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Decision-support and visualising tools for making good accounting decisions

Abstract

The primary aim of our research is to develop a robust empirical model of the innovative small firm, which is useful for guiding owner-managers in their quest for high performance. The proposed model explains performance by structural variables (e.g. employment, management, directors), intellectual property (e.g. patents filed and granted), and research support (e.g. phased R&D expenditure), within the firm. Our secondary aim is to use this model to develop a new decision support tool, created using visualisation techniques, that helps owner managers, and their accounting advisors, to achieve good returns (e.g. in terms of ROCE). Once estimated, prototyped, tested, and calibrated, this tool should help management accountants to inform the owner managers of entrepreneurial firms in ways of making better decisions within their firms, thereby improving performance. We illustrate our intent with prototype models, tested on provisional ORBIS and FAME datasets, for the world and for the UK.

1. Introduction

This paper has two objectives. Our primary objective is to create an empirical model that characterises the innovative small firm. This model shows how the firm's performance is determined by a range of structural variables, including intellectual property, and R&D expenditure. Our secondary objective is to restructure our empirical model into a novel decision support tool, that will enable better management accounting decisions. To these ends, our paper starts by reviewing the extant literature on decision support methods, followed by creating a taxonomy of decision support tools in management accounting which is appropriate to research work in accounting and finance. This identifies the categories of theoretical, theoretical/empirical, and empirical decision support tools, each of which is illustrated by previous work of the authors. These tools are rooted in the craft of visual representation of data, which affords intuitive insights to decision makers.

Our second objective is to build on this extant literature, to create a statistical model of performance in the innovating firm, with properties that lend themselves to visualisation presentation. We present early findings of our research using two illustrations. In the first, we present a visualisation of the relationship between performance (return on assets) and the number of files and grants of patents, using global ORBIS data on a sample of approximately 5k small firms. This uses a data cube with coloured coding to represent good (in green) or bad (in red) performance, with shades to indicate degrees of performance. In the second, we present an econometric model explaining performance (ROCE) by company staff, R&D spend and patenting, using a combined ORBIS and FAME dataset, of approximately 5k small firms. This is our prototype model, which awaits further development using visualisation methods.

The process of estimating, prototyping, and rigorous testing, is lengthy, but potentially very fruitful, as decision support tools can serve as a valuable resource. Our higher purpose is to equip professionals in accounting and finance with the means to better inform and guide owner-managers of entrepreneurial SMEs who are seeking superior performance. The development of a decision support system (DSS) with the potential to alleviate the challenges faced by entrepreneurs operating in highly competitive and financially demanding environments is an intriguing and valuable research objective. Such a tool, if successfully designed and implemented, could significantly aid entrepreneurs in making well-informed and rational decisions, thereby enhancing their capacity to achieve both innovative and performance-related goals. In the pursuit of this research agenda, a crucial initial step involves the clarification and refinement of our understanding of small firm performance. This clarification is essential because performance in the context of small businesses can be measured in various ways, ranging from straightforward binary variables such as whether a firm succeeded or failed (represented as 0 or 1, respectively), as proposed by Reid (1991), to more sophisticated performance rankings derived through cluster analysis, as demonstrated by Reid and Smith (2000). Moreover, it may also encompass complex performance indices generated through the utilisation of data reduction algorithms, as exemplified by the work of Power and Reid (2019).

It is our shared view, in agreement with Duan and Xu's (2009) assertion, that developing decision support systems tailored for Small and Medium Enterprises (SMEs) is particularly promising and worthwhile. This is because SMEs face a complex milieu, in which entrepreneurs, often acting as owner-managers, have to grapple with a deluge of information. Simultaneously they face the need to make swift decisions, often based on a limited set of key performance indicators such as liquidity, gearing, solvency, and productivity. These entrepreneurs are frequently placed under substantial stress, leaving them pondering a fundamental question: 'What should I do?' This paper sets out ways to address this question. In doing so, it recognises the pressing need for effective decision-support systems. These can empower entrepreneurs in SMEs to navigate their complex and demanding business environments, ultimately aiding them in 'making the right decisions' amidst the challenges of competition and financial pressure.

2. Literature Review

2.1 Decision-Support Systems

Decision-Support systems (DSS) depend upon the database, the model, and the interface between model and owner manager. The qualities one looks for in decision support systems have been expressed classically by Sprague (1980) as: (a) assistance on less structured problems, at the upper-level of management; (b) dependence on tools and techniques deployed on large data sources with good retrieval capabilities; (c) formulation and design that nominally requires only minimal computer proficiency by the user, despite their underlying complexity; (d) adaptability and flexibility, so that changes in the environment, and in the decision-making procedures, can be readily encompassed. To this end, Kremic et al. (2006) explored the benefits and risks associated with the decision to outsource decision-support, noting that the drivers of such decisions relate typically to either costs, strategies or politics. They noted that core competencies, i.e. the areas in which the organisation performs best, were less likely to be outsourced, because of desires to retain intellectually based advantages. Therefore, if decision-making is complex, and relies upon much sensitive proprietary knowledge, the function of decision-support is less likely to be subcontracted to an outsider.

Vanier (2001) examined retrospectively the nature of asset management in the construction industry, looking specifically at the use of decision-support tools for municipal infrastructure planning. In particular, when making decisions on asset management, the challenges of integrating into existing systems aspects related to computerised management, geographical location, and corporate legacy, was noted. Such decisions are complicated by information overload, conflicting goals, and an urgent need to prioritise. For example, managers need to weigh up the costs and benefits of financial versus technical considerations. Planning horizons for projects can range from the short – operational and technical - term to the longer – more strategic – term. And decisions cannot be taken in isolation but must be considered as a project within a larger overall network or system. Vanier (2001) observed that the development of information technologies would become critical to the success of decision-tools in the very near future and produced a visualisation of a decision-support tool for SimCity (2000), a city planning computer game. This illustrated quite clearly how a colourful and graphical depiction of key aspects of multiple business decisions (e.g., condition, risk of failure, maintenance costs, planning, objectives) could be easily integrated into the process of making quick but informed decisions.

On another tack, the focus of Krishnan et al.'s (2005) paper is upon accounting and auditing, when there are concerns about reliability of such data. Their field study identified the need for a decision-support system to be developed in train with an assessments of data reliability. They then used mathematical/statistical concepts to reduce a potentially large information set to a smaller set of key concepts which facilitate the decision-making process. Ultimately, their contribution to the literature is on data reliability, using accounting information systems as the setting for their research. They provide a methodology that can be applied to alternative accounting settings requiring decision-support tool, which incorporate both human judgement and algorithmic processes. On the related to the theme of auditing, Baldwin et al. (2006) explored opportunities for the development and use of artificial intelligence (AI), specifically looking at how issues of accounting and assurance might usefully be addressed. They acknowledge the need for a better awareness of the benefits of AI within the accounting profession, commenting on its potential application to a wide-range of decision-support areas. They report that part of the lack of success of AI so far in these areas is has been due to reluctant users, arising from their lack of neutrality to this new science. To overcome this aversion, they suggest some emerging, more refined, applications might win hearts and minds better, citing 'friendly' techniques like genetic algorithms, neural networks, fuzzy systems, and hybrid systems. These can be useful both for handling complex or qualitative data, and for reducing decisions complexity down to a simplified sets of rules.

Uusitalo et al. (2015) explore the potential for creating more effective environmental models. For such models high uncertainties of events are ubiquitous. Better estimates of the timing and gravity of adverse environmental events must be developed if such models are to be useful for decision-support. Some of these uncertainties can be illustrated through the use of graphs and probability distributions, for example, to assist in decision-making processes.

However, where the data and uncertainties are complex, probabilities can be difficult to assign and interpret. In Farid et al. (2005), for example, the authors present a decision-support tool used to assess strategies under uncertainty in the field of biopharmaceutical production. This allows decision-makers to consider simultaneously both the production aspects of the technology and the business aspects, such as they relate to cost, time, yield, throughout, resource utilisation and risk. This decision tool is deployed using Monte Carlo business simulations to gauge, for example, the effects of varying the throughputs, and to explore the scope for mitigate risk caused by uncertainties. In this work the authors are able to show that the use of a decision-support tool such as this can provide benefits to companies when they are managing their R&D portfolios with a view to moderating the cost of goods. In particular, they present graphical illustrations, through the means of 'tornado diagrams' (a type of bar chart) which 'allows for rapid visualisation of the inputs that are most significant, identified by the longer bars' (Farid et al., 2005, p.492). They suggest that the techniques they employ might be readily adapted for application across a wide range of decisions.

Along the theme of decision-support, Lawson et al. (2006) investigated ways of helping SMEs, in particular, to choose between alternative high-technology product developments, with a view to making the process of prioritisation clearer and simpler. They start by noting that prior research in the area of project selection and portfolio diversification has focussed on large companies, who use techniques such as risk analysis and scoring models. They have developed a simplified prototype model for fieldwork testing, developing flowcharts to graphically depict and classify the stages and types of project selection. This was further developed into a risk analysis flowchart. On a practical level, it was linked to simple spreadsheets which tracked graphically their decisions, and linked them to budgets, times-scale and cash flow over time. The main benefits of this simple model were that management found it quick and easy to use.

March and Hevner's (2007) paper was on how to successfully support management decisions, and to ensure that the data on which decisions are made are easily understood. They distinguish between intelligence based on internal and external data, and business intelligence based on actionable information resources, exploring the notion of data warehouses as repositories of all such information. Making sense of this information is facilitated by the use of information technology, which adopts online analytical processing (OLAP) tools to provide, for example, readily understood visualisations of the data, with a user-determined focus. Four objectives emerge from their work, as regards the nature of data warehouses: integration; implementation, intelligence and innovation. Of particular interest to us is the use of intelligence for decision-support. It is, they argue, dependent upon having the right data for the problem at hand ('environmental scanning') and using that data to meet a particular objective ('contextualization'). At all times, they note, the utility of outputs from analysis of a data warehouse in this manner is beneficial only if the human using that information is capable of reading and understanding it correctly. Therefore, ensuring clear and direct output from the analysis is crucial to the effective use of data warehouses.

On a similar theme, Andrienko et al.'s (2007) editorial for a journal special issue referred to the associated workshop on visualisation, analytics & spatial decision support, where the discussions centred around the need to ensure that human capabilities for analysis were not overwhelmed by the capabilities and computational techniques provided by modern technology. They argued that efforts to progress the research agenda of visualisation and computational support for decision-making have evolved independently, and that there is a need to better integrate the development of the two in tandem. To this end, they note the importance of visual representations and interfaces in analysis and reasoning.

New approaches to management accounting were considered by Talha et al. (2010). In particular, they were interested in why management accounting had earlier failed to keep pace with new technology but was now the discipline was beginning to see its advantages. These included offering an increased ability to meet customer needs, and to improve efficiency and profitability. Their study provides a methodical bridge from research in management accounting in the late 20th century to the early 21st century. They found that information technology now permeates every organization. This suggested that enterprise resource planning (ERP) systems could offer a means of consolidating all departments and functions into a single computerised system, yet nevertheless could service an individual department's specific needs.

Argyrou & Andreev (2011) further explore the use of technology in managing internal control within organisations. Whilst there is no statutory requirement governing the form of internal controls, various acts (e.g. Sarbanes-Oxley, 2002) have brought into focus the importance of these for ensuring good corporate governance (cf. US Congress, 2002), and ensuring the accuracy and validity of external financial reports. They focus on auditing standards, and the requirement for the auditor to assess the information technology controls surrounding the recording of the organization's transactions. To that end they design a tool for 'clustering accounting databases', to simplify the work of the auditor by providing visualisations of the data they need to assess. Their tool aims to simplify and rationalise large bodies of data into a comprehensible picture of performance, allowing the development of coding for a data visualisation toolbox with applications run via Matlab software.

Given the difficulties in making sense of the complexities of management accounting data, Pedroso and Gomes (2020) undertake to present a multidimensional approach to measuring the effectiveness of internal accounting systems in a sample of small to medium sized enterprises (SMEs). They reduce the analysis to four major dimensions of management accounting viz. scope, timeliness, aggregation, and integration. Their review of the literature finds that much of the previous research on management accounting systems is unnecessarily complicated, for example by the diversity of constructs used to measure key variables of management accounting. This lack of conformity makes comparison and validity of the results of investigative work more difficult to undertake. This also explains the drives of these authors to seek simplified, yet still multidimensional, measures. They use techniques like exploratory factor and confirmatory factor analysis, to make an initial analysis of the empirical data gathered, and thereby present a structural model of their findings. These works illustrate the impact of major constructs on managerial accounting systems, and ultimately on managerial performance. Whilst the paper presents well the diverse means of interpreting the extensive data available to understand how management accounting impacts upon an organisation, it is less clear about how their suggested 'tool' might be used for decision-support in practice. However, from a conceptual point of view, it provides an interesting possibility for moving forward in future research. Thus, current management accounting research builds on prior work on the use of information technology to enhance decision support as in the earlier work of Beaman and Richardson (2007). Further, new application areas can now extend further such work on new tools and techniques as has been suggested by research in other fields like health care, Hankins (2004), and sustainability (Segura et al., 2014).

Finally, Chesney et al. (2017) use the example of agent-based modelling (ABM) – 'a representation of a phenomenon or system, built from the interactions and behaviour of autonomous units or agents' (p.112) – to create a 'shadow account'. This, they explain (p.110), is 'a secondary account of a business which is used to audit or verify the primary account'. Arguing that stakeholders require comprehensive and reliable disclosure of the performance of the businesses in which they have an interest, such shadow accounts can provide a means of verification and evaluation of the data on performance. In this particular setting, the supporting information is generated through a computer simulation (of a carwashing business). It was used for the verification of the actual accounts of the same business. The authors find that their conception is useful and suggestive of what kind of decision-support tool could be readily implemented to support corporate actions in practice. Their expectation would be that such tools should make use of relatively simple visual techniques (e.g., graphics, scatter plots) to facilitate comprehension.

2.2 Visualisation

We currently live in a predominantly visual world, in which images often have greater communicative power than words or numbers alone. Data visualisation can play a crucial role in simplifying the comprehension of intricate datasets. Visualisation plays harmoniously on the human mind, aiding in the identification of patterns, trends, and anomalies within and between data (Card and Schneiderman, 1999; Bacic and Fadalla, 2016). When data scientists are immersed in complex projects, they require a means of grasping the data they are collecting to ensure efficient monitoring and adjustment of their processes. Simple visual representations of results, derived from intrinsically complex mathematics and algorithms, are found to be significantly more accessible to the mind, than are reams of extensive textual and numerical data (Lurie and Mason, 2007). The tools of these technological advances transcend industrial sectors. Hence their scope and impact cannot be underestimated (Schiuma et al., 2022). Today, an increasing number of companies employ machine learning and artificial intelligence to gather, process, and interpret large volumes of data. While the advantage of rapid and efficient data collection is evident, it necessitates a new, structured approach to sorting, comprehending, and conveying this data in a coherent manner, both to business proprietors and other stakeholders, including financial backers.

Given the above, our overarching research goal is to develop decision support procedures tailored to owner-managers of small and medium-sized enterprises (SMEs), who often have to contend with intense competitive and financial pressures. Part of this endeavour entails refining the definition of small firm performance (cf. Power and Reid, 2015), where metrics can range from straightforward binary variables (e.g. the survival or failure of a firm, represented as 0 or 1, respectively) as in Reid (1991), to more comprehensive performance rankings based on cluster analysis (Reid & Smith, 2000), or complex indices employing data reduction algorithms (Power & Reid, 2019).

In embarking on this research, we align with Duan and Xu (2009) in asserting that SMEs offer a promising domain for the development of decision support systems (DSS). Within the typical SME context, owner-managers often grapple with information overload while needing to make swift decisions, relying on a handful of key indicators such as liquidity, gearing, solvency, and productivity.

To exemplify the above, Power & Reid (2018) employed real options reasoning, involving advanced mathematical concepts, to furnish a straightforward tool for expedited optimal decision-making. They introduced 3D chromaticity plots, effectively 'colour maps,' as a visual aid for optimising small firm performance. These plots employ a 'heat map' to identify the most favourable (in red) and unfavourable (in blue) positions. In essence, they advise focusing on the peak of the performance surface, which corresponds to the reddest area.

As another illustration, Hsu & Reid (2021) harnessed extensive-form games, an area rooted in intricate mathematics, to assess the optimal selection of a financial reporting regime (such as US GAAP or IFRS) and the best means of supporting it. Their research demonstrated how the stated preferences of key company personnel can be utilised to craft metrics enabling owner-managers to adopt a user-friendly visual tool: the tree diagram, which allows for the elimination of branches with inferior net benefits, facilitating the selection of the optimal reporting regime and the best technique for its implementation.

Additionally, as a testament to progress in this field, Reid & Smith (2000) devised innovative methods for presenting complex data, such as in their study of the coevolution of accounting information systems. This research translated evidence regarding the sequencing of technology adoptions into visually informative, coloured graphics, highlighting the 'pre-requisites' and 'co-requisites' for technology co-evolution. To illustrate, use of modern computers necessitate electricity supplies and silicon chips as *pre-requisites*, while a modern decision support tool requires chromatic screens and 3D plotting software as *co-requisites*). Further contributions along similar lines include Reid & Smith (2010), which employed 3-D scatter graphs and dendrograms to map performance, through a cluster analysis of three key measures. This facilitated swift, lucid, and advantageous entrepreneurial decision-making.

3. Methods

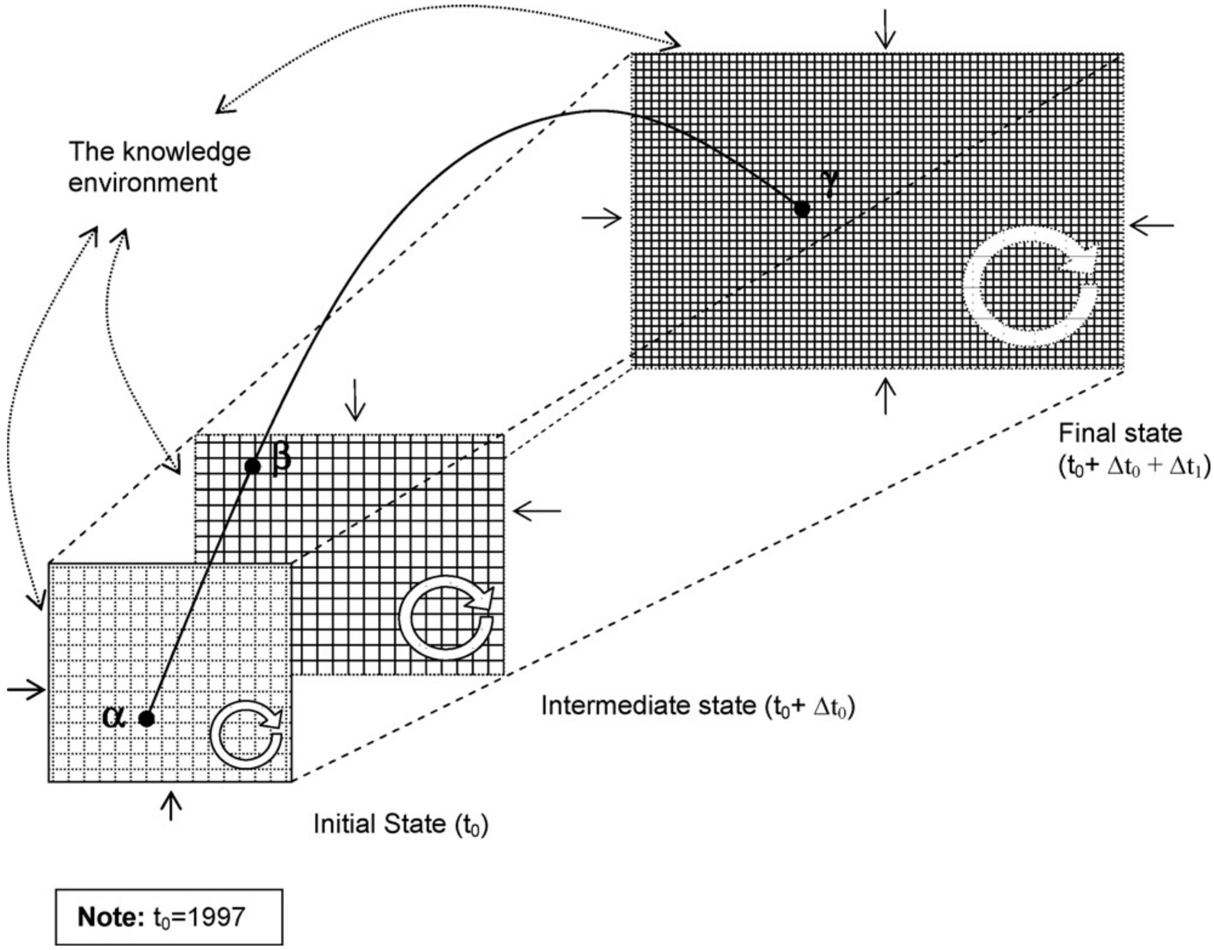
Our research approach builds on the extant research literature on data visualisation (e.g. Card and Schneiderman, 1999; Basic and Fadlalla, 2016), from which we seek inspiration in the crafting of practical tools supporting decision-making in small, entrepreneurial firms. Numerous research papers exist, which advocate diverse forms of tools, including those by Foil and Huff (2007), Al-Kassab et al. (2013), Reid and Smith (2009), Hsu and Reid (2021), and Power and Reid (2018). Our aim is to synthesise and amalgamate the insights of these diverse perspectives, seeking to discern their specific utility, particularly within the context of vulnerable early-stage entrepreneurial firms (Reid, 2007), which urgently require decision-making guidance and support. Below we present three past examples, from our prior research. These examples exemplify our approach, which can be classified as visualisation considered from the standpoints of: (1) theoretical analysis; (2) combined theoretical and empirical analysis; and (3) empirical analysis.

Example 1: Accounting information system development in small firms: visualisation from theory

Figure 1 presents a theoretical example of visualisation which is draws on Reid and Smith (2009). It looks at the evolution of the information system of a small firm over a significant period in the life of a firm, namely the first few years after start-up. This relatively technical approach was later developed more fully, for a more practitioner fashion in a management accounting context, in the book *Information System Development in the Small Firm: the use of management accounting,* by Mitchell et al., (2000). What this kind of visualisation intends to do, for academics in management accounting, is what academics in economics and management do for their disciplines, when faced with the potentially overwhelming complexity of theoretical approaches. That is, they condense pages of intricate reasoning, often using advanced mathematics, into a picture or diagram – the elemental form of visualisation.

Here, in Figure 1, the visualisation shows how the accounting information system of a small firm evolves over time. The three squares, or lattices of Figure 1 represent two dimensions of the accounting information system, and the grids upon them represent the granularity or complexity of the information system. The visualisation suggests complexity is increasing within the general *external* 'knowledge environment' - which itself has the effect of modify the accounting information system. In addition, the curved blank-arrows withing each of the three squared grids, represent the effects of *interna*l knowledge generation (e.g., learning-by-doing, R&D, customised internal accounting procedures) which will also modify the overall information system. time. The expanding dimension to the graphic represents the expansion over time (t) of the information system in terms of both scale and granularity, illustrated for three points in time, as in: t_0, $t_0 + \Delta\ t_0$, and $t_0 + \Delta\ t_0 + \Delta\ t_1$, with the increments in time illustrated by the symbol Δ, for three successive time periods.

Figure 1. Theoretical Visualisation

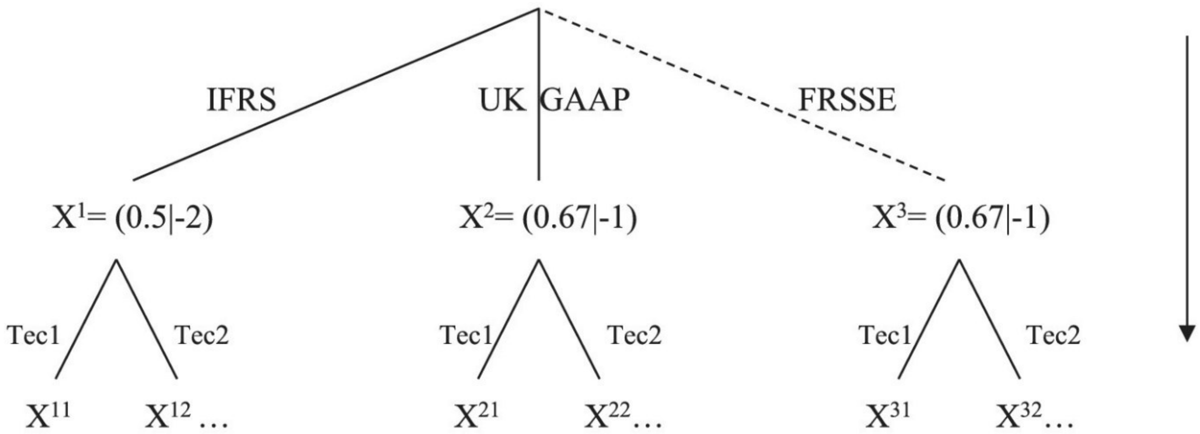


Source: Reid and Smith (2009)

The kind of visualisation in Figure 1 might be called 'theoretical' as its purpose is to illustrate - within 'one look' and no explicit data – just two key things of the several important ones that can happening over time: namely first, increased complexity, and greater granularity, in the potential form of the firm's information system; and second, the pathway that might be taken as a specific 'best' choice for the firm (e.g. in the sense of performance maximizing), as represented by the solid curved line, the trajectory from α through β to finally γ. Further, nuances on this narrative are introduced by: (a) the solid arrows (↑) external to each square grid, which represent the fruits of *external* influences to the knowledge environment (e.g., the open sales/marketing of new proprietary software for accounting procedures); and (b); the blank arrows within each of the three grids, representing the fruits of distinct *interna*l influences (e.g., customised internal software development, R&D expenditure).

Example 2: Theoretical/Empirical Visualisation

Figure 2: Decision Tree of UK Private Company Alpha



Notes to Figure 2:
(1) Utilities are given in the parentheses. Ratio utilities (B/C) are given first, followed by net utilities (B-C) e.g., for (B/C), X^1=0.5 < X^2 =0.67 suggests UK GAAP chosen.
(2) The arrow indicates the decision-making process is sequential, from regimes to techniques.
(3) The FRSSE is only applicable to subsidiaries' accounts. Hence, the FRSSE alternative is presented using the dashed lines.
(4) There is assumed to be no great difference in techniques across regimes.

Source: Hsu and Reid (2021)

Example 2 draws on Hsu and Reid (2021). It combines the relevant economic theory (cf. Simon, 1979; Osborne and Rubinstein, 2020), with empirical field work in the business enterprise (Reid, 1987). These diverse research tools are used to explore the choices made by small firms of financial reporting regimes (Tweedie and Seidenstein, 2005). Here, our specific interest is in the financial reporting regimes of private firms in the UK. The relevant theory deployed is of two kinds: utility theory and extensive games (cf. Osborne and Rubinstein, 2020, Chs.1, 16). The relevant visual tool used in this case is presented in Figure 2, in what is called a game tree (Osborne and Rubinstein. 2020, Ch.16).

In this instance, the game tree is designed to model the choices that a small motor retailer firm in the UK (anonymised as Company Alpha) had over the adoption of a financial reporting regime in the UK (cf. Schipper, 2005). The firm's alternatives were effectively UK GAAP, IFRS and FRSSE. Of these, the latter is a relatively new standard, imposing lower informational loading on a firm. It was introduced to help diminish the administrative load on small firms (viz. small entities, SE). In our case, fieldwork methods within businesses (cf. Reid, 1987), were used to obtain stated preferences, digitised in the interview, over the three possible regimes. Thus, preferences were calibrated by a face-to-face interview, using a Likert scale which allowed a calculation of ratio benefit B/C, or net benefit (B – C) or for each alternative, where B stands for benefit and C stands for cost. Under both ratio and net benefit calculations, UK GAAP was preferred to IFRS, as both 0.67 > 0.5 under ratio benefit (B/C) and -1 > -2 under net benefit (B-C) were indicated. UK GAAP was indeed implemented, in practice, by firm Alpha. It turned out that FRSSE was not feasible for firm Alpha, for institutional reasons: because it was only applicable to subsidiaries' accounts, which were not relevant to Alpha.

Example 3: Empirical Visualisation

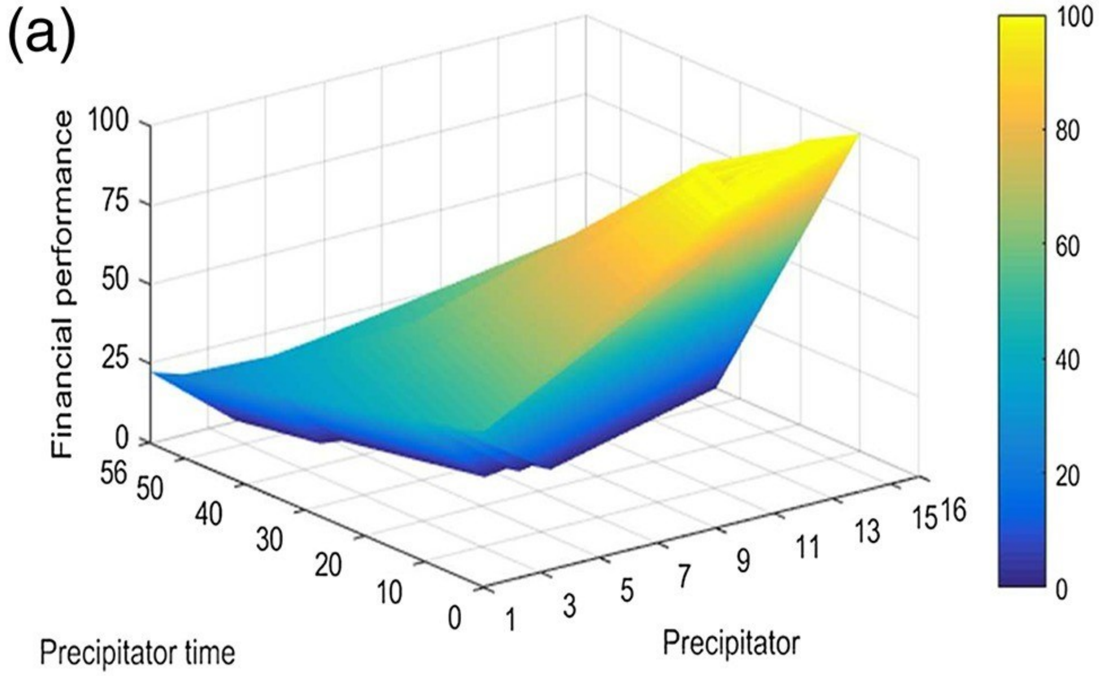


Figure 3: Heat map of firm performance and real option dimensions

Source: Power and Reid (2021)

Our third visualisation example (see Figure 3) concerns the financial performance of small firms, viewed from the perspective of real options analysis. Generically, a real option is an economic entitlement to a possibly valuable asset, to which the possessor has the discretion to right to progress, or to abandon, the realisation of its potential value (Luehrman, 1998). Typically, this choice is in the hands of managers within a large company, who must jointly decide on whether to undertake, or to abandon, such potential business opportunities, or investments, as promised good returns. In a small firm, this active (viz. 'strike') or passive (viz. 'desist') decision often falls solely on the discretion of the entrepreneur who launched the business (McGrath, 1999) . To express this in simple algebra, suppose a small firm has a value S. For X the exercise price, and C the value of holding the option, the inequality (S - X) > C is the condition which should be met if the real option is worth exercising.

The date underlying Figure 3 were from a sample of 396 UK small firms over the years 1985-2002. In form the dataset was a longitudinal unbalanced panel, and it contained 40, 000 data points, providing 'thick' data from annual face to face interviews over seventeen years. In the study we started with vertical axis being performance, founded on an index of 28 individual performance attributes (e.g. cash flow, costs, competition etc) composed on principles advocated by experts in performance measurement (e.g. Chrisman et al., 1998). Precipitators were thirty in numbers and were counts of things like changes to demand, competition, growth, costs, technology etc. Precipitator time was based on the time (in years) taken to implement a key change (viz. time to embed the investment).

In Figure 3 (a) here, the vertical axis is specifically financial performance, which is often the key dimension for the entrepreneur. This figure is a so-called 'heat map', a tool popular in the physical and biological sciences, first devised by software developer Cormac Kinney in 1991. In Figure 3, bad performance is represented in blue and good performance in yellow. An 'aerial view' of the performance surface, projected onto the space defined by the precipitator time/precipitator axes, indicates that the financial performance maximizing position for the entrepreneur's firm is when the precipitator time is low, less than 10, and the precipitators per se number between 9 and 16. In particular, the entrepreneur needs more than a few precipitator indicators like demand, cost, and growth for optimality. It is also possible (and fruitful) to refine the story one can read from the heat map, by considering in detail the gradients of the heat maps, which can tell you about the ease of getting to the optimum.

4. Empirical Analysis

Our empirical analysis is predicated on earlier work on the structure and nature of small firms, such as Power and Reid (2020), Reid (1991, 2007), Reid and Smith (2000), Smith (1998, 1999), Mitchell et al. (2000). From this, and similar works, which combine small-sample detailed fieldwork with large-sample econometric analysis, a clear vision of the small firm, and how it has adapted over the decades, is possible. This understanding extends to the firm's complement of active staff, their financial structure, and their innovation goals. But somehow this learning is not spilling out from academia to the business world. The project on which our research is predicated aims to make at least on small step towards building a bridge between the life of professor and the life of an entrepreneur.

We recognise that there are multiple variables which impinge on performance, and indeed that performance itself can be measured in many ways (cf. Power and Reid, 2020). Those to be considered, as regards performance, include the return on capital employed (ROCE, on which we focus), the Current Ratio (i.e. current assets/current liabilities), the solvency ratio, the liquidity ratio, and the gearing ratio. For example, 'structural variables' capture aspects of the resources of the firm, including the workforce, and how incentives are handled (e.g. by delegation and hierarchy). With the above in mind, our hypothesis is captured by the specification of equation (1):

Performance = F (Structural Variables; IP Variables; R&D Expenditure) + Random Errors (1)

We have investigated various data sources and undertaken some preliminary regression analysis using SPSS and Stata software. Initially, this was done with a simple random sample of 5000 small companies. This was selected from the Bureau van Dijk FAME database (2021) using their criteria for a firm being an SME. We were seeking to build a parsimonious decision model, using, for example, dependent variables like Return on Shareholders' Funds, Gearing, and Productivity, which are very familiar to owner-managers, and thus should provide a good basis for a decision-support tool, later in our research trajectory. Due to gaps in some variables, we did not end up with as large a sample size as we would have wished. However, by concatenating data from both ORBIS and FAME datasets a satisfactory solution was made, and the investigation could commence.

4.1 Preliminary Results

Using our combined ORBIS-FAME dataset, we can report on Model 1, in Table 1. It is in many senses a trial model. The first dependent variable we chose for modelling 'performance' in equation (1) was 'return on capital employed' (ROCE). This is regarded as a good baseline measure of how the small firm is performing, as it shows how well capital is being 'worked' or 'mobilised' to create profit. This in turn can have a positive impact on the prospects of the small firm growing.

Looking first at structural variables, we have several estimates of the impact that the staff within the small firm (to wit, employee, managers, directors) have on performance. As is common in models of this form, they show that shedding employees could improve the performance of the firm (see line 2, Table 1). This effect is significant at the 5% level. In small firms the main 'cost driver' is usually the workforce, but this does not necessarily imply that a good 'quick fix' for performance would be to lay-off staff (Reid, 1996, p. 31). Strategically, if not financially, retaining staff may increase the resilience of a firm in the long term. Recurring to our study, the only staff negative coefficients in Table 1 are on employees. Other elements of the staff complement (current directors and managers, and previous directors and managers), have insignificant impacts on performance, (see lines 3 to 5 in Table 1).

Table 1:

Regression Estimates

Variables		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	23.073	14.168		1.628	.108
	Number of employees Last available year	-.313	.156	-.199	-2.000	.049
	Number of directors & managers	.916	5.050	.527	.181	.857
	Number of current directors & managers	-.885	5.072	-.515	-.174	.862
	Number of previous directors & managers	-.122	5.098	-.019	-.024	.981
	R & D in GBP Last avail. Year	-.022	.009	-.532	-2.393	.019
	R & D in GBP Year – 1	.067	.020	1.665	3.398	.001
	R & D in GBP Year – 2	-.040	.016	-1.096	-2.582	.012
	R & D GBP Year – 3	-.022	.007	-.473	-3.219	.002
	Patent	13.868	21.186	.143	.655	.515
	Patent Pending	-12.200	14.630	-.129	-.834	.407
	Patent Granted	-7.806	19.842	-.082	-.393	.695

Model 1: Goodness of Fit

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.563[a]	.316	.216	41.927
				F = 3.16, p < 0.00

Moving on to other variables (see lines 6 to 9, Table 1), we see that all the research and development (R&D) variables (which do also have financial effects) do have significant coefficients. However, their impacts do differ. Most important, only the one-year lag on R&D has significant *positive* effects on performance, and with high significance (p = 0.001). At the same time, but in contrast to the staffing variables, which usually have insignificant variables, for R&D spend these variables are all significant, and in all but the one-year lag case, is negative in effect. It is important to pay attention to the standardised beta coefficients in the fourth column of Table1, as they tell a strong story. This simple device is defined by the product of the estimated coefficient (β) to the ratio of the standard deviation (s_x) of the regressor (x) to the standard deviation (s_y) of the regressand (y) as in: $\beta \times (s_x \div s_y)$. In Table 1, the crucial statistic is the positive, and proportionally largest, standardised beta coefficient of 1.665, in the fourth column, which relates to the one period lag of R&D expenditure. It emphasises the critical impact that the timing of the R&D injection of finance can have on the performance of the small firm. In this case, too late, or too early, are equally undesirable. Further research is necessary, but it suggests that the positive impact of R&D spend on performance is substantial and quite immediate: within a year, but otherwise negative.

Finally, as regards Table 1, we have the IP variables for patents in lines 10 to 12. Of these, the case of patent grant (line 12) is potentially the most important one, as it imparts a powerful right of exclusively to the possessor. But on the other hand it is expensive to maintain exclusivity, so many firms now prefer to use trade secrecy, as it imparts no knowledge to rival innovators, and economises on transactions. Despite the allure of patenting, all three patent variables are clearly insignificant. Concluding on Model 1, we see that there is a coherent story to tell, as regards the variables and their significance, and that the model is a good fit to the data overall, with a high correlation coefficient of 0.56, and a highly significant F-statistic: F = 3.16, $p < 0.00$.

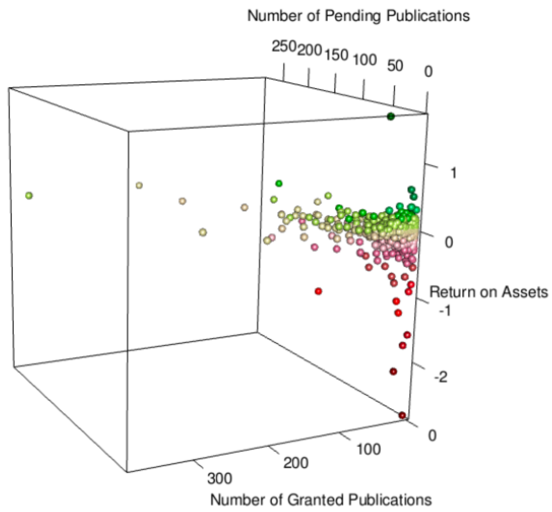
Our rough preliminary work has been subjected to three robustness check. Our results are robust to these alternatives. First, we have re-estimated equation (1) incorporating sectoral fixed effects, using sector codes 10 to 93 in two-digit form, and the results under Table 1 are reasonably sustained. Second, when the dependent variable of Table 1 has been substituted by the following alternatives: Current Ratio (the ratios of current assets to current liabilities);

Solvency Ratio (cashflow cover for long-term debt); Liquidity Ratio (ready cash available for meeting short-term debt), our results are still sustained under these alternative measures. Third, under an ANOVA test, of whether extra variables would improve the fit of the model significantly, denied that they would. Of course, necessary further estimation work is required, and is ongoing.

4.2. Empirical Visualisation

We now turn to contemporary work which involves the use of visualisation tools. Under an IMA grant we have been exploring the development of ways of viewing data, with subsequently using econometric back-up to the insights that we can get from visualisation. Part of that endeavour involves a mix of novel visualisation and appropriate applied econometrics, as in, for example, Power and Reid (2018). Our initial database for constructing the data cube in Figure 4 was ORBIS® Worldwide. This is a company dataset, produced by Bureau van Dijk (BvD), who are well-known for providing access to such extensive datasets. However, as ORBIS did not provide the micro financial detail on individual firms that we required, we also used another BvD database (FAME) to access accounting detail separately on, for example R&D expenditure and various performance and other company measures. The two datasets were then merged to form a random sample of about 5k that we used in our statistical work. A key feature of this database is that it has great detail on intellectual property, which includes counts of filing and grants of patents. We used this feature in our construction of the cube in Figure 4.

Figure 4: Data 'cube' of return on assets from patent activity (viz. files and grants).



Key to Figure 4
x-axis: Number of granted publications.
y-axis: Number of pending publications.
z-axis (vertical): Return on Assets (Profit or Loss for the year 2018 / Total assets in 2018).

Source: Current work of the authors (2023)

We see in this cube of Figure 4 several notable features. First, colour is used, as in the heat map of Figure 3. Following accounting conventions, the most desirable outcomes in the cube are coloured green, with an increased intensity in this colour meaning a more favourable outcome, in terms of return on assets. Conversely, the least favourable outcomes are coloured in red, and the more intense the red, the worse the outcome, again gauged by return on assets. Second, the 'weight' of observations is indicated by the density of bunching of the small, coloured balls. Third, most of the balls in the cube lie in the range of negative returns on assets, being below the zero on the vertical axis, suggesting, world-wide, it is not easy to run a profitable small private firm, and that intellectual property is not a panacea for success.

Fourth, the range of low returns is much wider than the range of high returns. Fifth, quite simply, the bright red and reddish balls (losses) greatly outnumber the green and greenish balls (profits). This emphasises the challenges to small business worldwide: beware, because poor returns are much more frequent than good returns. A more sophisticated version of this cube has been developed (but not included here) which can be rotated, allowing better and varied views of the dispersion of the data.

While it might seem superficially that holding intellectual property (IP), like patents, is a significant determinant of firm performance (like return on assets, as in Figure 4) this would be misleading. To drive home this point, looking at the last three lines of Table 1, which relate to UK data alone, we observe that all of three patent variables are undoubtedly insignificant. This prompts the remark that while visualisation tools can suggest good research leads, they can deceive the unwary viewer. In a further paper which builds on this one, the use of further econometric estimation shows that typically many IP variables have little impact on small private firm performance. Much more important are other factors, of which a key one is investment in R&D, as flagged in Table 1. This is a theme which will be investigated in our further work.

5. Conclusion

The creation of a decision support system (DSS), aimed at easing the hurdles faced by entrepreneurs in fiercely competitive and financially taxing landscapes, is an intriguing and valuable research pursuit. This tool, if skilfully crafted and put into action, holds the potential to significantly assist entrepreneurs in making well-grounded and logical decisions. Consequently, it could bolster their ability to attain both innovative breakthroughs and performance-based objectives. In pursuing this line of research, a pivotal initial phase involves refining our comprehension of small business performance. This refinement is crucial because evaluating performance in the realm of small enterprises encompasses diverse metrics.

We believe that tailoring decision support systems for SMEs holds particular promise and significance. SMEs provide a distinctive setting where entrepreneurs, often serving as owner-managers, grapple with a flood of information while being compelled to make rapid decisions, frequently relying on a limited set of critical performance indicators like liquidity, gearing, solvency, and productivity. These entrepreneurs face substantial stress when pondering the fundamental question about what actions to take. This paper has therefore aimed to tackle this pressing question, acknowledging the urgent requirement for effective decision support systems. Such systems have the potential to empower SME entrepreneurs, aiding them in navigating their intricate and demanding business environments. Ultimately, these systems could assist in making informed decisions, crucial in the face of competitive pressures and financial challenges.

In this paper, our primary objective has been twofold: not only to convey findings but also to stimulate the exploration of fresh avenues for decision support within the realm of accounting through the utilisation of visualisation tools. To accomplish this, we have outlined a preliminary taxonomy of visualisation tools, categorising them into three groups: theoretical, theoretical/empirical, and empirical. Each category delves into distinct techniques for decision support in accounting, drawing from various accounting perspectives. These include exploring the co-evolution of information systems, evaluating the selection of international reporting standards such as IFRS or FRSSE, and assessing the decision-making process related to exercising a real option. Our paper has clarified these diverse techniques, offering insights into decision support, grounded in these accounting perspectives. Moreover, it culminates by introducing new research problems and suggests possible new instruments for decision support, with possible implications for small firms on a global scale.

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