COMPLEXITY, FAST MOVING ENVIRONMENT, AND MANAGERIAL CHOICE

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INTRODUCTION

How do firms create or acquire resources that generate sustainable competitive advantage (Rumelt, 1984)? – one of the key research questions that the discipline of strategy deals with. Levinthal (1997) develops a model to explore the interrelationships between firm level changes and population level selection forces as firms traverse a rugged landscape made up of organizational forms and their fitness levels. Eisenhardt (1989) studies high velocity environments and the manner in which managers that represent firms make rapid decisions and at the same time consume more information. Cabral (2016) talks about a self-reinforcing process wherein cross firm differences in corporate reputation under asymmetric feedback from the stakeholder environment are sticky.

These findings are all the more pertinent given that in the analytics industry, for example, large sums of money are being invested into research and development teams. Focus has continually shifted from vanilla data analytics to subject matter like artificial intelligence, big data and parallel computing. Closer home, at the Institute of Operations Research and Management Science, we have a Certified Analytics Professional certification to meet such a demand for human resource trained at the intersection of mathematics, computing and business.

It would be interesting and relevant to investigate the manner in which the value of the firm’s resources evolves over time. How do feedback mechanisms under an asymmetric stakeholder response affect firm performance in fast moving environments? Which of the moves adaptation, imitation, or innovation is likely to generate a sustainable competitive advantage? I use a computer simulation to model such a framework.

The concept of loose coupling allows organizational theorists to posit that firm level changes can happen due to internal forces at a technical level (coupled) and due to outside forces at the industry level (loose-flexible) (Orton and Weick, 1990).

I also have the following questions in mind.

1) For tightly coupled systems is a policy of adaptation and/or imitation likely to reward the firm more than a policy of innovation?
2) For loosely coupled systems is a policy of innovation likely to reward the firm more than a policy of adaptation and/or imitation?

So, for systems that lie between loosely coupled and tightly coupled, what policy is likely to reward the firm more? And what does it mean for managerial choice?

LITERATURE REVIEW

Wernerfelt (1984) talks about the product and resource being two sides of the same coin - the traditional concept of strategy is framed in terms of resource positions whereas most of the economic tools that have been developed are on the product-market side. Barney (1991) builds on the assumptions that strategic resources are distributed heterogeneously across firms and that these positions are stable over time. Four empirical indicators of the potential of firm resources to generate sustainable competitive advantage – value, rareness, imitability and substitutability are discussed. How does the firm acquire such resources and who makes the decisions? Also how does the environment reward these decisions?

Hambrick and Mason (1984) discuss how organizational outcomes – both strategies and effectiveness are viewed as reflections of the values and cognitive bases of powerful actors in the organization. March and Simon (1958) have also argued that managers bring their own set of givens into the organization. Specifically, these givens reflect the decision-makers cognitive base: knowledge or assumptions about future events, knowledge of alternatives, and knowledge of consequences attached to these alternatives. Discussing high velocity environments, Eisenhardt (1989) in her paper talks about fast decision-makers and that they use more, not less information. They also develop more not fewer alternatives than do slow decision-makers. Decisions made on such a pattern of behaviours lead to superior firm performance. Do such high-velocity environments cause a rapid erosion of the firm’s resources? How does the firm change its resource position?

A common justification for organizational change is that the circumstances in which the organization finds itself have changed, thereby eroding the value of utilizing existing knowledge (Posen and Levinthal, 2012). Thus, it may seem apparent that organizations should adapt by innovating and generating new resources - however, this overlooks the possibility that the gains made by such a move may be eroded if change happens to be an ongoing property of the environment. In addition, the authors also go on to state that under some conditions, the appropriate response to environmental change is a renewed focus on exploiting existing knowledge and opportunities.

In fact Teece et. al's (1997) dynamic capabilities framework researches the methods by which a firm is able to create wealth in conditions marked by rapid environmental change. The competitive advantage is seen as resting on the distinctive ways of coordinating and combining firm resources, shaped by firm's asset positions, and the evolution path it has adopted. The authors then go on to state that identifying new opportunities and honing and organizing internal resources are fundamental to wealth creation. We would still like to know what combination of these strategies adaptation, imitation or innovation is better equipped to yield benefits to the firm - especially in conditions marked by rapidly changing environments. This also brings into focus the nature of the firm's structure and modularity in assisting such a policy mix. What is the role of the feedback mechanisms that operate between the manager and the stakeholder?

Loose coupling has proven to be a durable concept precisely because it allows organizational analysts to explain the simultaneous existence of rationality and indeterminacy without specializing these two logics in distinct locations (Orton and Weick, 1990). Loose coupling suggests that any location in an organization contains interdependent elements or modules that vary in the number and strength of their interdependencies. In tightly coupled systems a change in one module is likely to bring about a significant change in other modules. Because of such interdependencies the output of the machinery may not be clear. Is the manager likely to take smaller, more adaptive steps and learn by doing?

Ethiraj et. al (2008) set up three modular designs that vary in the extent of modularity and complexity. In each of these structures they examine the trade-off between innovation benefits and imitation deterrence. The results of their computational experiments indicate that modularization enables performance gains through innovation but, at the same time, sets the stage for those gains to be eroded through imitation. Here the between modules coupling is looser than the coupling that exists between the parts that make up a module. Does such a more flexible coupling between modules aide innovation?

Cabral's (2016) fundamental assumption is that, reputation-wise, a firm has more to lose from falling short of what is expected from it than it has to gain from exceeding expectations (an asymmetry reminiscent of prospect theory). The author's numerical simulations suggest that persistence in cross-firm differences is largely due to endogenous investment incentives: firms with higher corporate reputations invest more in corporate reputation. With stickyness expected in terms of cross firm differences, and reinforcing elements in play, investigating such a phenomenon is complex but interesting.

MODEL

Levinthal (1997) uses the NK landscape and models the complexity inherent in the relationship between the organizational form and the demand made on the firm by the environment. An entity or an organisation is considered to consist of N attributes. Each of these attributes can take on 2 values. Thus the fitness space consists of 2^N number of organizational forms. The contribution of each attribute is modeled as being dependent on K other attributes. Thus if the value of K is zero all the attributes are independent of each other. At the other extreme, if the value of K is N-1, each of the attributes is influenced by every other attribute.

A neighbourhood is defined as those forms that vary from the current organizational form by an attribute. Thus a firm having N attributes will have N firm forms in its neighbourhood. For high values of K, even a small change in the neighbourhood of organizational forms can yield a markedly different fitness value. The value of K determines the ruggedness of the landscape. Organisations are modeled as taking walks over such landscapes. A radical change is modeled by assuming that each of the N attributes is specified anew. Kauffman (1993) uses the term ‘long jump’ to identify the concept. Such jumps also capture the notion of an ‘innovative jump’.

March (1991) models organizational learning in great detail; the key features of this model are outlined below.

1) There is an external reality which is assumed to have M dimensions. Each of these dimensions can take on values -1, 1. The probability that either of these values can be taken on by the code is 0.5.

2) At each time period beliefs about reality are held by N individuals in the organization and by an organizational code of perceived reality. Each of the M dimensions can take on values -1, 0, 1. These values can change with time.
3) Individuals modify their beliefs as a result of enculturation into the organization. Specifically, if the organizational code has a value 0 on any of the M dimensions, the individual code doesn't change. For any other value on the dimension that the individual code differs from the organizational code, the individual belief changes to that of the organisation with a probability p1.
4) Also, the organisational code changes to those of the individuals when the individual code matches the external reality on more dimensions than the organisation. The probability that the organizational code will change to conform to that of the dominant belief in a group on any particular dimension depends on the level of agreement within the superior group and is valued at p2. Changes on the several dimensions are assumed to be independent of each other. This independence between bits can be likened to the value of K being zero in the NK model. Such a formulation also captures the idea of loose coupling.

Cabral's (2016) central assumption is that negative surprises are punished more severely than positive surprises are rewarded. In the model current reputation $r(t+1)$ is a function of the past reputation $r(t)$ and performance $q(t)$. Thus this reputation-updating mapping is from $R^2 \rightarrow R$. Past performance or quality is a function of the effort $e(t)$ that the firm puts in. All these concepts are measured in the same metric.

$q(t) = F(.|e(t))$ where F(.) is the cumulative distribution function of $q(t)$ given $e(t)$ and $E(q(t)) = e(t).$ One of the main assumptions of the reputation-updating mapping is formulated as below:

$R(q, r) = \lambda_l * r + (1 - \lambda_l) * q$ where $q < r$

$R(q, r) = \lambda_h * r + (1 - \lambda_h) * q$ where $q \geq r$

This is a convex update and we will be using something similar while modeling our reward structure. If the quality of the firm's product in that period is given by exactly $q(t) = r(t)$ (that is, if the firm lives up to expectations), then firm reputation in the next period, $r(t + 1)$, remains at the same level; that is, $r(t + 1) = r(t)$. If the firm's quality falls short of what is expected of it, then firm reputation in the next period drops to a lower level; that is, $r(t + 1) < r(t)$.. The author's primary assumption shares the feature that consumers are more sensitive to 'bad news' than to 'good news'.

Proposed Partial Model:

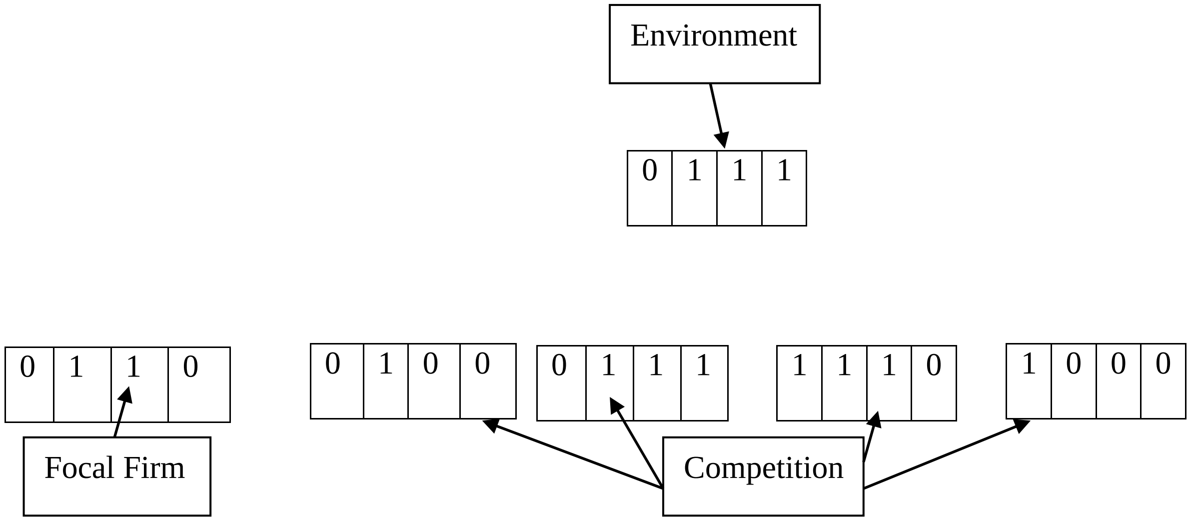

Fig. 1. Organisational Forms and the Environment

Managerial choice operates at the focal firm and we repeat this for each of the competitors. Adaptation for the focal firm means a move to its neighbourhood. The manager could also opt for an organizational form adopted by any of his competitors - an imitative move. An innovative move is a far-out jump with an aim to change the firm's policy drastically. The environment is assumed capable of demanding any of the organizational forms from the set of forms available. These environmental demands change rapidly with time.

We will assume a canonical multinomial logit model as the model of choice for the manager and specify the probability specification below. There are probabilities associated with sets A, A-(A∩B) (Adaptation), B (Imitation), and C (innovation).

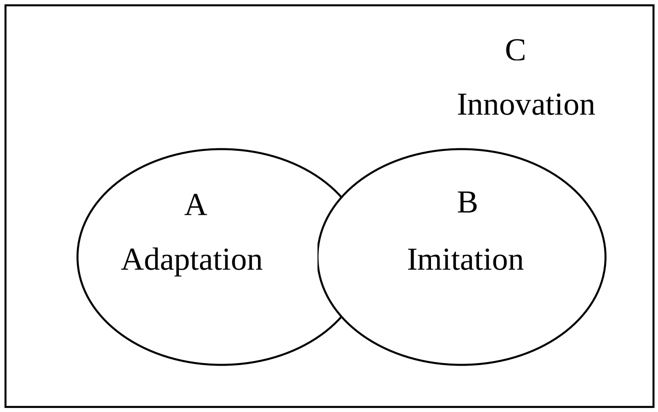

Fig. 2. Multinomial Logit Specification

$$\mathrm{P}(\mathrm{A} - (\mathrm{A} \cap \mathrm{B})) + \mathrm{P}(\mathrm{B}) + \mathrm{P}(\mathrm{C}) = 1 \qquad (1)$$

Let $\mathrm{P}\big(\mathrm{A} - (\mathrm{A} \cap \mathrm{B})\big) = \pi_1$, $\mathrm{P}(\mathrm{B}) = \pi_2$, $\mathrm{P}(\mathrm{C}) = \pi_3$. $\pi's$ here are a function of x^{T} - the covariate vector in our model - which comprises of the asymmetric feedback from the environment and the previous choice made by the manager.

$logit(\pi_j) = \log\left(\frac{\pi_j}{\pi_1}\right) = x_j^T \beta_j$ - where the first category is chosen as the reference category and $\pi_1 = \frac{1}{1+\sum_{j=2}^{J} \exp(x_j^T \beta_j)}$

This formulation in fact is a generalized linear model (Nelder & Wedderburn, 1972) as has been shown in equation (2) below. Let the number of outcomes in each of the categories adaptation, imitation and innovation be denoted by y_1, y_2, and y_3 respectively where $y_j \sim$Poisson (λ_j). Let $\sum_{j=1}^{3} y_j = n$ be the total number of outcomes where n ~ Poisson$(\lambda_1 + \lambda_2 + \lambda_3)$

If $f(y)$=$\prod_{j=1}^{3} \frac{{\lambda_j}^{y_j} e^{-\lambda_j}}{y_j!}$ then

$$f(y|n) = (\lambda_1/\textstyle\sum_1^3 \lambda_j)^{y_1} (\lambda_2/\sum_1^3 \lambda_j)^{y_2} (\lambda_3/\sum_1^3 \lambda_j)^{y_3} \frac{n!}{y_1! y_2! y_3!} \qquad (2)$$

In our partial proposed model, for tightly coupled systems adjacent bits also change along with the changes made by the manager. We measure the fitness as being a function of the environmental form demanded and the organizational form adopted by the firm. This fitness function operates at the bit level and we report the sum total.

Firm Fitness = environmental form demanded – the organizational form adopted by the firm (3)

Going forward we need to take a look at how the competition evolves from a game theoretic point of view.

ANALYSIS

De Jong (2006) gives a detailed description of an evolutionary algorithm (EV) which we specify below:

EV:

Randomly generate the initial population of M individuals (using a uniform probability distribution over the entire geno/phenospace) and compute the fitness of each individual.

Do for n time steps:

Choose a parent as follows:

- select a parent randomly using a uniform probability distribution over the current population.

Use the selected parent to produce a single offspring by:

- making an identical copy of the parent, and then probabilistically mutating it to produce the offspring. Compute the fitness of the offspring.

Select a member of the population to die by:

- Randomly selecting a candidate for deletion from the current population using a uniform probability distribution; and keep either the candidate or the offspring depending on which one has higher fitness.

End Do

We use a modified canonical form of the evolutionary algorithm as follows:

Do for n time steps (for all firms) :

Select a focal firm as a parent.

Use the selected parent to produce a single offspring by:

- making an identical copy of the parent, and then probabilistically mutating it to produce the offspring using any of these moves adaptation, imitation or innovation. The moves are made by assigning a multinomial logit choice structure for the manager who represents the firm. Compute the fitness of the offspring firm.

Select a member of the population to die by:

- Select the offspring firm to survive.

End Do

The author suggests a markov model formulation to capture the dynamics for an evolutionary algorithm. Specifically they capture the expected length of time (number of generations) it will take to reach s_1 (a fixed point) starting from our initial state s_m:

$\mathrm{fixed(m)} \; = \sum_0^\infty \mathrm{j} * \mathrm{prob}\big(\mathrm{m1(j)}\big)$; where $\mathrm{prob(m1(j))}$ is the probability of entry from s_m to s_1 in exactly j number of steps.

Thus,

$\mathrm{Prob(m1(j))} = \sum_1^{\mathrm{j}} q_{m1}(\mathrm{k}) * q_{11}(\mathrm{m} - \mathrm{k})$; where q_{ij}(t) are the elements taken from the state transition matrix, Q.

The author though comments that solving such formulations in a closed form is extremely challenging and even solving it numerically requires a considerable computational effort. So the evolutionary system in our proposed partial model is run empirically and the subsequent results are reported and analysed. This mode of reporting of simulation results and subsequent analysis is prevalent in the Administrative Science Quarterly.

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