# The Strategy Hypercube: Exploring Strategy Space Using Agent-Based Models

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**Abstract.** We demonstrate a method of representing a firm's strategy as its position and movement within an *n*-dimensional strategy space. We explore this space through the use of an agent-based model and provide preliminary results as to the appropriateness of different strategies under differing levels of environmental turbulence.

## 1 Introduction

Traditional management literature is based in a world that is assumed static, preferring models that assume a linear environment. Most of the models and methods available to strategists are not dynamic in nature, and have been criticized for being less than appropriate in today's turbulent, unstable environment. Such linear models may be reaching the end of their useful life for adding new insight to the strategy debate.

In order to produce a model that can cope with a dynamic environment, we first review the methods that have been used to carry out static analyses of the competitive environment. We introduce a new model that can cope with several strategic dimensions, based on but extending the strategic groups concept. We extend this methodology firstly by allowing *n* strategy dimensions in a strategic space that we term the 'strategy hypercube', secondly by enabling firms in our model to be truly heterogeneous rather than strictly homogeneous as in traditional industrial organization economics models, or homogeneous within heterogeneous groups as in the strategic groups paradigm. We extend the model to allow interactions not only between firms but also to 'value generating agents' that we position in the same strategy space.

We explore this strategy space using the technique of agent-based modeling, a technique that is being explored in other social science disciplines such as political science, conflict resolution, and within social systems generally, but as yet has not been fully utilized within the strategic management literature. We report preliminary observations based on simulated data from our agent-based model, in this instance applied to the banking industry, and discuss further a research agenda that can be investigated by use of this novel technique.

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## 2 Business Strategy

### 2.1 Traditional Models of Strategy

Traditional models of strategy are usually static in nature. Management scholars are used to analyzing firm strategies and classifying them into grids and matrices; however, when this form of analysis is used, little account is taken of how strategies change over time.

Hunt [12] first introduced the concept of strategic groups in his analysis of the home appliance industry; Porter [17] also used the term 'strategic groups' to represent the positioning of firms with respect to two strategic dimensions, such as the level of vertical integration and the level of specialization.

Porter [17] defines a strategic group as 'a group of firms in an industry following the same or similar strategy along the strategic dimensions'. Strategic groups analysis can take the form of a representation of firms on a two-dimensional plane whose dimensions are the strategic variables or dimensions appropriate to that particular industry.

Much of the strategic groups literature assumes that firms cluster into groups: firms are assumed to be static within the strategic groups paradigm – effort is paid to interpreting the grouping (or clustering) of firms, whereas little attention is paid to how the firms move within this strategy space (Fiegenbaum and Thomas [9]).

Authors such as Barney and Hoskisson [3] criticize the construct of using strategic groups, and propose that the assertions of strategic groups theory, firstly that strategic groups exist, and secondly that a firm's performance depends on strategic group membership, remain untested. Whilst the grouping of firms may be unproven, these authors do not criticize the validity of the construct of positioning firms in a strategy space.

Barney and Hoskisson [3] remind us that we have to consider the parent discipline of the strategic groups literature in order to place into perspective the biases that may be built in to using the strategic groups logic. Porter [17, 18] bases his research firmly in the Industrial Organization literature, where firms are considered to be homogeneous [20, 21]. Porter [16] uses the strategic group methodology in order to explain intra-industry performance differences.

Indeed, Barney and Hoskisson [3] point to the fact that, since the strategic groups concept represents a compromise between industrial organization economics 'and the traditional needs of the theory of strategy', a theory of strategy at the level of the individual firm should be developed. They point to several studies, including Barney [2] and Rumelt [20] under which firm performance depends on the idiosyncratic attributes of individual firms. The technique of agent-based modeling, described below, allows us to develop models and simulations where all firms are idiosyncratic – rather than being assumed homogeneous (as in traditional economic literature) or homogeneous with heterogeneous groups (as in strategic groups formulations). Agent-based models allow us to model an industry where firms are truly heterogeneous – and to produce results on this basis. In the past, researchers may have been limited by the lack of techniques available to study such complicated, heterogeneous systems more akin to an industrial environment experiencing high levels of turbulence.

Whilst the theoretical underpinning of strategic groups will not be used in this paper, partially on Barney and Hoskisson's [3] criticism of the technique due to its lack of robustness, the basis of using the strategic dimensions on which these firms are situated will be used. Hatten and Hatten [11]) state that '[strategic] group analysis can be used to bring key [strategic] dimensions into high relief'. We consider 'strategic space' to be a very useful conceptual tool to represent the strategy of a particular firm.

Whilst the strategic groups literature has seen the (static) position in strategy space as fully describing a firm's strategy, we shall extend this to include the way in which a firm moves in this strategy space. Indeed, we define the strategy of a firm as being the location and movement of the firm within the strategy hypercube.

### 2.2 Representation of Strategies

Porter's [17:131] represents firms on a two dimensional space, where firms are located on a plane at co-ordinates based upon their position with respect to two strategic dimensions, with clustering of firms indicating the strategic groups within the industry. This representation of strategic dimensions is very widely used, as it enables an easy understanding of the strategic positioning of firms and is therefore particularly successful as a didactic tool. Later research into strategic groups extended the Porter model to use multiple strategic variables. Hatten and Hatten [11] refer to the 'strategic space' resulting from multivariate analyses of strategic groups. However, a problem remains: how do we represent $n$-dimensional space? The solution may come in the mathematical device of a 'hypercube'. Whilst the positioning of firms using two strategic dimensions can be accomplished by representing the positioning on a plane, and whilst the positioning of firms using three strategic dimensions can be accomplished by representing the position of the firms within a cube, problems occur when one tries to represent firms on a space with a number of strategic dimensions exceeding three. However, higher dimensional space can be represented by using the mathematical notion of a hypercube: 'the analogue in a space of four or more dimensions of [a cube] in ordinary three-dimensional space' (*OED* [15]). We can therefore represent $n$-dimensional strategy space by using an $n$-dimensional hypercube. A representation of four-dimensional hypercube can be seen in Figure 1, below.

A firm's strategy can therefore be represented by the location and movement within the $n$-dimensional hypercube.

### 2.3 Exploration of Strategy Space: Agent-Based Models

Models run with the aid of computing techniques are, and have been for a long time, capable of working in higher dimensions and representing the co-ordinates of a firm in $n$-dimensional space. One advantage of using agent-based models over other computer based models is that they are capable of dealing with heterogeneous agents, or firms.

Agent-based models were partly inspired by the work of the Santa Fe Institute, who produced Swarm, a software package for multi-agent simulation of complex systems (Minar *et al.* [14]). More recently, packages such as RePast have been de veloped which are specifically designed for simulation of social science systems, and have been widely used in political science, finance, and economics (Collier [7]).

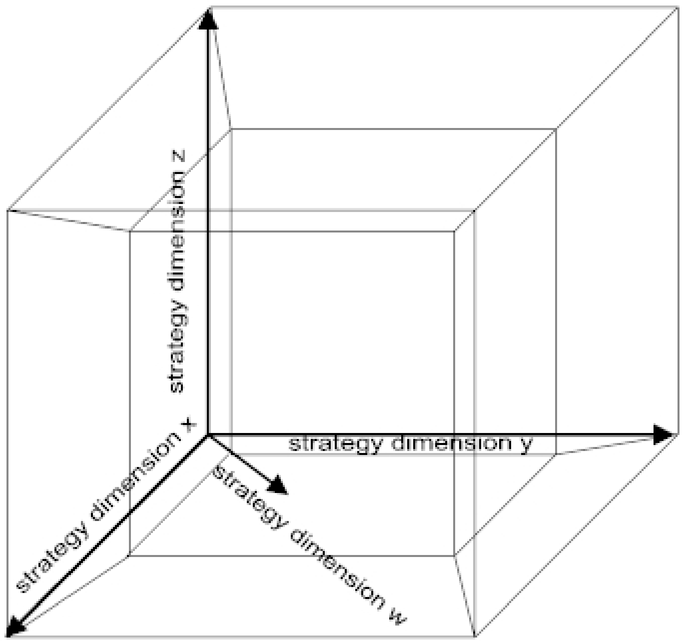


**Fig. 1.** Representation of a strategic hypercube having four strategic dimensions

To date, little use has been used of multi-agent simulation within strategic management. Such models do however offer an opportunity to produce simulated data that can be analyzed inductively, and aid intuition (Axelrod [1]).

The realization that the actions of one firm produce reactions within the system of firms has been widely accepted within the strategic management literature, building on the work of game theorists following von Neumann and Morgenstern [22]. However, game theoretic approaches to strategy have been criticized on the bases including the presumption that they may assume rationality of behavior (Camerer [4]). Further criticism can be leveled by the fact that game theoretical 'solutions' are usually in the form of [Nash] equilibria, and therefore are not ideally suited for a non-equilibrium system, an example of which is a turbulent industry. Agent-based models do not require equilibria to be found in order to be of use – indeed they do not require equilibrium solutions to exist. Output from the model can be used without the existence of an analytical solution, as with mainstream game theoretical solutions.

There are several advantages of using agent-based models over 'system-wide' approaches: they allow for heterogeneous agents, firms with different attributes such as profit, size, strategic location and dynamics can be modeled at the same time. Different types of agents, such as banks and customers can be modeled simultaneously. Systems can be 'open', that is agents can be created and destroyed according to the rules of the simulation; bounded rationality of agents can be incorporated: agents can be simulated whereby they have limited cognitive ability that can be different for each agent. The dynamics of the system need not be at equilibrium (a supposition of models such as those early strategy models whose roots are in neo-classical microeconomics); and emergent phenomena (such as self-organization) can be explored.

We now turn to the specific model, applied in this case to the example of the banking industry.

## 3 A Model for Banking Strategy

The banking industry has been described by D'Aveni [8] as one of the industries that may be considered 'hypercompetitive'. The concept of 'turbulence' has also been applied to this industry. Reger and Huff [19] identify strategic dimensions within the U.S. banking industry using a cognitive perspective. We set up an agent-based model that we intend to be used to understand strategies that may be appropriate in an industry such as this.

Firms are positioned in *n*-dimensional strategy space, and are free to move their position according to various schemata. The rate of movement of strategic position, the initial positioning, and the schema for movement can be different for each agent, thereby introducing heterogeneity amongst the firms.

We consider that competitive advantage is gained through relations with or capture of 'value generating agents' that are distributed in the same *n*-dimensional space. For the purposes of this initial simulation, to aid understanding of the model, we can simplify this assumption and assume that value-generating agents within the banking industry are customers.

The level of complexity of an agent-based model can be high, leading to a 'veridical' (Carley *et al.* [5]) model. However, we have chosen to produce a model that exhibits complex behavior whilst maintaining a high degree of parsimony. As in regression models, parsimony is favored in order to maintain ease of explanation.

Our model contains two types of agents: banks and customers. Customers are initially assumed to be fixed in strategy space. Of course, at first this may sound counterintuitive: for dynamic environments, surely we need dynamic customers? As we shall see below, a level of turbulence is created within the simulation without the need for dynamic value-generating agents. In her definition of strategic groups, Harrigan [10] states: 'strategic groups are comprised of firms who may compete for the same customers' patronage'; and thus we situate both customers and banks within the same strategic space.

One can represent the position of customers in this space as defining a 'fitness landscape' (Wright [23] [24]; Kauffman [13]) that promotes certain locations as being more preferable than others. A schematic representation of a fitness landscape can be seen in Figure 2 below.

Porter [16] defines two categories of firm – industry leaders and industry followers. Porter's definition is of leaders as being the largest firms in the industry, and followers are all other firms. In our model, we build on Porter's definition by defining the following strategies to be investigated:

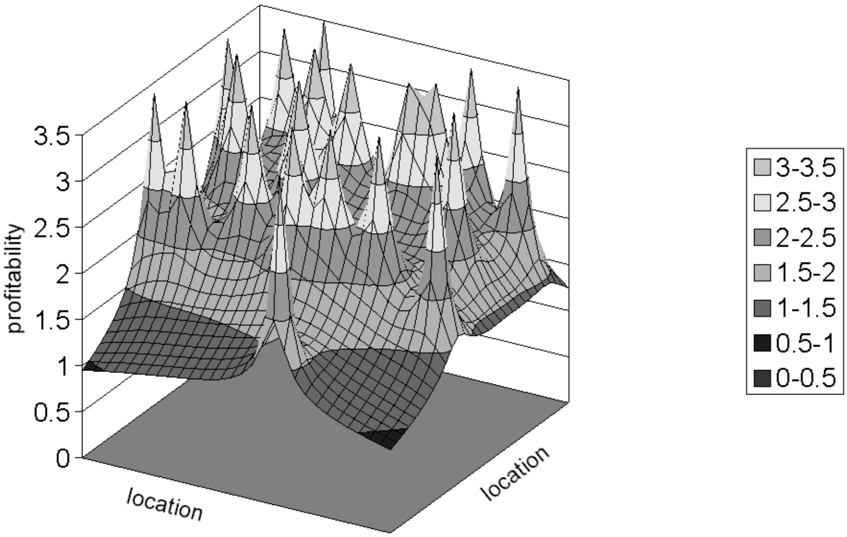


**Fig. 2.** Schematic Fitness Landscape produced by an inverse-square law acting on customers

- follow the leader – a firm adopting such a strategy moves their position at a constant vector within strategy space, the direction being along the line (in the *n*-dimensional hypercube) that joins the bank in question to the bank with greatest success (the lead bank). The speed of the movement can be controlled as a parameter within the model;
- do nothing – these firms do not change their position within strategy space;
- other strategies can be explored (such as withdrawing from the industry, merging with other firms, adopting a position at the 'center of mass' of the value-generating agents that are linked to the firm); these are however considered to be possible extensions to this simple model.

We further introduce a level of turbulence to the industry: by this we mean the level of stability of the value generating agents. In order to model the stability or turbulence of these agents, we allow them to travel randomly around the strategic hypercube. This is implemented by allowing the agents to take a 'random walk' where each time 'tick', the agent travels along one of the *n* dimensions, the selection of the dimension being randomly chosen, either forward or backward, through distance *T*. This allows the industry to exhibit a level of turbulence that can be varied by changing the level of *T*. Of course, if we set *T* to zero, this is the equivalent of a static environment, where all value generating agents do not move.

### 3.1 Methods and Resources

The RePast agent-based simulation framework, created at the University of Chicago, was used as a framework for creating the agent-based model. RePast is a software framework for creating agent-based simulations using the Java language. It provides a library of classes for creating, running, displaying and collecting data from an agent based simulation. An example of the output achieved can be seen in Figure 3, below.

### 3.2 Results and Analysis

1,000 runs of the model were executed, each being terminated after 1,000 'ticks' (time steps of the model). For each of these runs, the level of *T* (i.e. the step with which each of the customer agents took a random walk) was set at 0 (i.e. customers stable), 1, 2, 5, 10, 20, or 50. In this way, the turbulence parameter space for *T* was 'swept'. This resulted in 1,000 runs x 1,000 ticks x 7 levels of *T*, i.e. 7 million time steps or 'ticks' for the model. Results for this simulation series is shown in Figure 5 below. However, we also needed to compare the results of our simulation with the situation where all banks were stable, i.e. the test bank's strategy was to stay still (the same strategy as the other banks in the industry). A further 1,000 runs of the model were executed under the same levels of *T* for the same number of ticks per run, resulting in 7 million time steps. Overall, 14 million time steps were calculated for our model. At the end of each run, the profitability of the test bank was calculated, together with the profitability of the most- and the least- profitable bank within the industry. The level of the test bank's profitability was calculated as a percentage of the lead bank's profitability and plotted on a graph of percentage success (relative to the lead bank) vs. turbulence level vs. number of runs (out of 1,000) achieving this result.

The results of the simulation series where the test bank did not move – which we will term our 'control' run – are shown in Figure 4 above. This represents the strategy when the bank under question adopts a passive strategy, the only change in success coming from the change in the positioning of value-generating agents (which is analogous to the level of turbulence within the industry).

### 3.3 Observations

Whilst one must bear in mind the caveat that the results expressed here are from a simulated world, one can see from the results of the simulation (Figures 4 and 5) that there is a marked increase in success when a bank adopts a 'follow the leader' strategy as opposed to a 'stay still' strategy. This is to be expected, given costless movement through strategy space (see 'limitations of the model and extensions', below).

However, though one may initially think adopting a 'follow the leader' trajectory would result in a stable outcome, the model exhibited non-linear behavior. The reason for this was that, as our test bank traveled through the strategy hypercube, it passed closer to certain value generating agents and moved farther from other agents.

If one of these agents was connected to the lead bank, the change of configuration of that agent's connections may result in a change of leadership in the industry. This would mean that the test bank would then alter trajectory and move towards the new leader.

In this way, we observed cycles being set up where the change of the firm that is the leader would switch between two or more banks. This is an intriguing result in that customers need not be dynamic or turbulent in order to create a turbulent environment when observed from the bank's point of view. We call this endogenous turbulence, that is turbulence cased by the action and reaction of the firm agents that is

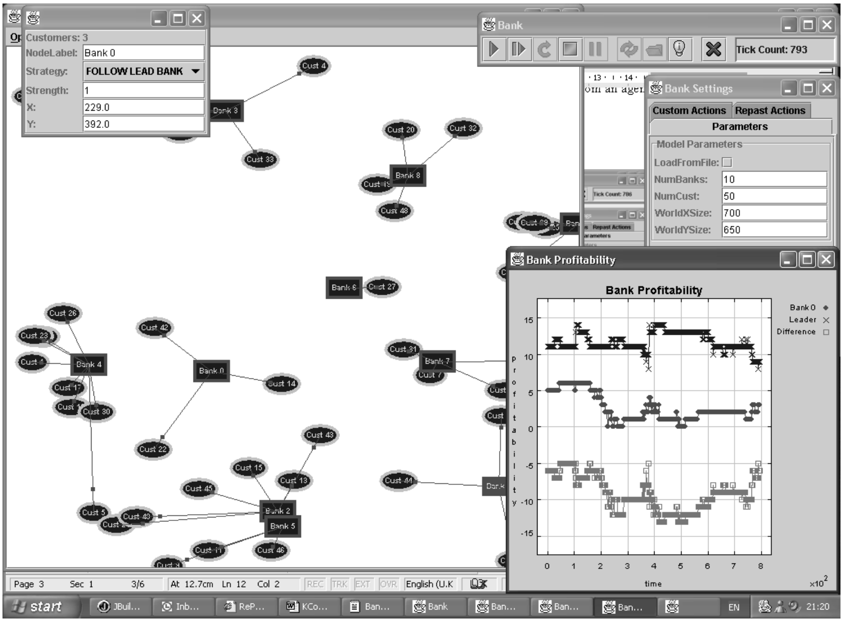


**Fig. 3.** Example of the output from the agent-based model

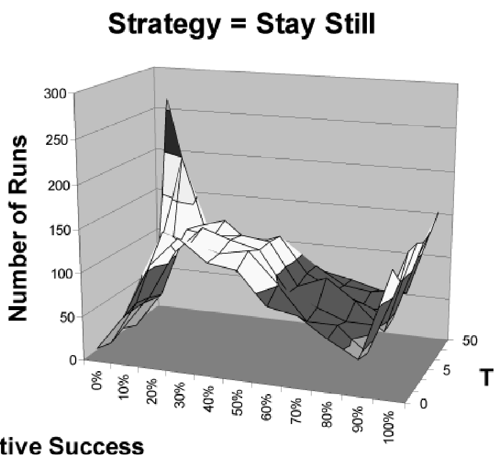


**Fig. 4.** Results from 1000 runs of the model where the bank's strategy is to stay still, and the level of turbulence *T* is 0, 1, 2, 5, 10, 20, and 50

not dependent upon there being a turbulent external environment. This is at odds with the conventional view of turbulence, where it is assumed that turbulence is caused by the external environment.


**Fig. 5.** Results from 1000 runs of the model where the bank's strategy is to follow the leader, and the level of turbulence *T* is 0, 1, 2, 5, 10, 20, and 50

### 3.4 Limitations of the Model and Extensions

We assume that there is no cost of moving in strategy space. This is of course a strong assumption, but one that is justified in this model on the grounds that we wish to explore the dynamics of comparing a 'follow the leader' strategy with a 'stay still' strategy. The interpretation of results becomes easier when there is only one parameter that is being swept. Were we to introduce a parameter for the cost of moving through the strategy hypercube, this would have the effect of making the interpretation of the results more difficult on the grounds that we would have to consider the interaction of the cost of moving with the strategy adopted by the test bank. We leave this as a future extension to the model.

Although the results herein describe only one simulation, one can see that this method could be extended to investigate phenomena such as: what are the results when the number of strategy dimensions is increased; what is the effect of the speed of change on the bank; what are the effects of customers moving in a correlated manner rather than taking a random walk?

### 3.5 Applicability of the Model to the ABSS and MAS Communities

The relevance of this paper to the agent-based social simulation ('ABSS') and multi-agent systems ('MAS') communities is that it is one output of a project – RePast – that unites both 'camps'. Software libraries such as RePast do a great deal to enable social scientists to participate in active modeling, even though a non-trivial understanding of computer languages such as Java is required. More simple interfaces as being developed in SimBuilder (as are other tools such as AScape, StarLogo, and NetLogo); this will only increase the availability of agent-based modeling to other social science researchers.

Conversely, the movement of the development of such tools from transdisciplinary institutions such as the Santa Fe Institute (original developers of Swarm, a precursor of RePast) to specific social science researchers (as in the case of University of Chicago Social Sciences Research Computing, the creators of RePast) can only help to develop tools that are relevant and therefore valuable to social science researchers, for solving problems that are pertinent in the specific literature, results of which are publishable in the literature of the specific discipline, rather than using multi-agent software tools merely as a means to an end.

This interchange of ideas, developers and users can only help to enhance the adoption of multi agent based simulation as a technique within the social sciences and within management research.

## 4 Conclusions

The purpose of this paper is to conceptualize a new way of looking at strategy, in terms of an $n$-dimensional strategy hypercube, a firm's strategy being the location and movement within this strategy space. Given the conceptual difficulties of visualizing this space, agent-based models are used to gain an insight into the strategic consequences of firms moving within this space.

Our simple model using the banking industry as an example of a turbulent environment produces some surprising, counter-intuitive results, namely the phenomena of endogenous turbulence and decreasing efficacy of having a 'follow the leader' strategy under extremely high levels of turbulence.

The joint conceptualizations of the strategy hypercube and its exploration using agent-based models opens a plethora of opportunities for strategy researchers.

The use of agent-based models is valuable in this context as it allows a problem (environmental turbulence from a firm's perspective) that has until now been too complicated to investigate satisfactorily using traditional management tools, to be investigated through a new technique. The research is driven from the premise that there is an unsolved problem in the management literature, not from the point of view that there is a novel technique that can be transplanted into a new discipline. The results do however open a fascinating and rewarding research agenda.

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