Co-evolution of Information Systems in Fast-Growing Small Firms

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ABSTRACT

The paper examines the co-evolution of different dimensions of information systems for a sample of fast-growing small firms. The investigation uses primary source longitudinal empirical evidence. The data are taken from a large database on the life-cycle experience of one-hundred-and-fifty new business starts over a four-year period. They were collected by face to face interviews with owner-managers of small entrepreneurial firms. Interviews were conducted using an administered questionnaire that covered the agenda of markets, finance, costs, business strategy, the development of a management information system, human capital, organisation and technical change. This work uses primarily the data on management information systems.

The basic approach used is to compare the attributes of the fastest and slowest paced firms, as identified by their growth rates. We then examine the evolution of these firms' management information systems. The measures used to identify changes in systems include: capital investment techniques, such as return on investment, residual income, net present value, internal rate of return and payback period; methods for managing costs, like just-in-time management, activity-based costing, quantitative risk analysis, value analysis, strategic pricing and transfer pricing; and using computer applications for storing information, project appraisal, financial modelling, forecasting and sensitivity analysis.

'Time lines' are graphed to show the points at which various features of information systems are introduced (e.g. data storage, forecasting, sensitivity analysis), and derived techniques (e.g. ROI, ABC) implemented. Firms are dichotomised into high-growth and low-growth groups. Comparisons are made within firms and across firms in terms of the co-evolution of different aspects of their accounting information systems.

Key Words: Co-evolution, accounting information system (AIS), small firms

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1. Introduction

This paper examines the extent to which features of the organisational form of successful small firms 'co-evolve'. This co-evolution 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 dynamic, and involves identifying the specific points in time at which certain forms of information system development occurred, for example, the first use of computers for storing information. One then looks at co-evolution in two senses. First, do fast-growing small firms, in general, have a 'modal' or typical sequence in which organisational form evolves. Thus, to illustrate, does use of a computer pre-date use of financial modelling? Second, does any specific firm have constellations of co-evolving activities occurring at the same time, or at least clustering in time? To illustrate, does a firm tend to undertake calculations for internal rates of return, net present values, and return on investment at the same point in time? The purpose of this article is to explore co-evolution in these two narrow senses. Though the focus is narrow, the novelty of our approach is the use of explicit, quantifiable co-evolutionary features within small firms, and statistical techniques for calibrating co-evolution.

2. Empirical background

The evidence we call upon uses small entrepreneurial firms in Scotland. The underlying study aimed to track one-hundred-and-fifty small business start-ups over a

four-year period. The evolutionary features of the small firms that were investigated included markets, financial structure, organisational form and innovation. As a supplement to this core research an additional study was created to 'piggy-back' upon it. This focused on the evolution of information systems within the small firm. There were many features of information systems that we considered, for the small firms under examination, but the predominant approach was to look at the management accounting system (MAS). Broadly speaking, the MAS is a set of data, rules and procedures for monitoring and controlling the small business enterprise. There were just ten features of the MAS that we followed on:

1. Who prepared accounts?
2. What information is available?
3. What methods were used to make capital investment decisions?
4. What methods were used for managing costs?
5. How does information flow around the business?
6. What information is gathered on performance and targets?
7. What factors influence the development of accounting information?
8. How complex is the accounting information?
9. How reliable is the accounting information?
10. How difficult is it to use the accounting information?

Complexity, as in 8, was measured under the headings of: effective planning and analysis; activation and direction of daily operations; problem-solving and decision-making.

Although all the information gathered provided a contextual background to any specific business, the key questions (and their answers) which were used for further empirical analysis were 3, 4 and 5 above. In particular, these questions were crucial in establishing 'time lines' for the adoption of certain procedures within the small firm. Thus question 3 asked which of a range of techniques for undertaking investment decisions were used (e.g. net present value, internal rate of return) within the firm, and (if used), when first used. Similarly, question 4 asked what methods were used for controlling costs (e.g. ABC, JIT etc) and (if used) when they were first used. Finally, question 5 asked whether software was used for handling information in the business, and (if so), when specific techniques (like forecasting, sensitivity analysis and simulation) were first used.

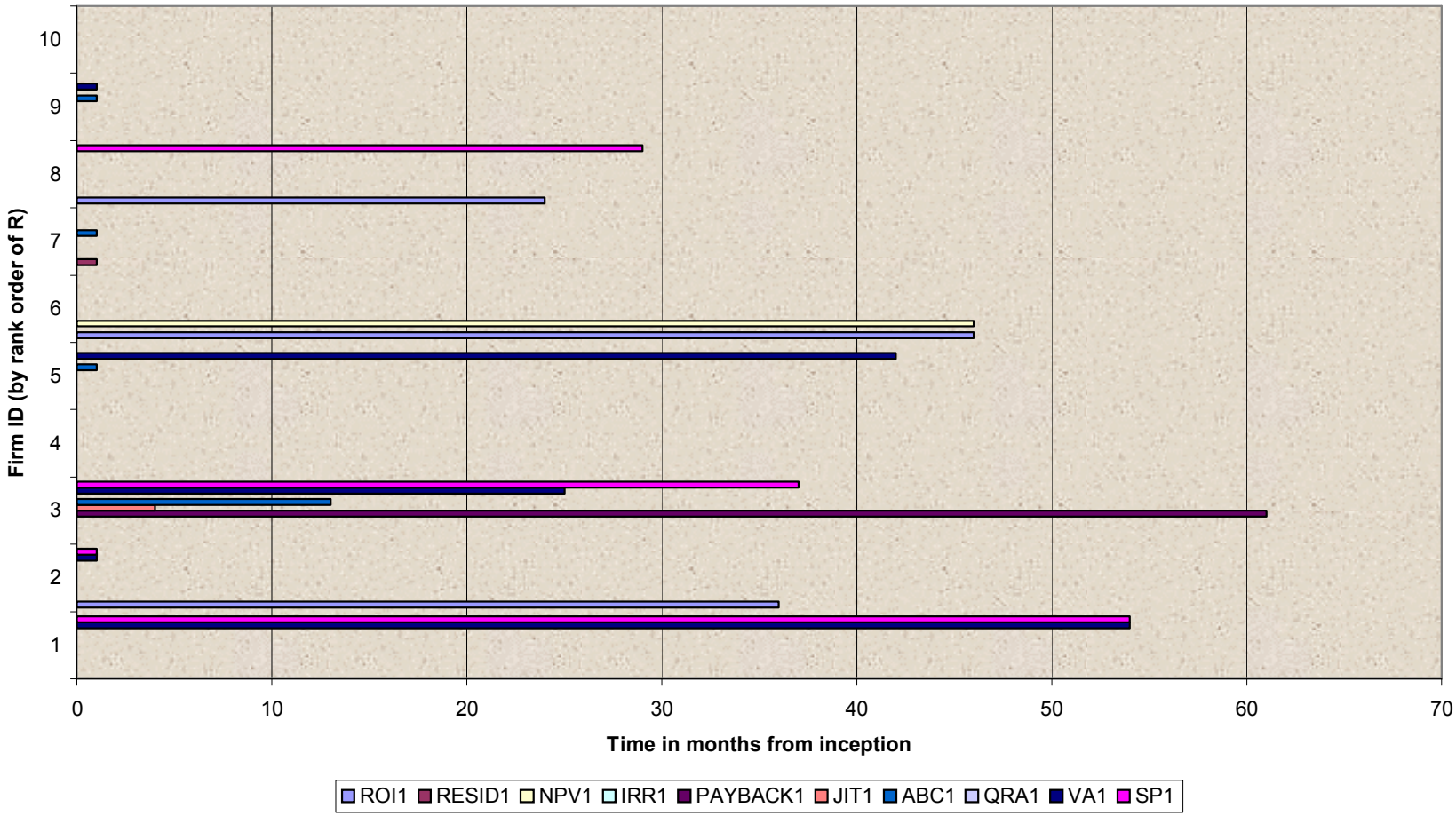
3. Time-Line Diagrams

Empirical 'time-lines' were first constructed for sub-sets of firms in our sample, to see whether there was a certain temporal order in which things happened. This would be evidence of a co-evolutionary tendency in small firm development. Figure 1 shows some time-lines for the adoption of procedures for monitoring and controlling the nascent small business. On the horizontal axis is time in months from inception of the firm, which extends, at maximum, to just over five years.

[Figure 1 near here]

The procedures considered (all under question 8) include: strategic pricing (e.g. product life-cycle pricing, price discrimination) (*SP1*); value analysis (e.g. identifying products or activities that have low value added) (*VA1*); quantitative risk analysis (e.g. expected outcomes, decision trees) (*QRA1*); modern accounting practices (e.g. JIT, automated manufactures) (*JIT1*); and a variety of methods for making decisions about

FIGURE 1: Fast-Paced Firms (top ten by sales growth)



capital investments, including the payback period (*PAYBACK1*), internal rate of return (*IRR1*), net present value (*NPV1*), residual income (*RESID1*) and return on investment (*ROI1*).

For all of these variables, we were able to determine, in face-to-face interviews, whether they were *relevant*, and *when* then procedures were adopted or implemented. The dates provided were then translated into months from inception. Thus the length of a bar in Figure 1 denotes the number of months which elapsed before a procedure was adopted.

The firms represented in Figure 1 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. We note several features of Figure 1. 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. 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.

Third, the introduction of procedures seems to be *intermittent*. It does not occur month by month, but is sporadic. Only Firm 3 seems to approach being an exception

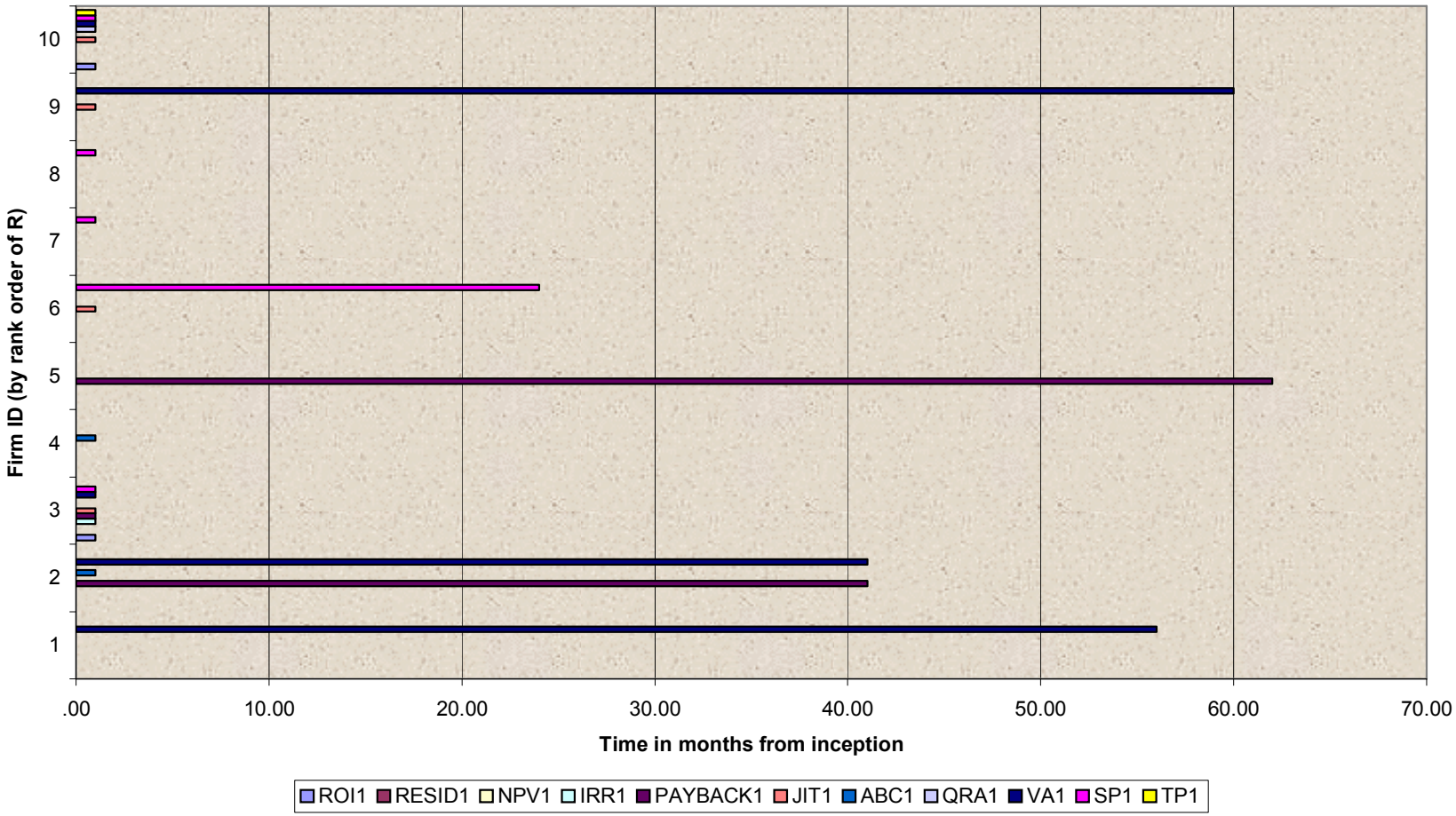
to this, introducing just-in-time production after about six months, activity based costing after about 15 months, value added analysis after about 25 months, strategic pricing after about 36 months, and payback period after about 62 months. Even for Firm 3, this pattern of evolution of procedures seems 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. Fourth, as with the early adoption of procedures, when procedures are subsequently adopted, this seems to occur in clusters. For example, Firm 1 adopts both strategic pricing and value added analysis after about 53 months, and Firm 6 adopts net present value analysis, and return on investment analysis after about 49 months.

Overall, the data in Figure 1, for high growth firms, suggests distinctive procedures for each firm, adapted to their own specific characteristics, an early stage of key procedures being put in place, followed by a later, intermittent process of putting in place additional features, typically at the same time.

[Figure 2 near here]

At the other end of the spectrum, consider the evidence in Figure 2. 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 2. 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 2: Slow-Paced Firms (bottom ten by sales growth)



Several features of Figure 2 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). 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 2, for slow-growth firms, suggest evolutionary features which are similar to those of the fast-growth firms of Figure 1. In common are the distinctive 'thumb-print' of procedure choices, the installing of key procedures shortly after launch, and the intermittent supplementation of procedures, beyond the launch. In this sense, both fast- and slow-growing firms seem to have some similar co-evolutionary features. The main differences that arise are that slow-growing firms are less inclined to innovate, in terms of procedures, post-

FIGURE 3: Instituting of Procedures by Above Median Growth Firms

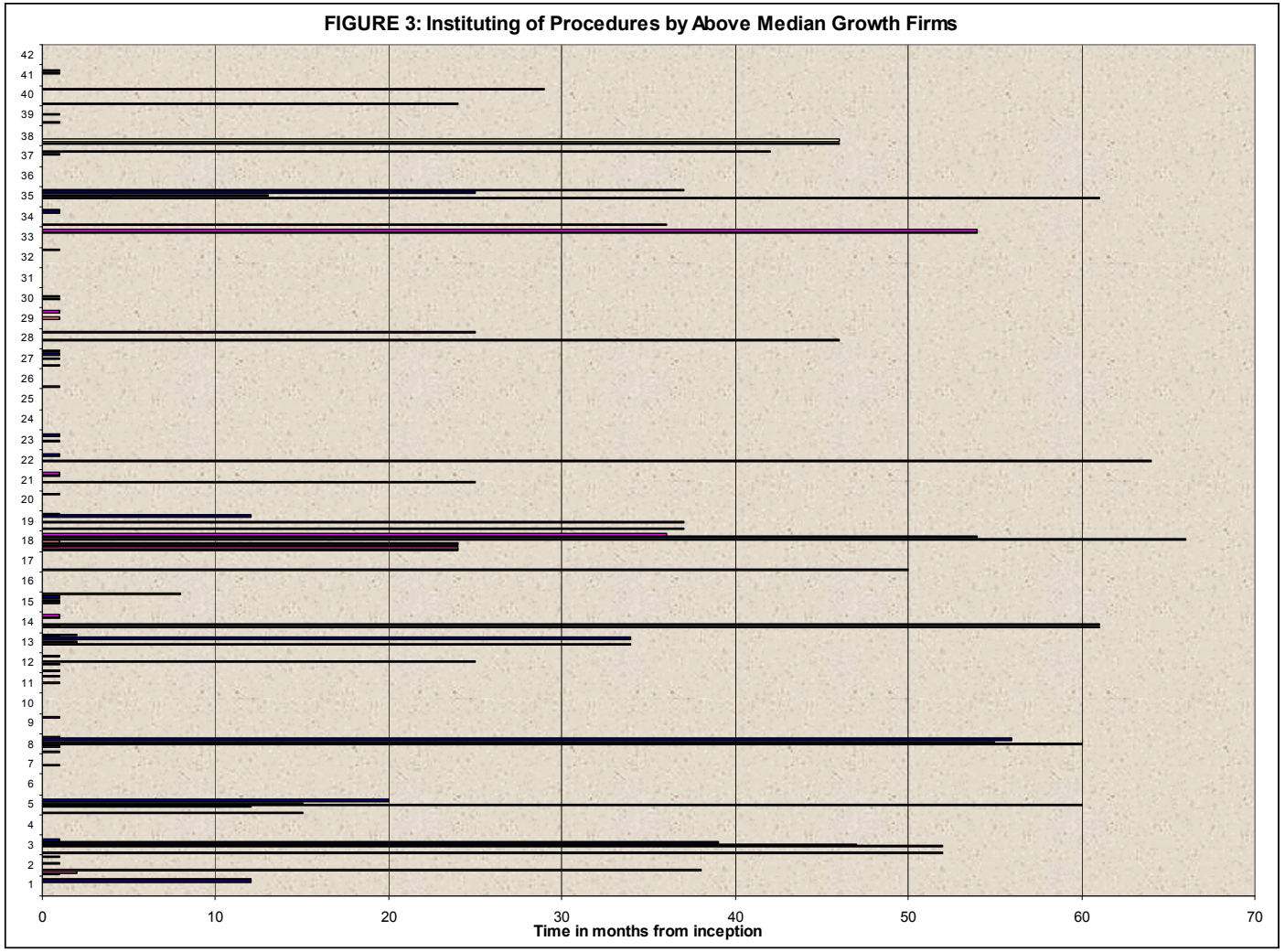
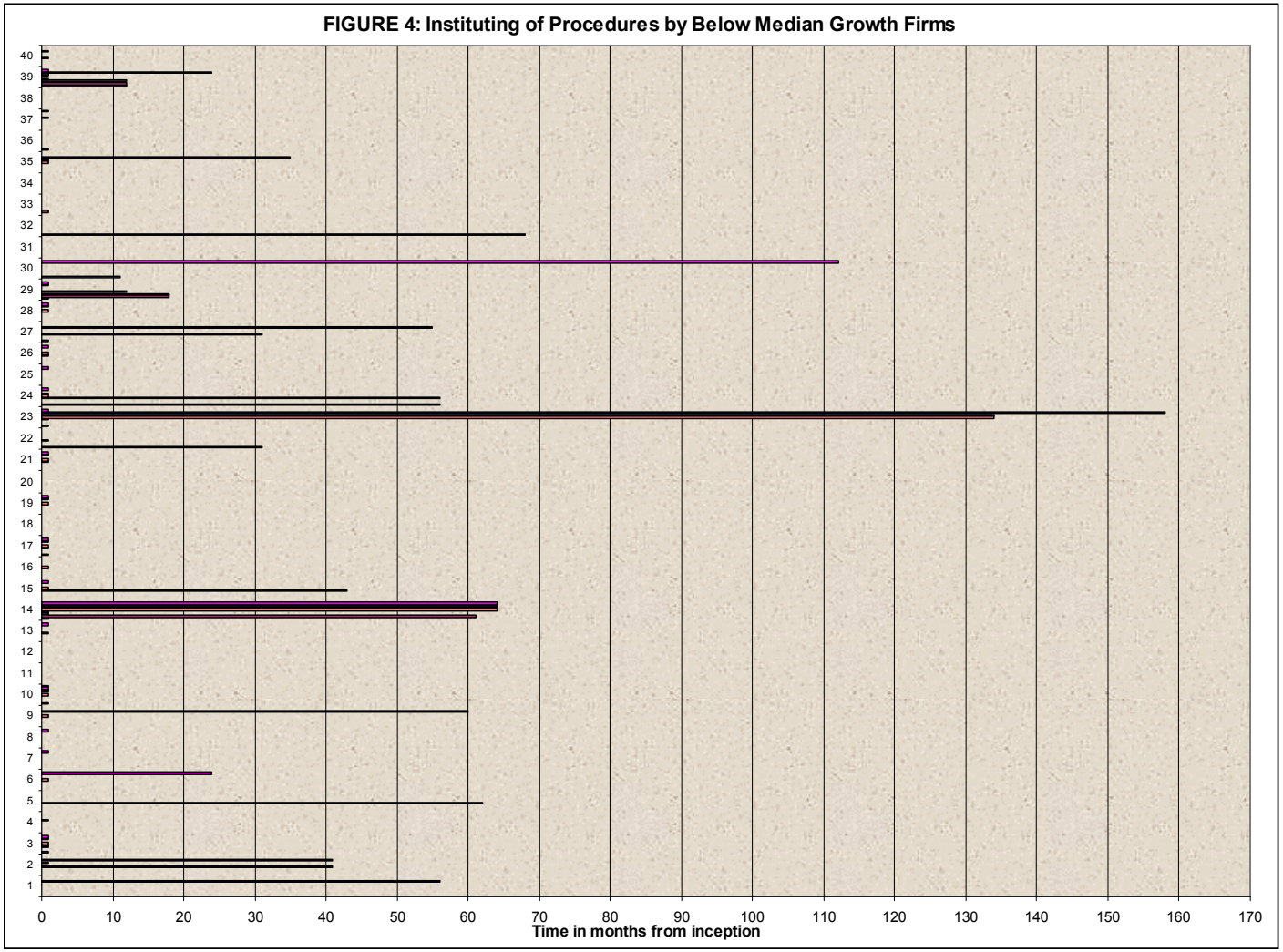


FIGURE 4: Instituting of Procedures by Below Median Growth Firms



launch; and, when they do so, are less radical in the procedural changes they institute, compared to their fast-growing brothers.

[Figures 3 and 4 near here]

As regards generalising these observations, the evidence of Figures 3 and 4 take the argument a step further. In Figure 3 we have that half of the sample with firms having growth rates above the median; and in Figure 4 no more than the median. Again, we have two distinctive choices of procedures for different firms, and the widespread initiating of procedures close to launch. Coincidence in timing of introduction of new procedures is also in evidence, and perhaps more so for the higher growth firms. Finally, there is a broader range of procedures undertaken (Figure 3) by the higher-growth, compared to the lower-growth (Figure 4) firms. This can be noted from the relatively heavy 'blocking' of lines in Figure 3, compared to Figure 4. 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 3, compared to Figure 4. These co-evolutions are only tentative, and await a more formal method of empirical testing; but they are suggestive of possible, and plausible, regularities in the evidence, concerning co-evolutionary structures, involving different sample splits and/or using different measures of growth, and the qualitative interpretations remain much the same. This is partly because growth rates, according to different measures, are typically highly correlated. For example, the Pearson correlation coefficient between sales growth is high ($r = 0.456$) and highly statistically significant (Prob. value = 0.000).

4. Descriptive Statistics

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.

[Tables 1 and 2 near here]

In Tables 1 and 2 we show the mean dates at which certain procedures were implemented, dating taking place from inception. The same abbreviations for procedures are used as in Figures 1 to 4. Standard deviations and numbers of observations are also shown. 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 (*ROI1*), net present value (*NPV1*), internal rate of return (*IRR1*), and the payback period (*PAYBACK1*) there does not seem to be a different pattern to evolution for fast-paced, compared to slow-paced, firms. In comparing Table 1 with Table 2, 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, in 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. This is, in our judgement,

TABLE 1: Descriptive Statistics for Fast-Paced Firms

	Mean	Std. Deviation	N
ROI1	24.0000	20.1224	12
RESID1	7.0000	11.3431	4
NPV1	36.5000	25.5147	4
IRR1	8.6667	13.2791	3
PAYBACK1	26.3750	24.6357	16
JIT1	17.8000	26.3852	10
ABC1	17.000	22.6826	13
QRA1	39.000	.	1
VA1	18.000	21.7342	17
SP1	11.3529	17.4426	17
TP1	2.6000	3.0496	5

TABLE 2: Descriptive Statistics for Slow-Paced Firms

	Mean	Std. Deviation	N
ROI1	14.3077	22.9724	13
RESID1	23.000	26.2932	4
NPV1	9.5000	12.0208	2
IRR1	4.6667	6.3509	3
PAYBACK1	15.9375	22.4513	16
JIT1	14.0667	36.9333	15
ABC1	20.0000	50.2693	7
QRA1	22.0000	36.3731	3
VA1	30.1765	41.0598	17
SP1	11.4000	27.8877	20
TP1	1.0000	.0000	2

most likely to reflect a defensive stance by the lower performing small firms, rather self-consciously checking how well they are doing, in the face of below average growth rates.

5. Statistical Inference

Finally, we come to consider what inferential tools can say about co-evolutionary patterns in our data. 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 procedures (e.g. like investment appraisal) is to imagine a process of judgement. In our case, it is a judgement about "what comes first?" Pivotal to this 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.

We then ask a question like: "what do you judge would come first, value added analysis, or the best technology (*BESTECH*)?" 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 (*VA1*) comes before implementation of best technology. Of course, opinions differ on rankings, so there is variation across firms on this. However, on Kendall's coefficient of concordance (the so-called W-test), the extent of agreement (measured by W = 0.250) is statistically significant at the 10% level (Prob. value = 0.083).

One can also extend this form of analysis to asking about the temporal ordering of strategic pricing (*SP1*) 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 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. Considering the procedures of storing data (*STORE1*) and strategic pricing (*SP1*) in relation to implementing best new technology (*BESTECH*), we find that the order in which procedures are typically adopted are strategic ricing (mean rank 1.5), storing data on a computer (mean rank 1.9) and adoption of best new technology (mean rank 2.6). This ordering suggests high concordance across firms (W = 0.316) and this is statistically significant at that five per cent level (Prob. Value = 0.031).

We believe the variable *STORE1* 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. 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 (*FINMOD1*), forecasting and simulation (*FORECAST1*), and sensitivity analysis (*SENSAN1*) are all only likely to be adopted procedures after the adoption of computers for storing information within the 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. 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, to get high- and low-growth sub-samples, we get more interesting results. We find that high-growth firms are less bound by requirements of evolution than low-growth firms. 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 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. 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 discerned.

6. Conclusion

This paper has made a tentative step in the uncharted territory of measuring co-evolutionary processes in small firms. 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' diagrams 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 orderings in which 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.
2. Key procedures tend to be installed close to inception.
3. Subsequent supplementation of procedures occurs intermittently, rather than systematically, suggesting exogenous influences impelling the adoption of procedures, post start-up.
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.

5. High-growth firms are more radical adopters of new procedures than low-growth firms.
6. For certain classes of procedures (*viz.* those relating to measuring return on capital), high-growth firms tend to adopt these procedures later than low-growth firms.
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).
8. High-growth firms are less enslaved to strict orderings of adoption of procedures than low-growth firms.

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

References

Carney, M and E Gedajlovic (2002) 'The co-evolution of institutional environments and orgnizational strategies: the rise of family business groups in the ASEAN region', *Organization Studies* 23(1), 1-29.

Chanaron, J-J, and D Jolly (1999) 'Technological management: expanding the perspective of management of technology', *Management Decision* 37(8), 613.

Chen, S (1997) 'A new paradigm for knowledge-based competition; building an industry through knowledge sharing', *Technology Analysis and Strategic Management* 9(4), 437-452.

Hung, S-C (2002) 'The co-evolution of technologies and institutions: a comparison of Taiwanese hard disk drive and liquid crystal display industries', *R&D Management* 32(3), 179-190.

Huygens, M, C Baden-Fuller, F A J Van den Bosch, and H W Volberda (2001) 'Co-evolution of firm capabilities and industry competition: investigating the music industry, 1877-1997', *Organization Studies* 22(6), 41.

Jenkins, M and S Floyd (2001) 'Trajectories in the evolution of technology: a multi-level stdy of competition in Formula 1 racing', *Organization Studies* 22(6), 945-969.

Jones, C (2001) 'Co-evolution of entrepreneurial careers, institutional rules and competitive dynamics in American film, 1895-1920', *Organization Studies* 22(6), 911-944.

Maula, M (2000) 'The senses and memory of a firm – implications of autopoiesis theory for knowledge management', *Journal of Knowledge Management* 4(2), 157.

Nachenberg, C (1997) 'Computer virus-antivirus coevolution', *Association for Computing Machinery. Communications of the ACM* 40(1), New York, 46-51.

Reid, GC and Smith JA (2000) 'The impact of contingencies on information system development', *Management Accounting Research* **11(4)**, 427-50.

Yates, J (1993) 'Co-evolution of information processing technology and use: Interaction between the life insurance and tabulating industries', *Business History Review* 67(1), 1-51.