $_3$=$_4$=$_5$=0, H_1= at least one of them is nonzero,

c. H_0: $_6$ to $_{26}$ =0, H_1= at least one of them is nonzero.

The restricted models corresponding to these hypotheses are respectively:

$$\alpha_I = \beta_1 + \beta_3 \sigma_N + \beta_6 D_1 + ... + \beta_{29} D_{23} + \nu$$

$$\alpha_I = \beta_1 + \beta_2 \alpha_N + \beta_6 D_1 + ... + \beta_{29} D_{23} + \gamma$$

$$\alpha_I = \beta_1 + \beta_2 \alpha_N + \beta_3 \sigma_N + \beta_4 \sigma_N \sigma_N + \beta_5 \alpha_N \sigma_N + \tau$$

A Wald test gives an F value equal to 935.04 for (a). The critical F value for 2 degrees of freedom in the numerator and 11886 in the denominator is about 3. Therefore we reject the null hypotheses (a). The Wald test gives an F value equal to 505.42 for (b). The critical F value for 3 degrees of freedom in the numerator and 11,886 in the denominator is about 2.6. Thus we reject the null hypotheses (b). The F value for (c) is equal to 0.43. The critical F value for 22 degrees of freedom in the numerator and 11,886 in the denominator is about 1.57. Therefore, we do not reject the null hypothesis (c) that the coefficients for the industry-specific variables are equal to zero. In other words, under this particular model, there is no significant difference in the relationship between risk and investment across industry types. Of course, the result could be due to common macroeconomic factors captured by the time dummy variables; however there is no significant difference in the relationship between risk and investment across time (F value 0.65).

From a qualitative point of view, regression (b) gives results that differ from regression (a). In regression (b), the coefficients for the expected profits' growth (measured as a percentage change in investment rather than the change in the \$ value of investments in model a) and its standard deviation are positive. The interaction variable is positive and significant while the coefficient on the variance term is significantly negative. Furthermore, we can reject the null hypothesis that all estimated parameters are equal to zero at a 0.05 level of confidence.

Theory predicts that $\frac{\partial I_t}{\partial \sigma_{NOPAT,t-1}} < 0$. In model (b) the total variation of I_t with respect to $_{NOPAT,t-1}$ is equal to:

$$\frac{\partial I_t}{\partial \sigma_{NOPAT,t-1}} = \beta_3 + \beta_4 \sigma_{NOPAT,t-1} + \beta_5 \overline{X}_{NOPAT,t-1} = 1.645 + -2.161*10^{-4}\ \sigma_{NOPAT,t-1} + 2.596*10^{-4}\,\overline{X}_{NOPAT,t-1}$$

Using the sample means for uncertainty and profitability, uncertainty and investments show unambiguously a positive relationship. As with model (a) we conducted alternative hypotheses testing using restricted least squares and the Wald test. Results showed that collectively and individually the independent and dummy variables explained the variance in investment. We also find Autos & Components firms, Banks, and Insurance firms tend to invest less than the Food, Beverages and Tobacco Firms; while Energy, Materials, Commercial Services and Suppliers, Consumers Durables and Apparels firms invest almost the same as Food, Beverages and Tobacco Firms, and Telecommunication services and Media firms tend to invest more. In addition to these results, the positive coefficients on all the time dummies, except for the dummy on 2002, suggest that levels of investment were, on average, higher than the 2003 base year. The coefficients are highest in absolute terms for the years 1997 to 2001, which is consistent with the boom that occurred in the late 1990's.

We reran regression model (b) using alternative definitions of uncertainty and expected profits' growth as presented before. When uncertainty is measured by the variability of NOPAT using the data from year t-1 back to year t-9, and the average NOPAT is weighted as in the previous regression, the coefficient for the standard deviation of the NOPAT was positive but statistically not significant at the 0.05 level of significance. This confirms that when looking at uncertainty, a shorter horizon back in the past better fits the research intent. When the expected profits are measured using either the simple average of the NOPAT in the last four years, t-1 to t-4, or the weighted average, $0.8*NOPAT_{t-1}+0.2*NOPAT_{t-2}$, or even the simple $NOPAT_{t-1}$ (model (d)), while the variance of the NOPAT is calculated considering the four most recent years, regression coefficients have the same sign and similar magnitude of those coefficients found running the first version of regression (b). Qualitatively, therefore we can conclude that, no matter how we define the variables in regression model (b), the data suggests a positive relationship between uncertainty and investments as well as between expected NOPAT and investments. This is a puzzling results. In model (a) using levels (i.e. $) we find evidence of hysteresis, but when the same data is converted to a measure of percentage change the results suggest a growth option. There is no rational explanation as to why a waiting option and a growth option can occur simultaneously when in theory they should be mutually exclusive.

Both models (c) and (d) also show a positive relationship between uncertainty and investments and a positive relationship between expected NOPAT and investments. Thus, in model (c) percentage changes from year to year provide insight into the relationship between uncertainty and investments. Chow tests indicate that firms in the food industry (Food, Beverages & Tobacco and Food & Staples) differ from firms in non-food sectors, such as Pharmaceuticals & Biotechnology, Financial (consisting of Banks, Diversified Financials, and Insurance) and Information Technology (consisting of Software & Services, Technology, Hardware & Equipment, and Semiconductors & Semiconductor Equipment). While the estimated coefficients for the food firms are significantly different from the estimated coefficients of the other sectors, the signs are the same. Thus, indicating that food firms tend to use investment strategies similar to those of other firms.

Conclusions

This paper sought to determine whether there is any empirical evidence of hysteresis in the capital investments of a group of food and non-food industries. The question was motivated by the emerging theory of real options. Under that theory it is argued that an increase in uncertainty may cause some firms to postpone capital investments until some later date in which uncertainty was reduced.
To examine the theory we obtained a large panel data set from the consulting firm Stern Stewart, covering the Fortune 3000 companies from the years 1985 through 2003. From this data we extracted data from 2685 firms covering 23 industries. We used regression analysis to test the hysteresis assumption. In general we would have been satisfied with a form of hysteresis if changes in capital investment were negatively related to cash flow uncertainty (measured by proxy as the net operating income after taxes). However, our approach can only be considered consistent with a hysteresis proposition since the behavioural characteristics cannot be distinguished from a classical attribute of risk aversion. In the alternative, if it was found that investment increased with uncertainty, this would provide evidence of growth options. Growth options emerge as the probability of a higher payoff increases with variance. However, even with such a finding in hand we have to be careful because it is entirely possible that such seemingly risk-loving behaviour can be the result of competition. That is, even if risk is increasing, firms still have to invest in order to remain competitive. Unfortunately, several theoretical constructs intersect in a rather ambiguous way that we can only use the term ‘consistent with’ rather than a more definitive statement.

Our results, which should be considered preliminary and as a work-in-progress, indicate that there is a significant relationship between risk and investment. What is meant by ‘significant’ is open to interpretation and model specificity. In one model, which simply regresses change in investment on change in NOPAT (model a) suggests an option to wait. That is with an increase in risk, investment is postponed. The remaining models suggest a longer term view and indicate that investment is related to growth opportunities caused by spikes in NOPAT (i.e. higher variance). Although preliminary, a rise in risk does not indicate an option to wait or hysteresis as a matter of course, but does suggest that in the short run hysteresis may exist but this can quickly be reversed if growth opportunities arise. In other words, investment decisions may be more dynamic, temperamental, and transitory than has previously been considered. Perhaps more important, should these results bear out to greater scrutiny, is the observation that growth options and waiting options are not mutually exclusive. They can coexist across investment strategies.

Finally, our original intent and focus was on the food industry. However in the analyses we found nothing unique about food firms that would cause us to believe that in matters of investment, food firms are distinguishable in strategy from other firms in other sectors.

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