An Empirical Examination of the Relationship Between Real Options Values and the Rate of Investment in the Food and Life Science Industries

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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. An important aspect of this paper is the development of a general economic model that imposes demand and supply shocks on the supply and demand functions, and thus allows for the derivation of a Brownian motion for prices that is a function of supply and demand elasticities, and the drifts, volatilities, and intensities of the shock variables. We show why hysteresis responses across industries with different elasticities should differ. Empirical results confirm that such differences occur. Perhaps most important, is that we find no evidence of hysteresis. In fact we find a positive relationship between changes in investment and uncertainty in profits over time. 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.

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Introduction

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. The concept of real options has been popularized in a number of books including Dixit and Pyndick, Trigeorgis, and Kulatilaka. The significance of these books is that they 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 a capital investment if the underlying cash flows are uncertain. It could be optimal to postpone the investment until uncertainty is resolved or ambiguity about future events is resolved. By postponing these investments it is argued that the expected net present value of the investment will be higher and as a result, shareholder value will increase. Under this proposition, the option to wait would suggest empirically that capital investments under conditions of increasing risk will decrease, but under conditions of increasing returns will increase. 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.

An alternative proposition is that increasing uncertainty can lead to increased investment. Under this theory, firms facing increasing uncertainty in cashflow 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.

These propositions contrast with the conventional approach to investment analyses. Under the conventional approach, an investment with a negative NPV will not be considered while an investment with a positive NPV will undergo further evaluation. Under the expected utility hypothesis a decrease in cash flows or an increase in uncertainty will lead to a decrease in the rate of investment, while an increase in cashflow and/or a decrease in uncertainty will lead to increased investment.

The forgoing raises the possibility of statistically testing for the two option types, or in the alternative the standard results of the expected utility hypotheses. Treating the three possibilities as hypotheses we have:

1) If capital investment decreases with increasing uncertainty, while cashflows either increase or decrease, then this would be consistent with hysteresis and the 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 cashflows are positive. If cashflows are positive then an ambiguity would arise that would not

permit a distinction between a reduction in investment due to hysteresis or risk aversion under the expected utility hypothesis.

The application of option concepts to capital investment analysis is relatively new. The real option approach provides a framework of how investments can be managed to address concerns caused by uncertainty and risk. However, it is still not clear as to whether businesses actually behave in a way that would maximize the options, or whether on a firm-by-firm basis there exists any relationship between uncertainty and investments. 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. From a theoretical point of view, the paper develops an equilibrium model that collapses key industry variables such as supply and demand shocks, and supply and demand elasticities into a single price diffusion. The goal of developing this model is to ultimately describe random price processes as a function of the industry parameters. It is through this mechanism that we illustrate why different firms in different industries should behave differently when it comes to the relationship between investment and uncertainty.

The theoretical development is developed in the next section. This is followed by an empirical assessment using panel data from the Stern-Stewart Company. The last section discusses the results.

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. The net present value is defined as the sum of all cash flows generated by a project, with each cash flow discounted back to the present. The discount rate used is the firm's risk-adjusted after-tax cost of capital. In contrast, the real option approach can be viewed as a stream of cash flows plus a set of options.

$$V* = V + F(\pi)$$

where $V*$ = value of the project; V = net present value of a project or investment; and $F(\pi)$ = option value. When a firm decides to commit resources in an irreversible project, it exercises its option to invest, by giving up the possibility of waiting for new information to arrive. This lost option can be considered as an opportunity cost that has to be included in the cost of the project. If the value of the opportunity cost is large relatively to the net present value of the project, the neoclassical investment rule that ignores it can be greatly in error.

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.

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, in a real options framework projects do not have 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 Black and Scholes has been suggested (see Constantinides and McDonald and Siegal)

To give a value to a simple option based on the value of the underlying risky asset Dixit and Pindyck developed a model using a continuous-time stochastic process of the value of the underlying asset or on the cash flow of the underlying risky asset that evolves as a random walk according to the following geometric Brownian motion with drift:

(1) $$d\pi = \mu \pi \, dt + \sigma \pi \, dZ$$

In (1), π is the state variable of interest (e.g. project cash flow), μ is the natural growth rate in π, or the drift parameter, σ is the standard deviation of the percentage change in π, and $dZ=\epsilon_t(dt)^{1/2}$ is an ordinary Wiener process where ϵ_t is a serially uncorrelated and normally distributed random variable with a mean of zero and a standard deviation of one. Since ϵ_t has zero mean and unit standard deviation, the expected value of dZ is equal to zero and its variance is equal to dt. In other words, the fact that dZ depends on $(dt)^{1/2}$ and not on dt implies that the variance of dZ grows linearly with the time horizon. It is also implicitly understood that a geometric Brownian motion, assumes that percentage change in the state variable, π, is normally distributed and that absolute changes in π are lognormally distributed.

Since most projects are not traded, an appropriate solution to the problem uses a dynamic programming approach. The objective function describing the option value can simply reflect the decision maker's subjective valuation of risk. This restriction has been overcome with Cox, Ingersoll, and Ross's (1985, Lemma 4) recognition that the value of real options can be determined utilizing an equilibrium model that adjusts the project return for the market price of risk. Using the Cox, Ingersoll, and Ross' Lemma 4, the stochastic process describing the value of the underlying can be written as follows.

(2) $$d\pi = (\mu - \lambda \sigma) \pi \, dt + \sigma \pi \, dZ$$

According to the equilibrium model that adjusts the project returns for the market price of risk, μ is the natural growth rate in π, λ is the market price of risk, and σ is the standard deviation of the percentage change in π. The term $\lambda\sigma$ is the market risk premium and the term $(\mu-\lambda\sigma)$ is equivalent to the Cox and Ross risk neutral measure. The market price of risk represents the reduction in the natural rate of return required to compensate investors for accepting non-diversifiable risk. For convenience, $\alpha = (\mu-\lambda\sigma)$ and

(3) $$d\pi = \alpha \pi \, dt + \sigma \pi \, dZ$$

In their model, Dixit and Pindyck added three boundary conditions to find the solution for the stochastic differential equation describing the value of the option.

These conditions are:

(4) $F(0) = 0$
(5) $F(\pi^*) = V(\pi^*)-I$

(6) $F'(\pi^*) = V'(\pi^*)$.

Where π^* corresponds to a certain level of the variable which triggers investment. $V(\pi)$ is the capitalized value of the current earnings stream; $V(\pi^*)$ is the present value of the investment at which it is optimal to invest; I represents the sunk or investment cost. $F(\pi^*)$ is the intrinsic value of the option at π^*.

Condition (4) says that if π is zero the option will be zero. It is an implication of the stochastic process described by (1). This condition is called the fixed lower boundary condition on the option's value. The other two conditions come from consideration of optimal investment. Condition (5) is the value matching condition. It says that, upon investing, when π reaches π^*, the firm receives a net payoff $V(\pi^*) - I$ which is equal to the option value. Condition (6) is the smooth pasting condition[1]. It says that the optimal time to exercise the option occurs for a certain level of π^* such that the incremental gain in options value exactly equals the incremental gain in net present value or option payoff. The smooth pasting condition ensures that at some point the option value and the options payoff curve will meet and become tangent.

Using the technique in Dixit or Pindyck the value of the option $F(\pi)$, and the optimal level of cash flow to proceed with investment (π^*), is given by

(7a) $$F(\pi^*) = \frac{\pi^*}{(r-\alpha)\cdot\beta_1}$$

or,

(7b) $$F(\pi^*) = \frac{I}{\beta_1 - 1}$$

(8) $$\beta_1 = \frac{1}{2}\,\frac{\sigma^2 - 2\,\alpha + \sqrt{4\,\alpha^2 - 4\,\alpha\,\sigma^2 + \sigma^4 + 8\,r\,\sigma^2}}{\sigma^2}$$

(9) $$\pi^* = \left[\frac{\beta_1}{\beta_1 - 1}\right]\cdot I\cdot(r-\alpha)$$

Uncertainty and Equilibrium

To investigate the investment strategy of agribusiness firms, we pursue an equilibrium modeling approach similar to that developed by Marcus and Modest (1986), and Turvey and Stokes (2002). The premise of the simple model developed is that the equations describing the

[1] Note that equation (3) is a second-order differential equation, but three boundary conditions have been set for its solutions. The reason is that although the position of the first boundary condition is known, the position of the second boundary is not. The so-called free boundary $V(\pi)$ must be determined as part of the solution. That requires the third condition.

economic variables determining random price and profit movements can be characterized as stochastic differential equations.

In this model the market is depicted as a simple stochastic supply and demand system with demand (10) and supply (11) equations as a function of the selling price (P), demand and supply elasticities ($-\varepsilon$) and (γ), and shock variables (s^{η}) and (h^{ϕ}) where the exponents η and ϕ are referred to as shock intensities. The good is assumed to be normal in that demand for it declines when the market price rises. We further assume constant elasticity functional forms.

The basic model structure is provided by

(10) $$Q_d = a\, s^{\eta}\, P^{(-\varepsilon)}$$

(11) $$Q_s = b\, h^{\phi}\, P^{\gamma}$$

The selling price, determined by the interaction between demand and supply, represents the primary source of uncertainty. Price uncertainty is due to both demand and supply uncertainty. Demand uncertainty is determined by the price elasticity of consumer demand and by the shock variable (s^{η}). The stock variable allows for shifts of the demand function, due, for example, to changes in consumer preferences or changes of competitive goods prices. Supply uncertainty is determined by the structure of the production cost. The cost of production depends upon a number of factors, including the available technologies and the price of the inputs (labor, capital, land, energy) that the firm needs. The shock variable (h^{ϕ}) allows for shifts of the supply curve, due to changes in the structure of the production cost or to other exogenous factors like, for example, the weather. In particular, it is assumed that h and s evolve over time according to;

(12) $$dh = \mu_h\, h\, dt + \sigma_h\, h\, dz_h$$

(13) $$ds = \mu_s\, s\, dt + \sigma_s\, s\, dz_s$$

The shock variables are represented as power functions of the underlying stochastic processes. The reason for structuring the model this way is allowing for the fact that different products can have different sensitivities towards economic shocks. It is assumed that the supply and the demand shock variables follow uncorrelated stochastic processes ($dz_h\, dz_s = 0$).

Equation (14) represents the equilibrium price, obtained by equalizing the demand and supply equations.

(14) $$P = \left(\frac{a\, s^{\eta}}{b\, h^{\phi}} \right)^{\left(\frac{1}{\gamma + \varepsilon} \right)}$$

From (14) we seek to determine the diffusion process of the equilibrium price over time given ds and dh in (11) and (12). In other words, we seek a process for the equilibrium price that follows the stochastic differential equation in (15). For simplicity we omit the subscript *e* indicating the equilibrium.

(15) $$dP = \nu_P\, P\, dt + \sigma_P\, P\, dz_P$$

As a result, the natural rate of growth ν_p in equilibrium price and the volatility σ_p of price are functions of the underlying market structure. Applying Ito's lemma to equation (15) provides the following results for the drift (16) and diffusion (17) of the equilibrium price.

$$(16) \qquad \nu_P = \frac{1}{2}\frac{(2\,\mu_s - \sigma_s^{\,2})\,\eta + (\sigma_h^{\,2} - 2\,\mu_h)\,\phi}{\gamma + \varepsilon} + \frac{\frac{1}{2}(\eta^2\,\sigma_s^{\,2} + \phi^2\,\sigma_h^{\,2})}{(\gamma + \varepsilon)^2}$$

$$(17) \qquad \sigma_p = \sqrt{\frac{\eta^2\,\sigma_s^{\,2} + \phi^2\,\sigma_h^{\,2}}{(\gamma + \varepsilon)^2}}$$

The drift of the equilibrium price is a function of the drift terms of the supply and demand shock variables (μ_s) and (μ_h), as well as the shock sensitivities (ϕ and η), the volatilities of the shock variables ($\sigma_h^{\,2}$ and $\sigma_s^{\,2}$), and demand and supply elasticities (γ and ε).

Price volatility is a function of the shock sensitivities (ϕ and η), volatilities ($\sigma_h^{\,2}$ and $\sigma_s^{\,2}$), and the supply and demand elasticities (γ and ε). The drift parameters are not argument in the measure of volatility. Equations (16) and (17) provide the requisite insight into how market structure affects price uncertainty.

Using the same approach we consider how market structure influences and affects randomness in the profit of the firms. The firm's operating profit (before fixed cost), indicated by π, has been calculated multiplying quantity demanded and price in equilibrium, and then subtracting the total variable cost (TVC). In this simple structure π is a proxy for the firm's operating cash flow.

$$(18) \qquad \pi = P_e Q_e - TVC$$

The total variable cost, calculated as the area below the supply curve, from the origin to the equilibrium point, is given by

$$(19) \qquad TVC = \int_0^{Q_e} \left(\frac{Q}{bh^{\Phi}}\right)^{\frac{1}{\gamma}} dQ = \left(\frac{\gamma}{1+\gamma}\right)\cdot\left(bh^{\Phi} P_e^{(\gamma+1)}\right)$$

Substituting (11) and (19) into the right hand side of equation (18) and rearranging gives the following equation, representing operating cash flows.

$$(20) \qquad \pi = \frac{b\,h^{\phi}\,P^{(1+\gamma)}}{1+\gamma}$$

We assume that the cash flow is subject to a stochastic process as follows. The stochastic process described below is a geometric Brownian motion with drift.

$$(21) \qquad d\pi = \mu^{*}\pi\,dt + \sigma^{*}\pi\,dz$$

The natural diffusion of π is economically dependent on the cash flow natural growth rate (μ*), and the cash flow variance (σ*); the task henceforth is to develop appropriate expressions of μ* and σ* that reflect the market structure of the different industries.
Applying Ito's Lemma to the cash flow function (18) gives

$$(22) \qquad d\,\pi = b\,h^{\phi}\,P^{\gamma}\,dP + \frac{1}{2}\,b\,h^{\phi}\,P^{(\gamma-1)}\,\gamma\,dP^2$$

Substituting the stochastic differential equation for the equilibrium price into (22), utilizing the fact that $(dt)^2$ equals zero, $(dz_P)^2$=dt, and dt*dz_P=0, gives

$$(23) \qquad d\,\pi = b\,h^{\phi}\,P^{(1+\gamma)}\,\sigma_P\,dz_P + \left(\frac{1}{2}\,b\,h^{\phi}\,P^{(1+\gamma)}\,\gamma\,\sigma_P^{\;2} + b\,h^{\phi}\,P^{(1+\gamma)}\,\nu_P\right)dt$$

Comparing equation (23) with the desired stochastic process of equation (21), and simplifying provides the following results for the drift and diffusion of the firm's cash flow.

$$(24) \qquad \mu^* \frac{1}{2}\,(\gamma\,\sigma_P^{\;2} + 2\,\nu_P)\,(1+\gamma)$$

$$(25) \qquad \sigma^* = \sigma_P\,(1+\gamma)$$

The natural growth rate of cash flow is a function of both the natural rate of growth ν_p and volatility σ_p of the equilibrium price, which in turn are functions of the variables describing the underlying market structure. The volatility of cash flow is a function of the volatility of the equilibrium price, which in turn is a function of the shock sensitivities, volatilities, and the supply and demand elasticities. The focal point is represented by equations (24) and (25), which are the parameters determining the cash flow dynamics. Comparative statics allow a comprehensive examination of how the parameters describing the cash flow dynamics are affected by changes in the structural variables inherent in the developed model. This examination provides insight into how market structure affects the firm's cash flow dynamics.
In particular, we are interested in investigating how the elasticity of the demand curve affects the growth rate and the variability of cash flow. Equation (26) shows how the growth rate (μ*) changes with regards to the elasticity of the demand curve.

$$(26) \quad \frac{\partial \mu^*}{\partial \varepsilon} = \left(-\frac{\gamma\,(\eta^2\,\sigma_s^{\;2} + \phi^2\,\sigma_h^{\;2})}{(\gamma+\varepsilon)^3} + \frac{\frac{1}{2}\,(2\,\mu_s - \sigma_s^{\;2})\,\eta + (\sigma_h^{\;2} - 2\,\mu_h)\,\phi}{(\gamma+\varepsilon)^2} - \frac{2\,\nu_P}{\gamma+\varepsilon} \right)(1+\gamma)$$

In general, the sign of the previous expression is ambiguous; however we can partition the range over which this effect is positive or negative. *Where expression (26) is positive,* ν_p *is positive (see expression 16), therefore* $\frac{\partial \mu^*}{\partial \varepsilon}$ *is unambiguously negative*. In other words, where expression (26) is positive, an increase in the demand elasticity decreases the cash flow growth rate. This is especially true when the demand volatility is high with respect to the supply volatility. *In contrast*, *when the supply volatility is high relative to the demand volatility, the expression*

$\frac{1}{2}(2\,\mu_s - \sigma_s^{\,2})\,\eta + \frac{1}{2}(\sigma_h^{\,2} - 2\,\mu_h)\,\phi$ *tends to be negative. When this expression is negative,* $\frac{\partial \mu^*}{\partial \varepsilon}$ *is positive if (27) is satisfied.*

$$(27) \qquad 2\,\frac{(\eta^2\,\sigma_s^{\,2} + \phi^2\,\sigma_h^{\,2})\,(1+\gamma)}{\gamma+\varepsilon} < (2\,\mu_s - \sigma_s^{\,2})\,\eta + (\sigma_h^{\,2} - 2\,\mu_h)\,\phi$$

Equation (28) shows how the variability of cash flow is influenced by the elasticity of the demand curve. Substituting σ_p in equation (24) and deriving it with respect to ε gives equation (28). *It shows unambiguously that an increase in the elasticity of the demand curve is associated with a reduction in the volatility of cash flow and therefore in risk.*

$$(28) \qquad \frac{\partial \sigma^*}{\partial \varepsilon} = -\frac{(1+\gamma)\sqrt{\eta^2\,\sigma_s^{\,2} + \phi^2\,\sigma_h^{\,2}}}{(\gamma+\varepsilon)^2} \le 0$$

We now investigate how the elasticity of the supply curve affects the growth rate and the variability of cash flow.

$$(29) \qquad \frac{\partial \mu^*}{\partial \gamma} = \nu_P\left(1 + \frac{1+\gamma}{\gamma+\varepsilon}\right) + \frac{1}{2}\,\sigma_P^{\,2}\left(1 + \frac{\gamma}{(\gamma+\varepsilon)^2\,(1+\gamma)}\right)$$

Expression (29) is positive when ν_p is positive. That is, when the price diffusion is non-negative, an increase in the supply elasticity increases the growth rate of firm cash flow.

$$(30) \qquad \frac{\partial \sigma^*}{\partial \gamma} = \frac{\sqrt{\eta^2\,\sigma_s^{\,2} + \phi^2\,\sigma_h^{\,2}}\,(-1+\varepsilon)}{(\gamma+\varepsilon)^2}$$

Equation (30) shows that the first derivative of the volatility of cash flow with respect to the elasticity of the supply curve, γ , is unambiguously negative when the elasticity of the demand curve is <1. *In other words, when the demand curve is inelastic, an increase in the supply curve elasticity decreases the volatility of cash flow and therefore risk. When the demand curve is elastic, an increase in the supply curve elasticity increases uncertainty and therefore risk.*

Having determined the characteristics of the underlying cash flows, we can now use option-pricing theory to value how the structural variables inherent in the developed model influence investment decisions. The real options model shows that the option value, $F(\pi*)$, depends upon both the growth rate and the variability of the firm's cash flow. In particular, $F(\pi*)$ tends to increases when the natural growth of the cash flow and/or its volatility increases. In fact, an increase in the natural growth rate of cash flow decreases $\pi*$, but increases the option value. When the natural growth increases, investments take place sooner than later. On the other hand, an increase in σ, increases $\pi*$ as well as the option value, and, that favors delaying investing. The increasing option value can be seen as an increase in the optimal waiting time to investment. *It becomes clearly evident that market structure, affecting both growth and volatility of cash flows,*

impacts also the option value to invest, and therefore the pace at which investment decisions are taken. For example, Equation (28) shows that a higher demand elasticity tends to be associated with a smaller volatility; therefore, all other things being equal, the results suggest a *working hypothesis that firms operating from an elastic demand basis are more likely, or able, to make investment decisions at a faster pace, or with less delay, than firms facing a much more inelastic demand curve*. Furthermore, Equation (30) shows that higher supply elasticities tend to be associated with a lower risk when the demand curve is inelastic. This conclusion suggests a *working hypothesis that firms facing an elastic supply and an inelastic demand will tend to invest at a faster pace than firms with either an inelastic supply, or an elastic supply and a more elastic demand*. On the contrary, when the demand curve is elastic, an increase in the elasticity of the supply curve tends to be associated with an increase in volatility and risk; investments will take place at a slower pace.

An Empirical Analysis of Investment Under Uncertainty

The second 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. 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, the aim is to show 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 theory as stated predicts that industries that face higher average demand elasticities will invest at a fast rate than industries with lower demand elasticity. We do not have the capability to estimate the demand and supply elasticities as presented in the simplified model structure above, since most firms are multiproduct firms. Rather, we take the economics as given, and assume that the elasticities and intensities affect firms in industry groups in different ways, with the differences implicitly expressed through their specific, but unidentified, elasticities and intensities. We examine the null hypothesis that the industry structure does not have any influence on the rate of investment. Rejection will support the model developed.

The data used in the analysis are from the 2001 Stern and Stewart Performance 1000. After deleting missing value we obtained a sample that runs from 1982 to 2000 and contains 410 firms. Nineteen industries are represented in the sample: Energy, Materials, Capital Goods, Commercial Services and Suppliers, Transportation, Autos and Components, Consumer Durables and Apparel, Hotels, Restaurants and Leisure, Media, Retailing, Food and Drug Retailing, Food, Beverage and Tobacco, Household and Personal Products, Health and Equipment and Services, Pharmaceuticals and Biotechnology, Software and Services, Technology, Hardware and 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. We obtain a general measure of uncertainty faced by firms 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 0.292. 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 (.002).

We find a positive, but weak, association (correlation coefficient equal to 0.177) 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 3690 observations show a very 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.

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) $$\alpha_I = \beta_1 + \beta_2\alpha_N + \beta_3\sigma_N + \beta_4\alpha_N\sigma_N + \beta_5 D_1 + \ldots + \beta_{22} D_{19} + \varepsilon$$

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, $\sigma_N = \sqrt{E\left[\left(NOPAT_t - NOPAT_{t-1}\right) - \left(E\left(NOPAT_t - NOPAT_{t-1}\right)\right)\right]^2}$ represents the variance parameter for the NOPAT, and $D_1 + \ldots + D_{19}$ are dummy variables for different industries.

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

(b) $$I_t = \beta_1 + \beta_2 \overline{X}_{NOPAT,t-1} + \beta_3\sigma_{NOPAT,t-1} + \beta_4 \overline{X}_{NOPAT,t-1} \cdot \sigma_{NOPAT,t-1} + \beta_5 D_1 + \ldots + \beta_{22} D_{19} + \beta_{23} T_{1998} + \ldots + \beta_{36} T_{1985} + \upsilon$$

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 , $\overline{X}_{NOPAT,t-1} \cdot \sigma_{NOPAT,t-1}$ represents the interaction between the

previous two variables, $D_1 + ... + D_{19}$ and $T_{1998} + ... + T_{1985}$ 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) and (d) consider instead percentage changes.

The third regression model examines the levels of investment in terms of percentages. The regression relates the percentage change in investment to the percentage change in NOPAT and the percentage change in the standard deviation. The difference between regressions (c) and (d) is that in (c) the year over year percentage change in investments is regressed against the year over year percentage change in NOPAT and standard deviation, whereas (d) regresses the percentage change in NOPAT and standard deviation lagged one period. In (c) the inference is that changes in investment are highly related to most recent changes in NOPAT, whereas in regression (d) the inference is that changes in investment are more heavily influenced by changes in previous years. In this latter case the inference is that there is a lag between the profit and risk signals and the time that investment is made. The regressions (c) and (d) are as follows:

(c) $$\alpha_{I\%} = \beta_1 + \beta_2 \alpha_{N\%} + \beta_3 \sigma_{N\%} + \beta_4 \alpha_{N\%} \sigma_{N\%} + \beta_5 D_1 + ... + \beta_{22} D_{19} + \varepsilon$$

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 .

(d)
$$I_t\% = \beta_1 + \beta_2 NOPAT\%_{NOPAT,t-1} + \beta_3 \sigma\%_{NOPAT,t-1} + \beta_4 NOPAT\%_{NOPAT,t-1} \cdot \sigma\%_{NOPAT,t-1} + \beta_5 D_1 + ... + \beta_{22} D_{19} + \beta_{23} T_{1998} + ... + \beta_{36} T_{1985} + \varsigma$$

where $I_t\% = \frac{I_t - I_{t-1}}{I_{t-1}}$ is the percentage changes of investments,

$NOPAT\% = \frac{NOPAT_{t-1} - NOPAT_{t-2}}{NOPAT_{t-2}}$ represents the percentage changes of the NOPAT,

$\sigma_{\%_{NOPATt-1}}$ represents the standard deviation of the percentage changes in the NOPAT.

In all regressions, D_1 to D_{19} represent dummy variables for the nineteen industries in the database. Dummy variables are defined as follows: D_i = {1 if the observation belongs to industry i_{th}, or 0 otherwise}. Food, Beverage and Tobacco is used as the 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 1999, 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. 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 center of the probability distribution to its tails, which means that there exists an increased 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. OLQ estimates for models (a), (b), (c) and (d)

	Model (a)	Model (b)	Model (c)	Model (d)
Dependent Variable	α_I	I_t	$\alpha_{I\%}$	$I_{t\%}$
β_1 (Constant)	-59.391	646.233	3.345	3.669
	(.400)	(.002)	(.192)	(.328)
β_2 (Growth)	1.943	.548	-.429	$1.465*10^{-2}$
	(.000)	(.000)	(.653)	(.955)
β_3 (Variance)	.477	1.519	$-3.75*10^{-2}$	$1.721*10^{-2}$
	(.000)	(.000)	(.751)	(.898)
β_4 (Interaction)	$-1.08*10^{-3}$	$-8.91*10^{-5}$	$5.985*10^{-3}$	$-2.45*10^{-4}$
	(.000)	(.099)	(.698)	(.919)
Adjusted R^2	.176	.073	-.010	-.002
F-statistic	5.167	14.869	.737	.689
	(.000)	(.000)	(.795)	(.913)
D.W.	2.124	1.936	2.106	2.012
N. Observations	410	6150	410	5740

*0.05 level of confidence

<u>*Regression model (a)*</u>: β_2, which refers to the expected growth of the profits, is positive. For an increase in one \$ of α_N, invested capital increases by \$1.943 thousand. β_3, which refers to the volatility of the profits, is also positive suggesting that an increase in profit's uncertainty is related to an increase in investments. The interaction variable between α and σ is significant, and the sign is negative. Theory predicts that $\frac{\partial \alpha_I}{\partial \sigma_N} < 0$. In model (a) the total variation of α_I with respect to σ_N, is equal to:

$$\frac{\partial \alpha_I}{\partial \sigma_N} = \beta_3 + \beta_4 \alpha_N = .477 - 1.08*10^{-3} \alpha_N$$

Therefore, $\frac{\partial \alpha_I}{\partial \sigma_N}$ will be negative if α_N is greater than \$441.66 thousand. Average α_N in the sample is \$38.137 thousand. In the sample, uncertainty and investments show a positive relationship. With an F-statistic equal to 5.167, we reject the null hypothesis that all estimated parameters are equal to zero. The t-test on individual coefficients shows the significance of

particular coefficients (in table 1 in brackets). The joint significance of the following sets of regression coefficients were tested with a Wald test under the following null hypotheses:

a1. H_0: $\beta_2=\beta_4=0$, H_1= at least one of them is nonzero,

b1. H_0: $\beta_3=\beta_4=0$, H_1= at least one of them is nonzero,

c1. H_0: β_5 to $\beta_{22}=0$, H_1= at least one of them is nonzero.

The restricted models corresponding to these hypotheses are respectively:

$$\alpha_I = \beta_1 + \beta_3\sigma_N + \beta_5 D_1 + ... + \beta_{23} D_{19} + \nu$$

$$\alpha_I = \beta_1 + \beta_2\alpha_N + \beta_5 D_1 + ... + \beta_{23} D_{19} + \gamma$$

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

A Wald test gives an F value equal to 13.54 for (a1), 12.28 for (a2). The critical F value for 2 degrees of freedom in the numerator and 388 in the denominator is about 3. Therefore we reject both the null hypotheses (a1) and (a2). The F value for (a3) is equal to 1.17. The critical F value for 18 degrees of freedom in the numerator and 388 in the denominator is equal to 1.66. Therefore, we do not reject the null hypothesis (a3) that the coefficients for the industry-specific variables are equal to zero. In other words, under this particular model, industry does not matter as we suggested in the theoretical section. In that section we suggested that industries facing different supply and demand elasticities will respond differently to levels of investment. Of course, the result could be due to common macroeconomic factors captured by the time dummy variables, which do show significant differences according to hypothesis a2.

From a qualitative point of view, regression (b) gives similar results as regression (a). As in regression (a), the coefficient for the expected profits' growth and its standard deviation are positive. The interaction variable is not significant and the regression has a low adjusted R squared of only .073. The F-statistic is equal to 14.869. Therefore, 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 $\sigma_{NOPAT,t-1}$ is equal to:

$$\frac{\partial I_t}{\partial \sigma_{NOPAT,t-1}} = \beta_3 + \beta_4 \overline{X}_{NOPAT,t-1} = 1.519 - 8.91*10^{-5}\overline{X}_{NOPAT,t-1}$$

Therefore, $\frac{\partial I_t}{\partial \sigma_{NOPAT,t-1}}$ will be negative if $\overline{X}_{NOPAT,t-1}$ is greater than \$17,048.26 thousand, but no firm has $\overline{X}_{NOPAT,t-1}$ bigger than that amount. In the sample, uncertainty and investments show unambiguously a positive relationship. As with model (a), we conducted alternative hypotheses using restricted least squares and the Wald test. Results showed that collectively and individually the independent and dummy variables explained the variance in investment. In regards to the various dummy variables the results suggest that Autos & Components firms tend to invest less than Food, Beverage and Tobacco firms, whilst 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 than Food, Beverages and Tobacco Firms. In addition to these results, the negative coefficients on all the time dummies suggest that levels of investment were, on average, lower than the 1999 base year. The negative coefficients are highest in absolute terms for the years 1989 to 1993, which is consistent with the recession that occurred in the early 1990's.

We reran regression model (b) using the alternative definition 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 negative 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 $NOPAT_{t-1}$, 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.

Both models (c) and (d) show very low F-statistics. This means that the regressions coefficients are not statistically different from zero. Percentage changes from year to year do not provide any insight into the relationship between uncertainty and investments. According to the specifications of model (b), uncertainty changes through time are due to both positive and negative changes in profitability. Obviously positive changes in profitability (increases in profitability) have a positive effect on investments and negative changes (decreases in profitability) tend to decrease investments. In other words, the direction of the changes in profitability matters for investment decisions. Uncertainty in model (c) is measured by the standard deviation of the profitability, which is a measure of squared deviations from the mean. The standard deviation, being a squared measure, doesn't allow for different directions (increase and decrease) of the profitability (although in regression model (a) this aspect should be captured by the variable α_I, and in regression model (b) by variables $\overline{X}_{NOPAT,t-1}$ and $\overline{X}_{NOPAT,t-1} * \sigma_{NOPAT,t-1}$).

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 place the problem in an industrial context we developed an equilibrium model of the firm that resulted in a single price diffusion that was a function of the supply and demand elasticities, as well as supply and demand shock intensities. The resulting stochastic differential equation added a great deal of market structure into the definition of the price diffusion (mean percentage change in prices) and volatility. The theoretical model indicated that we should expect differences in risk responses from firms in different industries. For example we showed, with some exceptions, that firms facing higher demand or supply elasticities would face less uncertainty than those with more inelastic demand and supplies. While theoretical, the exposition illustrated how important such factors can be in the investment decisions of firms. This is especially of importance in the food industry since, the food industry often faces highly inelastic supplies and demands.

To examine the theory we obtained a large panel data set from the consulting firm Stern Stewart, covering the Fortune 1000 companies from the years 1980 through 2000. From this data we extracted data from 410 firms covering 19 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 behavioral 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-seeking behavior 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, show across four separate models, that there is no evidence of hysteresis. In all cases we find a positive relationship between uncertainty and investment as well as profitability and investment. These results obviously challenge both the real options-hysteresis approach as well as the expected utility hypothesis. This in itself is an important finding, but the finding of results consistent with what is expected when growth options or competition are the main drivers of the firms investigated is also important.

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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