A TEST OF REAL OPTIONS LOGIC BY ENTREPRENEURS

By

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Abstract. The main hypothesis examines whether real options logic is applied by entrepreneurs in undertaking key organisational change (e.g. ownership, technology, location, line of business etc.). This is explored in a model of firm performance using data collected in face-to-face interviews with entrepreneurs on the level and timing of precipitating influences of organisational change and the level and timing of consequential adjustments following organisational change. Two econometric estimation techniques (e.g. Box-Cox regression with WLS correction and Heckman sample selectivity correction) were employed. Firm performance is explained in terms of a count of real options exercised, measures of the level and timing of precipitators and consequential adjustments, plus interactions between these measures to capture firm behaviour through a real options lens. Evidence was found of the value of holding real options until uncertainties are resolved. At this point the value of waiting is at its lowest.

Key words: Real Options, Strategic Flexibility, Performance, Small Firms

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1. INTRODUCTION

In this paper, we conduct a test of real options logic. Specifically, the value of two principles of real options reasoning are investigated: 1) The value of holding real options until uncertainties are resolved and the value of waiting is at its lowest (i.e. adopting a 'wait and see' approach) (Ingersoll and Ross, 1992; McDonald and Seigel, 1986); and 2) The value of staging resource commitments to organisational change, thereby limiting irreversibilities in event of withdrawal (Bowman & Hurry, 1993; McGrath, 1999). This is explored in a model of firm performance where interaction terms are included to capture simultaneous variation in the level and timing of precipitating causes of key organisational change identified by entrepreneurs, and of the level and timing of consequential adjustments following the organisational change (e.g. ownership, technology, location, line of business etc.). These interaction terms describe, in a novel way, firm behaviour through a real options lens. The evidence supports the first tenet of real options reasoning but only tentative evidence was found of the second. By implication, entrepreneurs should defer the exercise of real options until uncertainties are resolved and the value of waiting is at its lowest. By holding real options any longer, the entrepreneur risks that the opportunity is no longer 'in the money'.

Real options theory explains how the value of a new investment can be augmented by accounting for flexibility in the decision-making process (Bowman and Hurry, 1993; Luehrman, 1997; McGrath, 1997, 1999). A meticulous valuation of an organisational change captures its contingent nature (Donaldson, 1994). Both the direct (i.e. infrastructure requirements like increases in headcount, capacity etc.) and delayed (i.e. regulatory changes, network externalities, risk of pre-emption, loss of market share etc.) effects of organisational change must be considered in strategic decision-making (Miller and Folta, 2002; Folta and Miller, 2002; Arthur, 1994; Ingersoll and Ross, 1992; Lieberman and Montgomery, 1988; McDonald and Seigel, 1986). This is especially important under conditions of high uncertainty and risk. In this instance, the ability to exploit future options is likely to be very valuable for a firm, but uncertainty exists as to which options will be 'stars' in the future (Dixit and Pindyck, 1994). Indeed, we invest in ways that create real options to avoid over committing to a particular course of action before this uncertainty is reduced (McGrath, 1999). Viewing the staging of resource commitments to organisational change as a series of sequentially exercised options accommodates uncertainty (Bowman & Hurry, 1993). This approach facilitates project redirection (i.e. the exploitation of options to contract, expand, switch), advances learning and allows investment to be discontinued at the earliest possible time (e.g. option to abandon), while simultaneously conserving the firm's resources. Thus, by adopting real options logic, entrepreneurs can raise the strategic flexibility of their firm and consequently its long run prospects.

Real options logic was applied to resource allocation decisions to recognise the importance of valuing flexibility in strategic choices under uncertainty. Folta and Miller (2002) applied the logic to equity partnerships, Miller and Folta (2002) to market entry and McGrath and Nerkar (2004) to research and development decisions in the pharmaceutical industry. Developed in the context of large firms, the logic is applied in this paper to resource allocation decisions in a small firm context. With fewer resources the small firm may have a smaller portfolio of options available to it in comparison with larger firms. Yet the core principles of real options logic are as relevant to small firms, as they are to large firms (see Calcagini and Iacobucci, 1997; Laamanen, 1999; Cave and Minty, 2004).

Briefly, our ideas are developed as follows: Section 2 locates the two principles of real options logic to be tested in the extant literature. Section 3 discusses the primary source data and key variables used to test our hypothesis. Section 4 reports upon the results of a model of firm performance. This model was estimated in two ways; that is, by (1) Heckman sample selection estimation and (2) Box-Cox regression (with heteroskedastic adjustment). Interaction terms to capture behaviouristic tendencies suggested by real options logic are included as regressors in the model to test the practical significance of the logic. Finally, Section 5 summarises our primary results.

2. THEORETICAL ISSUES

Real options materialised from insights that many managerial decisions share common characteristics with decisions resolved by buying or selling options traded in financial markets.[1] The logic of real options was developed in the area of financial economics (Black & Scholes, 1973; Myers, 1977) but was extended in the management literature as a means of valuing strategic flexibility (Bowman & Hurry, 1993; Luerhman 1997, 1998; and McGrath, 1997, 1999). Strategic flexibility reflects how the firm situates itself to avail of future opportunities, challenges, new game plans or real options, see Carlsson (1989). It is the firm's capability to recognize major changes in the external environment, speedily commit resources to new courses of action in response to those changes and, realize and act quickly when it is time to stop or reverse existing resource commitments, see Shimizu and Hitt (2004).

[1] Myers (1977) recognising the similarity of stock options and organisational resource investments extended the option valuation process (see Black & Scholes, 1973) to include investments in organisational resources. The latter form of option was referred to as a real option, because typically it involved investments in real strategic assets (e.g. manufacturing plant, a distribution centre, or a firm's reputation). The owners of real options have the right, but not the obligation, to expand or contract their investment in a real asset at some future date.

A real option is commonly defined as any decision that creates the right, but not the obligation, to pursue a subsequent decision, see Janney and Dess (2004). McGrath (1999) likens entrepreneurial initiatives to real options whose value is fundamentally influenced by uncertainty. According to Bowman and Hurry (1993), *"options came into existence when existing resources and capabilities allow preferential access to future opportunities"* (p.762). Through an incremental choice process, the firm makes an initial decision or recognises the existence of a 'shadow option' and then adopts a 'wait and see' policy until the option materializes. During this 'wait and see' period any uncertainties are hopefully resolved. The second decision, or strike, of the option often occurs when new information becomes available reducing uncertainty about its future prospects. This often involves one, or more likely several, discretionary investments. Once the option is struck, new options for future exercise arise. The firm limits downside risk through this incremental pattern of staged investment by a) waiting until a real option is 'in the money' (NPV>0) to exercise the option, by b) providing itself with the inbuilt flexibility to abandon options which are 'out of the money' (NPV<0) and by c) providing itself with the ability to revise strategy by exercising a flexibility option (see Bowman and Hurry, 1993; Luehrman, 1998). We expand on the value of waiting and the value of staging investments to organisational changes through exercising a series of real options (i.e. a compound option) as opposed to making a single lump sum investment below.

2.1 The Value of Waiting

Research on real options has contributed to our understanding of the considerations surrounding the optimal timing of entrepreneurial initiatives by elaborating on the value of waiting (see Ingersoll and Ross, 1992; McDonald and

Siegel, 1986; Trigeorgis, 1991). For example, with the opportunity to invest in underutilised capacity, the commercialisation of a technology or the entry into a new market, a firm may choose to maintain flexibility by holding the option or increase its commitment to the strategy by exercising the option. However, early commitments involve sacrificing flexibility and raising the firm's exposure to the uncertainties of new markets. The value of this call option (*C)* or 'option to invest' prior to expiration can be expressed as follows; [2]

$$C=f(S, X, \sigma, T, r) \tag{1}$$

where *S* corresponds to the value of the investment including expected future cash flows and the option value of future growth opportunities. The exercise price, *X*, is the amount of money required to undertake the investment, σ is the uncertainty of the value of the investment (*S*).[3] The duration, *T*, is the length of time the investment decision may be deferred (i.e. the time to expiration). The risk free rate of return is given by *r* but its influence is weak and ambiguous for real options, see Dixit and Pindyck, (1994). Prior to expiration, the option will only be exercised when the value of the underlying asset (*S*) exceeds the exercise price (*X*) by more than the value of holding the option (*C*). This condition can be expressed as follows:

$$\mathrm{S} - \mathrm{X} > C\,(S, X, \sigma, T, r) \tag{2}$$

Greater environmental uncertainty (σ) has been argued to increase the inducement to delay irreversible investments (McDonald and Seigel, 1986). Deferring sunk investments is sensible because preceding in this way limits the firm's downside risk. Thus, we expect entrepreneurs to delay substantial investment decisions when uncertainty (σ) is high, see Bowman and Hurry (1993). When uncertainty is low

[2] See Trigeoris (1996) and Folta and Miller (2002).

[3] McGrath (1999), Fichman *et al*. (2005) and van Putten and McMillian (2004) argue that entrepreneurs should seek options with higher variance (i.e. greater uncertainty), because the potential gains are greater while the cost to access them is the same.

regarding future growth opportunities, the opposite is true. There are few enticements to delay the investment decision. However, investment will only occur when the real option is 'in the money' $(S > X)$ as opposed to 'out of the money' $(S < X)$. Thus, when uncertainty is low and the value of the investment opportunity is 'in the money', firms are more likely to exercise the option to invest. The value of waiting any longer in this instance is low.

The first option is waiting to invest and it pays to wait before committing resources until uncertainties are resolved [i.e. $S\text{-}X< C\ (S, X, \sigma, T, r)$]. Effectively, the firm is adopting a 'wait and see' approach (see Ingersoll and Ross, 1992; McDonald and Seigel, 1986). When uncertainties are resolved, the value of waiting any longer is low if $S > X$. After all, the cost of waiting is foregone revenues. This cost depends on the length of postponement, T, and the average discount rate over the time, r. A trade-off exists between the value of investing immediately with the value of waiting a bit longer. Deciding on whether to invest requires a case-by-case comparison of these two values.

There is evidence that long-lived small firms value the flexibility offered by a 'wait and see' strategy to resolve uncertainties before making irreversible investment decisions. A manufacturer of plastic injection mouldings in exercising the call option to change its product range implemented small, and relatively reversible, investments in marketing the new ranges in an effort to generate sales initially. Larger investments to increase the operational efficiency of their production were deferred until the new niche proved profitable. By adopting a 'wait and see' approach, the firm minimised its investment until uncertainties were resolved. This raised its option value to withdraw at minimal cost if this new niche failed to show profitability and enabled the firm to revise its strategy as circumstances unfolded. Similarly, a cardboard packing manufacturer built a reputation as a design house for new products before making irreversible commitments in dedicated technologies such as a computer aided design system (CAD). A 'wait and see' strategy was adopted before making irreversible commitments in new technology. A further example is given by a manufacturer of bulk bags who exercised a call option to engage solely in merchandising bags. However, the firm kept some remnants of a manufacturing facility in operation until the owner-managers were confident in the viability of engaging solely in this activity. This firm therefore adopted a 'wait and see' approach before divesting of its manufacturing facilities.

While these examples show the advantages of adopting a 'wait and see' approach, there may be opportunity costs to delaying the exercise of a real option. Early exercise decisions may be warranted if deferring the option to invest results in (1) cashflows or learning sacrificed (see Folta and Miller, 2002); (2) loss of early mover advantages (Lieberman and Montgomery, 1988) and (3) diminished opportunities to pre-empt rivals (see Folta and Miller, 2002). The latter reflects the shared nature[4] of some options (e.g. equity partnerships, market entry). Options which are proprietary[5] afford entrepreneurs more time (T) before they need to commit (e.g. market research). Pre-emption by a rival can cause an option to unexpectedly expire. Other phenomena like pending changes in regulation and predictable loss of market share are all costs associated with investing later rather than sooner (Luehrman, 1998). Thus, value may be lost as well as gained by deferring, and the proper decision depends on which effect dominates. The trade-off relationship

[4] Shared options are viewed as jointly held opportunities of a number of competing firms or of a whole industry, and can be exercised by any one of their collective owners (Trigeorgis, 1996; Miller and Folta, 2002)
[5] Proprietariness refers to the degree of exclusivity of a holder's claim to an option (Miller and Folta, 2002).

between the value of investing immediately with the value of waiting a bit longer is examined in the econometric estimation of a performance relationship in Section 4.

2.2 Compound Options

Strategies consist of a series of options explicitly designed to affect one another, Luehrman (1998). Referred to as compound options[6], they involve a complex series of nested investments (e.g. investments in new products, geographic markets etc.). They can no longer be treated as independent investments but rather as links in a chain of interrelated projects, the earlier of which are prerequisites for the ones to follow. An initial foothold investment confers privileged access to information[7] and opportunities for future investments (e.g. investments in product development or product commercialisation). Each stage completed gives the firm an option to complete the next stage (e.g. expand or scale up projects) but the firm is not obliged to do so (e.g. abandonment options). The investment problem, according to Dixit and Pindyck (1994), essentially boils down to discovering a contingency plan for making these sequential (and irreversible) expenditures. For compound options, Luehrman (1998), Bowman and Hurry (1993) and McGrath (1999) hold that firms should contain the costs of failure by staging investments, particularly investments that are irreversible[8] in nature. Adopting this strategy, plus putting in place appropriate monitoring systems, should increase the bundled value of a portfolio of options. McGrath (1999) states, "*By funding sequentially, and then putting in place,*

[6] A compound option, or an option on an option, gives the owner the right, but not the obligation, to buy (long) or sell (short) the underlying option, see Fouque and Han (2004).
[7] Learning options allow the entrepreneur to pay to learn about an uncertain technology or system, see Mondher (2003).
[8] According to Baldwin (1982), irreversibility may be caused by technological or environmental factors or by the relative cost of sunk capital over new investment. Irreversibility can be permanent, if the initial state is never regained, or temporary, if the initial state is returned after some time. But whatever it's origin, or duration, Baldwin (1982) states that the negative impact of irreversibility on the firm's future opportunities is relevant to investments, and appropriate adjustments for irreversibility should be incorporated into project evaluations.

mechanisms to spot signals of adverse changes in future value, and adjusting expenditure patterns accordingly, the price of a real entrepreneurial option may be contained" (p.24).

It is difficult to value compound options. Their value does not depend on the value of the cashflows generated from the exercise of the initial option but is, in part, a function of the embedded option(s), see Schmidt (2003) and Trigeorgis (1993). If we represent the value of a two stage compound call option as $C(S, t) = f[G(V, t), t]$ where t stands for current time and the value of the first stage option $C(S, t)$ is an increasing function of the value $G(V, t)$ of an embedded option, see Geske (1979). $G(V, t)$ represents a common type of embedded option, e.g. a growth option. The embedded growth option G is acquired if, and only if, the first option C is exercised. Anything that enhances the value of the second option G, also enhances the value of the first option C, because the value of the second option forms part of the underlying asset value of the first option. For example, if the risks associated with the first option, C, increase, then the value of the second option, G, rises because its volatility increases[9] (i.e. It becomes more valuable). However, the value of the first option also rises because the second expansion is part of the underlying assets, S, of the first. If a competitor pre-empts the product introduction, the value of option C and option G will both fall. In addition, if the time to expiration increases, the value of $C(S, t)$ rises reflecting the decreased present value of the future exercise price, Geske (1979).

Trigeorgis (1993) illustrates that the incremental value of an additional option, in the presence of other options (e.g. options to defer, abandon, contract, expand) is generally less than its value in isolation and deteriorates as more options are present.

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[9] In general, if the j-stage option is an increasing function of the variance underlying the series of options, then the value of the $j+1$ stage option is also an increasing function of the variance (Teisberg, 1993).

This implies that their individual values are not additive[10]. The degree of interaction would be small if the options were of opposite type (e.g. a put and a call option) than if they were of the same type (e.g. two call options). The former options would be additive but the latter are not as they would be exercised under similar environmental conditions. Trigeorgis (1993) shows that the results of comparative statics confirm the value of flexibility despite interactions. Such a series of options manifest familiar option properties. According to Trigeorgis (1993), interactions are seen to depend on the type, separation, degree of being in or out of the money, the order of options involved and factors that impact on the joint probability of exercise.

Errais and Sadowsky (2005) value staged investment opportunities and optimal exercise time using approximate dynamic programming techniques, while assuming that the firm is operating in an environment where market and technical uncertainty exist.[11] They consider a firm which is launching a new product onto the market. Before the product is commercialised, a number of staged investments, *N*, are required (e.g. market experiments). Each investment stage represents a decision

[10] This differs from decision tree approaches such as Mondher (2003) and Dapena and Fidalog (2003) who use expected net present value (ENPV) to value a nested investment (i.e. a compound real option). Mondher (2003) calculates ENPV in the presence of information costs as follows:

$$ENPV = \sum_{i=1}^{N} \rho_i \sum_{t=1}^{T} \frac{DCF_{it}}{(1+r_d)^t} + \rho_N \sum_{t=1}^{M} \frac{q_j CCF_{jt}}{(1+r_c)^t}$$

where:
$i = 1,\ldots,N$: an index of the *N* stages in the project,
ρ_i : the probability that stage *i* is the end stage for product *i*,
T: the time at which all future cashflows become zero,
DCF_{it}: the expected development stage cashflow at time *t* given that stage *i* is at the end of the stage,
r_d: is the discount rate for development cashflows,
$j = 1,\ldots,M$: an index of the quality of the product,
q_j : the probability that the product is of quality *j*,
r_c: is the discount rate for commercialisation cashflows,
CCF_{it}: the expected commercialisation stage cashflow at time *t* given for a product of quality *j*

[11] Market (exogenous to the firm and correlated with economic fundamentals) and technical (endogenous and depends on the level of initial investment made) uncertainty are assumed to be dynamically evolving and affecting the evolution of the value of the option through time. Tradability assumptions are made on the market uncertainty driving the value of the project whereas technical uncertainty is considered to be completely diversifiable and is assigned a market price risk of zero, see Errais and Sadowsky (2005).

regarding whether to invest, how much to invest, and when to invest. At the first stage, management must decide if the opportunity justifies the initial commitment of resources to the uncertain venture. According to Errais and Sadowsky (2005), the firm must invest 'I' in the interval $[\underline{I}, \overline{I}]$ per stage where '$\underline{I}$' denotes the minimum level of investment and '$\overline{I}$' denotes the maximum. The completion of a stage takes ΔT units of time regardless of the level of investment. Investment decisions are made at times $t \in \Lambda = \{T_0, T_1, ...T_i, ...\}$ where $T_i > T_{i-1}$ and $\Delta T = T_i - T_{i-1}$ for all $i \geq 1$ ΔT is assumed to be constant for each stage of investment. Accordingly, firms initiate funding decisions intermittently after ΔT units of time.[12] It is possible for a firm to delay investment at time T_i for any $i \geq 1$, for instance, in adverse market conditions and recommence investment at time T_{i+k} where $k \in \mathbb{N}$.

Let S_t be the value of the right to all future revenues of the commercial stage based on information available at time t. Likewise, X_t, is the value of the right to all future costs. The difference, S_t - X_t, reflects the Net Present Value (NPV) of these cashflow streams assessed at time t. Errais and Sadowsky (2005) align this multi-stage investment with a perpetual N-stage Bermudan option.[13] The revenue process is driven by market uncertainty and is assumed to be perfectly correlated with the tradable asset taken to be S_t itself. The value of S_t is assumed to be captured by the log normal process:

$$dS_t = \alpha_s S_t dt + \sigma_s S_t dw_t^{(1)} \tag{1}$$

[12] This pattern of staged funding in implementing organisational change corresponds reasonably well to the raw data on the timing of adjustments to organisational change which we collected on long-lived small firms, see Section 3.2.2 for a more detailed discussion.

[13] Schweizer (2002) characterises Bermudan options by their possible payoffs and region of dates R at which they can be exercised. A perpetual Bermudan option is an option that can be exercised at fixed specified dates in the future with no expiration date, see Boyarchenko and Levendorskil, (2002).

where $w_t^{(1)}$ is a standard Brownian motion characterising the market uncertainty driving revenues. Furthermore, S_t, accumulates dividends at the rate of δ_s. Thus, the market price of risk $w_t^{(1)}$, labelled as λ_1, is given by $\lambda_1 = (\alpha_s + \delta_s - r_f)/\sigma_s$ where r_f is the risk free rate of return.

The process of costs X_t is determined by both market and technical uncertainty. Similarly, the market uncertainty driving costs, denoted by Brownian motion, $w_t^{(2)}$, is assumed to be perfectly correlated with a tradable asset, c_t. This asset accumulates dividends at rate δ_c and follows the lognormal process:

$$dc_t = \alpha_c c_t dt + \sigma_c c_t dw_t^{(2)} \tag{2}$$

where the market price of risk $w_t^{(2)}$, labelled as λ_2, is given by $\lambda_2 = (\alpha_c + \delta_c - r_f)/\sigma_c$. According to Errais and Sadowsky (2005), if at time $t \in \Lambda$ there are j stages in the project remaining for completion and the firm decides to invest an amount I, the cost process that X_t will follow between t and $t + \Delta T$ for $i \geq 0$ is given by:

$$dX_t = \alpha_x(X_t, I, j)dt + \sigma_x X_t dw_t^2 + g(X_t, I, j)dz_t \tag{3}$$

The Brownian motion term z_t relates to technical uncertainty, which is endogenous to the firm and unrelated to $w_t^{(1)}$ and $w_t^{(2)}$. The growth rate $\alpha_x(X_t, I, j)dt$ and technical volatility level $g(X_t, I, j)$ are dependent on the investment level I and the number of stages remaining for completion j. Market volatility, σ_x, is assumed to be constant and independent of the level of investment.

Generally speaking, a larger proportion of start-up investment will usually accelerate learning by a firm (e.g. seen in the perfection of its technology, the improvements of its products and the enhancement of its distribution etc.), see Li

(2002). Errais and Sadowsky (2005) assume that there is more learning at the earlier stages of investment. This assumption can be expressed as follows: $\Delta_j g(X_t, I, j) = g(X_t, I, j) - g(X_t, I, j-1) > 0$.[14] Furthermore, as more money is invested in the project, the more technical uncertainty is resolved, i.e. $\partial g(X_t, I, j)/\partial I \geq 0$.

The value of the investment opportunity $V(S_t, X_t, j)$ at each $t \in \Lambda$ is a function of the underlying assets, S_t, the expected cost process, X_t, and the number of stages remaining for completion, *j*. However, to make the computations tractable future revenues, S_t, are considered fixed $\overline{S}$ and so is the level of investment *I* i.e. $I = \overline{I} = \underline{I}$. Errais and Sadowsky (2005) determine the value of the investment opportunity $V(X_t, j)$ at stage $j > 0$ by an iterative process using approximate dynamic programming techniques[15] , their knowledge of the value function $V(X_t, j-1)$ and the optimal investment process $I(X_t, j-1)$ in the previous step. From a numerical analysis, they found that the value of the investment opportunity $V(X_t, j)$ was decreasing in X_t at all stages. Also, for fixed X_t the difference in the value of the options at two successive steps, i.e., $V(X_t, j-1) - V(X_t, j)$, is decreasing in *j*. They say this could be justified by the fact that the extra investment of *I* made in $V(X_t, j)$ is discounted with a larger time horizon as you raise the number of stages and move away from the commercialisation stage.

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[14] Note when no investment is undertaken, no learning takes place and thus no technical uncertainty is resolved, i.e. $g(X_t, 0, j)$=0. There is no technical learning once the staged investments are completed i.e. $g(X_t, I, 0) = 0$.

[15] Other valuation approaches used in the literature include the general switching approach for valuing complex options [see Kulatilaka and Trigeorgis (1994); Kulatilaka (1995 a,b)]. Gamba (2002) employs a numerical algorithm based on simulation and extends the Least Squares Monto Carlo (LSM) approach presented in Longstaff and Schwartz (2001) for a multi-options setting.

In their examination of the optimal exercise of each successive stage or option, Errais and Sadowsky (2005) denote $\overline{X}^{j}$ as the optimal exercise threshold with *j* stages to go. Then, if the value of the expected costs is such that $X_t > \overline{X}^{j}$ the firm will decide not to fund the investment project. On the other hand, if $X_t < \overline{X}^{j}$ the firm will invest and advance to the next stage. The threshold value $\overline{X}^{j}$ can be found by solving:

$$I + \alpha \mathrm{E}\left[\hat{V}\left(X_{t+\Delta T}, j-1\right)\right] = \alpha \mathrm{E}\left[\hat{V}\left(X_{t+\Delta T}, j\right)\right] \tag{4}$$

where $\hat{V}(.)$ is the approximate value function obtained at each given stage *j*. The exercise threshold falls with the number of stages for completion. This relates to the fact that $V(X_t, j-1) - V(X_t, j)$, is decreasing in *j.* According to Errais and Sadowsky (2005), by investing at stage *j – 1* the entrepreneur will acquire the option $V(., j-2)$ in ΔT years from now. By investing at stage *j,* the entrepreneur will acquire the option $V(., j-1)$. However, by not investing in *j – 1,* the entrepreneur keeps the option $V(., j-1)$ at time $t + \Delta T$, and by not investing at *j*, he/she keeps $V(., j)$. Thus, the entrepreneur also has the incentive not to invest in *j – 1* with respect to *j*. However, if the difference between the two successive stages $V(X_t, j-1) - V(X_t, j)$ is decreasing in *j*, the higher the incentive to invest at stage *j – 1* with respect to *j* will be relatively more important than the higher incentive to wait.

Examining sources of uncertainty, the value of the option was found to increase with both market and technical uncertainty, as expected. However, the effect according to Errais and Sadowsky (2005) was found to be much stronger for market than for technical uncertainty, since market uncertainty will always be present, while technical uncertainty requires an investment to be resolved. However, for a risk averse firm, market uncertainty makes a firm more reluctant to undertake irreversible investment. Therefore, it demands a higher inducement to do so. Technical uncertainty, on the other hand, benefits the firm only if it can invest to take advantage of it.

Speeding up completion time by reducing the time between investment stages was found to raise the value of the option because it puts the final payoff closer in time. The increase is more striking when the costs X_t is low and the commercial stage has a high chance of being embarked on. Even when costs are high and investment is not currently optimal, a decrease in ΔT raises the value of the investment opportunity. It allows the firm to observe market information more often. Of course, Errais and Sadowsky (2005) argue that decreasing this time interval may not be possible for the firm beyond a certain point, technical considerations will put a limit on the minimum time that a stage could take to be completed.

In addition, Miller and Folta (2002) establish that the potential to pre-empt or avoid being pre-empted, is essential to motivate sequential investments. Furthermore, they establish that the feasibility of pre-emption presupposes uncertainty is, at least in part, subject to manager's control (i.e. technical uncertainties can be resolved). Pre-emptively exercising a compound option may lock in access to scarce information or resources relevant to the next investment stage. To the extent that uncertainty can be reduced and uncertainty reduction enhances value through pre-empting rivals, managers should accelerate their multi-stage investments relative to when uncertainty is beyond managerial control (i.e. market uncertainty).

The entrepreneur must constantly strive to enhance the value of the chain of nested options by balancing the opposing influences of these variables (i.e. time, uncertainty, number of stages of investment, level of investment and pre-emption). McGrath (1999) argues that the investment made in one real option may pay off by resolving issues surrounding other real options, even if the first was a failure. She states, "*complete accounting of a real option's worth requires an understanding of the other options in play*" (p.15). According to McGrath (1999), "*the key is not avoiding failure but managing the cost of failure by limiting exposure to the downside while preserving access to attractive opportunities and maximizing gains*" (p.16).

2.3 Model

The value of these two principles of real options logic described above are investigated in this paper: 1) The value of adopting a 'wait and see' policy before exercising real options; and 2) The value of exercising a chain of real options (i.e. 'a strategy') in incremental phases until uncertainties are resolved thereby limiting irreversibilities in event of withdrawal. Using this logic effectively, entrepreneurs can minimise losses while preserving potential gains.

Paddock *et al.*, (1988) and Berger *et al.*, (1996) show that the value of the firm is the combined value of the assets already in use and the present value of the future investment opportunities. Bloom and van Reenen (2002) also model firm value as a function of the values of embodied patents (i.e. exercised real options) and disembodied patents (i.e. proprietary real options). We empirically test real options logic using a model of firm performance where variation in firm performance (*Perform*) is explained by a count of real compound options that the firms has exercised over its life, RO_L, and some of the determinants of the value of a real option [i.e. $C=f(S, X, \sigma, T, r)$]. In general terms, we can model firm performance as follows:

$$\text{Perform} = f[\text{RO}_\text{L}, S_t - X_t] \qquad (5)$$

Substituting (2) for NPV or $S_t - X_t$ gives[16]

$$\text{Perform} = f[\text{RO}_\text{L}, C\,(S, X, \sigma, T,)] \qquad (6)$$

[16] The risk free rate of return, given by *r*, is not included as its influence has been found to be weak and unclear for real options, see Dixit and Pindyck, (1994) and Ross and Ingersoll (1992).

In this specification, S_t, is also a function of embedded options e.g. $G(V, t)$. In our data, key organisational changes are construed to be real options. Thus, RO_L represents a count of these over the life of the firm. Typically, key organisational changes are strategic in nature and are disconnected from the regular decisions undertaken by the mature small firm on a daily basis. Examples include changes in ownership, legal form, technology, location, innovation, line of business etc. They involve a series of investments $[I_1, I_2 .... I_{j-1}, I_j]$ and thus represent compound real options. We approximate the level of investment by counting the number of consequential adjustments following organisational change i.e $[a_1, a_2 .... a_{j-1}, a_j]$ a proxy for $[I_1, I_2 .... I_{j-1}, I_j]$ in real options terminology. In a practical sense, it captures only the number of options in the chain of real options (i.e. the number of incremental phases of investment) and is a weak proxy for the level of investment I_j at each stage, or its value $V(., j)$, though it does provide an indication of the extent of commitment. We approximate the level of volatility, σ, by counting the number of precipitating influences $[p_1, p_2 .... p_{j-1}, p_j]$ preceding the exercise of the real option or, in other words, the key organisational change.[17] Using real options logic, the larger the array of factors included in the variable, σ, the higher the option value of the firm (see McGrath, 1999). Organisational changes taking on a relatively high count of precipitating influences are likely to have more unpredictable returns and this provide a good approximation for environmental uncertainty associated with real options. Time, T, is broken down into two intervals, precipitator time, pt, and adjustment time, at, for this study to enable us to test our two principles of real options logic. Precipitator time, pt, represents the period between the recognition of the real option

[17] In Errais and Sadowsky's (2005) terminology, the level of market uncertainty is more likely to be encapsulated by the count of precipitating influences (or environmental influences) whereas the number of stages of adjustment capture technical uncertainty (i.e. a higher number of stages of adjustment would suggest greater technical uncertainty).

(RO_L) and the exercise of the option [i.e. It presents the period when it paid the firm to adopt a 'wait and see' policy given that S-$X< C\ (S, X, \sigma, T, r)$]. Adjustment time, *at*, is the period between the exercise of the first call option [or execution of staged investment I_1] to the execution of the final call option [or of staged investment I_j]. After elaborating on these variables, equation (6) can be expanded as follows.

$$\text{Perform} = f[\text{RO}_L, \Sigma p_j, \text{ pt}, \Sigma a_j, \text{ at}] \quad (6)$$

Greater details on the measurement of these variables are provided in Subsection 3.2. Here, we turn to our test of the logic of real options.

In Section 4, initially we estimate the base model outlined in equation (6). This performance relationship is specified, at this time, in general terms, as follows:

$$\text{Perform} = \beta_0 + \beta_1 RO_L + \beta_2\, Precipitator + \beta_3 PrecipitatorTime + \beta_4 Adjust + \beta_5 AdjustTime + u_{1i} \quad (7)$$

where 'Σp_j' is approximated by '*Precipitator*', '*pt*' by '*PrecipitatorTime*', 'Σa_j' by '*Adjust*' and '*at*' by '*AdjustTime*' and where $u_{1i} \sim N(0, \sigma)$. To test the logic of real options two interaction terms are included in performance relationship (7) as follows:

$$\text{Perform} = \beta_0 + \beta_1 RO_L + \beta_2\, Precipitator + \beta_3 PrecipitatorTime + \beta_4 Adjust + \beta_5 AdjustTime$$
$$+ \beta_6 (Precipitator * PrecipitatorTime) + \beta_7 (Adjust * AdjustTime) + u_{1i} \quad (8)$$

We now will outline how the logic of real options is examined using this specification beginning with an analysis of the value of waiting.

To examine whether there is value in holding real options until uncertainties are resolved [i.e. adopting a 'wait and see' approach] the marginal effects for *Precipitator* and *PercipitatorTime* are analysed. The latter effects are specified as follows:

$$\delta E(Perform)/\delta Percipitator = \beta_2 + \beta_6\, PercipitatorTime \quad (9)$$

$$\delta E(Perform)/\delta PercipitatorTime = \beta_3 + \beta_6 Percipitator \quad (10)$$

There is evidence of this principle of real options if β_6 is significantly negative, ($\beta_6 < 0$). In this stance, we see from equation (9) that the marginal effect of a higher number of precipitators (or volatility factors) on performance is reduced (assuming β_2 is positive) when the length of precipitator time (or 'wait and see' period) increases. The cost of deferring a real option is foregone revenues (or performance) and the value of these revenues decreases as precipitator time (i.e. the postponement period) increases. Other opportunity costs to delaying investment were outlined above (i.e. learning sacrificed, pre-emption etc.). This effect suggests the value of latter would also reduce performance as precipitator time increases. Furthermore, the marginal effect of longer precipitator duration (i.e. adopting a 'wait and see' policy) on performance (assuming β_4 is positive) is reduced when the numbers of precipitators (or volatility factors) increase. As the number of precipitators increase, this indicates that more uncertainties are resolved. This is the case as the count of precipitators was gathered retrospectively. Thus, when uncertainty is low there are diminishing returns to delaying the investment decision and adopting a 'wait and see' policy.

Similar expressions can be written for marginal effect of *Adjust* and *AdjustTime* and are give by:

$$\delta E(Perform)/\delta Adjust = \beta_4 + \beta_7 AdjustTime \quad (11)$$

$$\delta E(Perform)/\delta AdjustTime = \beta_5 + \beta_7 Adjust \quad (12)$$

These provide evidence of the value of staging investments in exercising a chain of options. In general, it is argued that by investing sequentially the costs of the real option can be contained (see Bowman and Hurry, 1993; McGrath, 1999). However, Errais and Sadowsky (2005) argue that the value of the real compound option $V(.,j)$ falls as the number of stages increase and that speeding up time to completion may increase the value of the option. As a result, the scenarios presented here are more complex. Firstly, examining expression (11) we find the marginal effect of a higher number of adjustments (i.e. stages of investment) on performance is reduced when the length of adjustment time increases (assuming $\beta_4 > 0$, $\beta_7 < 0$). Under these conditions, the staging of investments can raise performance by reducing the costs of failure limiting the firm's exposure to irreversible investments. When the adjustment time is increased this reduces the value of the option, and thus performance, as it places the final payoff further away in time. It could also be argued that a higher number of adjustments signal greater commitment to the real option. The firm has already sunk a number of irreversible investments and thus to recover some of these irreversible commitments it needs to speedily commit further. This may also be to take advantage of new learning (Li, 2002; Errais and Sadowsky, 2005). It may also be the case that the effect of the number of stages of adjustment on performance is strengthened by a longer adjustment time, ($\beta_4 > 0$, $\beta_7 < 0$). A longer adjustment time increases firm value because it decreases the present value of the future exercise price. Further, it is argued that extending the adjustment time could attenuate possible downside risks. Examining expression (12), we find that the marginal effect of longer adjustment duration on performance is reduced when the numbers of adjustments increase (assuming $\beta_5 > 0$, $\beta_7 < 0$). As explained above, a longer adjustment time increases the value of the real option, and thus performance because it decreases the present value of the future exercise price. Increases in the number of adjustments can reduce this effect for reasons outlined by Errais and Sadowsky, (2005) and Trigeorgis, (1993). Errais and Sadowsky (2005) find that when X_t is fixed that the value of the real compound option $V(.,j)$ falls as the number of stages increase, and by implication it has a negative influence on performance ($\beta_4 < 0$). Trigeorgis (1993) concurs and found that the value of incremental options is less than its value in isolation and declines as more options are present. It could also be argued that the effect of a longer adjustment time on firm value is strengthened as the number of stages of adjustment increase (i.e. more irreversible investments) (assuming $\beta_5 > 0$, $\beta_7 > 0$).

In estimating the base model (7), Power and Reid (2005) found tentative evidence that there is value in holding real options until uncertainties are resolved. However, it was found that the entrepreneur may fail to capture some of this value by waiting for a prolonged period of time (i.e. there is diminishing returns to adopting a 'wait and see' approach). Tentative evidence was also found of the value of staging resource commitments to organisational change. We formally test the empirical relevance of real options logic in Section 4 below.

3: DATA AND VARIABLES

This Section presents information on the database and the variables employed in econometric estimation. A description is provided of how these variables are defined, and an explanation is given of how these variables were measured in the survey instrument.

3.1 Database

The data set was based on interview evidence obtained from 186 owner-managers of small firms in Scotland. These firms were selected from three 'parent' samples of Scottish small business enterprises, Leverhulme (1985-1988), Telephone Survey (1991) and Leverhulme (1994-1997), see Table 1. Data was available on 63 surviving long-lived small firms and 123 non-surviving firms, see Power (2004). More parsimonious data was available for both the 63 surviving long-lived small firms and 123 non-surviving firms. For example, variables like industrial sector (*Sector*), start year (*StYear*), sales in the early years of trading *(StSales*), full-time employees (*FtEmployees*) and part-time employees (*PtEmployees*) were used in Section 4 below to correct for sample selection bias, see Table 2 for a definition of these variables[18]. Data on these variables was gathered earlier in the life of the firms in the sample (corresponding to periods following the names of the 'parent' samples in parentheses above). Detailed information on organisational change and performance was collected on 63 surviving long-lived small firms between October 2001 and February 2002, see Power (2004). The new variables generated are described in Section 3.2 below. Long-lived small firms[19] are defined as firms which were classified as small firms at start-up, have been trading for more than 10 years and were still in operation at the time of re-interview. Similar definitions of maturity have been adopted by Smallbone *et al.* (1992, 1995). The 63 long-lived surviving firms interviewed were indeed mature (25 ½ years on average; median age of 22). The average sizes of firms (and the corresponding standard deviation), in terms of full time equivalent employees, were as follows: 5.94 (5.85), sole proprietorship; 7.91 (4.08), partnership; and 22.19 (27.69), private company.[20]

***Table 1.* The Extraction of the Sample**

[Place Table 1 approximately here.]

***Table 2.* Definition of variables used in main text**

[Place Table 2 approximately here.]

3.2 Variables

[18] Complete data only exists on all these variables for 123 non-surviving firms as opposed to 129 eligible non-surviving firms identified in Table 1.
[19] Changes in the ownership, scale, principal activities and management of small firms do not change this definition (or selection criterion). Firms can undertake a number of changes and nevertheless be believed to be the same firm (i.e. the activities of the firm perpetuate), see Penrose (1959). Firm death signifies the 'discontinued existence' of the small firm, see Kay (1997).
[20] Of the sample of 63 long-lived small firms, one (1.6%) was a sole trader operating from home, fifteen (23.8%) were sole traders operating from business premises, nineteen (30.2%) were partnerships and twenty-five (44.4%) were private limited companies.

This Subsection considers the key variables used in formally investigating real options reasoning in a model of the performance of the long-lived small firm. Firstly, a comprehensive explanation is provided of how the key variables are defined and calibrated. Summary statistics for each of the key variables used in the econometric modelling are displayed in Table 3 below.

Table 3. **Mean, Standard Deviation and Range of Each Variable**

[Place Table 3 approximately here.]

3.2.1 Real Options

Here, a count of real options, RO_L, is measured by a frequency count of the number of changes, Y, undertaken by the mature small firm over its lifetime. Thus, it is approximated by $\sum Y_i$, where Y_i is the occurrence of a change i. From a diverse list of eighteen organisational changes, Y, including features like ownership, technology, location, line of business, capacity, investment, product range, market positioning, and diversification, owner-managers were asked to record the occurrence of a key organisational changes and the year in it occurred.[21] A count of real options, $RO_L = \sum Y_i$, was approximated using this data. According to this measure, a relatively high number of organisational changes suggest that the mature small firm is exercising a number of real options and is perhaps experiencing a high level of turbulence[22]. It is observed from Table 3 that on average the RO_L score is eight over the lifetime of the long-lived small firm [i.e. Range was 14, the maximum RO_L score was just 16]. An RO_L score of 5 or less (the lower quartile) was received by firms experiencing low

[21] Owner-managers were not restricted to those listed. They were authorised to specify other main changes if they wished.

[22] Reilly *et al.* (1993) defined turbulence as organisational changes encountered by the firm that were "*nontrivial, rapid and discontinuous…such as rapid growth, merger and hostile takeover*" (p.167). These organisational changes are in the nature of real options. Fluctuations in patterns of demand across product varieties or plant locations, displacement of existing technologies by alternatives, regulatory restrictions, and the displacement of existing products by new and superior substitutes, are potential drivers of turbulence (see Geroski, 1991, Chp 3; Dunne and Roberts, 1991; Sutton, 1997; Confraria, 1998; Segarra and Callejón, 2002).

levels of turbulence, whereas a score of 9 or more (the upper quartile) was received by firms experiencing a high level of turbulence.

3.2.2 Measurement of 'Precipitators' and 'Consequential Adjustments'

Measures of the level and timing of precipitators of organisational change and of the level and timing of consequential adjustments of organisational change were acquired as follows. For the key changes recorded by each long-lived small firm, the owner-manager was requested to choose those three which were most important to the running of their business, since start-up[23]. Then, a simple diagrammatic device (see Figure 1) was used in interviews with owner-managers to examine the attributes of organisational change, namely 'precipitating influences' and 'consequential adjustments'. The term 'precipitating influences' was employed to represent the forces, which led to organisational change or the exercise of the real option. It captures changes in the volatility (and consequently the value) of the real option over time. Data on the count of precipitators was gathered retrospectively thus as the number of precipitators identified increase, this indicates that more uncertainties are resolved. Likewise, the term 'consequential adjustments' was employed to represent those adaptations or 'staged investments', which 'followed-on' from exercising the organisational change or compound real option. This diagrammatic device was advantageous as it made explicit the pattern of causal relationships. It was straightforward to get owner-managers to approximate the periods of time that occurred between precipitating influences and organisational change, and between organisational change and consequential adjustments.

Figure 1. **Explanation of Causation**

[Place Figure 1 approximately here.]

[23] Note only two firms in the sample had less than three main organisational changes.

On a show-card, the owner-managers could record precipitating influences and consequential adjustments from a broad list of 30 likely categories for the three organisational changes that the owner-manager had identified (in the format displayed, in an abbreviated way, in Figure 2). This Figure indicates some of the factors we were concerned with. Other examples include entry into new niches, investments in trade intelligence and changes in cash-flow etc.[24] A count of the number of precipitating influences (P) and a count of the number of consequential adjustments (A) provides some insight as to the effect of key changes, or the exercise of real options, on the operations of the firm. The number of precipitating influences was measured by $P = \sum p_{jm}$ where p_{jm} is the occurrence of precipitating factor *j* for each change, or real option, *m*. In a similar manner, the number of consequential adjustments was measured by $A=\sum a_{jm}$ where a_{jm} is the occurrence of adjustment, or 'staged investment', *j,* for each change, or compound real option, *m*. The average number of precipitating causes of organisational change (*Precipitators*) and the average number of consequential adjustments (*Adjust*) following organisational change across the three most important strategic changes identified by each firm, measured by $\sum_{c=1}^{3} P_c / \sum_{c=1}^{3} m_c$ and $\sum_{c=1}^{3} A_c / \sum_{c=1}^{3} m_c$ respectively, was 5.27 and 7.31 respectively. As the latter average number of consequential adjustments is greater than 1, it implies that the key organisational changes invariably involved a number of nested investments. Thus, these key organisational changes are characterised by the features of compound real options or multi-staged investment projects.

***Figure 2.* Response Format for Calibrating Change**

[Place Figure 2 approximately here.]

[24] For more information on the sequence by which the data were elicited see Power (2004) or Power and Reid (2005).

Using real options logic, the larger the range of factors included in the variable *Precipitator,* the higher the option value of the firm (see McGrath, 1999). Organisational changes taking on a relatively high count of precipitating influences are likely to have more unpredictable returns. There is greater uncertainty associated with these changes. According to Fama & Miller (1972), increased volatility of the underlying asset increases the value of the option, because the potential gains are greater, but the potential losses become no worse. Organisational changes encompassing a relatively high count of consequential adjustments (e.g. changes in line of business, location) represent those which involve greater levels staged irreversible investments. Thus, they embrace a relatively higher level of sunk costs or commitment (Ghemawat, 1991). There is a tendency for organisational changes which involve a high count of precipitators to involve a large number of consequential adjustments. The average number of consequential adjustments (*Adjust*) is significantly positively correlated with the average number of precipitators (*Precipitator*) (i.e. Pearson's R=0.661, p-value=0.0001). This provides tentative evidence that organisational changes, that necessitate a large amount of irreversible investments, induce the owner-manager to adopt a '*wait and see'* strategy, scrutinizing the environment for more precipitators of change in an effort to limit exposure to downside risks.

For each of the three main organisational changes identified by the owner-manager, the length of time from the appearance of precipitating influences to the organisational change (*PrecipitatorTime*) and the length of time from the organisational change to changes in adjustment factors (*AdjustTime*) was recorded. *PrecipitatorTime*, P_t, was approximated as the length of time lapsed between the identification of the first precipitator by the owner-manager and the exercise of the real option [i.e. the maximum the length of time lapsed between each precipitating factor j and the occurrence of main organisational change m, pt_{jm}, or $Max(pt_{jm})=P_t$]. *AdjustTime, A_t,* was calibrated by the length of time lapsed between the exercise of the real option and the final consequential adjustment[25] [i.e. the maximum length of time between the occurrence of main change m and each consequential adjustment j, at_{jm}, or $Max(at_{jm})=A_t$]. In a similar vein, these measures were initially calculated for each of the three most important organisational changes. Then, average measures across the three most important changes were computed. On average, *PrecipitatorTime* is marginally less than *AdjustTime* with values of 16 and 17 months, respectively[26].

In stable markets, the shorter these time periods (i.e. *PrecipitatorTime, AdjustTime*) are, the long-lived small firm should exercise real options promptly, particularly when $S > X$. This varies in uncertain environments. When small firms are operating in environments which are subject to high risk and uncertainty, adopting a '*wait and see*' strategy, inspecting the environment to detect precipitating influences of organisational change, before exercising a strategic option, is prudent (see Bowman and Hurry, 1993). Moreover, it was found that *PrecipitatorTime* and *AdjustTime* are significantly positively related (Pearson's R=0.33, p-value=0.008). In a sequential chain of strategic options, each option exercised provides preferential access to the next option in the chain. However, further options in the chain may not be exercised unless they have matured and the value of waiting is at its lowest. Staggering

[25] Consequential adjustments were instigated intermittently, adhering to a pattern suggested by Errais and Sadowsky (2005). For example, following the exercise of the option to change the ownership of a Chandlery, adjustments in cost and the headcount occurred immediately, adjustments in product niches served occurred within 12 months whereas adjustments in capacity, growth and cashflow occurred almost 36 months later. At 24 months investment was suspended temporarily.
[26] The measures of average *PrecipitatorTime* and average *AdjustTime* adopted above, differ from those discussed Power and Reid (2005) but represent an improvement on these measures, see Power (2004) chp8. for an explanation.

consequential adjustments to organisational changes in this manner, may lengthen the adjustment time, and thereby generate a positive relationship between precipitator time and adjustment time.

There was no preliminary evidence of a relationship between *Precipitator* and *PrecipitatorTime* [Pearson's R=-0.031, p-value=0.809]. However, there was some evidence of a relationship between *Adjust* and *AdjustTime* at the 10 percent significance level. The average number of consequential adjustments (*Adjust*) is weakly positively correlated with average consequential adjustment time (*AdjustTime*) [Pearson's R=0.24, p-value=0.057]. This indicates that adjustments are staggered for organisational changes or real options which involve a large number of adjustments or staged investments (i.e. more time is allowed to elapse before the instigation of incremental adjustments to balance possible irreversibilities or downside risks). These relationships will be explored further in Section 4. First, we will examine our measure of performance.

3.2.3 Performance

Performance was measured by a quantitative index based on qualitative data, the design of which is described in detail in Power and Reid (2005) and in Power (2004). This approach is based on more modern techniques for performance evaluation in entrepreneurial firms (Wickham, 2001), the deployment of scorecarding systems for performance appraisal (Epstein and Manzoni, 2002) and, more generally, the findings of papers highlighting the importance of multidimensional performance measures in the context of new and growing ventures, Sandberg and Hofer (1987) and Chrisman *et al.* (1998).

To assess how owner-managers judged their firm's ability to survive over the long haul, the following line of inquiry was adopted: "*We'd like to know what has* *kept you in business down the years. Some things are good for business and some things are bad. What effect have the following had?"* Based on actual experience of running the business, owner-manager's were asked to rate twenty eight dimensions of their firm's performance in the format displayed, in an abbreviated way, in Figure 3, that is: strategy (9 dimensions); finance (4 dimensions); organization (4 dimensions); and business environment (11 dimensions). Other examples of the dimensions scored include competition, customer loyalty, technology, cashflow, capital requirements, market positioning, cost control, differentiation, advertising, diversification, operational efficiency, skills and filling product gaps. A cross was placed on the continuum ranging from 0 to 100 with respect to each dimension of performance to indicate its impact, 'bad' or 'good', on performance, see Figure 3. If an item was not applicable, owner-managers were requested to declare this. A rating of zero for a particular dimension signified a very negative influence on performance whereas a rating of '100' denoted a very positive influence and '50' a neutral influence on performance.

***Figure 3.* Response Format for Performance Indicator**

[Place Figure 3 approximately here.]

The overall performance index was generated by summing the scores allotted to each performance dimension and normalising the aggregate figure attained by the number of performance dimensions applicable to a given owner-manager's firm (i.e. the total score was divided by the number of items rated). Out of a maximum performance score of 100, the average long-lived small firm scored 67; the range was 49 to 90. Low performers had a performance rating between 49 and 62 (i.e. the lower quartile) and high performers had a performance rating of 73 to 90 (i.e. the upper quartile). An analysis of the responses of entrepreneurs on various dimensions to performance provides some revealing data on our measure. Examining mean ratings greater than 73% (i.e. denoting good performance), the key influences on performance are considered to be quality (88%, 12), customer loyalty (82%, 15.8), product mix (81%, 12.8), skills (80%, 16.7), operational efficiency (78%, 15.5) and diversification (76%, 16.5). The standard deviation is presented after the mean percentage score. High mean scores and low standard deviations imply some consensus amongst owner-managers on factors which encourage survival over the long haul. Factors which are not as essential, or even harmful, to long-run survival of the firm include competition (54%, 23.3), substitutes (50%, 22.9), debt (48%, 26.3), regulation (47%, 22.7), rivals' innovations (45%, 23.2), and new entrants (43%, 21.5). These low mean score influences have higher standard deviations, indicating less agreement amongst owner-managers about their consequences for long run survival. This is not surprising as these dimensions relate to aspects of the small firm's environment (e.g. regulatory, competitive) over which it has little control. By contrast the firm has considerable control over more positive influences like quality, product differentiation, skills and operational efficiency.

This multidimensional approach is advantageous as variable specific effects encompassed in single questions regarding performance are diluted producing a more inclusive (and stable) measure of performance allowing common influences to come through (DeVellis, 1991). The reliability and validity of this new performance index were investigated by Power (2004). Cronbach's (1951) alpha coefficient, used to infer internal consistency of the inclusion of influences in the performance index, was 0.78, exceeding Nunnally's (1978) recommended level of 0.7. Confirmatory factor analysis revealed that the data fitted nicely to hypothesized multidimensional measurement model[27] proposed by Sandberg and Hofer (1987) and Chrisman et al. (1998) [$\chi^2(16) = 9.9762$; $p = 0.868$], see Power (2004). Examining correlations with accounting measures of performance, we find that the long run performance indicator is weakly positively correlated with net profits [Pearson's R = 0.165, Prob. Value < 0.1] but weakly negatively correlated the level of indebtedness of the firm [Pearson's R = -0.208, Prob. Value < 0.05] in 2001. Thus, in these cases, the long run performance indicator is behaving as expected. Our examples, such as correlations between the performance index and headcount and asset growth and performance confirm the confidence we have in our performance measure and can be seen in Power and Reid, (2005) and in Power (2004). We therefore would argue that our subjective measure both acts as a reasonably good surrogate for objective measures of performance. It appears that entrepreneurs 'act' on their own appraisals.

4: RESULTS

This Section examines empirically the appropriateness of real options logic in explaining how long-lived small firms respond to precipitators of organisational change (see Miller and Folta, 2002; McGrath, 1997, 1999; Luehrman, 1997, 1998; Bowman and Hurry, 1993). Estimates of performance relationship (7), (8) and (13), the latter which is specified below, are analysed in testing real options logic. Equation (13) builds on equation (8). Three additional regressors are included in the relationship. The square of *RO* is included to test whether the relationship between the count of real options and performance is U–shaped convex (positive second derivative) or concave (negative second derivative). The variable *Age* and the square of *Age* are also included to capture possible learning effects, and to control for the

[27] The Sandberg and Hofer's (1987) measurement model described new venture performance as a function of entrepreneurial attributes, strategy and industrial structure whereas Chrisman et al. (1998) extended this model to include resources and organizational structure.

different life histories of the long-lived small firms (see Agarwal and Gort, 2002; McGrath and Nekar, 2004). Equation (13) is given as follows:

$$\text{Perform} = \beta_0 + \beta_1 RO_L + \beta_2 RO_L^2 + \beta_3 Precipitator + \beta_4 PrecipitatorTime + \beta_5 Adjust + \beta_6 AdjustTime + \beta_7 (Precipitator * PrecipitatorTime) + \beta_8 (Adjust * AdjustTime) + \beta_9 Age + \beta_{10} Age^2 + u_{1i} \quad (13)$$

Two estimation techniques are applied in estimating performance relationship (7) (8) and (13), that is, a Heckman sample selection model and a Box-Cox regression model. Heckman sample selection estimation (Lee, 1982, 1983; Heckman, 1976, 1979; Davidson and MacKinnon, 1993), a two step estimation procedure[28], was applied as we expected sample selection bias to exist[29]. As it happens, our measure of performance (*Perform*) and explanatory variables (vis *RO, Precipitator, Adjust, PrecipitatorTime* and *AdjustTime*) are only observed for long-lived small firms and not for all firms (i.e. including non-survivors). The Box-Cox transformation (see Davidson and MacKinnon, 1993; Box and Cox, 1964) was employed to discriminate between functional forms[30]. The functional form is dictated by the parameter λ which is estimated itself as part of the procedure. It incorporates the possibility of no transform at all (when λ=1) and the possibility of a logarithmic transformation (when

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[28] Initially, a binary probit model of the long run survival of small firms of the form $S = X\beta + u$ is estimated. S represents a binary variable set equal to '1' if the firm survived but to '0' otherwise. The matrix X contains observations on those variables thought to affect the long-run survival of small firms. The vector β includes the estimated parameter coefficients and $u \sim N(0, 1)$. From the binary probit estimation, the inverse Mills ratio (lambda) is calculated. The latter is then used as an additional regressor in the estimation of the performance equation. This procedure provides consistent estimators under certain regularity conditions.

[29] Significance differences have been shown to exist between survivors and non-survivors (see Reid, 1991, 1999; Audretsch, 1991; Mata and Portugal, 1994, 2002; Wagner, 1994; Mata *et al.* 1995; Doms *et al.* 1995; Audretsch and Mahmood, 1995; Cressy, 1996; Fotoloupos and Louri, 2000). Thus, the survival of small firms is unlikely to be random. Therefore, our observed measure of performance of the sample of survivors is possibly biased upwards.

[30] Buchinsky (1995), Demos and Goodhart (1996) and Matsuda (2005) among many others adopt the Box–Cox transformation to perform this function in empirical analysis.

λ=0).[31] The use of the Box-Cox transformation model allows one to introduce nontrivial interactions among the covariates in a parsimonious way.

From a preliminary ordinary least squares regression of performance relationships (7), (8) and (13), a chart of the residuals against the predicted values suggested that the residuals were rising with values of the predictors. To rectify this, the ordinary least squares model was weighted by a reciprocal of *Sales.* In fact, a linear proportional relationship of the reciprocal of *Sales* to the absolute value of the residuals was found to be significant using the Glejser test for heteroskedasticity, see Davidson and McKinnon (1993), ch. 11. The improper application of Box-Cox model in the presence of heteroskedasticity can give very misleading results. Zarembka (1974) demonstrates that while the Box-Cox test is robust to departures from normality, it is sensitive to heteroskedasticity and in fact the estimate of λ transformation is biased in the direction of stablizing the error variation. Sarkar (1985) and Seaks and Layson (1983) describe the Box-Cox technique when combined with a weighted least squares correction for heteroskedasticity. Here, we estimated the Box-Cox regression model with a weighted least squares correction for heteroskedasticity (*N=63* survivors). The Box-Cox regression model was one where the independent variables[32] were transformed by λ. The maximum likelihood

[31] Likelihood ratio tests can be used to test hypotheses about the values of λ. For a test of the linear (λ=1) model (or lin-log, λ=0) the test statistic is

$$\chi^2(1) = -2\left[L(\lambda = 1 \text{ or } 0\ ) - L(\tilde{\lambda})\right]$$

This statistic can be compared with a χ^2 distribution with one degree of freedom.

[32] Four Box-Cox transformations were examined (e.g. the dependent variable by θ, the dependent and independent variables by λ and so on). The most appropriate Box-Cox regression model was one, which transforms the independent variables using λ. Lambda is significant using this specification at a p-value =0.01 for equations (7), (8) and (13), see Table 6. In general terms, this model is expressed as follows:

$$y = \beta_o + \beta_1 x_1^{(\lambda)} + \beta_2 x_2^{(\lambda)} + ... + \beta_k x_k^{(\lambda)} + \varepsilon$$

estimates of the parameters are presented in Table 4 and their associated elasticities[33] in Table 5. We also apply the Heckman Sample Selection model to estimate performance relationships (7), (8) and (13) for the entire sample of 186 firms (i.e. 63 long-lived small firms and 123 non-surviving firms, see Subsection 3.1). Data on industrial sector (*Sector*), start year (*StYear*), sales in the early years of trading *(StSales*), full-time employees (*FtEmployees*) and part-time employees (*PtEmployees*) was used to estimate the selection relationship (see Table 2 for definitions of the variables). By way of comparison, the estimates of the Heckman Sample Selection model are presented in Table 6 and their associated elasticities[34] in Table 7.

***Table 4.* Results of the Box-Cox Estimation**

[Place Table 4 approximately here.]

***Table 5.* Box-Cox Regression- Elasticities at Mean**

[Place Table 5 approximately here.]

***Table 6.* Results of Heckman Sample Selection Estimation**

[Place Table 6 approximately here.]

***Table 7.* Heckman - Elasticities at Mean**

[Place Table 7 approximately here.]

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where

$$x^{(\lambda)} = \begin{cases} \dfrac{x^{\lambda}-1}{\lambda} & \text{if } \lambda = 1 \text{ then a linear model is appropriate} \\ \ln x & \text{if } \lambda = 0 \text{ and a semilog model is appropriate} \\ \dfrac{1}{x} & \text{if } \lambda = \text{-}1 \text{ and a reciprocal model is appropriate} \end{cases}$$

for situations in which the independent variable x is known to be positive. A value of '1' was added to all raw values of *PrecipitatorTime* and *AdjustTime* to convert zero values to positive values. A value of '1' is added as Seaks and Layson (1983) note that Box-Cox technique when combined with a weighted least squares correction for heteroskedasticity (where the heteroskedasticity is proportional to variable Z_i not a regressor) requires not only that the variables be positive. It also requires that $X_{ij}>1$, so that $\ln X_{ij}^{\lambda}$ can be computed.

[33]According to Savin and White (1978), it is only meaningful to compare the elasticities for different estimations of the Box-Cox model. The regression coefficients are not of particular interest since they apply to the transformed variables and not the original variables.

[34] In the Heckman sample selection estimation, elasticities are calculated using the following formula δlog y/δlog x which gives the percentage change in y for a 1 percent change in x.

It is observable that the results are comparable for equations (7), (8) and (13) across both estimation methods (e.g. Heckman Sample Selection estimation, Box-Cox regression model). Referring first to the results Box-Cox regression model, we find that reciprocal (λ=-1) and semi-logarithmic models (λ=0) are both strongly rejected, see Table 4. The linear model (λ=1) cannot be rejected for equations (7) and (13) but is rejected but only at the 5% significance level for equation (8). Thus, these results (λ=1) provide us with confidence in examining the linear specification of the performance equation in the Heckman sample selection model. Turning to the results of the Heckman Sample Selection model, we find that the correlation between the disturbances in the performance and selection equations, ρ, is close to zero in each equation, suggesting that selectivity bias is not a major problem. In fact, a likelihood ratio test of the null hypothesis, ρ=0 for each equation, could not be rejected providing evidence confirming this finding[35]. This helps explain the comparability of the results across estimation techniques, given that there was no correction for sample selection bias in the Box-Cox estimation, and particularly as λ=1. The correction for sample selection bias presented in Table 6 is rudimentary. The coefficient on sales early in the lifecycle of the small firm (*StSales*) is the only variable which shows any signs of significance. Giving it interpretation, we find it confirms prior evidence that initial size conditions have a positive impact on long-run survival; a 1% increase in mean sales earlier in the lifecycle was found to increase the probability of survival by

[35] A test of independent equations (ρ=0) yielded the following results for the three equations:
Equation (7): χ^2 =0.49, d.f.=1, p-value = 0.4835.
Equation (8): χ^2 =1.36, d.f.=1, p-value = 0.2441.
Equation (13): χ^2 =0.11, d.f.=1, p-value = 0.7423.
In each case, we cannot reject the null hypothesis that ρ=0 i.e. the equations are independent.

0.2%.[36] For a more detailed discussion of this survival equation, see Power and Reid (2005). In any case, in interpreting the results of our analysis, we focus our discussion on the results of the Heckman sample selection estimation displayed in Tables 6 and 7, on a precautionary basis, because these estimates have been corrected for selectivity bias.

Before interpreting the estimates and exploring the empirical relevance of the logic of real options, we examined whether the addition of the interaction terms (e.g. *Precipitator*PrecipitatorTime, Adjust*AdjustTime)* raised the variation in performance explained. A likelihood ratio test was used to examine whether the explanatory power of equation (8) was raised in comparison with equation (7) with the inclusion of the interaction terms i.e. *H0:* $\beta_6=\beta_7 = 0$. The test produced a χ^2 statistic of 11.34, which is considerably higher than the relevant $\chi^2_{0.05}$ (2) significance point of 5.99. In this instance, the extended equation (8) which includes interaction terms is the preferred model. Thus, the inclusion of the interaction terms raises the explanatory power of the model and signals that the real options logic captured by these interaction terms has explanatory power also. A comparison of equation (13) with equation (8) was also conducted to examine whether the inclusion of age variables *(Age, Age^2)* and the square of RO_L ($RO_L{}^2$) used to account for nonlinearities in this variable (i.e. a U-shaped relationship with performance, see Power and Reid 2005) have explanatory power. The likelihood ratio test produced a χ^2 statistic of 15.42, which is considerably higher than the relevant $\chi^2_{0.05}$ (3) significance point of 7.81. Therefore the preferred model specification is equation (13), the extended

[36] Similar evidence is available for the U.S. (Evans, 1987a, b; Hall, 1987; Dunne *et al.* 1989), Canada (Baldwin, 1995), the U.K. (Dunne and Hughes, 1994), Portugal (Mata and Portugal, 1994; Mata *et al*., 1995) and Germany (Wagner, 1994).

model.[37] Jointly the interaction terms, the age variables and *RO* squared explain a significant amount of the variation in performance. Similar results for comparable likelihood ratio tests are obtained by comparing the three model specifications using the Box-Cox regression results presented in Tables 4.[38] In our analysis of the appropriateness of the logic of real options below, we interpret the regression coefficients of the extended model (13) in Tables 6 and 7. We will refer to the comparable results of the Box-Cox regression model presented in Tables 4 and 5 where differences emerge. Turning now again to the logic of the value of waiting.

4.1 The Value of Waiting

According to real options logic, it pays to adopt a 'wait and see' approach before committing resources to a new venture until uncertainties are resolved [i.e. $S-X< C\ (S, X, \sigma, T, r)$]. Once uncertainties are determined, the value of waiting any longer is minimal, particularly if $S > X$, as foregone revenues is an implied cost of waiting. Expressions (9) and (10) the marginal effects for *Precipitator* and *PercipitatorTime* capture this logic. Examining expression (9) initially, we observe first that the coefficient on the number of precipitating influences (*Precipitator*) was positive and highly significant implying that greater uncertainty raises performance. A positive relationship between the value of the option, and thus firm performance, is expected as uncertainty or volatility increases, see McGrath (1999). The size of the effect is considered large judged by its elasticity. A 1% increase in the mean count of

[37] This is also confirmed by a likelihood ratio test applied to a comparison of the specification of the model in equation (13) with that of equation (7). This produced a χ^2 statistic of 26.76, which is considerably higher than the relevant $\chi^2_{0.05}$ (5) significance point of 11.07.

[38] A likelihood ratio tests to compare the model specifications (7), (8) and (13) estimated using the Box-Cox regression model produced the following results:
A comparison of extended eqn (13) and reduced eqn (7) yielded a χ^2 =21.2, d.f. =5, p-value =0.0007.
A comparison of extended eqn (13) and reduced eqn (8) yielded a χ^2 =8.77, d.f. =3, p-value =0.0325.
A comparison of extended eqn (8) and reduced eqn (7) yielded a χ^2 =12.43, d.f. =2, p-value =0.002.

precipitators (*Precipitator*) increases performance by 0.13%. But there are diminishing returns to adopting a 'wait and see' strategy (e.g. sacrificed learning, foregone cashflows, preemption, late entry, missed opportunities etc.) in an effort to resolve further precipitators. According to the negative sign on the interaction term (*Precipitator*PrecipitatorTime),* the marginal effect of the identification of a higher absolute number of precipitators (*Precipitator*) on performance is reduced; the longer the firm waits to initiate organisational change (*PrecipitatorTime*). This effect is significant. By holding a real option for a prolonged period of time the entrepreneur risks that it will no longer be 'in the money'. Thus, it is important for an entrepreneur to weigh up the value of investing immediately with the value of waiting a bit longer in light of the available information or resolved uncertainty. The size of the elasticity on the interaction term is not inconsiderable at -0.10. This suggests that on observing an increasing number of warning bells or negative influences in the environment (*Precipitator*), the entrepreneur must compare its needs for further information to resolve uncertainties, with a greater impetus to act quickly (i.e. shorter *PrecipitatorTime*). Thus, there seems to be evidence to support the logic of adopting a 'wait and see' policy. However, at all times the entrepreneur must consider the costs and benefits of exercising a strategic option now, or in the future.

Turning now to expression (10), we observe that the sign of the coefficient on *PrecipitatorTime* in equation (13) is positive and significant. A positive coefficient conveys the clear value of waiting until uncertainties are resolved. By adopting a 'wait and see' strategy the firm defers irreversible investments and limits its exposure to downside risk. The latter improves firm performance, which is in line with real options reasoning (see Miller and Folta, 2002; Ingersoll and Ross, 1992; McDonald and Seigel, 1986). However, the elasticity of 0.09 is slightly lower than that of -0.10, the elasticity of the interaction term (*Precipitator*PrecipitatorTime),* in model (13). The effect of a longer *PrecipitatorTime* or ‘wait and see’ period is reduced as the number of *Precipitators* of organisational change increases. Indeed, as more uncertainties are resolved it does not pay to wait any longer. Otherwise, the potential risk of late entry, or the prospect that the opportunity is going ‘out of the money’ (or has passed), is high. Indeed, there are diminishing returns to the adoption of a ‘wait and see’ strategy. This evidence concurs with the findings of Folta and O’Brien (2004) who find that the option to defer dominates growth options in most contexts.

Here, we find empirical evidence of the logic of real options and particularly the reasoning surrounding the adoption of a ‘wait and see’ policy as outlined by Ingersoll and Ross (1992) and McDonald and Siegel (1986). There is a positive value of waiting but this value is reduced as more uncertainties are resolved. Then the opportunity costs of waiting set in such as forgone revenues, learning sacrificed etc. The entrepreneur must balance the value of waiting to invest, and the added flexibility this brings, with the costs of waiting to invest. This analysis is usually conducted on a case-by case basis, see Luerhman (1998). However, Luerhman argues that active entrepreneurs *“are doing more than merely making exercise decisions. They are monitoring the options and looking for ways to influence the underlying variables that determine option value and, ultimately outcomes” (p. 90).* McGrath (1997) suggests that firms can act to shape contingencies in their favour, and reduce uncertainty, through making idiosyncratic investments to increase revenue streams or reduce the costs of commercialisation. Certainly, they both advocate an active portfolio management approach.

4.2 The Value of Staging Investments

Real options reasoning argues that an entrepreneur should invest sequentially to contain the costs of a real option (i.e. a compound option), particularly if the investments are irreversible in nature. We consider expressions (11) and (12) which describe the marginal effects of *Adjust* and *AdjustTime* on firm performance (*Perform*) to assess the empirical relevance of this logic. Analysing expression (11) at the outset, we observe that the coefficient on *Adjust* is positive but not significant. In any case giving it interpretation, we find that a higher number of stages of adjustment (*Adjust*) following the exercise of a compound option, other things being equal, increase the performance of the small firm. This affirms real options reasoning. Staging investments raises performance presumably by reducing the costs of failure through limiting the firm's exposure to irreversible investments. Its elasticity is not inconsiderable at 0.04%. The effect of increasing the length of the adjustment time on the influence of the number of stages of adjustment is mixed. The interaction between the number stages of adjustments (*Adjust*) and the time it takes for all adjustments to occur (*AdjustTime*) is negative in equation (8), but positive in equation (13). This makes its interpretation difficult. The coefficient on the interaction term is not significant also.

A negative coefficient would suggest that a higher number of stages of adjustment on performance (*Adjust*) on performance is reduced; the longer the firm spreads out its adjustments to organisational change (*AdjustTime*). Thus, increases in the option value, derived from increased flexibility, may come at a cost. In support, McGrath and Nerkar (2004) argue that the value of an option (i.e. or an incremental investment) if not exercised is subject to diminishing returns with the passage of time. Thus, the entrepreneur cannot postpone investment indefinitely without risking the erosion of the value of the option. On the other hand, a positive coefficient would hold that a higher number of stages of adjustment on performance (*Adjust*) on performance is increased; the longer the firm spreads out its adjustments to organisational change (*AdjustTime*). It could be argued that a longer adjustment time increases firm value because it decreases the present value of the future exercise price. Moreover, Bowman and Hurry, (1993), Luehrman, (1998) and McGrath, (1999) hold that extending *AdjustTime* could attenuate possible downside risks by limiting fixed costs (X_t) and irreversible investments (I_t) until uncertainties are resolved. This arguably increases the collective value of the portfolio of options (or consequential adjustments) and the flexibility of the firm thereby explaining the positive effect on performance.

Turning now to expression (12), we observe that the sign of the coefficient on *AdjustTime* had a positive and a highly significant impact on performance in equations (7) and (8) but is insignificant in estimates of equation (13). Giving it interpretation, 1% increase in time to adjustment (*Adjust*) increases performance by 0.06%. The sign of this effect is surprising. Generally, a longer adjustment time reduces the value of the real option, and thus performance, as it places the final payoff further away in time. The explanation offered above by Bowman and Hurry, (1993), Luehrman, (1998) and McGrath, (1999) is more intuitive. Extending *AdjustTime* could contain the potential costs of failure until uncertainties are determined. It seems this policy has a positive impact on performance. Assuming the effect of increasing the number of stages of adjustment on the influence of the length of adjustment time on performance is negative. Then, the effect of a longer adjustment time (*AdjustTime*) on performance is reduced; the greater the number of stages of adjustment (*Adjust*). This effect supports the findings of Errais and Sadowsky (2005) and Trigeorgis (1993). Errais and Sadowsky (2005) holds that when X_t is fixed that the value of the real compound option $V(.,j)$ falls as the number of stages increase. Similarly, Trigeorgis (1993) found that the value of incremental options is less than its value in isolation and declines as more options are present. When the coefficient on the interaction term is positive, the impact of a longer adjustment time (*AdjustTime*) on performance is increased; the greater the number of stages of adjustment (*Adjust*). According to Kort *et al.* (2004), if a firm decides to undertake the project in two stages, it gains the flexibility in choosing the optimal timing of investment separately for each stage and it can refrain from committing resources in the second stage if the market conditions are unfavourable. This strategy raises firm flexibility however it is also costly. Kort *et al.* (2004) holds that undertaking a project in two stages is more costly than a lump sum investment. Dixit and Pindyck (1994) argue that higher uncertainty favours sequential investment rather than one lump sum investment.

Here, confirmatory evidence of the value of staging investments in a sequential chain of real options is weak. While the number of stages of adjustment had a positive effect on performance, its impact was not significant. The coefficient on the interaction term (*Adjust*AdjustTime)* did not yield conclusive results either. There is some evidence that a longer adjustment time has a positive and significant effect on performance [at least in estimates of equations (7) and (8)]. This would suggest that extending the investment period would contain the potential costs of failure until uncertainties are determined lending some support to real options logic. One reason for the unclear evidence of the value of staging investments may be the complexity of the relationship between options in chain of investments. Trigeorgis (1993) discusses the complexity of accounting for the value of real options in the presence of interactions (a function of type, order, degree of being 'in the money' etc.). In this context, valuing flexibility by adding individual option values seriously exaggerates their true worth. This is particularly the case when the values of real options are two or more call options, the main type of options discussed here. This may make it difficult to analyse the value of staging investments, and its relationship to performance.

4.3 Count of Real Options (RO_L)

By reference first to Table 6, we find that the count of real options (RO_L) had a negative and significant impact on our measure of performance. Judged by elasticities at the means, this variable has a relatively large impact on performance Indeed, a 1% increase in the mean count of real options reduces performance by 0.32%. It seems that firms which exercise a greater number of real options expose themselves to the costs of failure more often which negatively impacts on performance. Excessive organisational change (or execution of real options) appears to be to the detriment of the long-lived small firm's performance (see Power and Reid, 2005). This is in harmony with Shimizu and Hitt (2004) view who argue that a firm which continuously changes course may *"vacillate, waste resources, and eventually fail"* (p.45). According to McGrath (1999), the issue is not avoiding failure but managing the costs of failure (e.g. limiting fixed costs, irreversible investments etc.).

We test an insightful explanation for this proposed by Reid and Smith (2000). They hold that the relationship between organisational change (or likewise real options) and firm performance tends to be U shaped. Both poorly performing firms (or 'stagnant' firms in their terminology) and highly performing firms (or 'adaptive' firms in their terminology) tend to be relatively active in undertaking changes, compared to moderately performing firms. Stagnant firms are active in introducing organisational changes, just to survive, whereas adaptive firms are very active in introducing organisational changes, to enhance performance and encourage growth. It may be that there is only a small amount of 'adaptive firms' in the sample encountering positive dynamics, and a much larger amount of relatively 'stagnant' firms propelling the negative relationship between RO_L and *Perform*. The count of real options squared ($RO_L{}^2$) was included as an additional regressor in performance relationship (13) to capture this effect. The impact of this variable was found to be positive but not significant and thus is not given any further interpretation here. By implication, the relationship between the count of real options and performance is monotonic in nature.

4.4 The effect of Age

The effect of Age is included in equation (13) to consider potential learning effects and to control for the different life histories of long-lived small firms. The coefficient on *Age,* and the square of *Age,* is significant in explaining the long run prospects of the mature small firm. A convex U-shaped relationship exists between age and performance. Age has a negative effect on performance (high elasticity of -0.39). Judged by elasticities at the means, this variable has a larger impact than any other does on performance. This effect mirrors the inverse relation found between age and firm growth rather than the positive relationship found between age and firm survival (see Evans 1987a, b; Liu *et. al.,* 1999; Reid, 1993; Dunne *et. al.* 1989, Variyam and Kraybill, 1992; Dunne and Hughes, 1994; Heshmati, 2001). It seems that the long run prospects of the small firm deteriorate as the firm gets older, however at a decreasing rate. The elasticity of the coefficient on the square of age is positive, and not inconsiderable at 0.15. Performance is a convex function of age. This is a fitting result. If performance fell at an increasing rate, the long run survival of these mature small firms would be precarious.

4.5 Summary

The results of the Heckman Sample Selection estimation and the Box-Cox regression are broadly similar across equations (7), (8) and (13). This is not surprising given that the null hypothesis that λ=1 could not be rejected in the Box-Cox estimation implying that a linear specification of the performance equation was appropriate. Furthermore, the null hypothesis that ρ=0 also could not be rejected implying that sample selection bias was not issue. In any case, we prefer the results of Table 6 because they are careful about sample selection, and because, at the margin, any adjustment for it might have a marginal impact upon the performance equation. The results of equation (13) in Table 6 are arguably the most satisfactory in terms of overall significance, individual coefficient significance and magnitudes of elasticities. The Wald Chi-square which jointly tests whether the coefficients of the model (13) equal zero was rejected [χ^2 =20713.76, d.f. =11, p-value =0.0000]. Similar tests for equations were conducted for equation (7) and (8), see Table 6.

Reflecting on the set of results presented in Table 6, there is evidence of an interaction between the number of precipitating influences of organisational change (*Precipitator*) and the time lapsed between the identification of the first precipitator and the organisational change (*PrecipitatorTime*). The sign of this interaction term is negative indicating that there are diminishing returns to adopting a 'wait and see' policy. The small firm faces the danger that the real option will no longer be 'in the money'. This interaction effect offers support for the empirical relevance of the real options approach. The effect of the second interaction, between the number of stages of adjustments and the time lapsed between the change and the final adjustment (*Adjust*AdjustTime*), is difficult to interpret given the switch in signs, from negative to positive, in specifications of equation (8) and (13). Also, the coefficient on this interaction term is not significant. Therefore there is no clear evidence of support for the value of staging adjustments to organisational change. Similarly, Trigeorgis (1993) found difficulties in deciphering the value of investing sequentially for a series of real options, where interactions inevitably exist. Merit was found in undertaking a 'wait and see' strategy but this diminishes overtime as uncertainties are resolved. The flexibility a 'wait and see' strategy offers a firm in its investment decisions lends some support for embracing a real options approach for resource allocation decisions within the firm.

V. CONCLUSIONS

Following real options logic, we observe that the entrepreneur should hold real options until uncertainties are resolved and the value of waiting is at its lowest. Such a strategy reduces downside risk, conserves the firm's resources and raises the flexibility of the firm. An opposing force exists urging the entrepreneur to act quickly in response to a growing number of precipitators of change (or increased resolved uncertainty). When uncertainty is low, the entrepreneur delays an investment which is 'in the money' at his pearl. He bears an increasing risk of pre-emption, loss of market share, late entry etc. Never mind he is sacrificing foregone revenues. Thus, there are diminishing returns to adopting a 'wait and see' policy. This effect was captured by an interaction term included in econometric estimations.

Once a real option is exercised there was evidence that the entrepreneur should lengthen the time period over which staged investments are undertaken. Delays in adjustments may have beneficial consequences for performance through a reduction in uncertainty. It acts as a constraint on the level of irreversible investments. In keeping with this logic, the firm should make small investments initially, and larger investments when uncertainties are resolved, thereby limiting sunk costs in the event of a withdrawal. By contrast, Li (2002) holds that a larger proportion of start-up investment will usually accelerate learning by a firm. Thus, the entrepreneur would have to weigh up the costs and benefits of raising the size of his initial investment. Concrete evidence of the value of staging adjustments was not found when an interaction term was included in the estimation to capture this effect. According to Trigeorgis (1993), there are difficulties in capturing the complex network of forces at play in the presence of compound options.

Nowadays, options are valuable principally because of new realities in the economy such as information intensity, instantaneous communications, high volatility etc., see Mondher (2003). On a case by case basis, the entrepreneur must determine if the potential gains are large enough to warrant the costs of implementing a change in strategy or exercising a real option. Given evidence of the applicability of real options logic, entrepreneurs must learn to act in ways which increase the strategic flexibility of the firm, and ultimately its performance. Poor application of the logic of real options may after all have negative consequences for performance, as we observe that excessive implementation of organisational change (or real options) has strong negative consequences for performance.

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Table 1: The Extraction of the Sample

	Parent	Extracted			Survivors	
		Survivors	Non survivors	Total	Non response	Interviewed
Leverhulme (1985-1988)	86	25	61	86	5	20
Telephone Survey (1991)	160	50	63	113	20	30
Leverhulme (1994-1997)	150	15	5	20	2	13
Total	**396**	**90**	**129**	**219**	**27**	**63**

Note: In total, there were 396 firms in the three parent samples combined which were interviewed earlier. However, to identify long-lived surviving firms only 219 firms met the necessary criteria for selection (i.e. age >10 years). A sample frame of 90 long-lived small firms (or the surviving firms), which were at least ten years old, were identified from the sample frame of 219 firms. These firms were traced using the search engine on the online Yellow Pages (see http://www.yell.co.uk). Sixty three of these firms agreed to be re-interviewed.

Table 2: Definition of variables used in main text

Variable	Definition
Age	Age of firm, in years.
Adjust	Count of adjustments averaged over three main changes = $\sum a_{jm}/3$, where a_{jm} is the occurrence of adjustment j for each main change m.
AdjustTime	Length of time between change m and the implementation of the last adjustment = Max $(at_{jm})/\sum_{c=1}^{3} m_c$, where a_{jm} is the occurrence of adjustment j for each main change m.
FtEmployees	Number of full-time employees at start-up.
RO_L	Count of main changes over life of long-lived small firm = $\sum Y_{i,}$, where Y_i is the occurrence of a change i.
Perform	= $\sum f_i/n$, where f_i is the self appraised score between 0-100 for each factor averaged overall factors 1 to n which were applicable.
Precipitator	Count of precipitator factors averaged over the three main changes = $\sum p_{jm}/3$, where p_{jm} is the occurrence of precipitator factor j for each main change m.
PrecipitatorTime	Length of time between the first precipitator and change m = Max $(pt_{jm})/\sum_{c=1}^{3} m_c$, where pt_{jm} is the length of time between each precipitator factor j and the occurrence of each main change m.
PtEmployees	Number of part-time employees at start-up.
Sales	Sales in 2001.
Sector	=0 services (SIC 61-99), 1 =manufacturing (SIC 01-60).
StSales	Sales at first interview (1985 for SBE, 1991 for telephone, 1994 for Leverhulme) at 2001 prices.
StYear	Year the business was established.
Survival	=1 survivor, 0 otherwise

Table 3: Mean, Standard Deviation and Range of Each Variable

Variable	Mean	Standard Deviation	Min	Max
RO_L	7.90	3.8	2	16
Precipitators	5.27	2.72	1	15.67
Adjust	7.31	3.33	1.67	16
PrecipitatorTime	15.98	13.53	0	56
AdjustTime	16.65	16.44	0	70
Perform	67.35	8.10	49.11	90.43

Table 4: Results of the Box-Cox Estimation

Regressors	Coeff. *(Chi2, df=1)*	Coeff. *(Chi2, df=1)*	Coeff. *(Chi2, df=1)*
RO_L	-2.0352*	-2.3614*	-3.1731**
	(29.634)	(32.634)	(4.693)
RO_L^2	-	-	0.1121
			(2.326)
Precipitator	1.6565*	3.3973*	2.2213*
	(11.128)	(12.49)	(8.178)
Adjust	0.1175	0.9656	0.5874
	(0.059)	(1.726)	(1.100)
PrecipitatorTime	-0.3536*	0.2967	0.7245**
	(5.481)	(0.894)	(5.835)
AdjustTime	0.6785*	0.7948**	0.3576
	(87.669)	(5.103)	(1.581)
*Precipitator*PrecipitatorTime*	-	-0.2115*	-0.1734*
		(8.402)	(9.019)
*Adjust*AdjustTime*	-	-0.017017	0.0056
		(0.166)	(0.030)
Age	-	-	-1.5286**
			(4.229)
Age^2	-	-	0.0240***
			(2.801)
Constant	98.3808*	99.3064*	108.1692*
	(187.982)	(138.671)	(84.897)
Lambda	0.9716*	0.9653*	0.9754*
	(0.0169)	(0.0155)	(0.0154)
Sigma	5738344	1.59e+07	4725257
Chi-square	87.6694	138.671	104.1236
d.f.	6	8	11
Chi-square ($\chi^2_{.05}$)	12.5916	15.5073	19.6751
Lambda =-1	-1219.545*[a]	-1219.545*	-1219.545*
	(333.37)[b]	(345.79)	(360.26)
Lambda =0	-1211.6354*	-1211.3416*	-1205.7185*
	(317.55)	(329.39)	(332.60)
Lambda =1	-1054.1903	-1048.951**	-1040.6168
	(2.66)	(4.61)	(2.40)

Notes: *significant at p-value=0.01; ** significant at p-value=0.05; ***significant at p-value=0.1; [a] Restricted Log Likelihood; and [b]Likelihood Ratio Statistic χ^2

Table 5: Box-Cox Regression- Elasticities at Mean

Regressors	Elasticities at mean	Elasticities at mean	Elasticities at mean
RO_L	-0.1856	-0.1941	-0.3085
$RO_L{}^2$	-	-	0.1271
Precipitator	0.0830	0.1535	0.1187
Adjust	0.0080	0.0593	0.0427
PrecipitatorTime	-0.0361	0.0273	0.0790
AdjustTime	0.1110	0.1172	0.0623
*Precipitator*PrecipitatorTime*	-	-0.1017	-0.0986
*Adjust*AdjustTime*	-	-0.0208	0.0081
Age	-	-	-0.3264
Age^2	-	-	0.1274
Constant	0.9297	0.8460	1.0898

Table 6: Results of Heckman Sample Selection Estimation

Regressors	Coeff. *(Std. Error)*	Coeff. *(Std. Error)*	Coeff. *(Std. Error)*
RO_L	-1.4571*	-1.5597*	-2.1454**
	(0.1622)	(0.1675)	(0.9629)
$RO_L^{\ 2}$		-	0.0681
			(0.0458)
Precipitator	1.1810*	2.0881*	1.5863*
	(0.2881)	(0.5345)	(0.5157)
Adjust	0.1195	0.5719	0.3867
	(0.3067)	(0.4256)	(0.3819)
PrecipitatorTime	-0.1745***	0.1982	0.5576*
	(0.0897)	(0.1772)	(0.1942)
AdjustTime	0.4054*	0.4065**	0.1888
	(0.0298)	(0.1946)	(0.1876)
*Precipitator*PrecipitatorTime*		-0.1086*	-0.1105*
		(0.0378)	(0.0358)
*Adjust*AdjustTime*		-0.0066	0.0064
		(0.0219)	(0.0206)
Age		-	-1.2167*
			(0.4661)
Age^2		-	0.0186**
			(0.0082)
Constant	66.4948*	61.9791*	78.93365*
	(1.804)	(2.3169)	(5.00518)
Selection Equation			
Sector	0.0398	0.0398	0.0398
	(0.2002)	(0.2002)	(0.2002)
FTEmployees	-0.00358	-0.00358	-0.00358
	(0.0120)	(0.0120)	(0.0120)
PTEmployees	-0.0135	-0.0135	-0.0135
	(0.0172)	(0.0172)	(0.0172)
StYear	-0.0032	-0.0032	-0.0032
	(0.0111)	(0.0111)	(0.0111)
StSales	4.94e-07**	4.94e-07**	4.94e-07**
	(2.50e-07)	(2.50e-07)	(2.50e-07)
Constant	-0.3264	-0.3264	-0.3264
	(0.9079)	(0.9079)	(0.9079)
Mills-lambda	618626.3	948046.4	238316.8
	(915376.6)	(843857.3)	(778220.4)
Rho	0.1055	0.1758	0.0506
Sigma	5864461.2	5392890.6	4710744.6
Wald chi2	13421.77	16102.09	20713.76
d.f.	6	8	11
Prob>chi2	0.0000	0.0000	0.0000

Notes: *significant at p-value=0.01; ** significant at p-value=0.05; ***significant at p-value=0.1

Table 7: Heckman - Elasticities at Mean

Regressors	**Elasticities at mean**	**Elasticities at mean**	**Elasticities at mean**
RO_L	-0.2147	-0.2299	-0.3165
$RO_L{}^2$	-	-	0.1171
Precipitator	0.0957	0.1692	0.1287
Adjust	0.0132	0.0630	0.0426
PrecipitatorTime	-0.0288	0.0327	0.0922
AdjustTime	0.1071	0.1075	0.0500
*Precipitator*PrecipitatorTime*	-	-0.0937	-0.0954
*Adjust*AdjustTime*	-	-0.0145	0.0141
Age	-	-	-0.3944
Age^2	-	-	0.1500
Constant	1.0153	0.9469	1.2070
Selection Equation			
Sector	0.0171	0.0171	0.0171
FTEmployees	-0.0228	-0.0227	-0.0227
PTEmployees	-0.0429	-0.0427	-0.0427
StYear	-0.2736	-0.2725	-0.2725
StSales	0.1966	0.1958	0.1958

Figure 1: Explanation of Causation

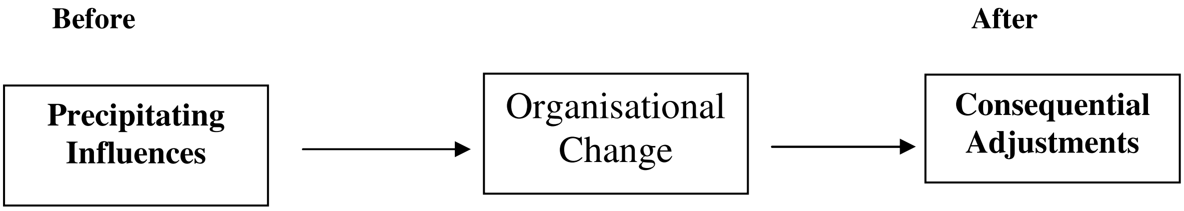

Figure 2: Response Format for Calibrating Change

Time	*Before*	*Factors*	*After*	Time
		1. Headcount		
		2. Demand		
		3. Technology		
		4. Marketing		
		… ………		
		… ……		
		… …….		
		29. Stock		
		30. Other [Please Specify]		

Figure 3: Response Format for Performance Indicator

4.1 We'd like to know what has kept you in business down the years. Some things are good for business and some things are bad. What effect have the following had?

[Show with a cross whether the effect was good or bad.]

Quality

Growth

Debt