

**A Coevolutionary Analysis of Organisational Systems and Processes:  
Quantitative applications to information system dynamics for small  
entrepreneurial firms in Scotland**

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# **A Coevolutionary Analysis of Organisational Systems and Processes: Quantitative applications to information system dynamics for small entrepreneurial firms in Scotland**

## ***Abstract***

We present a quantitative, dynamic analysis of coevolution in the new firm. Organisation is treated as a *process*, rather than a *state*, involving the simultaneous evolution of interacting systems within, and between, small firms and their environment. Our quantitative analysis uses primary-source, time-elapsing data, obtained by face-to-face interviews with entrepreneurs. We found a link between performance and micro-evolutionary experience. High performers were more innovative, more radical 'change makers', more willing to 'wait and see', and more willing to use 'soft' technologies than low performers.

**Key Words:** Coevolution, accounting information system (AIS), small firms, performance, organisational form, innovation, 'soft' technology

**JEL Codes:** D21, D8, D92, M21, M41, O33

# **A Coevolutionary Analysis of Organisational Systems and Processes: Quantitative applications to information system dynamics in small entrepreneurial firms**

## **1. Introduction**

This paper develops a new analysis of coevolution<sup>1</sup> [Ehrlich and Raven (1964), Lewin, Long and Carroll (1999), Jones (2001), Hung (2002)] in the setting of the nascent small business enterprise. The coevolutionary perspective [Kieser (1989), Baum and Singh (1994)] draws on a wide variety of literature, including the historical perspective of North (1990) and Reid (1989), emphasising path-dependence, and the business strategy approach of Mintzberg (1987), emphasising mental models. The roots of coevolutionary ideas lie in the work of Ehrlich and Raven (1964), and Norgaard (1984). The former started the literature in the field of biology, relating the development of butterflies and plants to a coevolutionary framework. The latter was the first to introduce the concept into social sciences, addressing environmental issues, and thence into the accounting literature. The focus of the coevolutionary approach is on the relationship between the organisation (in this case the small firm) and its technical environment. The firm is conceived of as an open system that evolves in response to internal and external forces [Carney and Gedajlovic (2002), Huygens et al (2001)].

The novelty of our analysis is that it is both quantitative and dynamic, which we believe to be an advance over qualitative, longitudinal, case study methodologies [Jenkins and Floyd (2001), Carney and Gedajlovic (2002), Kieser (1989), Nachenberg (1997)]. In terms of the extant literature, our approach focuses on multiple levels within the firm, investigating what McKelvey (1997, p.360) calls 'microevolution'. It considers organisational structures in small firms (including accounting information systems) to be *processes* (rather than *states*), which are subject to change over time. Our approach is coevolutionary in that it examines the simultaneous evolution of interacting systems within, and between, small firms and their environment. We use primary source data, obtained from face-to-face interviews with owner-managers of small entrepreneurial firms in Scotland.

It is found that each small firm has a distinctive evolutionary history (e.g. in terms of organisation and information systems). This is a function of specific initial conditions, and of a distinctive and path-dependent evolutionary process. Despite this individuality of each firm's historical evolution, it was found that there were also common features apparent in the small firms of the sample. First, the introduction of new procedures was irregular, rather than time phased. For example, they did not occur

at regular quarterly intervals, as they might do as a consequence of internal review. This suggests that adaptation was not just driven by internal ‘management logics’ [Dijksterhuis et al (1999)], but also by external environmental factors, or by forces of rival enterprises. These will not follow strict temporal patterns (e.g. monthly, annual, quarterly) as do internal reviews.

Second, the sequencing of adaptations was similar across all firms. This suggests both that all small firms are ultimately driven to change partly by common environmental factors, and also that common ‘management logic’ does prevail, in the sense that, even if the timing of adaptations may vary widely across firms, the sequencing of them is similar, and driven by a common logic. Third, performance was found to influence microevolutionary experience. High performers (judged by sales growth) were more innovative, more radical change-makers, more willing to ‘wait and see’, and more willing to use ‘soft’ technologies, than low performers.

These results were developed by creating and analysing ‘time lines’ of organisational developments within small firms; and by the statistical analysis of the sequencing of adaptations within such firms. We believe our paper to be the first to apply explicitly statistical methods to coevolutionary effects in small firms. This approach is in contrast to the widely used method of longitudinal case studies for the analysis of coevolutionary processes [e.g. Koza and Lewin (1999) on the global accounting industry, Djelic and Ainamo (1999) on the luxury fashion industry, and Rosenkopf and Tushman (1998) on the flight simulation industry]. In turning away from these qualitative case study methodologies, we are seeking to rise to the challenge issued by McKelvey (1999), to investigate coevolution using explicitly quantitative methods, applied to time-phased sequences of firm-specific adaptations at the microeconomic level.

The general area of research from which this paper arises is that concerned with the relationship between information systems (including, specifically, management accounting systems, MAS), organisational architecture [Simon (1962), Tushman et al (1985)] and dynamic processes [Baum and Singh (1994), Henderson and Clark (1990)]. Our context is the small entrepreneurial firm, whose internal structure, and its response to (and impact upon) its environment we were able to study because of our use of fieldwork methods [cf. Mitchell, Reid and Smith (2000)].

Our approach involves a shift away from issues of vertical control through hierarchy to those of lateral coordination [Williamson (1992)], allowing for the flexible evolution of the small firm, in terms of the adoption of new organisational forms, information systems and technologies (both for internal

organisational use and for production per se). This approach, as advocated elsewhere by Hopwood (1996), extends to a consideration of relationships between, as well as within, organisations. At heart, Hopwood's (1996) approach is coevolutionary, though initially conceived within a narrower organisational perspective. When developed, this approach extends to embrace chaos and complexity, and the emergence of self-organisation in the face of informational abundance [Chen (1997), Lewin et al (1999)].

We develop our ideas in the following order. In Section 2, we explain the theoretical background to our research, and develop a new model of the evolving firm. There, we propose a new schema for explaining the dynamics of small firms. This runs in terms of interactions between the small firm over time, and its knowledge environment. Both internal and external forces for change are seen to be at work, with the small firm both being governed by, and attempting to govern, its environment. In Section 3, we develop further our coevolutionary approach, building on the theory of Section 2. This takes us into discussion of matters like architectural innovation [Henderson and Clark (1990)], management logics [Dijksterhuis, Van den Bosch and Valberda (1999)] and self-organising systems [Chen (1997), Foster (1997)]. The test methodology is expounded in Section 4. Here, a formalisation of the data structure is developed, and used to show how propositions on coevolution can be tested for our sample of small firms, using statistical rankings methods on time elapsed data. Section 5 then explains the methods by which data were obtained, by reference to the specific instrumentation used, so that the theory developed earlier can be tested, using the methods expounded in Section 4.

Sections 6 through to 8 report on our empirical analysis of coevolution, using our specified models and methods. Section 6 is concerned with performance and coevolution, and has three parts to it. The first two parts identify fast and slow growth small firms within the sample, and draw inductive conclusions about their relative coevolutionary experience. The third part looks at the whole sample of small firms, and reports on inductive conclusions about common coevolutionary experience. Section 7 is concerned with coevolutionary effects in the use of capital investment and cost management techniques. Section 8 looks at coevolution in relation to the important reference point of the adoption of best technology within the firm, and displays how our chosen statistical techniques can be put to work. Section 9 concludes the paper and summarises key findings. Considered as a whole, our paper seeks to answer the call made by McKelvey (1999) for the use of time based sequences of firm-specific adaptations at the micro level. Preliminary work in this area includes studies by Baden-Fuller et al

(1999), Hanaoka and Sakarno (1999) and Hunter (1999a, b). Our approach is more thoroughgoing than these works in our commitment to using time based sequences of firms' adaptations, and to quantitative analysis of these sequences, using techniques of statistical inference.

To summarise, this paper examines the extent to which features of the organisational form of successful small firms 'coevolve'. This coevolution involves both activities within and between firms. Such activities are crucial to the organisational form the small firm assumes. Our focus is on information systems in their overt form, emphasising business application like investment appraisal, pricing policy and financial modelling, all of which are information intensive activities. The analysis is explicitly dynamic, and involves identifying the specific points in time at which certain forms of information system development occurring, such as the first use of computers for storing information. One then looks at coevolution in two senses. First, do fast-growing small firms, in general, have a 'modal' or typical sequence in which organisational form evolves? This focuses on organisational changes that are reflected in accounting information system (AIS) development. Thus, to illustrate, does the use of a computer pre-date the use of financial modelling? Second, does any specific firm have constellations of coevolving activities occurring at the same time, or at least clustering in time? To illustrate, do firms tend to undertake calculations for internal rates of return (IRR), net present values (NPV), and return on investment (ROI) at the same point in time? The purpose of this article is to explore coevolution in these two specific senses. The novelty of our approach is the use of explicit, quantifiable coevolutionary features within small firms, and statistical techniques for calibrating coevolution.

## **2. Theoretical Background**

Like a number of other authors, we chose to develop our theory using a Figure. However, unlike these other forms of 'model', ours is explicitly analytical, rather than descriptive or taxonomic. For example, Van den Bosch, Volberda and de Boer (1999; pp.554, 560) present a diagram which describes the coevolution of absorptive capacity and the knowledge environment; and Lewin, Long and Carroll (1999; p.537) present a schematic diagram which illustrates the taxonomy of micro- and macro-coevolution. Our own Figure 1 ('The Evolving Firm') presents a new model in figurative form, which can be used to explain the theoretical approach behind our research, and how this can be related to our evidence. Essentially, we have data on the small firm at several points in time. For simplicity, we are

assuming just three points in time,  $t_0$ ,  $(t_0+t_1)$  and  $(t_0+t_1+t_2)$ . At these times, the small firm is observed in what we have called initial, intermediate and final states. Though there is certainly, in a strict sense, an initial state (viz. small firm inception), there need not be a final state, in the sense of terminal state (e.g. just prior to liquidation of the business). Our Figure simply denotes three points in time at which we measured the firms.

**[Figure 1 near here]**

A considerable understanding of the coevolutionary argument can be obtained from Figure 1. The initial architecture of the firm [Henderson and Clark (1990); Simon (1962)] is represented at launch by a square grid in the initial state ( $t_0$ ). The dimensions of this might be measures of scope and flexibility [for example, Grant (1996)]. One point within this grid ( $\alpha$ ) is identified, and the trajectory of this point ( $\alpha, \beta, \gamma$ ), as the firm evolves, is traced from initial ( $t_0$ ) to intermediate ( $t_0+t_1$ ) and final ( $t_0+t_1+t_2$ ) state. This illustrates that one specific aspect of the organizational structure of a small firm might serve different purposes, at different stages in the firm's evolutionary history (or, as it is sometimes called, 'life cycle'). Thus this point has different positions ( $\alpha, \beta, \gamma$ ) in 'organisational space' over time (Figure 1).

Further, it will be noted that, in this case, the complexity of the firm is altering over time [cf. Chen (1997); Simon (1962); Anderson (1999)]. In the case illustrated in Figure 1, the grid is becoming finer and finer, as the firm evolves. Note that this does not deny any position at all in organisation space to the point ( $\alpha$ ) originally identified in the initial state. However, its position changes (to different coordinates within the grid,  $\beta$  and  $\gamma$ ) as the firm becomes more complex.

Complexity itself is increased by pressures from within the firm, driven by creative re-combination of existing knowledge [Kogut and Zander (1992), Henderson and Clark (1990)]. This internal process is illustrated schematically by the dark curved arrow circling back on itself. In the work of Lewin, Long and Carroll (1999, pp. 536-37), which is heavily influenced by the writings of McKelvey (1999) and March (1991), this is regarded as 'micro-evolution'.<sup>2</sup>

This increasing complexity of the organisation (e.g. in terms of task diversity, and varieties of new procedures) can, as Anderson (1999) points out, push an organisation to 'the edge of chaos', encouraging high levels of adaptability and flexibility [Brown and Eisenhardt (1998), Ilinitich et al (1998)]. McKelvey (1999) too has focused on this drive to organisational adaptation, and considers that the fostering of emergent processes, like allowing natural 'product champions' to emerge

spontaneously from sales and technical personnel, will accelerate the pace of organisational change. Lewin et al (1999) and Dijksterhuis et al (1999) push this argument further by suggesting that being 'on the edge of chaos' encourages the emergence of new 'management logics', driven more by principles of self-organisation than of command and control. This approach moves the argument some distance from the earliest treatments of behavioural theories of the firm by the likes of Cyert and March (1963), which emphasised the role of organisational slack, and of rules of thumb, based on satisficing heuristics [Simon (1957, 1972)], rather than emergent processes and management logics.

As well as becoming more complex, in response to internal forces of creativity within the organisation, more fully exploiting re-combinative possibilities, the small firm is also open to outside influences from its knowledge environment. This can stimulate an increase in absorptive capacity [Cohen and Levinthal (1990)]. In turn, this will raise the innovative potential of the small firm. This interaction with the environment can take many forms, all of which contribute to endogenising, at least partly, the organisational structure of the firm. Rival businesses are part of the environment, and so also are government bodies, extending to the institutions they fund, like Enterprise Trusts (ET) and Local Enterprise Companies (LEC). We already know, from small business strategy [e.g. Reid, Jacobsen and Anderson (1993)], how much influence customers, rivals and suppliers can have on small firms' actions, leading to significant organisational change. In a broader context, this is confirmed by a contingency theory based approach to organisational change in the small firm [Reid and Smith (2000)].

Our current approach goes even further, in terms of the influences it embraces. In this context, organisations to which small businesses are affiliated, like Scottish Business in the Community, or interest groups of which they are members, like the Federation of Small Business (FSB), allow small firms to affect their environments in a significant way. This can be either by extracting local concessions for members, because of the force of representation by officers of the national network, or by generic benefits (e.g. cutting of 'red tape', more favourable taxation treatment) arising from effective lobbying in Westminster by the FSB and the Forum of Private Business (FPB) on behalf of small business owners. In such cases, one might expect shared coevolutionary effects to occur across all firms.

As a result, the way in which the small firm's architecture is configured in the final state (time  $t_0 + t_1 + t_2$  in Figure 1) is the product of many forces. Some are internal, and some are external, and the latter assume various levels of generality, from rivals to local government, to central government, for

example. Internal change is partly driven by external forces. Further, external forces are not entirely exogenous, but rather are influenced by both the individual and collective actions of small firms.

### **3. The Coevolutionary Perspective**

Here, the small firm is represented figuratively as moving from a certain organisational form in the initial state (time period  $t$ ). This initial form is represented figuratively as a square. There are influences on the firm (see arrows pointing in) from the knowledge environment. This could include other firms, new technologies, and government activity. If assimilated, they modify the form of the firm. The firm need not be passive in the face of this, and may attempt to adapt its organisational form, in the light of influence from the knowledge environment. It may produce new products that better match rivals' products in the marketplace; it may buy in new technology that will enhance its efficiency and/or innovative capacity; or it may take advantage of government legislation aimed to stimulate innovation, and obtain a grant to re-skill staff, or to install new plant and equipment. In turn, the firm can influence its knowledge environment. Rivals may react to new products the firm produces; innovators may welcome feedback from the firm about new technologies they have bought in, and are learning to use; and government is open to the lobby process, and may adopt grant regimes in response to pressure applied in this way (e.g. through trade associations, or small business interest groups like the Federation of Small Business).

The extent to which such responses occur depends on whether the knowledge environment is stable or turbulent [Cohen and Levinthal (1990)]. The firm itself has a kind of collective capacity to modify its form, with a view to improving its function. Schumpeter (1934) was one of the first to recognise the ability of firms to 'bootstrap' their own new developments with existing resources. More recently, Henderson and Clark (1990, p.12) have put the matter well, when they said, 'the essence of an architectural innovation is the reconfiguration of an established system to link together existing components in a new way'. In the Figure, this is represented by an arrow curling back on itself, within the plane that represents the architecture of the firm. Kogut and Zander (1992) point out that an aspect of new knowledge is simply the re-configuring and utilising of existing components of knowledge in a new way. Indeed, research is well named as an activity, as partly what it involves is looking over existing knowledge, to see if components of it can be combined in novel and fruitful ways.

Of course, in practice, both forces are at work – new knowledge being drawn in from the knowledge environment, and new knowledge being created from the firm’s resources itself. Grant (1996) properly argues that one of the key purposes of the firm is to integrate and use knowledge, whether of external or internal origin. Its capacity to do so depends on the dimensions of efficiency, scope and flexibility. In the treatment of Cohen and Levinthal (1989, pp.569-70), an influential definition of *absorptive capacity* is given; it being ‘the firm’s ability to identify, assimilate, and exploit knowledge from the environment’ where the ability to do so depends upon the ‘stock of minor knowledge [which] constitutes the firm’s absorptive capacity’. What is missing from this argument is the notion that the existing stock of knowledge can itself be enhanced internally in the way suggested by Kogut and Zander (1992). In a later work, Cohen and Levinthal (1994, p. 227) come closer to Kogut and Zander (1992), but still emphasise external knowledge over internal.

Van den Bosch, Valberda and de Boer (1999) emphasise how the development of absorptive capacity, in the sense of Cohen and Levinthal, can be viewed through the lens of authors like Kogut and Zander (1992), Grant (1996) and Henderson and Clark (1990), all of whom emphasise endogenous knowledge enhancement within the firm. Van den Bosch et al (1999) argue that more reconfiguration of existing knowledge in the firm depends on three combinative capabilities, those of *system*, *coordination* and *socialization*.

Taking leads from Dijksterhuis, Van den Bosch and Volberda (1999) we can consider ‘management logics’ as a source of coevolution. These management logics are the sets of reasoning, beliefs and values that drive management theory and practice. Older management logics could include use of communal command and control for quality management, and the use of linear cause-and-effect reasoning for organisational processes. More modern management logics would include treating the organisation as a natural, rather than necessarily rational, system; and treating the organisation as open, and hence subject to indeterminacy and uncertainty, as in contingency theory. The latest form of management logic might be described as post-industrial, and favours the ‘substantive rationality’ approach, according to which firms are self organising, because of their possessing reflective capacities, and being peopled by individuals who are able to recognise and renew themselves.

#### 4. Test Methodology

Having explained, in terms of Figure 1, what our basic theoretical framework is, we need to develop a suitable notation that will take us from theory to empirical testing. The three basic components of our theory are firms, their procedures, and points in time. As we shall see below, the raw data or variables we are working with are elapsed times, measured in months. Therefore, our basic notation is

$$(t_i; F_j; P_k)$$

where  $t_i$  denotes a point in time, like January 1997,  $F_j$  denotes a specific firm, like *OneStop Roofing*, and  $P_k$  denotes a specific procedure, like the adoption of ‘just in time’ (JIT) production practices. Organizationally, the firm can be thought of as a set of procedures. Our approach to notation reflects the concern of our research with what McKelvey (1997, p.360) calls ‘microevolutionary’ features. In short, we are looking at the fine detail of each firm’s functioning, at each point in time. In Figure 1, this fine detail has been represented at three distinct points in time, for a given firm, by three rectangular grids of increasing fineness.

To illustrate the use of our notation and the purposes to which it may be turned, consider the point in time of January 1997 ( $t_i$ ), when Firm 50 ( $F_j$ ) in our sample introduced, for the first time, a procedure ( $P_k$ ), which we shall label 6, say, just-in-time production (JIT). Suppose that, also in this time period, this same firm introduced internal rate of return (IRR) (which is procedure 4), and activity based costing (ABC) (which is procedure 7). Then we would say that procedures 6, 4 and 7 (viz. JIT, IRR and ABC) had *coevolved*. The reasons for this coevolution may have been dictated by a ‘management logic’, relevant to Firm  $F_j$ , which other small firms may share, Dijksterhuis, Van den Bosch and Volberda (1999).

More generally, we can think of the firm as a set of assets (**A**) and technological capabilities (**C**). The assets may be human, material, financial etc. The technological capabilities may be organisational, scientific, managerial etc. The evolutionary experience of the firm is then represented by the dual sequences of assets and capabilities: (**A**<sub>*t*</sub>, **C**<sub>*t*</sub>). This generates the micro-evolutionary experience of the firm. Micro coevolutionary features relate to the structures of assets and capabilities within the firm. To illustrate, if an element of **A**, say  $a(t)$ , is put in place at time  $t$  (e.g. the hiring of a person at time  $t$  with a specific skill, like management accountancy), and this permits an organisational adaptation, or change in technological capability,  $c(t+\tau)$  in **C**, to take place  $\tau$  periods later, at time  $t + \tau$ , which would not otherwise have occurred, we say that is  $a(t)$  a *coevolutionary prerequisite* to  $c(t+\tau)$ .

For example, this organisational adaptation could involve introduction of variance analysis as a control system within the firm.

**[Figure 2 near here]**

This general approach is illustrated in Figure 2. It displays ‘time lines’ of assets and technology, from a zero base to the left. Assets are put in place at time  $t$ , denoted  $a(t)$  on the upper time line, and technology is put in place after a  $\tau$  period elapse of time, denoted by  $c(t+\tau)$  on the lower time line. The elapsed time  $\tau$ , between installation of an asset and development of technological capability is shown between two arrows in the lower time line. Here,  $a(t)$  is a coevolutionary prerequisite to  $c(t+\tau)$ . Also illustrated, is the case in which an asset is put in place at a later time than  $t+\tau$ , called  $t'$ , at which point a new technological capability  $c(t')$  is also put into place. They go together, and this clustering is straightforward coevolution. In our analysis, we consider both completely synchronous coevolution of this type, and of the pre-requisite type, in the form represented in Figure 2.

Our data appear in a less general form than formalised in the last paragraph. Therefore we often simply refer to procedures, than to assets and technological capabilities. In fact, this can involve both the installation of assets (e.g. a PC or a fax), the development of technological capability (e.g. financial modelling, emailing). With these definitions behind us, the six propositions we will be testing are as follows:

**Proposition 1**

*The specific capabilities of small firms will lead to each firm adopting distinctive procedures as they evolve.*

The argument here is not that common coevolutionary features are absent, but, rather, that each small firm, because of its concatenation of special circumstances (e.g. family history, location, specific factors of production) will have a unique evolutionary path. Even so, despite this uniqueness, there may well be common coevolutionary features, both within and between firms, as captured by the further propositions below. To illustrate, in Reid (1998), which looked at adaptive organisational forms in the venture capital world, it was found that every investment house had a distinctive house style. Yet there remained overarching principles governing all investment house activity, which could be captured by treating the investor as a principal and the investee as an agent, in a contractual framework that involved the ‘trading’ of risk bearing for information sharing.

**Proposition 2**

*The introduction of new procedures within the evolving small firm will be intermittent, rather than continuous, or strictly periodic.*

This proposition is supported by the literature on punctuated equilibrium [see Miller and Chen (1994), Gersick (1991)]. Essentially, the argument is as follows. Building on the theoretical developments surrounding Figures 1 and 2 above, we see the small firm as an organisational form, developing over time, by an interaction between the firm and its environment, and a reconfiguration, and augmentation, of internal procedures (including, notably, the accounting information system). These coevolutionary activities aim to increase the fitness of the small firm to follow an evolutionary path which ensures long-term survival. Many adaptations therefore are responsive to environmental changes which are, at root, random events (e.g. the introduction of new technologies within the industry, the bottoming-out of an economic recession). To illustrate by a rather fuller example, consider the work of Jenkins and Floyd (2001) on coevolutionary effects in the Grand Prix automobile racing arena. They refer to three major technological ‘critical incidents’ (the engine as structure rather than propulsion, ‘ground effect’, and ‘boxer’ piston configuration) which radically disturbed previous equilibrium or stasis. More generally, in the absence of such random events, the firm would reach stasis or equilibrium after a few periods, and would remain so, fully adapted to its environment. However, in the presence of such random events, this equilibrium will be ‘punctuated’ by organisational adaptations that are not driven by systematic forces. Thus coevolutionary adaptations will be intermittent, rather than continuous, and non-systematic, rather than periodic, as regards their timing.

**Proposition 3**

*Slow-growth firms will be less inclined to innovate, and less likely to adopt radical procedures post-launch, than fast-growth firms.*

It is known that the inherent flexibility of small firms, compared to large firms, makes them relatively well adapted to innovation. However, one of the key precipitators of innovation is market opportunity [Power and Reid (2002)]. In the absence of it, innovation will be timid and incremental; whereas, in the presence of it, as the potential payoff is so high, innovation is likely to be radical, involving the adoption of new technologies, the entire replacement of old procedures, and so on, rather than tinkering with existing technologies and ‘tweaking’ old procedures. At root, fast growth creates better high-risk, high-return opportunities for the fast-growing, adaptive small firm.

**Proposition 4**

*Faster-growing firms will adopt real-options approaches to investment, and will therefore more often adopt 'wait and see' strategies for investment than slower-growing firms.*

The real options approach to the growing small firm in the earliest literature looked at an option as the set of growth opportunities arising from a firm's resources and capabilities. More recently, this reasoning has been refined to strategies for sequential resource investment. Here, the emphasis is on so-called 'flexibility options', which help to generate strategic change. For example, McGrath and Nerkar (2001), in their longitudinal study of patenting in the pharmaceutical industry, found evidence for such options reasoning in operation at the portfolio level of R&D investment. Essentially, options reasoning reminds us that we are not compelled to exercise the option, even if it is 'in the money' ( $NPV > 0$ ). There is a value in waiting for the best point in time at which to exercise the option. The value of this approach to the firm is in attenuating downside risk, by not being precipitate in investing (e.g. by locking yourself into an irreversible investment situation), and choosing exactly the right moment to take advantage of the upside when exercising the option. It is a relatively refined investment strategy, more typical of high-performing, fast-growth, high investing small firms. Therefore, in seeing relatively late adoption dates for new technologies, or the implementation of new procedures, in small firms, one should not necessarily conclude that they are literally slow off the mark. Rather, they may be adopting a rational, and evolutionarily sound, strategy for successful adaptation and survival.

**Proposition 5**

*Sequencing of adaptations will be similar across all firm types.*

Ultimately, all adaptations, caused by coevolutionary interaction with the environment, are subject to the same 'management logics'. These are defined as systems of reasoning, inference, beliefs and values, functioning at the macro level within the firm, that govern both practice and theory. Dijksterhuis et al (1999) have shown that management logics can be a source of coevolution. Essentially, what they do is to bind together systems of thought that will be used coherently for guiding adaptations within the firm. Many aspects of management logics are incontrovertible. To illustrate, modern financial modelling really does require a computer. True, much of the logic was worked out in the pre-computer age and, even now, implementation of models could be undertaken using an abacus or logarithms. However, management logics indicate that computers and software are coevolutionary

prerequisites to financial modelling. We would therefore expect that a common sequence of adaptation, leading to the adoption of financial modelling as a standard procedure, would be: purchase of computer; purchase of software; training of personnel. This would be true of all firms, whatever their evolutionary histories, or unique characteristics: they would all be governed by the same management logics.

**Proposition 6**

*Faster-growing firms will be less dependent on hard technologies (e.g. computers) in developing soft results, like strategies or forecasts.*

The faster-growing small firms, provided they are not over-trading, tend also to be the higher performing and better managed small firms. Part of this success can be attributed to their adaptability, including the cognitive flexibility of their managerial cadres and supervisors. It may seem that hard technologies like mobile phones, faxes and PCs are the be all and end all of technological change. However, inherent in every firm are ‘soft technologies’, which are ways of doing things involving human operatives, which may have greater or lesser innovative and creative content. Especially in areas which involve looking to the future, and devising contingent courses of action, superior efforts at generating new ideas can have a major impact on adaptation and survival [Djelic and Ainamo (1999); Jones (2001); Koza and Lewin (1999); Drucker (1992)]. On the other hand, even the best hard technology in the world, in unimaginative, uncreative hands, can be a deadweight on the progression of the small firm. To a great extent, successful small firms are able to work with hard technologies in a creative way but, more than this, go beyond hard technologies to areas of the imagination and vision which are crucial to evolutionary success, but still essentially man-based, rather than machine-based, areas of endeavour.

This paper uses a novel way of addressing the time lines data, by using a nonparametric test of the analysis of variance [Gibbons (1985, Ch.13)]. We have seen from the formalisation of coevolution above that coevolutionary processes may involve procedures happening at the same time, or some procedures starting before others. In the latter case, one procedure may be a coevolutionary prerequisite to another. This clustering, or ordering, in time can be used as the basis for a rankings test. If firms share coevolutionary experience (e.g. because of the impact of the knowledge environment on their organisational form) this should lead to observations of the same temporal

ordering of adaptive events (e.g. the use of value added analysis before the adoption of best technology in the sample of firms). What counts here is not so much *when* events occurred, as the *order* in which events occurred. Suppose  $n$  small firms rank  $j$  such events according to the ranking matrix  $\mathbf{R} = R_{ij}$  where  $(i = 1, \dots, k; j = 1, \dots, n)$ . A row of  $\mathbf{R}$  tells you the order in which events occurred for a given firm; a column tells you the rank order of a specific event for all firms. If all firms had identical coevolutionary experience, every element (viz. rank order) of each column would be identical. In this case, the average column total would be  $k(n+1)/2$  and for completely common experience across firms, the sum of squares of deviations from the column total would be:

$$\sum [jk - k(n+1)/2]^2 = k^2 n(n^2 - 1)/12 \quad (1)$$

The actual observed sum of squared deviations would be:

$$S = \sum R_j - k(n+1)/2]^2 \quad (2)$$

Where  $R_j$  is the  $j$ 'th column total. Equation (1) can be shown to be equal to  $kT$ , where  $T$  is the total sum of squares of deviations of all ranks from the average rank [Gibbons (1985, Ch.13)]. The value of  $kT$  lies between zero and  $k^2 n(n^2-1)/12$ . Its maximum occurs when all firms have the same coevolutionary experience, and its minimum occurs when there is statistical independence of coevolutionary experience across firms. The measure of concordance amongst firms is measured by:

$$W = s / kT = 12S / k^2 n(n^2 - 1) \quad (3)$$

This  $W$  is known as Kendall's coefficient of concordance. It equals one for complete concordance, and zero for complete lack of concordance, amongst firms. The sampling distribution of  $W$  is approximated by  $k(n-1)W$ , which is a  $\chi^2$  distribution with  $(n-1)$  degrees of freedom [Gibbons (1985, Ch.13)]. It is this test which we refer to when we talk of the  $W$  test, Kendall test or concordance test.

## 5. Empirical Background

We have set out our theory and methodology above, and now turn to the body of evidence on which we shall undertake our quantitative analysis, within the framework established. In essence, the data we have on coevolution were obtained from a fieldwork study of the inception and growth of 150 small, entrepreneurial firms in Scotland. All evidence was gathered by face-to-face interviews with owner-managers over the period 1994 to 1998. The first three years of fieldwork were financed by the Leverhulme Trust, and the last year (1997-98), which is the one relevant to this paper, was finance by

the Research Foundation of the Chartered Institute of Management Accountants (CIMA). The latter focused on information systems, augmenting earlier material on markets, finance, costs strategy, organisation, technical change etc.

The full details of the administered questionnaire are not strictly relevant to this paper, so we will be brief. Over 600 quantitative variables, and over 50 qualitative variables, were gathered per interview, in each of the four years. However, here, we only use a small subset of the data explicitly, and where we do so, we have given the exact form of questions used for data extraction in the Appendix to this paper. These questions were largely in a section of the questionnaire on management accounting systems (MAS) (Qs. 8.3, 8.4 and 8.5.3 of Appendix), but also involved one (Q. 7.6 of Appendix) on technical change. Essentially, data gathered using these questions were used to explore sequencing of adaptations along the lines discussed above in Section 2, and illustrated in Figure 2.

Questions such as these were asked of the 105 owner-managers in our sample still in business in Scotland over the period 1997-98. Fieldwork contacts were obtained through the Enterprise Trust network in Scotland, a set of some 50 small enterprise stimulating units, functioning at the local level. Of these, 18 cooperated in providing contacts with owner-managers in seven regions: Grampian, Tayside, Fife, Lothian, Central, Strathclyde and Borders. In terms of the geography of Scotland, those sub-samples cover the main areas of economic activity in Scotland, following a roughly reverse L-shape from the North East, down the East coast to Edinburgh, and across the Central Belt to Glasgow and the Borders. The constitution of the sample is known closely to resemble large (23,000) Scottish enterprise samples of that same period, over many attributes. For example, our sample had 55% sole traders, 19% partnerships and 27% private companies, whereas the corresponding figures for the Scottish Enterprise sample were 48%, 21% and 30% and, for the UK as a whole, were 55%, 26% and 19% . As in the Scottish Enterprise sample, and for the UK as a whole, services represent approximately two-thirds of economic activity in our sample. We therefore regard our sample as representative of Scottish small firm economic activity over that period, and largely similar to UK activity over the same period. The typical firm was young (less than three years old on first contact), and a micro-firm (less than 10 employees). Further sample details are available in Reid (2003).

Concerning the specific questions used, all four allow us to examine sequencing of adaptations, and the coevolutionary prerequisites mentioned in Section 2 above. Referring to the Appendix, Q.8.3 asks when capital investment techniques (e.g. NPV, IRR, residual income etc) were first used in the small

firm. Q.8.4 asks when specific methods for managing costs (e.g. ABC, strategic pricing, JIT, throughput accounting etc) were first implemented in the small firm. Then Q.8.5.3 asks when specific computing intensive techniques (e.g. financial modelling, forecasting and simulation) were first used in the small firm. Finally, in a different part of the questionnaire, owner-managers were asked (see Q.7.6, Appendix) when they had implemented their most important technology since start-up. As two-thirds of our small firms were in services, new production technology was interpreted liberally, in interviews with owner-managers, as being any new technology which facilitated the supply of a firm's goods or services.

It will be noted that all the data obtained from the small firms in this context are, technically, time elapsed data. They tell you when a certain action was taken, within the evolutionary history of the small firm. Referring back to Figure 1, as new techniques are adapted, the 'grid' becomes more complex over time, as the relationship of one technique (e.g. financial modelling) to another (e.g. value analysis) becomes more complex. Once adopted, a technique (e.g. ABC) may be a persistent feature of the small firm's activities (as in the trajectory of  $\alpha$ ,  $\beta$ ,  $\gamma$  of Figure 1), but its relationship to other features of the small firm may become different (viz. a new position in the grid) and more complex (viz. lying within a grid of finer mesh).

Our interest is in showing what relationships these time elapsed data on organisational features of small firms have to one another. The way we do this is to construct the empirical equivalents of the theoretical time lines of Figure 2 (see Section 6 below). Subsequently, these data are subjected to statistical analysis (see Sections 7 and 8 below) using the techniques for analysing sequences expounded in Section 2 above. We turn now to these tasks.

## **6. Performance and Coevolution**

This section develops its argument by reference to empirical implementation of the theoretical time lines first introduced in Figure 2 above. Recall that, in that Figure, the micro-evolution of certain aspects of organisational structure or procedures ('management logics') are displayed (e.g. the installing of certain assets, or the adoption of certain techniques). This is done by indicating the point in time at which the organisation changes. Thus the relationship of one change to another is represented by a time lag. This implies that the data being generated are of 'time-elapsing' form: they

tell how much time elapsed before another change occurred. These are the fundamental data of our empirical analysis.

In our diagrams (Figures 3, 4 and 5 below) the time from inception of the small firm to the adoption of any new structure, or procedure, is represented by a thin, horizontal bar, whose length measures this elapsed time. In this way, coevolutionary structure is clearly displayed. Most obviously, it displays the way in which equilibrium, or stasis, for small firms is irregularly interrupted, or punctuated equilibrium [Eldredge and Gould (1972), Somit and Peterson (1989)]. More generally, it allows us to display time-phased sequences of firm-specific adaptations at the micro level, as suggested by McKelvey (1999), and only broached in a preliminary, informal way, using qualitative, longitudinal case studies, by Baden-Fuller et al (1999), Hanaoka and Sakano (1999) and Hunter (1999a, b).

The analysis proceeds in three steps, all of which are motivated by the desire to link performance with coevolutionary experience. In the first two parts (6.1 and 6.2 below), a sharp contrast is deliberately made between the high-performing ('fast-paced' in 6.1) and low performing ('slow-paced' in 6.2) small firms. By looking at the extremes, in terms of performance across the whole sample, key differences are thereby highlighted. In the third part (section 6.3) reference is made to the full sample, this time split into above and below median growth firms. This helps to generalise the inductive findings of the previous two sections.

### **6.1 Fast-paced firms**

Figure 3 shows some time-lines for the adoption of procedures for monitoring and controlling the nascent small business [cf. Jenkins and Floyd (2001)]. On the horizontal axis is time in months from inception of the firm, which extends, at maximum, to just over five years.

**[Figure 3 near here]**

The procedures considered (all under question 8) included: strategic pricing (e.g. product life-cycle pricing, price discrimination) (*SPI*); value analysis (e.g. identifying products or activities that have low value added) (*VAI*); quantitative risk analysis (e.g. expected outcomes, decision trees) (*QRAI*); modern accounting practices (e.g. JIT, automated manufactures) (*JITI*); and a variety of methods for making decisions about capital investments, including the payback period (*PAYBACKI*), internal rate of return (*IRRI*), net present value (*NPVI*), residual income (*RESIDI*) and return on investment (*ROI*).

For all of these variables, we were able to determine, in face-to-face interviews, whether they were *relevant*, and *when* the procedures were adopted or implemented. The dates provided were then translated into months from inception. Thus the length of a bar in Figure 3 denotes the number of months which elapsed before a procedure was adopted.

The firms represented in Figure 3 were chosen because they represented the top fastest growing firms in the sample, as measured by the annual growth rate of sales revenue. Thus each integer on the vertical axis represents the identifier for a particular high-growth firm and, for that firm, horizontal bars indicate which procedures were adopted. On the horizontal axis we measure time in month. Thus the length of a horizontal bar tells you how long it took to adopt a new procedure in the small firm. We note four key features of Figure 3. *First*, only a limited range of procedures is introduced by any one firm (and sometimes none, as for Firms 10 and 4). *Second*, some procedures are introduced very early in the evolution of firms. For example, Firm 2 introduces strategic pricing and value-added analysis very early, Firm 5 introduces activity based costing early, Firm 7 introduces activity-based costing and residual income analysis early, and Firm 9 introduces value-added analysis and activity based costing early. By ‘early’ or ‘very early’ we mean within the first few months of existence. Further, these procedures are often introduced at the same time - this is true for Firms 2, 7 and 9. This indicates coevolutionary content, in that it is apparently not effective at the micro level to introduce procedures in isolation from one another. We suggest that these core actions define a kind of ‘thumb-print’ for the small firm, identifying those key procedures early on, which are important to the subsequent performance and survival of the business [cf. Henderson and Clark (1990)].

*Third*, the introduction of procedures seems to be *intermittent*. This is the phenomenon of ‘punctuated equilibrium’ [see Gersick (1991), Tushman and Romanelli (1985), and Miller and Chen (1994)]. Absence of change, or ‘stasis’, in organisational form represents a kind of dynamic equilibrium. This is only periodically ‘punctuated’, or interrupted. Such punctuation permits new procedures to be adopted, whereby a new equilibrium (or stasis) is achieved. We note that stasis is active, rather than passive. It has to be sustained. It can be regarded as synonymous with ‘resilience’, in the short run. In our data, we have an intermittent pattern which does not occur month by month, but rather is sporadic [cf. Van den Bergh and Goudy (2000)]. Only Firm 3 seems to approach to being an exception to this, introducing just-in-time production after about six months, activity based costing after about 15 months, value added analysis after about 25 months, strategic pricing after about 36

months, and payback period after about 62 months. Even for Firm 3, this pattern of evolution of procedures seems relatively sporadic - it certainly does not occur at regular 'review' intervals. This suggests that the procedures are being introduced because of external precipitating factors, rather than because of regular organisational reviews [Dijksterhuis et al (1999); Lewin et al (1999)]. These are coevolutionary effects, in that external change is driving internal change [cf. Figure 1]. *Fourth*, as with the phasing of early adoption of procedures, when procedures are adopted later, this too seems to occur in clusters [cf. Van den Bergh and Gowdy (2000)]. This is also a coevolutionary effect, as apparently procedural changes require that several components of the organisational architecture need to change at the same time viz. they must coevolve. For example, Firm 1 adopts both strategic pricing and value added analysis after about 53 months, and Firm 6 adopts both net present value analysis, and return on investment analysis after about 49 months.

Overall, the data in Figure 3, for high growth firms, suggests distinctive procedures for each firm, adapted to their own specific characteristics [cf. Kogut and Zander (1992); Henderson and Clark (1990)]. This suggests that small firms, as a group, do not share network effects entirely. This is similar to the discovery of national effects in the fashion industry, caused by both differing conditions and by hysteresis. There is an early stage of key procedures being put in place, which is followed by a later, intermittent process of putting in place additional features, typically at the same time [Maula (2000)].

## ***6.2 Slow-paced firms***

At the other end of the spectrum, consider the evidence in Figure 4. This relates to slow-paced firms in the sample. Data on the same variables, including an extra one for transfer pricing (TP1), are presented. One does not expect high-growth firms, as in Figure 1, to have a necessarily different intensity of use of information systems, compared to low-growth firms, as in Figure 4. We know that steering clear of business failure makes as much demand on monitoring and control systems as does negotiating high success [cf. Reid and Smith (2000)].

**[Figure 4 near here]**

Four features of Figure 4 are also noteworthy. *First*, again a limited range of procedures is used. Further, beyond the start-up phase, this range is severely limited. *Second*, again some procedures are put in place early on in the life-cycle; indeed, considerably more so than in the case of fast-paced firms.

We also get the rather characteristic ‘thumb-print’ of procedure choices by individual firms in the slow-paced case. Several of these firms put procedures in place shortly after launch, notably Firm 3 and 10, which both put six procedures in place close to inception. In fact, eight of the ten slowest growers did put at least one procedure in place early on.

*Third*, again the introduction of procedures seems to be intermittent. There is, however, notably less activity in introducing procedures, post-launch, for the slow-paced firms. Only half these slow-paced firms put any procedures in place after the launch phase, and of these just one (Firm 2) introduced more than one procedure (in this case, only two, value added analysis and payback analysis). This suggests a kind of low level equilibrium, or stagnant form of stasis, which is hamstringing further development. *Fourth*, when procedures are adopted, as with those at start-up, they tend to occur simultaneously. Post launch, the only case of multiple adoption of procedures had this feature. Thus both value added and payback were adopted as new procedures by Firm 2, around the forty-first month.

Considered overall, the data in Figure 4, for slow-growth firms, suggest evolutionary features which are similar to those of the fast-growth firms of Figure 3. That is, both firm types are subject to coevolutionary effects. In common are the distinctive ‘thumb-print’ of procedure choices, the installing of key procedures shortly after launch [Lewin et al (1999); Dijksterhuis et al (1999)], and the intermittent supplementation of procedures, beyond the launch. In this sense, both fast- and slow-growing firms seem to have some similar coevolutionary features [Chen (1997); Simon (1962); Anderson (1999)].<sup>3</sup> The main differences that arise are that slow-growing firms are less inclined to innovate, in terms of procedures, post-launch [Chanaron and Jolly (1999); Brown and Eisenhardt (1997); Henderson and Clark (1990)]; and, when they do so, are less radical in the procedural changes they institute, compared to their fast-growing brothers. Thus there are internal dynamics which may stifle or suppress microcoevolutionary potential.

**[Figures 5 and 6 near here]**

### **6.3 Full sample of firms**

As regards generalising these observations, the evidence of Figures 5 and 6 takes the argument a step further. *First*, in Figure 5 we have that half of the sample for which firms have sales growth rates above the median; and in Figure 6 that half of the sample for which firms have growth rates no more than the median. Again, we have two distinctive choices of procedures for each individual firm, and

also the widespread initiating of procedures close to launch [cf. Kogut and Zander (1992)]. *Second*, coincidence, in terms of the timing of introduction of new procedures, is also in evidence, and perhaps more so for the higher, compared to the lower, growth firms. *Third*, there is a broader range of procedures undertaken (Figure 5) by the higher-growth, compared to the lower-growth (Figure 6) firms. This can be noted from the relatively heavy ‘blocking’ of lines in Figure 5, compared to Figure 6. Finally, the fast-growing firms are more inclined to continue to institute new procedures, as evidenced by the higher proportion of time-lines extending further along the time axis, in Figure 5, compared to Figure 6 [cf. Cohen and Levinthal (1990)]. These conclusions are only tentative, and they await confrontation by a more formal method of empirical testing, as below. However, tentative though our conjectures may be, but they are suggestive of possible, and plausible, regularities in the data. These concern coevolutionary structures [cf. Lewin et al (1999); McKelvey (1997, 1999); March (1991)]. We have done further work on time-lines, involving different sample splits and/or using different measures of growth, and we are encouraged by the finding that our qualitative interpretations remain much the same. This suggests they have some robustness. This robustness partly arises because growth rates, according to different measures, are typically highly correlated. For example, the Pearson correlation coefficient between sales growth and employment growth is high ( $r = 0.456$ ) and highly statistically significant (Prob. value = 0.000).

## **7. Coevolution of Capital Investment and Cost Management**

We move on now to more formal methods of exploring the data. If we look at the sample split into high and low performers, using the median sales growth rate as the splitting point, we find there are significant differences between the dates at which procedures were put into place by the two types of firm.

**[Table 1 near here]**

In Table 1, columns (a) and (b), we show the mean dates at which certain procedures were implemented, where the dating is taking place from inception. The same abbreviations for procedures are used as in Figures 3 to 6. Note that some procedures (e.g. quantitative risk analysis, transfer pricing) are not commonly used by either class of firm. As regards the whole range of procedures, it is not clear whether one type of firm tends to be an early or a late adopter of procedures. However, as regards the specific class of procedures which relate to investment return, namely rate of return on

investment (*ROI*), net present value (*NPVI*), internal rate of return (*IRRI*), and the payback period (*PAYBACKI*) there does not seem to be a different pattern to evolution for fast-paced, compared to slow-paced, firms. In comparing columns (a) and (b) of Table 1, we see that fast-paced firms adopt these procedures considerably later, on average, than slow-paced firms. Thus, to illustrate, they adopt both rate of return on investment and payback period procedures, on average, ten months later than slow paced firms. It is of note that these are by far the most common forms of investment appraisal procedures used by both types of firms. Further, there is an almost identical lag, on average (10 months), for adoption of these procedures, between slow- and fast-paced firms. We do not find it surprising that the better performing groups of firms should be slower to adopt explicit investment appraisal procedures, given the use of real options reasoning, as stated under Proposition 4. This is, in our judgement, most likely to reflect a defensive stance by the lower performing small firms, with them rather self-consciously checking how well they are doing, in the face of below average growth rates.

## **8. Adoption of Best Technology**

Finally, we come to consider what inferential tools can say about coevolutionary patterns in our data as they relate to the pivotal factor of adoption of best technology. The evidence is limited, and the empirical hints are elusive, but there do appear to be interesting regularities in our data, even at the level of our preliminary analysis. A helpful way of looking at the evolutionary paths taken by these small firms, in terms of their introduction of new procedures (e.g. like investment appraisal) is to imagine a process of judgement [cf. Zollo and Winter (2002)]. In our case, it is a judgement about “what comes first?” Pivotal to how we approach this question is another variable from our administrative questionnaire, *BESTECH*. This is defined as the time in months which had elapsed between start-up and the most important implementation of new production technology in the small firm [cf. Chanaron and Jolly (1999)].

Having determined by questioning the value of *BESTECH*, we are then in a position to ask a question like: “what do you judge would come first, value added analysis, or the best technology?” The mean rank, across firms which provided answers to both questions, was 1.25 for value added analysis, and 1.75 for best technology. Thus, on average, value added analysis (*VAI*) comes before implementation of best technology for our sample of small firms. Of course, opinions differ on rankings amongst our small firms, so there is at least some variation across firms on this matter. However, on Kendall’s

coefficient of concordance (the so-called W-test), the extent of agreement (measured by  $W = 0.250$ ) is actually statistically significant at the 10% level (Prob. value = 0.083).<sup>4</sup> Small firms differ somewhat, but on the whole agree that value added analysis precedes the most important implementation of new technologies.

One can also extend this form of analysis to asking about the temporal ordering of strategic pricing (*SPI*) compared to implementation of best technology (*BESTECH*). The answer is that procedures for strategic pricing are typically prior to the adoption of best new technology, and the W-statistic is 0.445, which is statistically significant at the five per cent level (Prob. value = 0.013). We also find that the use of forecasting and simulation (*FORECAST*) is prior to adoption of best technology ( $W = 1.00$ ; Prob. value = 0.002) and this too is highly statistically significant. Further, the use of computers for storing data is typically prior to the use of best new technology ( $W = 0.468$ ) and this is also highly statistically significant.

To slightly vary the frame of reference, we can also ask about the temporal relationship between more than one procedure being adopted and the implementation of best new technology [Lewin and Volberda (1999); Helfat and Raubitschek (2000)]. Considering the procedures of storing data (*STOREI*) on a computer and strategic pricing (*SPI*) in relation to implementing best new technology (*BESTECH*), we find that the order in which procedures are typically adopted are strategic pricing (mean rank 1.5), storing data on a computer (mean rank 1.9) and adopting the best new technology (mean rank 2.6). This ordering enjoys high concordance across our small firms ( $W = 0.316$ ) and this result is statistically significant at the five per cent level (Prob. Value = 0.031).

We believe the variable *STOREI* is particularly salient, as it tells you how long after inception it took the small firm to use computer software to store data, at a time (early 1990s) when computers were not widely used in such businesses, and before the likes of Microsoft Windows had made their use more accessible and user-friendly.<sup>5</sup> Of course, you do not need to have this capability to engage in financial modelling, for example, but it certainly helps, one would think. We find that, typically, financial modelling (*FINMODI*), forecasting and simulation (*FORECASTI*), and sensitivity analysis (*SENSANI*) are all only likely to be adopted as procedures *after* the adoption of computers for storing information, within the small firm. The respective W-statistics are 0.218, 0.174 and 0.333, with corresponding Prob. Values of 0.020, 0.046 and 0.025. That is, these results are all significant at the five per cent level. We find that yes, indeed, the use of computers to store data is typically an evolutionary pre-

requisite to the adoption of relatively complex procedures like financial modelling, simulating, forecasting and sensitivity analysis [cf. Chen (1997)]. The evidence says that you do not have to do it that way around, but it surely helps.

To end this section, we should say that we have not yet fully explored all relationships in the data. There are important issues to address, like how sensitive are the results reported in this section to decomposition of the data. This route forward may yield some interesting results. To illustrate, the mean rate of sales growth for the sample is 46%. If we split the sample about this mean (rather than about the median, as we did previously), to get high- and low-growth sub-samples, we get further interesting results. We find that high-growth firms are less bound by requirements of evolution than low-growth firms [cf. Cohen and Levinthal (1990)]. For example, whilst storing data on a computer assuredly comes before financial modelling for low growth firms ( $W = 0.375$ ) and this result is highly statistically significant (Prob. value = 0.014), the same is not true for high-growth firms. In this case, financial modelling has a mean rank of 1.56 and storing data on a computer has a mean rank of just 1.44, so the latter only just has priority. The coefficient of concordance ( $W$ ) is low at 0.037, and is not statistically significant (Prob. value = 0.564). Similarly, forecasting is definitely predicated on computing for low-growth firms ( $W = 0.231$ ; Prob. value = 0.083), but only marginally so for high-growth firms ( $W = 0.100$ ; Prob. value = 0.317), where the mean rank for forecasting is 1.55 and for storing data on a computer is 1.45. The latter is only just prior to the former. This all suggests higher levels of human capital in fast-growth firms, with modelling procedures, as an intellectual process, being less contingent on the presence of computing facilities [cf. Reid and Smith (2000)]. It also suggests there are more complex empirical features of our data than we have yet been able to unearth. In this new area of research, there is much that remains to be discovered and understood.

## **9. Conclusion**

This paper has made a tentative step in the uncharted territory of measuring coevolutionary processes in small firms [cf. Lewin and Volberda (1999)]. The raw material of the study has been primary source data on small firm information systems, gathered in the field, through face-to-face interviewing techniques. These data allow us to identify those points in time after inception at which new procedures are introduced into the firm. We are interested in questions like: do certain procedures tend

to get adopted at the same point in time; or do they need to be adopted in a certain order over time? Further, are patterns of adoption of procedures sensitive to the performance of small firms?

Our analysis proceeded by three means. *First*, we used ‘time-lines’ Figures to detect patterns of adoption of procedures over time. *Second*, we examined descriptive data on the timing of adoption of procedures. *Third*, we utilised methods of statistical inference, based on non-parametric tests of concordance, to analyse the significance of the orderings in which new procedures were adopted.

Our results are necessarily tentative, but do suggest the following:

1. There is a distinctive ‘thumb-print’ of procedures adopted by each firm. This provides support for Proposition 1 above.
2. Key procedures tend to be installed close to inception; a new inductive finding.
3. Subsequent supplementation of procedures occurs intermittently, rather than systematically, suggesting exogenous influences impelling the adoption of procedures, post start-up. This implies support for Proposition 2 on punctuated equilibrium.
4. The adoption of procedures after inception tends to occur at the same point in time for any given firm, again suggesting adaptive responses to exogenous influences. This is a coevolutionary effect, and a new inductive finding.
5. High-growth firms are more radical adopters of new procedures than low-growth firms. This provides support for Proposition 3.
6. For certain classes of procedures (*viz.* those relating to measuring the return on capital), high-growth firms tend to adopt these procedures later than low-growth firms. This provides support for a real options approach to investment, as stated in Proposition 4.
7. There are definite temporal patterns of adoption of procedures evident across all firms (e.g. financial modelling tends to occur after a computer has been installed). This provides empirical support for Proposition 5.
8. High-growth firms are less enslaved to strict orderings of adoption of procedures than low-growth firms, and are, in that sense, more flexible. This is a new inductive finding.
9. High performing small firms seem less dependent on ‘hard’ technologies like computers for developing ‘soft’ procedures, like scenario planning and strategies for the future. This supports Proposition 6.

Whilst these results are provisional, they are suggestive of the potential fruitfulness of the coevolutionary perspective in the analysis of small firm dynamics.

### *Acknowledgements*

We express thanks to our sponsors for funding the fieldwork on which this research is predicated viz. The Leverhulme Trust, and the Research Foundation of the Chartered Institute of Management Accountants (CIMA). Further, we extend our appreciation to owner-managers of new small businesses in Scotland, who gave so generously of their time, over a period of years. Finally, the authors remain responsible for all views expressed in this paper, and for all errors of omission or commission it may contain.

### *Endnotes*

- <sup>1</sup> We look at internal forces explicitly, focusing on the information system, and at the external forces implicitly, focusing on observed coevolutionary patterns [Baum and Singh (1994)].
- <sup>2</sup> This is by contrast to the term ‘macro-evolution’, which relates to competitive dynamics, and the institutional environment. They would then see ‘coevolution’ as relating to the two-way causation between macro- and micro-evolution. This can be a useful simplification of what is meant by coevolution, but by its simplification misses several intrinsic features of the coevolutionary approach e.g. path dependence and irreversibility.
- <sup>3</sup> Not the least of which being that, in the sense of Maula (2000), they are open to the environment, but ‘organisationally closed’ i.e. all change is to internal structure.
- <sup>4</sup> See Gibbons (1985, Ch.13) for details.
- <sup>5</sup> In another context, this interaction between data storage and managerial procedures is documented by Yates (1993) in the context of punched-card tabulating equipment and business processes in the US life insurance industry. Also of relevance here is Chanaron and Jolly (1999) on technology as a factor which has an impact on management method and practice.

**APPENDIX**

**8. DEVELOPMENT OF MAS**

8.3 Could you tell me if you use any of the following methods to decide about capital investment?  
When did you first use them (month/year)?

	<b>Used?</b>	<b>When?</b>
(a) return on investment i.e. a measure of profit ÷ a measure of investment	<input type="checkbox"/>	_____
(b) residual income i.e. net surplus on a project	<input type="checkbox"/>	_____
(c) net present value i.e. net discounted project cash flow	<input type="checkbox"/>	_____
(d) internal rate of return project	<input type="checkbox"/>	_____
(e) payback period i.e. years to +ve net cash flow	<input type="checkbox"/>	_____

8.4 I shall describe some methods for managing costs. For those methods that you do use, could you tell me when they were first implemented (m/y)?

	<b>Used?</b>	<b>When?</b>
(a) modern production practices e.g. JIT, automated manufacturing	<input type="checkbox"/>	_____
(b) modern accounting practices e.g. ABC, throughput accounting	<input type="checkbox"/>	_____
(c) quantitative risk analysis e.g. expected outcomes, decision trees	<input type="checkbox"/>	_____
(d) value analysis e.g. by identifying products or activities that do not add value	<input type="checkbox"/>	_____
(e) strategic pricing e.g. product life-cycle pricing, price discrimination	<input type="checkbox"/>	_____
(f) transfer pricing e.g. using profit centres, pricing of components	<input type="checkbox"/>	_____

8.5.3 Do you use spreadsheets or other computer software for handling information within your business?

- (a) Yes  (b) No

If 'Yes', for which of the following do you use this technique, and when (m/y) did you first start doing so?

	Used?	When first used?
(a) storing data	<input type="checkbox"/>	_____
(b) project appraisal e.g. NPV, IRR	<input type="checkbox"/>	_____
(c) financial modelling	<input type="checkbox"/>	_____
(d) forecasting and simulation	<input type="checkbox"/>	_____
(e) sensitivity analysis	<input type="checkbox"/>	_____

7.6 Which of the following statements best reflects your experience of using new production technologies in your firm?

**[N.B. relate this to your experience since the last interview, by reference to developments like automation, robotics, numerically controlled machines]**  
**[tick one only]**

**[Hand Respondent Sheet 7.6]**

- (a)  we haven't used new production technologies
- (b)  we have implemented new production technologies, but rarely successfully
- (c)  we have implemented new production technologies, but not always successfully
- (d)  we have generally been successful in implementing new production technologies

If (b), (c) or (d), when was your most important implementation of new production technologies since start-up?

\_\_\_\_\_ month/year

**[Retrieve Sheet 7.6 from Respondent]**

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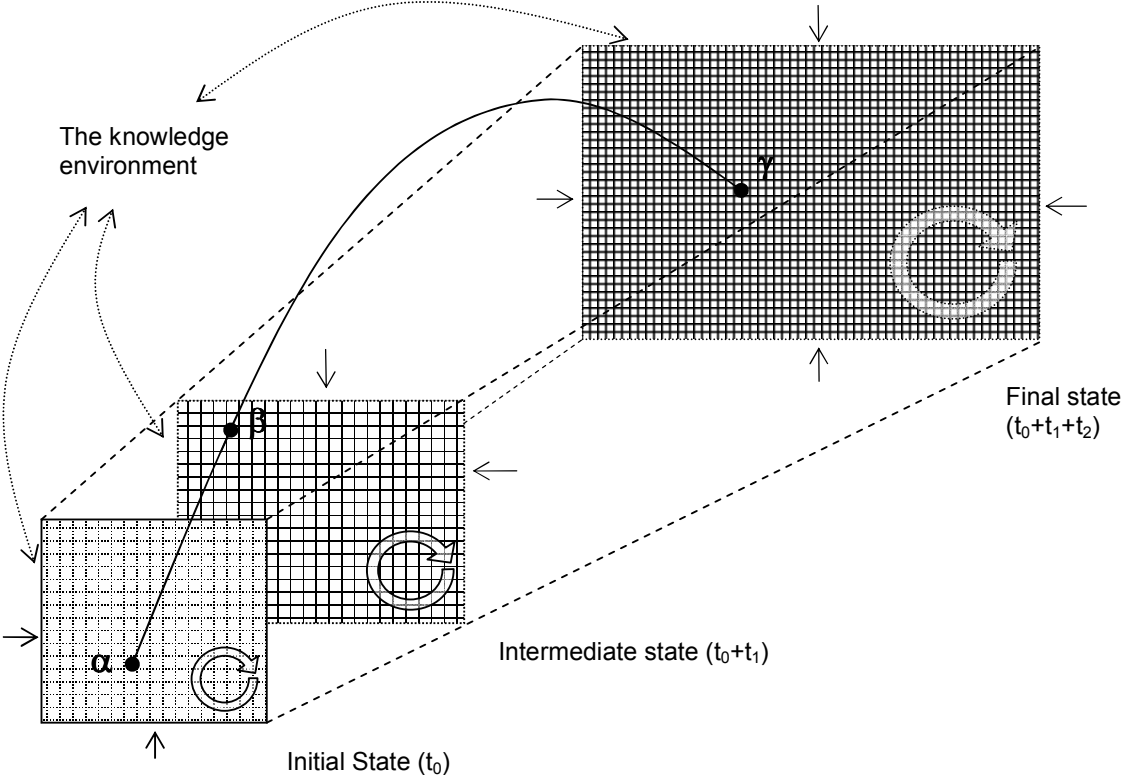
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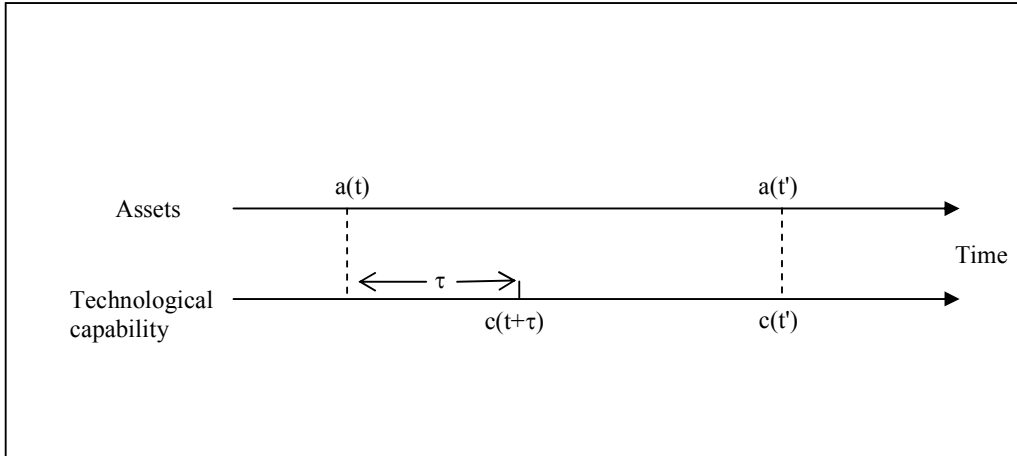
**TABLE 1: Mean Times for Adoption of Procedures by  
Fast-Paced and Slow-Paced Firms**

<b>Procedure</b>	<b>(a) Fast-Paced Time to Adoption</b>	<b>(b) Slow-Paced Time to Adoption</b>
<i>ROI1</i>	24.0000	14.3077
<i>NPV1</i>	36.5000	9.5000
<i>IRR1</i>	8.6667	4.6667
<i>PAYBACK1</i>	26.3750	15.9375
<i>RESID1</i>	7.0000	23.000
<i>JIT1</i>	17.8000	14.0667
<i>ABC1</i>	17.000	20.0000
<i>QRA1</i>	39.000	22.0000
<i>VA1</i>	18.000	30.1765
<i>SP1</i>	11.3529	11.4000
<i>TP1</i>	2.6000	1.0000

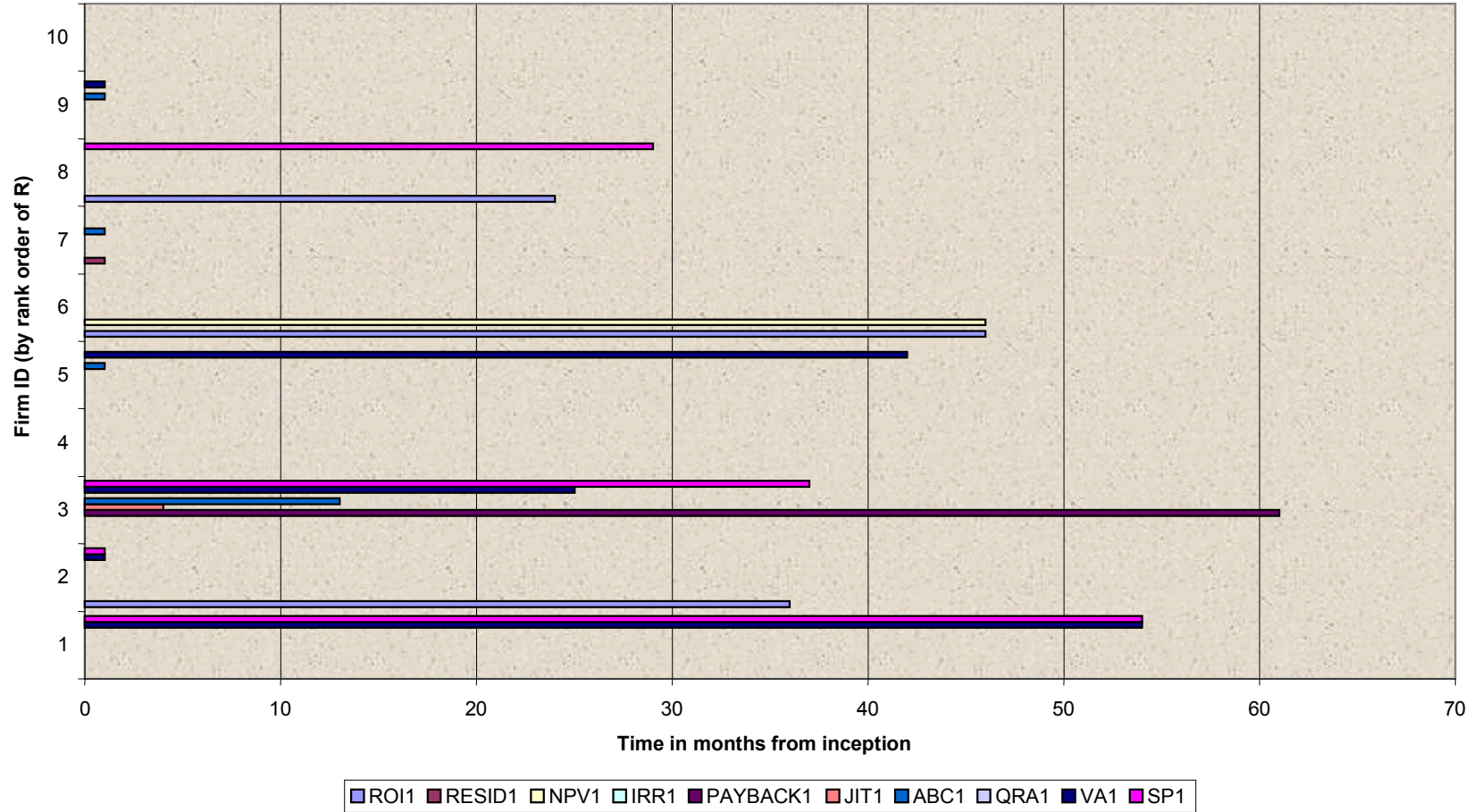
Figure 1: The Evolving Firm



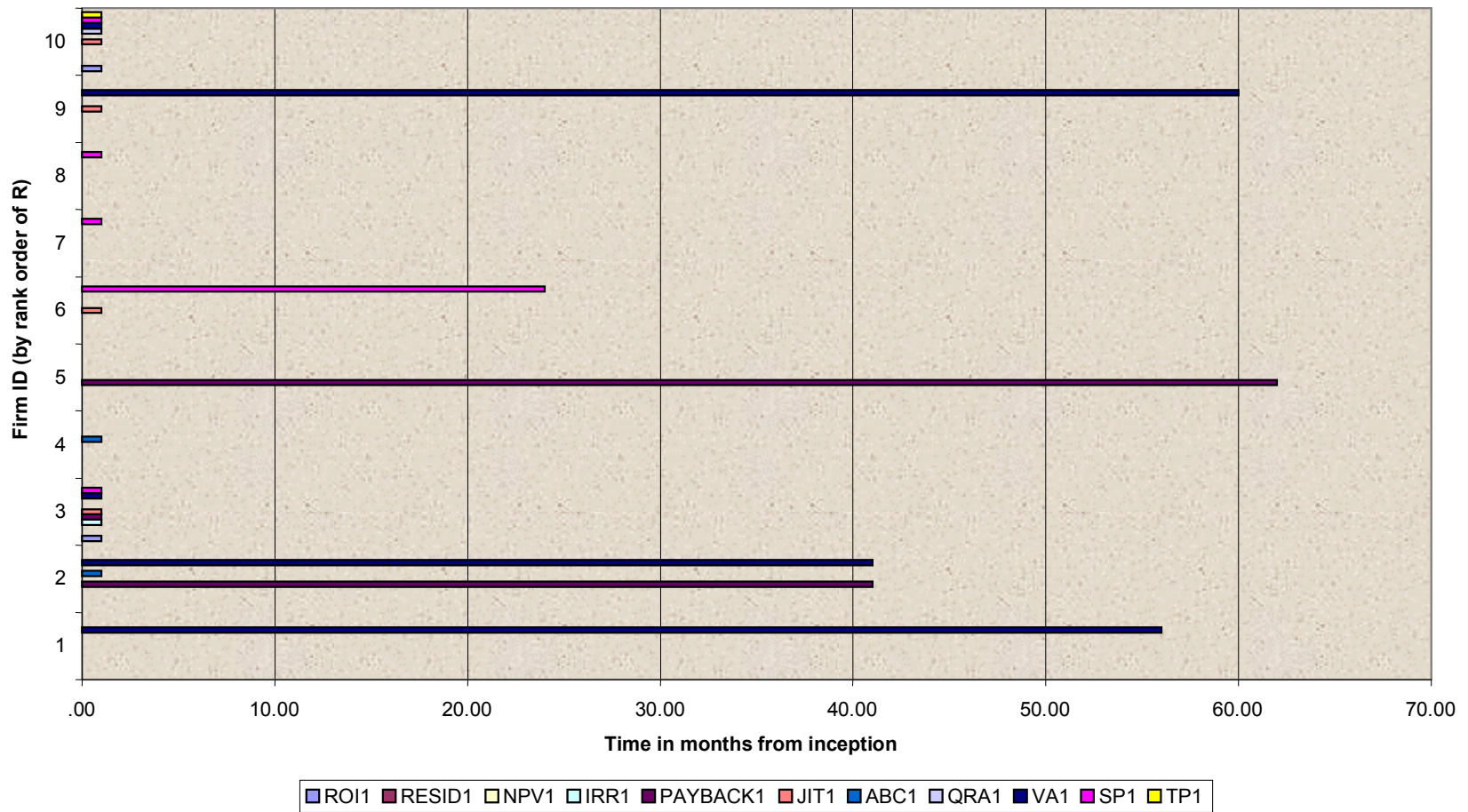
**Figure 2: Time Lines of Coevolution**



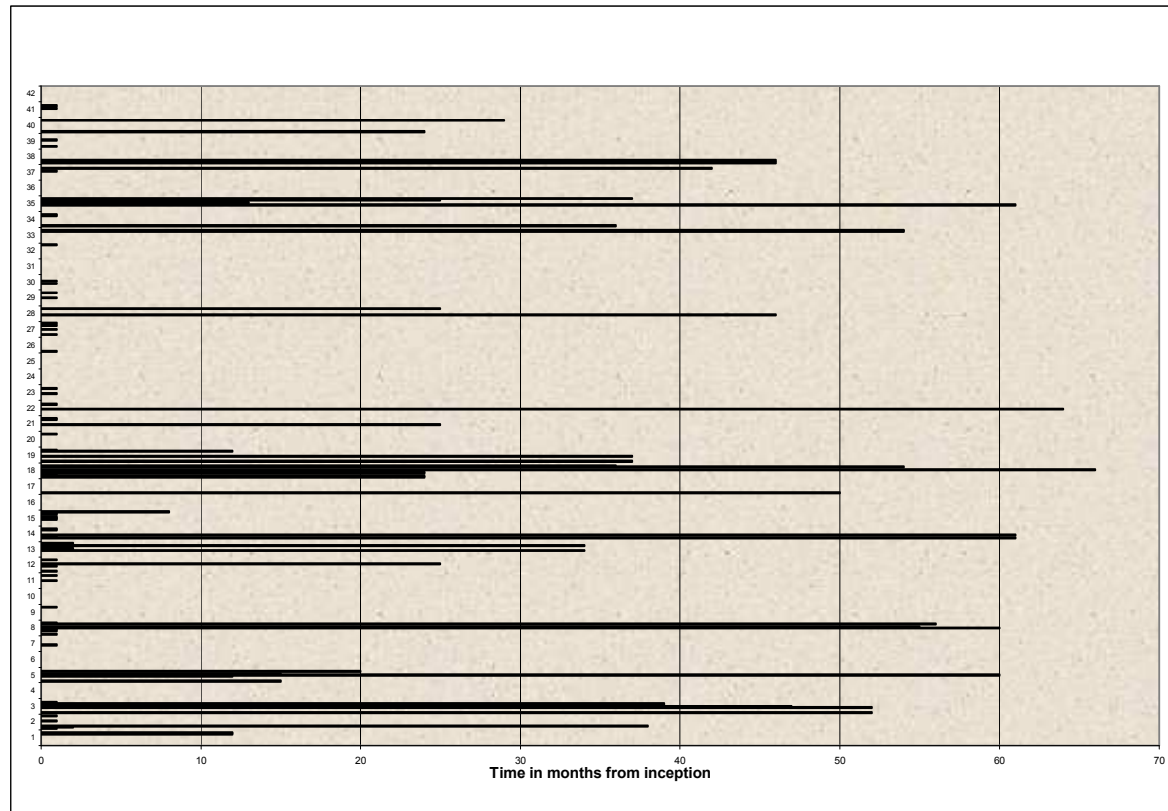
**FIGURE 3: Fast-Paced Firms (top ten by sales growth)**



**FIGURE 4: Slow-Paced Firms (bottom ten by sales growth)**



**Figure 5: Instituting of Procedures by Above Medium Growth Firms**



**Figure 6: Instituting of Procedures by Below Medium Growth Firms**

