Modelling the value of external networks for knowledge realisation, innovation, organisational development and efficiency in SMEs

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Abstract: A 3D folded pseudo-Markov net is presented that illustrates a knowledge-based theory of the growth of SMEs via their knowledge assets. Modelling using Markov chain Monte Carlo methods (i.e., shooting virtual balls down the fold and plotting their final scatter distribution) has indicated significant financial gains if 50% individuals in management were 'innovators' but those results did not account for external networks of the managers involved. Results show for improved performance, the possession of relevant networks to realise 'just-in-time' knowledge from external sources appears approximately as important as internal innovation. With open internal information gatekeeping, the ratio of innovators in management can be as low as 1:6. It is known that start-ups with a large proportion of innovators are likely to perform better than those where innovators are added later on, but these results indicate that the difference can be evened out if latecomers can access external 'just-in-time knowledge'.

Keywords: financial returns; growth; innovation; just-in-time knowledge; management; Markov; modelling; networks; organisation; SME.

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1 Introduction

For the majority of the last century the supremacy of the large corporation as the economic driver for national wealth (see e.g., Galbraith, 1967) led to the dominant theory of the firm being the resource-based view (RBV). This theory argues that the basis for any competitive advantage of a firm lies within valuable tangible and/or intangible resources that are at the firm's disposal (for one review, see e.g., Wernerfelt, 1984). The distinction between tangible and intangible was first investigated in depth by Amit and Schoemaker (1993), who divided resources generally into resources (goods that are tradable and available to many firms) and capabilities, which are more specific to a particular firm. This latter division has become the tentative basis of the knowledge-based view (KBV) of the firm; its supporters (e.g., Spender, 1996) believe, probably correctly, that knowledge-base(s) and the capability of utilising suchlike within an organisation will affect overall organisational performance.

The roots of the KBV of the firms can be found in classical economics (e.g., Penrose, 1959) but in the 1960s, uncertainty amongst the 'smokestack' industries was widespread and may have partly been due to the unwarrented assumption that there only are a certain number of branches of industry and that therefore understanding and controlling these will inevitably lead to optimal performance (for review see e.g., Mellor, 2003). However the IT revolution of the 1990s showed that, against dogma, it was possible to make business where no previous industry or business existed, leading to the so-called 'sunrise' industries, of which software (e.g., Microsoft®) and biotech (e.g., Genentech®) are widely cited examples. Furthermore, recombining knowledge in an entrepreneurial way led to more innovation, where existing business process were radicalised to form new 'value chains', involving the faster delivery of products that were both better and cheaper, with e-commerce being a prominent example. Many scholars believe that this break-up of markets – the so-called 'post-Fordist era' – was actually the natural result of the downswing in the last Kondratieff cycle (Kondratieff, 1935), which introduced a period of 'creative destruction' (Schumpeter, 1942). Certainly the 'dot-com bust' of the year 2000 and the major world recession barely a decade later changed the national and international economic landscape radically away from one featuring the large corporations, to a situation where large enterprises (defined as those employing more than 250 individuals) are well outnumbered by small and medium sized enterprises (SMEs) by a factor of over 1: 500 (exact figures vary according to source and probably by the hour) and SMEs anecdotally account for 60–75% of national employment; the Bank of Montréal (http://www.bmo.com/) in 2005 highlighted the role of SMEs in the Canadian national economy.

The constant churn in the SME environment against an uncertain economic background has led several authors to point out the importance of harnessing and managing innovation (e.g., Kotler and Trias de Bes, 2003) to better enable agile responses to changes in the mercantile ecosystem (Senge, 1990 – or for a more recent contribution see Garvin et al., 2008). Broadly speaking, SMEs reap relatively short-term Schumpeterian profits by means of incremental innovation, where managing internal knowledge networks for 'mutual inspiration' can give rise to transient yet often significant competitive advantages (see e.g., Mellor, 2003). However given the massive changes that have occurred in the intervening time since the acceptance of RBV, it would be a dangerous proposition to pursue a RBV 'policy' today and even the main KBV theoreticians like Nonaka and Takeuchi (1995) and the late Max Boisot (e.g., Boisot, 1998) do not address this new environment.

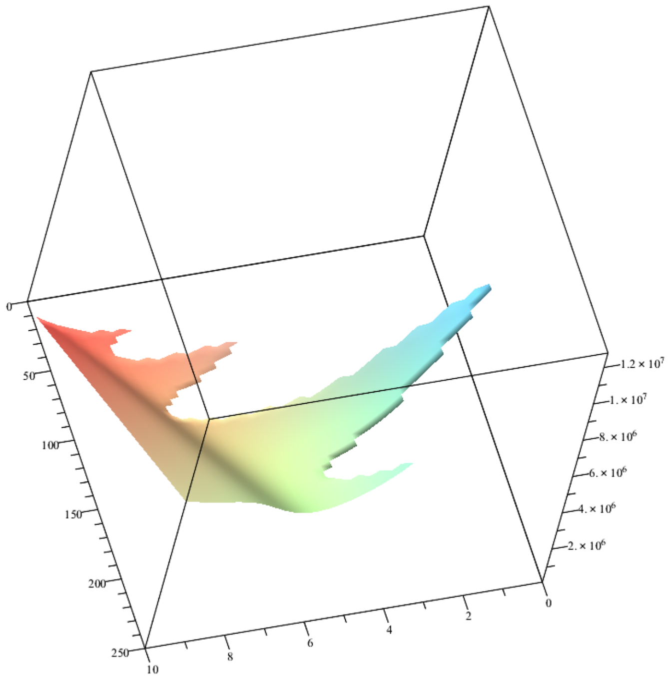
Against this background Mellor (2011a, 2011b) published an attempt at updating KVB especially for SMEs by aligning knowledge management with innovation and securing these in a framework of entrepreneurship: the first model (Mellor, 2011a, 2011b) was an 3D landscape showing the potential for innovation in a growing organisation and was called 'knowledge valley theory' (KVT). Computer-aided mathematical modelling later showed that KVT successfully accounted for all major aspects of the evolution and development of the SME (Mellor, 2011a, 2014a) from start-up and during its growth. Later, Mellor (2014b) used Markov chain Monte Carlo (MCMC) methods in virtual simulations to put financial values on the effect of adding innovation in high-innovation and low-innovation environments. However the figures resulting from the first Mellor (2014b) model indicated that a rather unrealistically high proportion (50%) of employees should be innovators i.e., that a half of the management should be innovators in order to reproducibly realise significant financial gains. One possible explanation for this high figure is that the Mellor (2014b) model only took internal networks into account and neglected the effect of external networks, the importance of which has been understood in a qualitative sense for some time (e.g., Kogut, 2000). Thus this work uses MCMC techniques similar to before (Mellor, 2014b) to model and quantify the effects that the possession of external knowledge networks by individuals may have, on the potential performance of the firm.

2 Modelling

The 3D fold 'knowledge valley' used is shown in Figure 1 and has previously been described in Mellor (2011a, 2011b, 2014a).

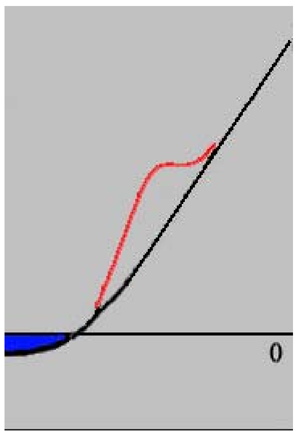
MCMC involves recognising the 3D fold as a Markov net. In Monte Carlo modelling virtual 'balls' are bowled along the net, usually from the origin and a scatter plot is made of their impact on the opposing side, which for ease of viewing are typically represented as impact density functions (Mellor, 2014b). Figure 2 provides an example of this, derived from the results described previously in Mellor (2014b).

Figure 1 The 3D fold also known as knowledge valley with on the abscissa the origin at 0 employees and that x-axis extending to 250 employees (see online version for colours)



Notes: The ordinate y-axis represents annual turnover in GBP (value at 2008) and the Z-axis is benchmarked openness to innovation, with 0 (zero hindrance) being very innovative, representing the 'Schumpeterian' side of 'knowledge valley' and the opposite end of the scale (10) representing the 'Dickensian' side

Figure 2 The density function derived from the scatter plot obtained on the Schumpeterian side of the 3D fold when innovators were added to middle management layer at a ratio of 50: 50 (see online version for colours)



Note: Zero indicates the (horizontal) boundary of profitability

With two important exceptions, the Monte Carlo modelling in the present communication was performed as in Mellor (2014b): the modelling consists of injecting virtual 'Monte Carlo' balls randomly down the valley from the origin along connections between nodes whilst distorting the net (the fabric of the valley) according to selected variables which can be programmed into the algorithm being investigated and then plot the result so that trends can be discerned. Since all nodes are directly connected to each other, they are always 'nearest neighbour' and sweeper code was thus added prevented to prevent balls going backwards, as described previously (Mellor, 2011b). The experimental run ends when the last of 1,000 balls reach the right-hand side of the valley – their exit points being impressed as a scatter plot on the J-curve (the Z-axis of the 3D fold). Monte Carlo balls bowled down the valley from the origin and where the valley consists of a completely uniform net, will arrive in a random fashion i.e., they will arrive on the Z-axis showing no peaks or troughs. Plots are derived by graphing the number of impacts per unit length against unit on the Z-axis. The Z-axis represents value, so a peak of Monte Carlo balls arriving there strongly implies an increase in value for the organisation. It is possible to distort the net – add variables – and then see by analysing the resulting scatter plot if the factor under investigation has added any value or not. Each experimental run was repeated ten times.

The two important exceptions to the above are: firstly, in order to economise on the considerable computing power needed, modelling was performed only on that side of the valley called 'Schumpeterian'. This was because the difference in gradient between the curves of the 'Schumpeterian' and 'Dickensian' sides of the 3D fold is known (e.g., Mellor, 2011b), thus knowing the result (in terms of the scale parameter of the scatter plot) on the 'Schumpeterian' side, the corresponding values on the 'Dickensian' side can be relatively easily calculated using Fourier transformation.

The second exception is that MCMC was performed as before but previously all Monte Carlo balls started at the origin of the fold and a variable number of 'innovators' were placed in a band corresponding to a middle-management salary as described before (Mellor, 2014b). However in the experiments described in this communication, the focus is on packets of useful information arriving from individuals outside of the organisation. Thus in the modelling reported here, the same overall number of balls were rolled down a fold in an exactly similar way as before, except that a variable proportion of these balls appeared 'spontaneously' in a random fashion within the innovator band. Experiments tested the proportion of balls at 33: 66, 50: 50 and 66: 33. This is meant to simulate the number of innovations (number of balls) being constant while the number of innovators responsible for them was varied, the balls appearing at random represent inspiration coming in from outside the organisation (and thus can appear anywhere along the band). The ratios represent one innovator using their network to harvest two innovations (33.3: 66.6), one innovator bringing in one inspiration from outside (50: 50) and finally the network value being one inspiration from outside for every two innovators in the organisation (66.6: 33.3).

3 Analysis and findings

So-called 'normal' probability density functions of (Gaussian) distributions exhibit a scale parameter (σ, or 'small sigma') of 1.0. For this type of Function, values of scale parameter of 3.0 and above do not in practice exist, because curves with such large scale parameter values would essentially be flat. Scatter plot distributions resulting from MCMC experiments recorded to date in this system have been found to be platykurtic (i.e., flattened) and exhibiting a scale parameter of typically between 1.5 to 2.9, depending on the number and placing of innovators in the 3D fold (Mellor, 2011b, 2014a, 2014b). Even placing 100% innovators in a continuous band did not drive the value of the scale parameter to reproducible values under 1.12. It is assumed that optimisation of the innovation process will result in values of scale parameter approaching unity (one) although there are presently no theoretical grounds to assume that values of scale factor less than one can be achieved. Never the less, values of scale parameter that are nearer to unity (one) are taken to mean an improved optimisation of the innovation process.

Experimental runs were similar to those described previously (Mellor, 2014b) starting with every second individual in the management band being regarded as a double-node innovator. Innovators are placed randomly within this band and in this scenario the value of the scale parameter scores around 1.5. This value thus functions as the control value.

Experimental runs were then performed using the same number of Monte Carlo balls in each run but of which 33.3%, 50% and 66.6% started from the origin and the remainder started from any random point within the band. This represents the situation of one innovator using their network to harvest two external innovations (33.3: 66.6), one innovator bringing in one inspiration from outside (50: 50) and one inspiration from outside for every two innovators in the organisation (66.6: 33.3). The resulting values of scale parameter are shown in Table 1.

Table 1 The effect of changing the proportion of MC balls starting at the origin of the fold on the scale parameter of the resulting scatter plot

Source mix	*Scale parameter (value)*
One innovator abd two external sources	1.12
One innovator and one external source	1.38
Two innovators and one external source	1.46
Innovators only	1.50

Note: Please note that these results only apply to the 'Schumpeterian' slope of the knowledge valley fold (as shown in Figure 2)

It can be seen from Table 1 that innovators capable of effectively calling in 'just-in-time knowledge' dramatically tightened the scatter plot distribution, indicating that they can indeed add significant value to the organisation. The 'innovators only' score represents the situation where half of all individuals in middle management are innovators, often exhibiting multi-skilling ('T-shaped' or 'A-shaped' skills, for further explanations see e.g., Katz, 2004; Tsai and Huang, 2008; Mellor 2011b, 2014b). This value was taken rather serendipitously and largely because the lowest value of scale parameter obtained to date was using 100% of individuals being innovators (Mellor, 2014b) and this was regarded as being so seldom in practice as to be highly unrepresentative. The value obtained for 100% innovators was 1.12 (Mellor, 2014b), from Table 1 it can be seen that this value is exactly similar to that obtained using highly externally-linked innovators. This shows that the ratio of innovators in management can be as low as 1: 6 of all individuals provided that the innovators have active external networks to gather relevant 'just-in-time knowledge' as well as clear open internal information gatekeeping, enabling solutions, suggestions etc. to be acted upon in an effective way.

How many external network contacts an individual needs is of course a moot point; certain individuals may have 100s or thousands of contacts but the absolute number will of course be relatively meaningless if they are not relevant to the problem at hand. Action on these 'mutual inspirations' must also be effective; Kirton (2003) also showed that problems with information gatekeeping will grow to significant proportions for those innovative individuals outside the 'consensus group'.

None the less, Table 1 does show that individuals with only a half chance of realising an action using information or knowledge obtained from an external source can have a modest effect on the potential performance of the organisation. This was raised considerably when the innovators internal and external conditions were such that each innovator could achieve an average of one effectively actionable solution or inspiration per innovator.

In the MCMC modelling, the number of external solutions harvested per individual could have been made to be higher than two per innovator (the 33.3: 66.6) situation e.g., to 25: 75 but this was not modelled in this work because an organisation that has so many problems that one out of every four problems (or indeed even more) need to be solved using outside sources, will be an organisation that has poor long term prospects of survival.

In a previous work, Mellor (2014b) kept the number of innovators constant, but changed their placing upstream (earlier in the organisations development) or downstream (later in the organisations development) in a Pareto distribution. The results indicated

> "… placing innovators upstream and downstream (i.e., historically earlier or later in a developing organization) strongly imply that hiring innovative managers into an existing and expanding medium-sized organization that is already populated by a well-established class of less innovative managers can add value. The results also however imply that putting an innovative middle-management in place early in the development of an SME is significantly more likely to result in adding value for the organization. Thus adopting high innovators from the very start implies the highest potential returns…." (Mellor, 2014b)

The lowest value of scale parameter obtained in those experiments was 1.21 and Table 1 shows that well-connected innovators can bracket this value (1.12–1.38). This implies that the statement of Mellor (2014b) quoted above should be modified to:

> "Organizations launched with a large proportion of innovators and where in the later growth stages few innovators are added, are still likely to perform better than those where innovators are added later over an earlier less innovative layer. However the difference can be evened out if latecomers are able to access and effectively use inspiration or 'just-in-time knowledge' gathered from their external networks."

The results presented here (Table 1) show that multi-skilled innovators with good networks are much more valuable than being a multi-skilled innovator alone. Indeed, it may be that a non-innovator with a good network is as valuable as a multi-skilled innovator lacking an effective network and that a reasonable mix may be innovators together with well-connected non-innovators.

In the same paper Mellor (2014b) also noted that "…adding innovators to high-innovation SMEs does not provoke an absolute increase in returns, but performance levels are reached earlier…." and added in relation to high-innovation environments that "…the only point however where innovators can be added and the shape of the scatter plot exceeds the base curve is right at the very tip; the highest paid executive. Even at this point gains using the current model appear marginal, however as described below the current model contains constraints, and thus future experiments may clarify if adding innovators to top positions does in fact add value and may indicate how much…" (Mellor, 2014b). Since the simulations reported here were already running on the 'Schumpeterian' side of the fold, it was irresistibly tempting to perform this modelling. To put it in layman's terms is it 'what you know' or 'who you know'? How exactly do the very highest paid directors of innovative companies earn their lucrative salaries, or are they over-paid? The figures used previously imply that for a company of 250 employees the financial difference in annual organisational performance that adding innovators at the very top could make, will mostly be zero, but around 25% of the area represents added value up to approximately £$9*10^5$. This figure thus represents what a particular top director of the largest SME may earn without negatively affecting organisational performance, but it does not indicate if this figure has be 'earned' by dint of work or network. Indeed, the question 'what fraction of top directors are innovators' becomes meaningless. None the less, modelling was attempted in order to investigate this point further and distinguish between the two possibilities but the results were not statistically meaningful due to too few numbers of points at that narrow part of the curve i.e., while a max salary of £900.000 in maximum one quarter of cases would appear to be a correct result, no absolute veracity could be attached to that figure due to the lack of sufficient numbers of individuals in this position and furthermore it could not be verified if that amount was justified by the possession of networks. That is not to say that achieving sufficient statistical significance to satisfy e.g., a t-test is not theoretically possible, but simply that repeating the run so often so as to be able to achieve this number would far exceed the computational power available at the present time. Thus in practice it would be easier to adopt a completely different approach e.g., to determine the salaries of top SME directors (by industry sector) as a proportion of the company turnover.

Table 2 Calculated values of scale parameters of scatter plot distributions imitating the effect of changing the proportion of MC balls starting at the origin of the fold

Source mix	*Calculated scale parameter (value)*
One innovator and two external sources	1.15
One innovator and one external source	1.41
Two innovators and one external source	1.49
Innovators only	1.50

Note: Note that these results apply to the 'Dickensian' side of the knowledge valley slope only

To consider the value of 'innovators' versus 'networkers' in low-innovation SMES: Table 1 showed the values of scale parameter were obtained on the 'Schumpeterian' side of the Knowledge Valley fold. Although in the experiments reported here no modelling was performed on the low innovation/'Dickensian' side, Fourier transformations of values from the 'Schumpeterian' side do however make it relatively simple to imply what they would be on the Dickensian side (Table 2).

As shown in Table 2, the effects of individuals on the 'Dickensian' side of the Knowledge Valley fold possessing networks enabling the effective use of external 'just-in-time' knowledge, basically parallels that seen on the 'Schumpeterian' side. It is not immediately clear why the values are slightly different – implying a lower efficiency in every case – but this effect has been observed before (see the Pareto distribution experiment described in Mellor, 2014b) and ascribed to the generally slower 'mercantile metabolism' of 'elephants' (for nomenclature regarding SMEs, see Birch, 1989), which are regarded as large SMEs on the slopes of low-to-medium innovation (Mellor, 2011b).

4 Conclusions

There are many reports in the management literature pointing out the value of multi-skilling (also known as 'T-shaped' or 'A-shaped' skills, for further explanations see e.g., Katz, 2004; Tsai and Huang, 2008) in adding innovation and thus potential value to organisations (e.g., Hitt et al., 2001; and more recently Østergaard et al., 2011). More recently, MCMC modelling has largely confirmed that professionals that are innovators by virtue of multi-skilling have the potential to add value to SME-sized organisations (e.g. Mellor 2011b). The knowledge valley fold (Mellor, 2011b) moreover makes it possible to distinguish between how many innovators, how much they innovate (and how) and where they are in the organisation – and indeed where the organisation is on a Schumpeterian scale. This is in contrast to all previous studies that are unable to distinguish between these variables and do not consider the environment that such individuals are embedded in.

Using MCMC modelling, Mellor (2011a, 2014a) explained the evolution and development of the SME. Continuing with the model, Mellor (2011b, 2014b) reported that adding innovators at middle management level to highly innovative environments does not increase total financial performance but rather enables the organisation to realise the theoretical higher financial performance faster. One exception to this could be using intrapreneurship i.e., the corporate spinning out of areas not aligned with the core competencies of the parent organisation. Results from MCMC have also indicated that adding middle-management innovators to low-innovation SMEs can contribute rapidly and markedly to potential financial performance; however caution is required to avoid unwittingly precipitating a dangerous process in the organisation akin to business process reengineering (Mellor, 2014b).

The major topic of the present work deals with the importance of external networks. It has been known for some time that these are very important for the innovation process (e.g., Granovetter, 1983) but the effect was not previously quantifiable. More recently it was thought that every second manager needed to be an innovator if significant advantage were to be obtained (Mellor, 2014b), but the present work refines this result and shows that by accounting for 'just-in-time' knowledge to arrive via networks and then being effectively acted upon, the ratio of innovators in management can be as low as 1: 6. The value of active external networks – when combined with clear open internal information gatekeeping – appears to be around the same value as the innovation arising from multi-skilling itself. Previous studies were largely case-based (e.g., Hitt et al., 2001;

Katz, 2004; Tsai and Huang, 2008; Østergaard et al., 2011) and thus have been unable to differentiate between these two factors because multi-skilling probably implies a larger and more diverse network for the individual involved anyway. The value of ‘just-in-time’ knowledge is so great that it may even be able to compensate for non-innovative management, always providing that the internal information gatekeeping is open to change.

Adding more innovators to high-innovation SME middle management does not improve financial performance; merely it shortens the time need to achieve it. Nevertheless there may also be special situations where total financial performance in high innovation organisations could be improved upon, which is not by having more and more innovators in middle management, but namely by having highly networked individuals in the very highest paid positions. At this high position on the ‘peaks of performance’ (Mellor, 2011b) there will be few individuals, highly networked externally to the organisation, with clear vertical information gateways internally within the organisation so that problems can be clearly communicated upwards, solved in the external network and the solution transmitted down again. Such individuals may be ‘multi-skilled’, although this factor is – relatively speaking – of lower importance.

5 Future directions

Previous modelling has accounted for an ″innovation-driven’ model of the evolutionary stages of the SME (Mellor, 2011a, 2011b, 2014a), has contributed to explaining the effects of an innovative management structure (Mellor, 2014b) and the effects of external networks (this communication). In this work the assumption has been that operational problems can rise ‘bottom up’ to well-connected senior positions, be communicated to others in different organisations (individuals and innovators presumably equally well-anchored internally) in a communication flow relatively unhindered by information gatekeepers. However the factors affecting external networks (density, flux, support mechanisms etc.) are unknown. What is known is that with intensified competition and globalisation, national and regional systems are increasingly hoping on being able to create specific ‘knowledge ecosystems’ that together with public/private business incubators and venture capital should be able to connect a reputable science-base with advanced knowledge and business to foster what the European Commission calls Technological Districts (European Commission, 2013) along the lines of previous and apparently-serendipitously successful examples like Silicon Valley, Silicon Fen, Silicon Corridor, Silicone Roundabout and many other place names that omit reference to the tetravalent metalloid element 14 (for a recent review see Lerro and Jacobone, 2013). Unfortunately both research and everyday experience agree that successful technological districts with high levels of competitiveness and growth are not the automatic result of clustering knowledge-intensive organisations in any given geographic proximity (e.g., Agarwal et al., 2010). Thus a Markov analysis of the nature of the matrix in which the organisations are embedded may explain the success (and failure) of initiatives concerning ‘economic clusters’ and help in the planning of new ones.

Consequently future models and modelling will investigate the density, strength, flux and, support mechanisms etc. of external networks between organisations and the ability of many organisations to cluster together to successfully form a ‘meta-organisation’.

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