Inductive Modelling of an Entrepreneurial System

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Abstract—*We describe the development of a novel approach to generating theory about the behaviour of an entrepreneurial or start-up system. The new technology business creation system in and around the cities of Bath and Bristol in the UK was analysed using an inductive modelling approach that hybridises grounded theory with system dynamics, a technique we have called grounded systems modelling. Three models that represent the stages of development of an idea through to successful exploitation have been derived from the data – i) Spotting an opportunity, testing and validation; ii) Realistic equity position, and iii) Scale up and exit. From these models a number of useful dynamic hypotheses have been developed which can be tested by suitable longitudinal studies. The results are discussed in the context of entrepreneurial research and a critique of the methodology is offered.*

Keywords—*System dynamics, grounded theory, inductive modelling, entrepreneur, entrepreneurialism, venture capital, start-up.*

1. Introduction

The source of creative new ideas is the essential starting point and main ingredient that drives the entrepreneurial system and thus the role of the entrepreneur is critical. However, if studying entrepreneurialism requires an understanding of what exactly *is* an entrepreneur then this is an area of research that is fraught with issues of definition (Gartner, 1998). There are also selection effects in play, we tend not to observe failed entrepreneurial acts because they are difficult to find, particularly those that fail at the early stages of idea formation. Failure or success for an individual involved in entrepreneurial activity raises all of the motivational questions concerning risk and reward that would feature as part of the analysis and theorising around individual entrepreneurial behaviour. However, the entrepreneurial or start-up *system* is observable in all its states of success and failure by fairly simple to obtain measurements – its study will naturally reflect the aggregate of individual behaviours.

The most fundamental and simple theory of entrepreneurialism is that of the entrepreneurial profit (Schumpeter, 1936). This is the monopoly profit that can be earned by capital that has been invested in an entrepreneur's innovative, creative, actions in a particular, or new, market for as long as the entrepreneur's advantage can be sustained over competitors. However, the current state of entrepreneurial research reveals much complexity from trying to understand how to translate the relative simplicity of Schumpeter into practical, actionable (normative) theories (Low and Macmillan, 1988).

The start-up system can be viewed as existing as a means of solving a problem – the conversion of financial investments in new ideas into new business ventures that achieve significant returns to the owners of that investment, and the need of the wider economy for growth. The research problem can thus be described as the need for developing a normative theory that can make predictions about the factors that impact the creation and success of new business ventures.

In order to provide manageable scope for a study, the start-up system in and around the cities of Bath and Bristol in the UK was chosen as the source of primary data. Whether this can be considered as a cluster (Porter, 1998) was left as an open question.

2. The Development of a Suitable Systems Methodology

2.1. Choice of Research Methodology

A systems approach was implicit in the research question and using system dynamics seemed an obvious modelling approach to expressing theories about dynamic behaviour of a complex system. However, the system dynamics methodology as expressed by (Sterman, 2000) and many others specifically counsels against modelling an entire system rather than modelling to address a specific problem. However, In this case the problem was simply a question about factors that impact the dynamic performance of a start-up system.

The research study poses a very open question and this naturally led to a research methodology biased towards an ethnographic, inductive, approach. Therefore it was decided to collect primary data by interviewing a representative set of stakeholders in the system and building the models from there. Grounded Theory (Fendt and Sachs, 2008, Glaser and Strauss, 1967, Strauss and Corbin, 1998) provided a convenient starting point for developing methodology and therefore effort was focussed on finding a way of linking, or hybridising, grounded theory with system dynamics, an approach we have called Grounded Systems Modelling.

2.2. Linking from Grounded Theory to System Dynamics

The motivation behind grounded theory as described by (Glaser and Strauss, 1967) is "*the discovery of theory from data*". Such theories are not abstract or deductive; instead the intent behind them is to create "*theory suited to its supposed uses*". Since grounded theories are based on extensive interview data they are usually quite enduring and well suited to the need to provide predictive and explanatory descriptions of behaviour.

(Strauss and Corbin, 1998) offer a methodology for conducting qualitative research and describe the rôle of a grounded theorist; literally the creator of grounded theories. By grounded theory they mean theory "*derived from data, systematically gathered and analyzed through the research process*". The methodology does not start with theory but allows theory to emerge from data. Strauss and Corbin describe theorizing as "*conceiving or intuiting ideas*" and their formulation into a "*logical, systematic, and explanatory scheme*". It is also intentionally iterative, in that hypotheses should be "*checked out against incoming data*".

Few researchers have linked an essentially inductive research methodology with system dynamics modelling. (Repenning and Sterman, 2002) adopted this stance in work on modelling and understanding failure in process improvement projects. (Morrison, 2003) provides an excellent thesis explaining the "*start and fizzle*" of organisational change based on extensive ethnographic studies of an automotive manufacturer in the USA attempting to implement lean manufacturing ideas. (Burchill and Fine, 1997) describe a similar approach that they call Inductive Systems Diagrams methodology. Their intent was to "*develop variables which have* *significant explanatory power and are intimately tied to the data*". The cause and effect between these variables is then captured using causal-loop models. They claim that their advantage over pure system dynamics modelling by itself is that all the variables and their causal relationships are "*grounded in interview data*". By extension, this applies to stocks and rates too. The model thus becomes the expression of the theory. However, whilst agreeing with this, they do seem to entirely miss the point of simulation in system dynamics and the generation of dynamic hypotheses.

A modeller, skilled in the art of system dynamics modelling and its use in a consultative setting (Sterman, 2002, Sterman, 2001, Coyle and Morecroft, 1999, Coyle, 1998), or using group model building (Visser, 2007, Vennix, 1996, Rouwette et al., 2002, Andersen et al., 2007) would argue that their models are naturally grounded; models after all do not appear out of thin air. However, by using the methodology and experimental techniques of grounded theory provides an explicit linkage and an *audit trail* from stakeholder interview data to models.

2.3. Practical Steps and Use of CAQDAS

NVivo v7 from QSR International Pty Ltd was chosen as the Computer Aided Qualitative Data Analysis Software (CAQDAS) to support analysis and coding of the interview data. The interview transcripts were loaded into NVivo and the process of developing and hierarchically grouping concepts, coding, and writing memos was carried out entirely within NVivo. The use of CAQDAS tools such as NVivo help in that during the process of coding it is possible to jump directly to creating and editing memos in order to capture thoughts as questions about "*what is going on?*" as they arise (Di Gregorio, 2003).

NVivo supports two types of coding nodes, free and tree nodes. Free nodes were used during the early open coding stage to develop categories without initial thought to their linkage. However, as more interviews were carried out and during the process of coding it became possible to begin to link categories together hierarchically, i.e. categories and sub-categories started to become evident. The process of organising the free nodes into a hierarchical structure, or tree nodes in NVivo, corresponds to the process of axial coding (Strauss and Corbin 1998, pp. 123 – 142). By the time approximately 75% of the interviews were completed the tree node structure in NVivo had become fairly stable. During the coding process, Straus and Corbin was used as a guide to heighten awareness of the nuances of conducting qualitative analysis and as a practical methodology to follow in coding the transcribed interview data especially on these points:

- to develop "In Vivo" concepts – where the name of the concept is a word or words taken directly from respondents,
- during open coding, breaking data into parts that could be "*compared for similarities and differences*", and then grouped together into "*more abstract concepts termed categories*", and
- axial coding that relates categories to their sub categories, the process to "*Systematically develop and relate categories*".

A degree of quantitative analysis of the coded data was introduced by looking for links between categories that were not part of the coding tree. Whilst an influence diagram seems to arise naturally from axial coding there is an orthogonal set of information available arising from the way in which NVivo manages the codes and this was used to provide a pointer towards causal loops. An intuitive coding approach led to frequent use of more than one code for many sections of the text. As a consequence, categories from different parts of the axial coding tree can be linked by the text itself, which is still quite in keeping with the idea of developing theories grounded in the text. The number of words coded by two or more categories determines the degree of linkage between categories. This type of analysis is supported in NVivo by using the matrix query facility. Therefore, a matrix query was created to generate the cross-correlation of all the coding categories used i.e. how each concept is linked together by common text by counting the number of words simultaneously coded by the row and column categories of the query. The correlation was computed using the "NEAR content" setting and proximity parameter set to "overlapping".

The resultant 110x110 matrix was quite difficult to manipulate in NVivo but it could be exported to MS Excel where it could be managed using simple macros written in VBA code.

The interpretation of these category links is that they are candidate causal links that could be represented in a causal loop diagram, in addition to those that arise naturally from the influence diagrams derived from the hierarchical coding process. The list of potential causal links was generated by reading off the (row, column) number pairs from the Excel spreadsheet and then indexing back to the list of categories from NVivo. This loop between the Excel/VBA tool and NVivo was used repeatedly to search for significant causal relationships.

In principle the significant category links from the NVivo matrix query could be fed via some formatting process into a system dynamics modelling tool and whilst this would generate correct syntax the construct is meaningless because it would create bi-directional causal loops i.e. the matrix query will link category A with category B symmetrically at some level of significance, but there is obviously no information about direction of causality. Also, the category names themselves do not convey a clear sense of direction, delays are not shown, and there is too much clutter.

Instead the links were pruned using the following process for deciding inclusion, directionality, and significance:

- Significance was determined by the number words simultaneously coding both concepts; more than a 1000 was considered as a useful threshold.
- All the coded text corresponding to the significant correlations was extracted from NVivo (by double clicking on the cells in the matrix) and re-read to confirm the significance of the correlation and to understand the meaning and direction of any causality.
- Elimination of auxiliary variables – chains of category links were shortened where the intermediate categories would have led to an overabundance of auxiliary variables in the models.

Whilst the methodology developed seemed a reasonable approach it is clear that linking the tools from the world of the grounded theorist to that of the system dynamics modeller is an active area of research.

3. Grounded Systems Models of an Entrepreneurial System

3.1. Data

Interviews were carried out with 13 people representing a broad range of roles in the start-up system in and around the cities of Bath and Bristol in the UK during a two-month period at the end of 2007. The total duration of the interviews was just over 14 hours and the transcripts constituted a data source of 113,000 words.

Whilst it would have been consistent with the grounded systems methodology described to present the models together with the supporting data in the form of quotations this would have led to an excessively long conference paper and therefore have been omitted.

3.2. Development of the Models

A convenient summarising perception generated from the interview data is that entrepreneurialism and its relation to equity funding is basically the story of trying to bridge two different types of gap. The first is the gap in the market that the entrepreneur senses and seeks to fill with an offering, probably arising from some new invention or technical/process improvement (Gap 1). The second is the funding gap that has to be crossed and represents the ability of an entrepreneur to take the idea through an investment process to actually build an operation capable of delivering the offering (Gap 2). Thus opportunities in the market are filled with suitable ideas and an investor arrives at a decision on suitability by a complex process of sense making.

The essence of the start-up system is that it exists as a consequence of entrepreneurial creativity; this is the primary driving force. The process of crossing both these gaps requires thinking of the behaviour of the entrepreneurial system as something that takes idea creation through to some successful conclusion; an end-to-end process from idea generation through revenue creation to successful exit.

It seemed clear from the data that moving from the perception of a gap in the market and idea generation (Gap 1) to transitioning the funding gap (Gap 2) cannot be achieved in a single action; there is an essential first step – the creation of the initial venture or proto-company and this makes the beginnings of an interesting dynamic picture. The proto-company becomes the vehicle for building an initial prototype or pilot project, which tests the market.

In fact, it is the proto-company activities associated with Gap 1 that are crucial and may show the entrepreneur alternative routes than equity funding i.e. for some ventures crossing Gap 2 may not be necessary. However, focussing on chasing equity funding, crossing Gap 2, may even prove a hindrance to crossing Gap 1 which is absolutely essential.

The model developed from the data using the methodology described consists of three main models and these are described in detail in sections §3.4 – §3.6.

3.3. Underlying Stocks and Flows

The stocks and flows view of the start-up system is built on the measurable quantities of the system. From a portfolio or holistic perspective, rather than individual entrepreneur, the important stocks and rates are:

- The quantity of equity funds available at any one instant of time to fuel new ventures at various stages, the rate at which the funds are invested and the rate at which returns are generated
- The number of companies in each stage of equity funding (e.g. Seed, Series A, subsequent stages) and the rates of transition between them, rates of exit, and rates of failure from each stage.

An abstraction has been introduced and two terms (stocks in the models) defined to describe and simplify the funding status of new firms:

Proto-Companies: to denote those companies at the formation stage that have not yet required or sought equity funding and are focussed on Gap 1 objectives; and

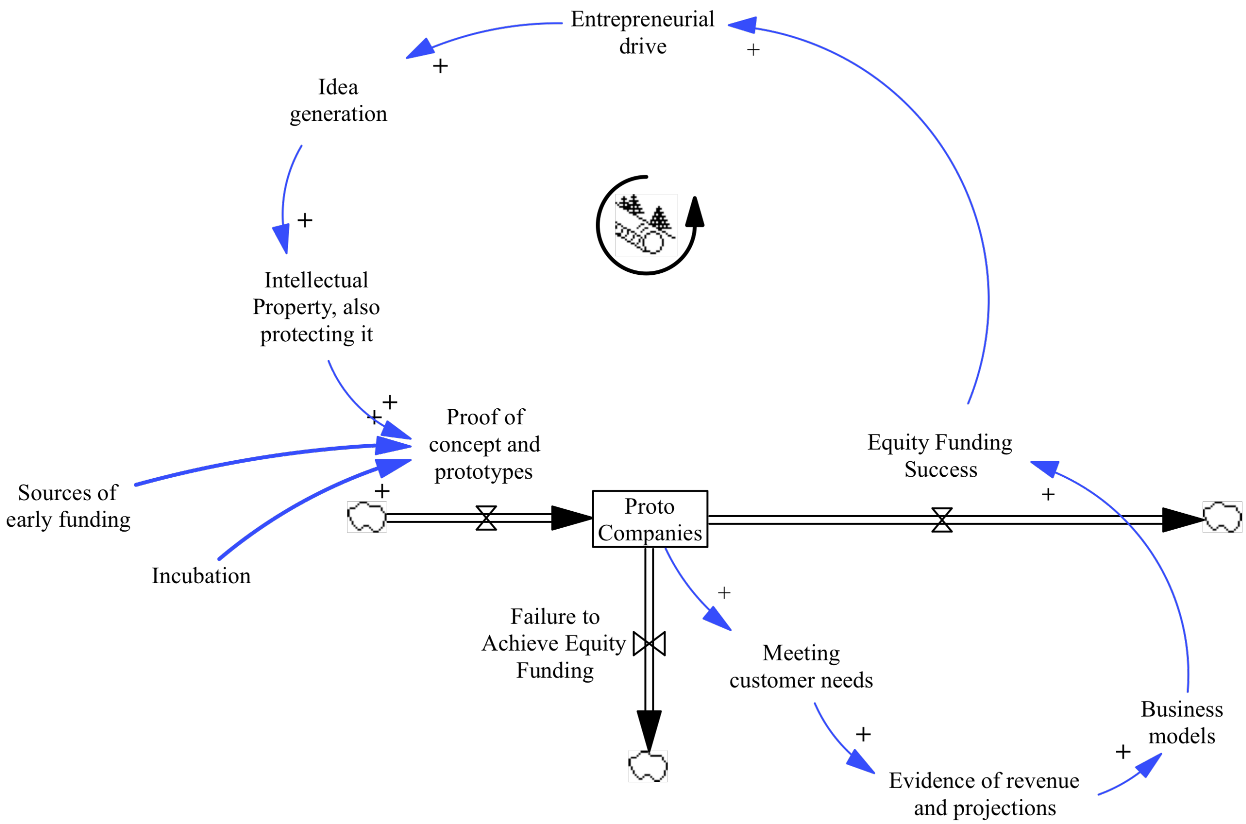
Equity-Funded: for those companies that have achieved Seed, Series A and subsequent rounds of funding in exchange for equity and have therefore crossed Gap 2.

From an initial stock of Proto-Companies, which is constantly being replenished by new idea generation, and focussed on Gap 1 activities, a certain fraction are successful at achieving equity funding depending on transitioning Gap 2. For any given system all of these quantities and rates are measurable and therefore available as parameters for models for validation purposes.

3.4. Spotting Opportunity, Testing and Validation (SOTV)

The model for Gap 1 transition has been captured as a loop called Spotting Opportunity, Test and Validate (SOTV) as shown in Model 1. This seems to be the basic first step that an entrepreneur goes through in order to arrive at both the business model, which captures the hard data from this trial and forms the essence of the story that will be used in the attempt to convince the equity investor(s) to invest in the idea. It is also the direct evidence that customers' needs are being met; the latter often referred to as "*reference customers*". Arriving at a business model, which becomes the focus of transitioning Gap 2, still requires a source of investment and this is likely to come from the entrepreneur personally and from whatever sources can be used to get the idea tested. The overwhelming impression from the interviews was that all the effort or energy was placed in the process of searching and investigating opportunities.

The SOTV loop is interpreted as follows. New ideas are generated as a consequence of entrepreneurial drive and these in turn lead to the creation of intellectual property that needs to be protected appropriately. From this, proof of concepts and prototypes can be created so long as there are adequate sources of early funding or access to incubation. Proto companies thus arise. Proto companies exist to demonstrate that they can meet customer needs by generating evidence of revenue and making projections. These data then form the basis of business models that are then used to argue the case for equity funding. The business model is thus a repository of the evidence that Gap 1 exists, that it can be filled, and an argument for the value that can be achieved from building an operation to deliver the offering that addresses the gap.

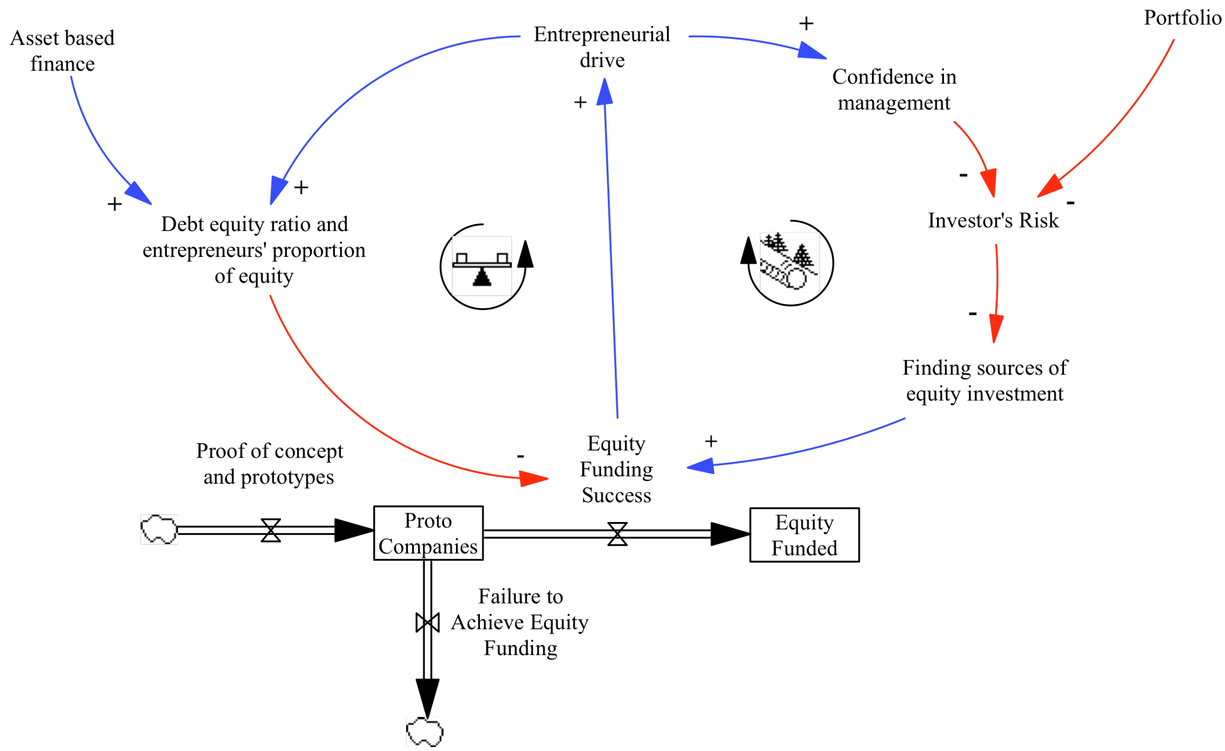


Model 1. The Spotting Opportunities, Testing and Validating (SOTV) loop.

It is successful exits that inspire entrepreneurs and increases their drive for more success. In this model the success at generating equity funding is used as a proxy for successful exits. The loop is thus reinforcing leading to exponential growth, until some exogenous limit is met – the most likely being the availability of equity funding. Growth is dependent on adequate sources of early funding and access to incubation. If these were to drop below some threshold then the loop is still reinforcing but in this case leading to an exponential decay to zero in the number of proto companies in existence.

3.5. Realistic Equity Position (REP)

The model for crossing Gap 2 has been captured as the Realistic Equity Position (REP) loops as shown in Model 2. As already mentioned, equity funding is not always the best way forward for an entrepreneur and that crossing Gap 2 may not be necessary, particularly for the cases where debt financing is available or if a licensing approach can be taken. If the entrepreneur can only realise value by building an operation that requires equity financing then the problem of dilution arises.



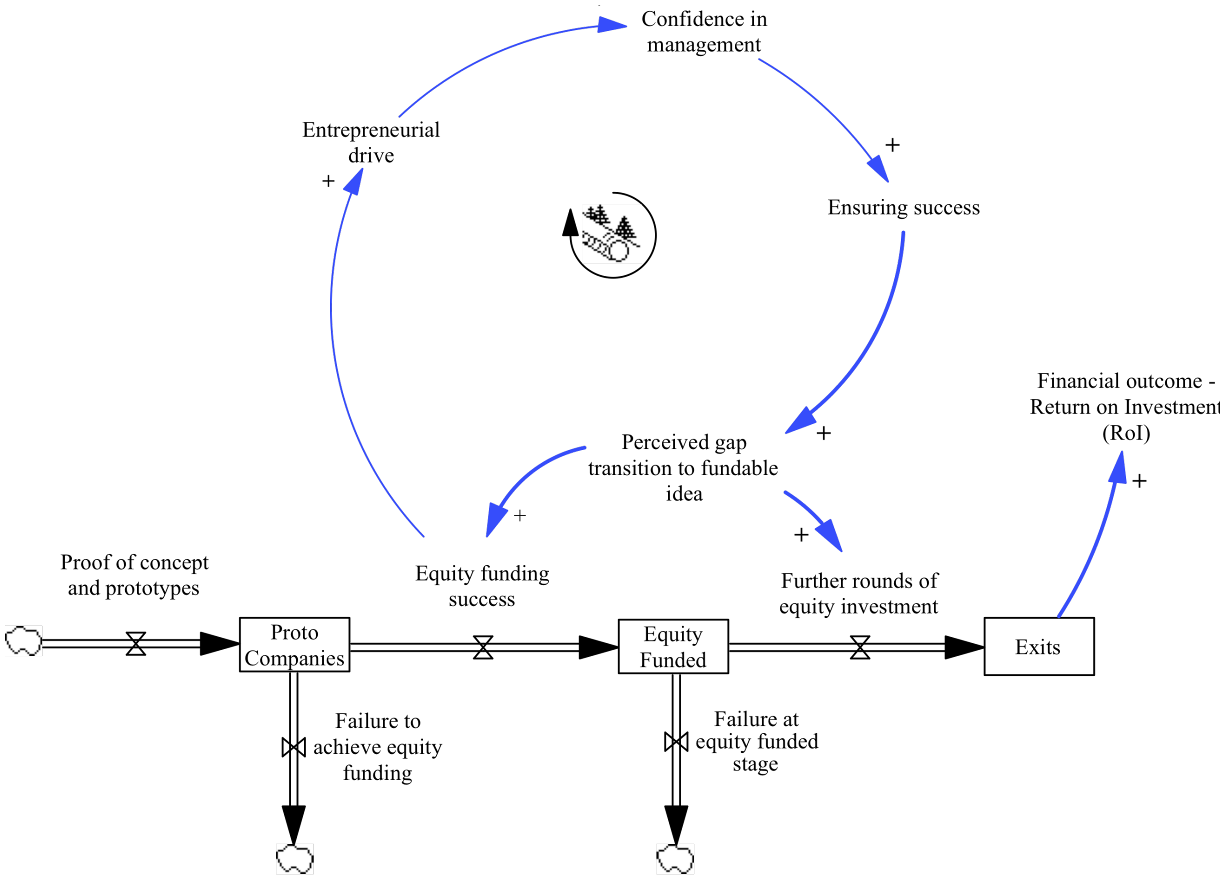
Model 2. The Realistic Equity Position (REP) loops.

The REP loops can be interpreted as follows. Entrepreneurial drive at this point in the development of the company is directed towards convincing equity investors of the business case and also potentially corralling together more than one equity investor in order to achieve the investment required. As entrepreneurial drive increases the debt/equity position of the resulting company is likely to be altered in the favour of the entrepreneur i.e. the entrepreneur will try to negotiate a lower equity stake from investors, potentially taking on more debt as an alternative. This will reduce the likelihood of securing equity funding, as the equity investors will be trying to maintain the highest possible equity stake in exchange for their investment. This is thus a negative feedback loop. Acting in opposition to this is a reinforcing loop that arises from increased entrepreneurial drive leading to higher confidence in management that reduces investor's risk and thus improves the chances of finding equity investment. The dynamic behaviour of the system is likely to be complex but a reasonable dynamic hypothesis can be formulated as follows. As entrepreneurial drive increases the overall impact at first will be to reinforce the reduction in the investors' attitude to risk and thus improve the chances of finding an acceptable level equity funding. However, as entrepreneurial drive increases above some threshold then there is a likelihood that the entrepreneur will start to seek an unrealistic equity position from the point of view of an investor. At this point, the balancing feedback loop becomes dominant and entrepreneurial drive works against transitioning Gap 2 and thus away from equity funding success.

Measurable factors which impact this behaviour are i) the entrepreneur's access to asset based (secured) finance – as this increases the chances of achieving equity funding go down; and ii) the investor's portfolio position – as this improves the investor's attitude to risk is likely to go down and thus lead to a better chance of achieving equity funding.

3.6. Scale Up and Exit (SUE)

Having crossed Gap 2 and achieved equity funding the company is focussed on growth to become a viable long-term firm. The equity investors, including the entrepreneur, will be looking to realise their investments by selling their equity stake at some point in the future, an exit, and this is typically achieved through a private equity sale (acquisition) or by IPO.



Model 3. The Scale Up and Exit (SUE) loop.

The sequence of staged investments necessary to achieve a state suitable for exit has been collapsed into the single stock <Equity funded> in the models developed so far. However, in order to take into account exits and the factors that impact achieving a successful exit the new stock <Exits> has been introduced and is shown in Model 3. The SUE loop is a simple reinforcing feedback mechanism. The success of the growth phase is a consequence of repeated trips around the REP loops crossing Gap 2 every time to transition between funding rounds e.g. Seed → Series A, Series A → Series B and so on. The equity funded company is almost certainly acquiring more customers and constantly testing the market during this growth phase so Gap 1 is repeatedly crossed, in effect the SOTV loop is in constant operation even for the companies that have already crossed Gap 2. The consequences of this dynamic behaviour are discussed in more detail in §4.2. The variable <Ensuring success> was introduced as a summarising category for a whole number of contributory factors arising in the data, the most significant, by number of sources, being the following:

- access to coaching,
- the role of Non Executive Directors (NEDs),
- appointing an experienced MD/CEO,
- legal support,
- suitable recruitment, and
- availability of suitable control levers, in the sense of warranties etc.

3.7. The Start-Up System

The original perception that the start-up system is directed towards searching and finding the right opportunities implied that the system was goal seeking. However, goal seeking has specific meaning in system dynamics modelling and implies negative feedback i.e. the negative feedback conveys some sort of error or difference signal between the target (goal) and the current state. Whilst the VC/start-up system has no such target and like the wider economy is predicated on continual growth, and growth arises in a dynamic system through positive feedback, a reinforcing causal loop. Throughout the development of the models we have used success at gaining equity funding as a source of feedback to entrepreneurial drive – success leads to increased drive. With the exception of the balancing loop in the REP model, where increased drive is likely to lead to less success at achieving equity funding, this has always led to reinforcing feedback. Therefore we can conclude from the models that the start-up system is characterised by a number of reinforcing feedback loops which will lead to exponential growth in the number of proto- and equity funded companies but with three exceptions:

1. If sources of early funding or incubation drop below a threshold then the SOTV loop will actually operate to drive an exponential decline in the number of proto-companies towards zero.
2. As entrepreneurial drive rises above a certain level it is likely that the success rate in achieving equity funding will go down as entrepreneurs shift the balance of funding towards asset based (debt) financing. Policy variables affecting this will be access to asset-based finance, which will act in the same direction to push the success rate down, and the strength of investor's portfolios that will act in the opposite direction by improving the investor's attitude to risk and therefore willingness to take less of an equity stake in an investment.
3. Exponential growth will eventually run up against one or more exogenous limits. The most likely encountered will be the finite limit on the source of equity funds.

From the overall pattern of reinforcing feedback in the models leading to exponential growth moderated by these three exceptions a relatively simple picture of dynamic behaviour emerges. From a macro economic point of view this system is the (needed) source of new technology business ventures in the region and if we are not observing exponential growth in the number of equity funded businesses then one of these 3 limits is likely to be in operation. The current economic climate suggests that it is the exogenous limit on the supply of equity funds that is restricting growth, however it could also be lack of early funding and incubation that could be stifling the formation of proto-companies. Whichever is the cause can be easily tested by a suitably designed study. Answering the question quite simply requires measurement of the rates of companies coming forward to seek equity funding, and the subsequent success rate of achieving equity funding. If the former is going down then limit 1 is the cause, if the latter then limit 3.

4. Discussion

4.1. Relevant Entrepreneurialism Literature

(Strauss and Corbin, 1998) caution against an *a priori* literature review suggesting it might stifle the process of making discoveries. Therefore, the review here focuses on literature relevant to the models that have been developed.

(Shane and Venkataraman, 2000) provide both a definition of entrepreneurship and a rationale for why it should be studied. The core of their conceptual framework consists of two straightforward lines of enquiry – "*the reason why entrepreneurial opportunities exist and why some people, and no others, discover and exploit them*" and the "*different modes of exploitation*". The essence of this core is that an entrepreneur holds the unique belief that a new "*means-end relationship*" exists for a set of resources that can be assembled into an offering that would be a better use of them from a market price point of view. In which case, the possibility of entrepreneurial profit arises when an individual realises that an opportunity exists and has value. The corollary of this follows simply, if the entrepreneur's belief is wrong then the venture will fail, and if it is not unique then competition will already exist and entrepreneurial profit making opportunities already exploited.

The existence of a unique belief arises fundamentally from the creation of information asymmetries that the act of exploitation will eventually diffuse away until a new equilibrium position is achieved (Schumpeter, 1936). Conversely, the market must allow these asymmetries to exist for some period of time, e.g. through copyright and patent laws to protect intellectual property, to enable an entrepreneur to profit from his activities else there would be no incentive (Baumol, 1968). This explanation provides a good conceptual framework in which to understand the SOTV loop. The existence of a unique belief may arise spontaneously, but some considerable effort needs to be expended in order to assemble evidence that it is unique, that there is value, and that entrepreneurial profits could arise from exploiting the opportunity. Inductive modelling confirms that the practical repository and communication vehicle for this evidence is the business plan for the new venture.

The exploitation of an entrepreneurial opportunity forms the second substantive part of the (Shane and Venkataraman, 2000) framework and they break that down into the decision making process and the actual modes of exploitation. Modelling in this paper has conflated these two parts due to a selection effect that has led to considering the creation of new firms as the only mode of exploitation. The decision making process clearly equates to the sense making influence in transitioning the funding gap in Model 2, which is primarily the communication of the opportunity to the sources of equity investment requires to fund the operation necessary to exploit it.

Whilst (Shane and Venkataraman, 2000) provide a useful conceptual framework for explaining certain empirical phenomena in entrepreneurial studies they are not proposing any theories of entrepreneurialism and this is a frequently occurring criticism in the literature; where are the predictive, normative theories? An early frequently cited reference is the work of (Low and Macmillan, 1988). They used a framework consisting of six key dimensions of research design in order to analyse entrepreneurial literature and to critique the state of entrepreneurship research. Their overall conclusions point to weak theory development, lack of longitudinal studies, and absence of research that addresses issues of causality.

> "*Recent years have seen only limited examples of research designs that develop a priori hypotheses. Consequently, formal modelling and experimental research have lacked a foundation for development*"

Of particular relevance is their analysis of research into the "*strategic adaptation*" perspective, i.e. the strategies adopted by the individual entrepreneur in order to exploit opportunities, and the shift towards a "*population ecology*" view, i.e. the environment is the dominant factor selecting for success. They also note a lack of *a priori* hypothesis generation, by which is taken to mean not based on empirical evidence. The shift to a population ecology viewpoint is particularly relevant given that this is well suited to system dynamics modelling.

(Aldrich and Martinez, 2001) take an *"evolutionary approach"* (Low and MacMillan's "*population ecology"*) by asking how entrepreneurs apply their knowledge to acquire and exploit resources and how these entrepreneurial efforts fit with environmental forces. Their conclusions are interesting in that they note

> "*endogeneity is an ever-present problem, because many variables have reciprocal causal relationships…feedback from outcomes modifies entrepreneurs' strategies*"

Which seems to demand a plausible methodology that can explicitly deal with causality, feedback and complex dynamic behaviour. This was 2001 and there was no reference to any sort of systems thinking or system dynamics modelling.

By concentrating on the system rather than the individual the need for a definition of entrepreneur disappears, yet there are clearly individuals within the entrepreneurial system that drive the system to produce valuable outputs as the inductive modelling has shown. The advantages of this shift in analytical focus and its impact on the magnitude of research carried out is described by (Bygrave and Hofer, 1991) in relation to strategic management and they use the example to argue for a similar shift in focus for entrepreneurial research, i.e. from the *"characteristics and functions of the entrepreneur"* to that of the *"entrepreneurial process"* which they define to involve *"all the functions, activities and actions associated with the perceiving of opportunities and the creation of organizations to pursue them."*. This is extremely useful if we equate their definition of process with the definitions of an entrepreneurial system adopted in this paper since Bygrave and Hofer state, *"if researchers could develop a model or theory to explain entrepreneurial processes, they would have the key that unlocks the mystery of entrepreneurship"*.

Whilst not a conclusion as such, (Murphy et al., 2006) provide entrepreneurship researchers with this observation, and challenge, on a suitable theory

> "*From a systems perspective, optimization in the neoclassical sense…requires activity in one area of a system to drive activity in other areas almost programmatically…However, the novelty of entrepreneurial discovery suggests a unique, unpredictable event…which implies disequilibrium. Such breakouts are outside the existing system's boundary conditions in important ways and frustrate the implicit equilibrium assumptions of person-centric approaches based on statistically reliable variables. Such assumptions do not set the bounds on the problem effectively because entrepreneurial discovery entails expansion of many different kinds of resources. Thus entrepreneurship theory must be logically compatible with such growth*."

4.2. Behaviour of the individual firm or entrepreneur

The development of the models has been focussed on describing and investigating system behaviours not those of the individual firm or entrepreneur for the reasons stated in the introduction. However, in terms of the properties of an ideal model as proposed by (Hofer and Bygrave, 1992) this is considered a serious weakness. For this reason an interpretation of the trajectory of a single firm has been attempted in relation to the key causal loops.

Economic theories such as the principal-agent problem discussed by (Macho-Stadler and Perez-Castrillo, 2001) and as elaborated on in depth by (Amit et al., 1990b, Amit et al., 1990a) specifically in the context of the start-up system provide considerable insight into the potential behaviour of entities within a system. With this in mind we have presented the possible behaviour of an individual firm in Figure 1 as an interpretation of the models.

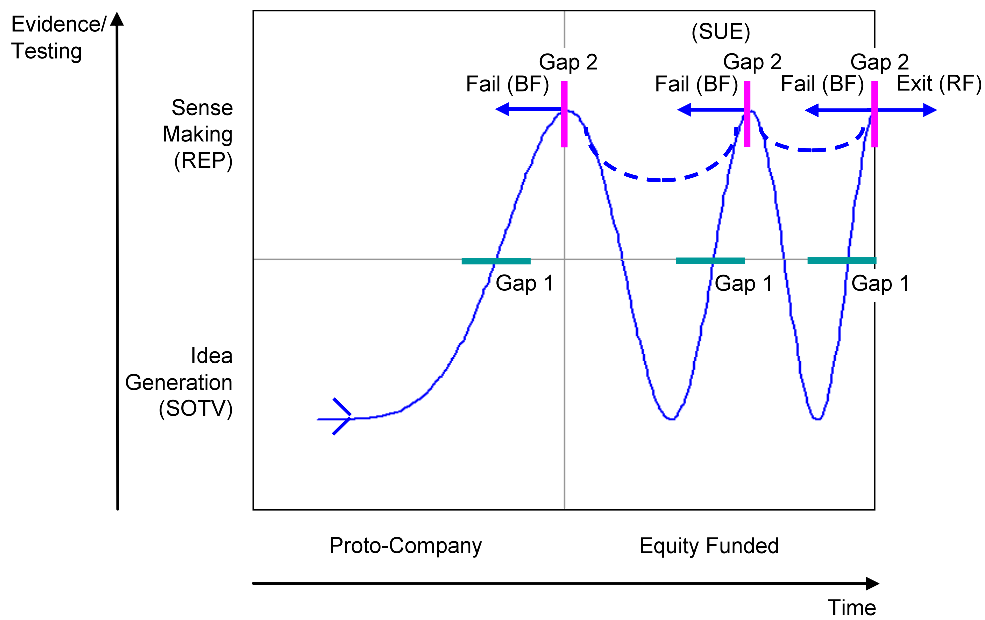


Figure 1. Potential trajectory of a single start-up business against Gap 1 and Gap 2

The main loops in SOTV and REP are represented on the Evidence/Testing axis and the time axis is self evident. Time is spent by the Proto-Company in the SOTV loop until Gap 1 is crossed. At which point the entrepreneur is seeking equity funding and engaged in negotiation with potential VCs in a process of sense making leading to potential crossing of Gap 2. Proceeding through stages of equity funding the firm crosses Gap 2 each time a new deal is struck (e.g. Seed → Series A, Series A → Series B). Failure at any point generates balancing feedback for the system, although clearly for the individual firm this is likely to mean irretrievable failure of the venture. The REP/equity funded quadrant also corresponds to the SUE loop in operation. The firm will also be constantly testing the market, as its offering develops, represented by the loops back into SOTV and in effect crossing Gap 1 again. However, there may be firms where this is not necessary, as indicated by the dotted trajectory. The final crossing of Gap 2 represents achieving a successful exit and the generation of reinforcing feedback in the system.

The main causal loops in SOTV, REP and SUE all depend on <Entrepreneurial drive> as the primary source of energy to fuel the VC-start-up system and this variable is likely to have the most significant effect, over the other variables, in improving the rate of crossing Gap 2. However, the simplicity of this is made more complex by the effect predicted in model 3, situations where entrepreneurial drive is so high that the entrepreneur seeks a deal-breaking equity stake and in fact finances the firm from other sources than equity funds. This is almost identical to the effect predicted by (Amit et al., 1990b). Whereas the dynamic systems model predicted this as a consequence of balancing feedback in the REP, Amit, Glosten and Muller have derived their hypothesis rigorously from agency theory and the adverse selection problem as neatly summarised in (*ibid* Figure 1). This observation suggests that any behavioural logic expressed in equations attached to key auxiliary variables in a system dynamics model need to be either properly grounded or derived empirically from well known theoretical results, as in the case here with agency theory.

4.3. Validation

The models developed in this paper have been simulated to generate hypotheses related to the predicted dynamic behaviour of the start-up system. Since these are hypotheses of dynamic or time dependent activity ranging over many years testing can only take place by suitable longitudinal studies. An important concept for the design of such a study is defined scope. Model simulations will only be meaningful if there is consistency of measurement and that will only be achieved when the precise boundaries of the system are defined before any specific quantitative longitudinal studies are undertaken.

The contributing factors are derived from the axial coding and describe other variables that have an impact on those that are part of a study. This will provide a source of additional questions to help clarify the meaning of the variables during experiment design. Other sources of quantitative data are readily available for certain industry sectors.

All of the interval data measurements can be reasonably obtained by construction of suitable questionnaires using 1 – n scales. Superficially these look like Likert scales. However, a Likert scale returns ordinal data that are not amenable to mathematical operations. The requirement to run simulations of the model using variables based on these data means that they must be interpreted as intervals (Stevens, 1946). A value of <Entrepreneurial drive> = 4.0 will have twice the effect on dependent auxiliary variables in a model as a value of <Entrepreneurial drive> = 2.0. Furthermore, if <Entrepreneurial drive> is measured across a number of entrepreneurs it must be possible to average the result (e.g. <Entrepreneurial drive> = 3.1, N=20 respondents). Therefore, treating these data as ordinal and the scales as Likert-like would be incorrect. (Hofer and Bygrave, 1992) discuss this problem at length specifically in the context of studying entrepreneurialism together with that of dimensionality and surrogate variables. (Fowler, 2003) also discusses the use of soft measures in system dynamics modelling and argues strongly for the use of "*soft stocks*". Given that the dynamic hypotheses arising from this work are about likely behaviours rather than numerical predictions we believe objections such as those arising from (Coyle, 2000) are mitigated.

Dimensionality is also problematic. None of the reported work on *grounded* systems modelling (Burchill and Fine, 1997, Morrison, 2003, Repenning and Sterman, 2002) really discussed the executable nature of the models and therefore the question of quantification of the variables. The stocks chosen in all the models are measurable. Since stocks are the integration of the flows leading into and out of them, the units of the flows will be in terms of per unit time e.g. creation rates as Proto-Companies/month. Similarly the other variables in the causal loops must be dimensionally consistent.

However, whilst the measurement units (dimensionality) of the stocks are clear there is still ambiguity over the actual way in which the count is made. The amount of time spent as a Proto-Company or Equity Funded clearly depends on the individual firm. In order to carry out a simulation using any of the models it is necessary to consider whether to use a fixed time or to use a distribution for these times. A distribution makes more sense and therefore each of the stocks must be measured in a way that provides the same parameters as used in the model. A normal distribution was used throughout the process of modelling and therefore both the mean and the standard deviation would be required. However, if a simple average is all that is available from the analysis of future data; i.e. it is only possible to say that on average firms spend a certain number of months at each of the two stages then a single parameter distribution would be required such as the exponential.

4.4. Critique of the Methodology

There are few examples in the literature of the methodology that has been called grounded systems modelling in this paper and these have been listed in §2.2. As a hybrid methodology that combines grounded theory with system dynamics it seems to offer a tool to the researcher to generate useful and testable hypotheses about dynamic behaviour. However, the most vigorous criticism can be levelled at the reliability of the findings; the selection and number of interviewees, the process of coding and the interpretation of axial coding into system dynamics models all introduced sources of bias. Which of these would cause the greatest source of discrepancy with another researcher would require further work to understand. However, it is estimated that in order of greatest to least sensitivity to bias it would be (coding) >> (interviewee selection) >> (axial coding to system dynamics modelling) i.e. reliability is probably more of a problem with grounded theory than interpreting the results of axial coding into system dynamics models especially where the latter was helped by the use of matrix queries.

We have attempted to address the question of the validity of the research by including considerable detail about how the methodology was implemented. Was this in fact the best methodology to use for understanding dynamic behaviour of the start-up system? Other approaches could have been taken especially those based on agent based modelling. However, the fact that there was evidence from other researchers coupling system dynamics to inductive methods such as grounded theory was a strong motivation for adopting this approach. The capability to explore dynamic behaviour through simulation was also crucial; as (Berends and Romme, 1999) conclude,

> *"system dynamics is the most sophisticated simulation approach currently available for social scientists"*.

The question of the generalisation of the results can only really be answered by follow-on quantitative and longitudinal studies.

4.5. General Observations

Modelling in a management context is an analytical process designed to elicit understanding and generate predictions, usually as a tool to aid decision making, rather than an activity that intentionally and solely sets out to generate hypotheses to be tested in further experimentation.

However, the problem of validity and the generalisation of the results has not been adequately resolved in this paper and does require further experimental work. Although this experimental research is directed at the specific need for generalisation it is hoped that the results do in fact stand by themselves as a demonstration of the value of the methodology, especially the use of simulation as a management research tool which is all too often overlooked (Berends and Romme, 1999), and that future work is directed at refining and using it in a context that can provide immediate benefit as a practical management tool.

5. CONCLUSIONS

The study investigated the dynamic behaviour of a start-up system in an attempt to build an understanding of its characteristics through modelling. The research methodology developed consisted of the hybridisation of grounded theory with system dynamics modelling – which has been called grounded systems modelling. The application of an inductive systems modelling approach to entrepreneurial research is apparently unique.

The results from the analysis of the interview data have been expressed in a number of system dynamics models that have been simulated to understand their dynamic behaviour. An additional descriptive model based on the notion of 'Two Gaps' was also developed partly to address the need for interpreting the models of a system in the context of a single new venture.

The research deliberately avoided the question of defining an entrepreneur because of definition and selection effects yet studied entrepreneurialism from a systems perspective. However, the two gap descriptive model and the main causal loops together provide a source of normative (actionable) theory for the individual. The accumulation of evidence of intellectual property, of meeting customer needs, of future revenues, the development of a prototype and the overall packaging into a business plan together form a signal, in the sense of the principal-agent problem from economics, to the source of equity funding as the competence of the entrepreneur and veracity of drive.

The grounded systems modelling methodology has demonstrated an approach to developing theory in entrepreneurial research. The results address the concerns expressed in the entrepreneurial research literature about both the lack of, and the problems associated with, theory development as described by (Hofer and Bygrave, 1992, Low and Macmillan, 1988). However, this must be tempered by the need for validation as discussed in §4.3and the critique developed in §4.4. Finally, (Amit et al., 1993) state that

> *"It is our conjecture that the work that will overcome the complexities and make the major contributions to entrepreneurship research will be the studies that use new interdisciplinary approaches to modelling."*

It is hoped that this work has lived up to the ideal of that prediction if not its actuality.

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