Using cellular automata modeling of the emergence of innovations

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Abstract

Introducing innovations and new products to the market is an essential activity for leading firms. Firms wishing to exploit the advantages of pioneer status strive to attain exclusivity in their discovery of a new market need. Our work introduces some insights relating to the clarification and representation of the dynamics of market awareness of an emerging need. The implications of eliciting knowledge from consumers are discussed, and the probability of competitors attaining “pioneer” status in the market is examined. A low probability of achieving the objective of an exclusive and original discovery of an emerging need via marketing research is indicated. We use Stochastic Cellular Automata to model the collective dynamics grounded in the study of local interactions between agents. Using this paradigm, we show that due to extreme volatility of discovery probabilities concentrated in a short time span, there is a high probability that at least one other competitor will discover the same need before, or concurrently with, its discovery by the firm in question, if traditional exploration is applied. Consequently, a firm is unable to ensure that its discovery of a new need is a singular, pioneering event. A model to assess the odds that the emergent need discovery is exclusive (based on parameters that can be collected during the survey itself) is proposed and evaluated. © 2001 Elsevier Science Inc. All rights reserved.

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1. Introduction

In recent years, new product development has been guided by the primacy of customers' needs. Accordingly, one of the dominant approaches for generating new product ideas is by eliciting clients' descriptions of their problems with current products and proposed improvements they may suggest [1,2]. Those ascribing importance to the customer’s voice advocated the incorporation of market-based information even as early as new products ideation and R&D stages of development [3–5]. Indeed, this approach has proven itself as quite productive, and has been successfully implemented in new product development. Additionally, it has led to the formulation of important methods that enable predictions of the success of new product innovations by providing criteria such as sales levels and market share [6,7]. Thus, an important theme in this stream of research focuses on how market attributes and consumers’ perceptions impact on the performance of new products in terms of their development, rate of adoption, attainment of market share, and other performance predictors.

Indeed, many marketing research techniques aim at generating new product concepts from the elicitation and assessment of current consumer preferences and choices (e.g., [8–10]). However, the ability to elicit truly original concepts through marketing research methods is questioned by recent studies. Their principle arguments can be classified as (1) doubts regarding consumers’ ability to provide reliable information beyond their personal experience of knowledge (see [11]), and (2) arguments regarding market dynamics of the awareness propagation that has a phase transition that reduces the odds for an exclusive discovery of an emergent need during the first phase (for more details, see [12]).

How do emergent needs propagate in the market? The latent nature of the process may be a contributing factor to the fact that scant attention has been given to the evolution of market awareness to emerging needs (from the stage of a latent need to the stage of an active need) and its implications on the search for new product concepts. Empirical study of the process is also impeded by inadequate documentation of the elicitation of awareness of emerging needs and its correlation with firms that lost their pioneer status to competitors. Lack of documentation is understandable from the firm’s perspective. Although market awareness is measured and modeled with respect to new product diffusion (e.g., [13]), firms do not have the technology or resources to map market awareness for a product that has not yet been conceived. As we later clarify, to the extent that such tracking may be attempted in the earlier stages of such a process, the larger the sample and the more sophisticated the research technology necessary for its initial detection. Strangely, then, we lack the data necessary to develop a theory of the contribution of marketing research to the possibility of being “first and alone to the market.”

Before proceeding to solve this dilemma, it is important to examine the prevalence of the phenomenon of two competitors simultaneously introducing the same product or innovation.

The history of innovations includes many cases that attest to the phenomenon of simultaneous innovations, even “really new” innovations. For example, Bell was not the first to invent the telephone, but he more aggressively negotiated with firms to apply his invention [14]. Edison was not the only light bulb inventor (in fact, there were almost 30
inventors working on light bulbs at the time, one of which concluded its R&D phase before Edison [15]). Superior public relations and commercialization operations contributed to the singular recognition of both Edison and Bell. In the field of consumer products, numerous observations verify the pervasiveness of simultaneous innovations, for example, Coca Cola and Pepsi Cola were developed with similar taste and marketing offers (headache relievers) by two different pharmacists in two different states, with no knowledge of one another [16]. Even in science, theories and papers are concurrently published on common discoveries, despite an absence of communication between the authors (e.g., differential mathematics was published concurrently by Newton and Liebnitz; the AIDS discovery, etc.).

Addition support for our proposition regarding the frequency of the phenomenon of simultaneous discovery/invention has been noted by marketing literature. Lieberman and Montgomery [17] noted that, when sufficiently tapering the market niche definition used in PIMS questionnaires for identifying pioneers, virtually all firms could be identified as pioneers. Buzzell and Gale [18] also found that more than half of all business units are perceived as pioneers (the classification also ascribed to multiple competitors within the same market segment).

The implication of the phenomenon for firms which, in the context of new product development, wish to pursue a strategy of being “first and alone” in the market necessitates a deeper understanding of its dynamics and an ability to predict its consequences. In this article, we propose a model of market dynamics regulating competition between innovators and estimate a firm’s probability of being “first and alone” in the market. Our model is grounded in the Stochastic Cellular Automata modeling (e.g., [19]), and it incorporates interfirm competition for the exclusive discovery of emergent marketing awareness. Our model indicates that reliance on marketing research embodies a low probability of leading to an exclusive discovery of an emergent need. Hence, pioneer status (being “first and alone” in the market) can not be achieved by exclusive dependence on market-based information. The possibility of estimating a firm’s probability of preceding its competitors in addressing an emergent need using parameters accessible in a field survey is also discussed.

2. The Framework of the emerging market awareness process

Consumers and firms (hereafter agents) may become aware of a formerly unrecognized need either by self-discovery, or through communication (i.e., an agent may be informed by an agent who is already aware of the need). The first path can be viewed as a spontaneous change in the agent’s awareness to his/her problems and preferences (or those of other agents), while the second is a result of an interaction with other agents by a word-of-mouth mechanism. These two determinants are reminiscent of the variables that govern diffusion of technological innovations, echo systems, contagious diseases, and sociological systems [24].

1 Pioneering also has disadvantages; for discussions on pioneering and its effects on product and firm success/failure see [20–23].
A necessary analysis of the characteristic dynamic patterns in the emergence of need awareness processes could be conducted in two ways. Alternative aggregate models (similar to diffusion models) of the collective behavior may be fitted to this type of propagation. The second method is grounded in a network analysis approach [25,26], which may be developed and from which aggregate consequences can be deduced.

The first approach exploits and builds on the advantage of an available data base of accumulated knowledge (in terms of observable behaviors) and experience as articulated in the marketing literature (see [27,28]). However, because corresponding coefficients in the propagation of awareness process are simply unknown (there are no existing measures of awareness development to an emerging need), we use a “bottom-up” approach of modeling illustrated by network analysis (for a review of the advantages of this approach, see [29,30]). We adopt the stochastic cellular automata modeling approach, which is an important tool in complexity modeling theory (see [31,32] for more details). This framework of choice, extensively studied and applied to diverse domains, has recently been implemented as an integral element of a computational network analysis [26,33]. Moreover, some of its advantages have been demonstrated in [19] in the context of diffusion of innovation. Lately, the complexity studies and agents’ behavior schemata have attracted increasing attention in organizational science [34].

In contrast to modeling techniques that use the aggregated characteristics of the population to simulate changes in the characteristics of the whole population, cellular automata models are simulations of global consequences, based on local interactions of members of a population. These individuals might represent plants and animals in ecosystems, vehicles in traffic, people in crowds, or autonomous units in a physical system. The models typically consist of an environment or framework in which interactions occur between different types of individuals that are defined in terms of their behaviors (procedural rules) and typical parameters; the state and the changing parameters of each individual are both tracked over time.

The first attempt to understand complex system behavior can be traced to the Ising model, first proposed in 1924 by Ernst Ising. Despite its deceptively simple appearance, this consequently well-established model explains and predicts deterministic phenomena in nature. The power of an Ising model stems from its rich consequent dynamics, effected through a notable parsimonious structure. The Ising model attempts to imitate a process in which individual elements (e.g., atoms, animals, protein folds, biological membrane, social elements, etc.) modify their behavior in relation to the behavior of other individuals in their vicinity.

Initially solved analytically, enhanced computer performance allowed more complex simulations as computational solutions to Ising models became more common and were used as research tools in the investigation of complex systems. The first class of these models was the cellular automata model type (CA), originally conceived by Ulam and von Neumann in the 1940s to provide a formal framework for investigating the behavior of complex, extended systems [35]. Cellular automata models are dynamic systems in which space and time are discrete variables. The cellular matrix (grid) is n-dimensional, where n is usually 1, 2 or, in rare complex cases, 3. A cellular automaton consists of a regular grid of cells, each of which can be in one of a finite number, k, of possible states. Status of cells is updated
synchronously in discrete time steps according to a locally identical interaction rule. The identical rule operating on each of the adjacent cells in a neighborhood is essentially a finite state machine, usually specified in the form of a rule table (also known as the transition function or interaction rule), by which the state of any single cell is determined by the previous states of the cells in its neighborhood [36–38].

The neighborhood of a cell consists of a configuration of some of its surrounding (adjacent) cells. For unidimensional cellular automata models (having a total of \(2r + 1\) cells), each cell is connected to \(r\) local neighbors (cells) on either side. For two-dimensional cellular automata models, two types of cellular neighborhoods are usually considered: five cells, consisting of the cell along with its four immediate nondiagonal neighbors (Von Neumann configuration), and nine cells, consisting of the cell along with its eight surrounding neighbors (Moore configuration). When considering a finite-sized grid, periodic boundary conditions are frequently applied, resulting in a horizontal circular cylinder for the one-dimensional case.

Cellular automata have provided extremely simple models of common differential equations such as the heat and wave equations [39] and the Navier-Stokes equation [40]. Cellular automata models also provide a useful discrete model for a branch of dynamical systems theory, which studies the emergence of well-characterized collective phenomena such as ordering, turbulence, chaos, symmetry-breaking, fractality, etc. [41].

Over the years, cellular automata models have been applied to the study of general phenomenological aspects of nature and social dynamics, including communication, computation, construction, growth, reproduction, competition, and evolution [42–45].

Consider the following scenario: a new, important need emerges, unnoticed by all but a few uniquely attuned individuals who spontaneously discover the need (i.e., not as a result of any interaction with other agents already aware of this need). Gradually, the awareness of the need is diffused by a word-of-mouth mechanism that informs unaware agents about the new need, along with additional agents experiencing spontaneous discovery. From a market perspective, this transition from latent to active need (characterized by market awareness) can be viewed as a diffusion process that can be modeled using the bottom-up approach. For each agent, two stages of awareness can be defined: “0,” representing a state of nonawareness, and “1,” representing awareness (of the emerging need). Two mechanisms govern the transition from “0” to “1”: spontaneous discovery—by which an agent becomes aware of the emergent need independently of other agents, and word of mouth—by which a proximal agent, i.e., his neighbor, is instrumental in creating awareness. The model assumes the potential of all cells to transform from “0” to “1.” As a simplifying assumption, we also assume that the new need is a “sufficiently important new need,” conforming to the intuitive understanding of an agent as one who never “forgets” a significant need and determining an absence of depletion (irreversibility of transformation).

For each agent, the transformation probability by each mechanism may be denoted, with \(P\) as the probability for spontaneous, discovery-driven transformation and \(q\), the probability for word-of-mouth-induced awareness. In principle, the aggregate results of \(P\) and \(q\) represent a diffusion process by which all agents ultimately undergo the transition from “0” to “1,”
culminating in a state of complete market awareness of the emerging need. This simple transition function is presented in Table 1.

Fig. 1a–c depicts a two-dimensional matrix of agents and the dynamics of the propagation process at three points in time: (a) original state, (b) low awareness, and (c) almost complete market awareness of the need (saturation of awareness).

2.1. Competition in the discovery of emerging needs

Expanding the above, \( m (m = 1, 2, 3 \ldots) \) firms (in which \( m_1 \) is the firm under examination) regularly observe the market and proactively conduct investigations with the aim of identifying emerging needs. Assume that \( m_1 \) randomly (and continuously over the course of the emerging awareness process) samples agents to discover the need. Probability of emerging need discovery is contingent upon the effectiveness of market research efforts, and the absolute quantity of agents in the sample whose state is “1” (note that each firm samples different individual agents). This aspect of the model represents the practice of qualitative market research efforts (e.g., focus groups or in-depth interviews) conducted by a firm for the purpose of generating ideas for new products.\(^2\)

2.2. Method

Models of this type are frequently solved computationally [46]. By running a simulation to “monitor” the propagation of the awareness process and the competition between the firms attempting to discover it, its implications for one firm’s exclusive discovery of the emerging need can be observed and analyzed.

To capture the complexity of the process, simulations were conducted with 22,500 agents\(^3\) in a 2D matrix (150 × 150), over a wide range of values of \( P \) and \( q \) (0.001 > \( P > 0.1 \) and 0.001 > \( q > 0.1 \); in increments of 0.0001). Simulations were performed separately on a range of \( m (m = 1, 2, \ldots, 9) \), resulting in 80,000 simulations of the process of propagation of awareness, from an initial, latent state to a complete market awareness (saturation) of an emerging need and its discovery by the competitors in the model.

At each time step along the process (defined as a transition in matrix states), all firms randomly sample the market (sample size of all firms was set as 1%). In each simulation,

\(^2\) In this model we adopt a stringent condition of equal quality of marketing research efforts of the various competitors.

\(^3\) The size of this array concurs with previous researches (e.g., [19]).
1 (time of need discovery by \( m_1 \) – the firm under consideration) and \( t_c \) (time of discovery of emergent need by the first of its competitors, defined as \( m = 2, 3 \ldots 9 \)) were measured. We define \( dt \) as \( t_c / t_m - 1 \), where \( dt > 0 \) signifies an exclusive discovery, i.e., a situation in which \( m_1 \) discovers the need before any of its competitors; \( dt < 0 \) is the opposite case.

The derivative of \( dt \) (denoted as \( dt' \)) as a function of time, was numerically computed to estimate the phase transition aspect of the process. Tracking the progression of \( dt' \) and the relationships between \( dt \) and the various predictors (such as the passage of time from the beginning of the propagation of awareness, the number of aware agents, number of competitors) highlights the competition between firms engaged in an active analysis of agents’ needs by direct agent-based research and the probability of each competitor in the market to be the first to discover the need.

Finally, the probability for a specific firm of attaining pioneering status based exclusively on sampling data is analyzed, and a model is proposed based on nondimensional parameters of the sample that can be measured during the survey.

2.3. Results

Results of the simulations indicate that the propagation of awareness process is indeed governed by an S-shaped propagation curve. Fig. 2 illustrates one case of propagation of awareness for \( P = .01 \) and \( q = 0.1 \), in which \( n \) denotes the proportion of aware individuals in the total market size and \( t \) is nondimensional. This expected S-shaped pattern was constant over the entire range of \( P \) and \( q \).

Define a logistic \( dt \) (denoted as \( DT \)), which accepts the value 1 for any \( dt \) larger than zero and a value of zero for \( dt \) smaller or equal to zero. The probability for any firm to be first and alone in the market (when relying exclusively on the strategy of market inspection) can be estimated in this model by counting the cases in which \( DT \) receives the value 1, of the total number of simulations performed.\(^4\) Moreover, this (percentage) value is sensitive to the

\(^4\) Note that by defining \( DT \) as 1 when \( dt > 0 \) captures the aspect of not only being first, but also of being alone, i.e., the second competitor to make the discovery is separated in time by one, arbitrarily defined, unit of \( t \).
number of competitors in the market \((m)\). Table 2 presents a breakdown of the percentages of \(DT\) as a function of \(m\). In the case of eight competitors \((m = 9)\), over the entire ranges of \(P\) and \(q\), \(m_1\) attained pioneer status (i.e., \(m_1\) was “first and alone” to discover the emergent need) in only 6.3\% of the cases. This stands in contrast to the intuitive estimation of 11.11\% based on equal probabilities for each of the firms.

It is also interesting to note how the probability of being “first and alone” is significantly affected by the duration defined sufficient for the attainment of exclusivity. Instead of the above time margin of \(\Delta t = 0\) representing the duration in which the company may utilize its pioneer status, being alone in the discovery, a more stringent condition is applied, i.e., \(\Delta t = 3\), representing, for example, the required time for completion of the firm’s R&D activities. Table 3 highlights the cases in which a firm completes its R&D stage before a competitor discovers the same, emerging need (being “first and alone” and able to surprise the competitors). Note that in the case of \(m = 9\), the chance of completing planned R&D activities is reduced to 0.5\%.

![Fig. 2. An illustration of simulated propagation of awareness, \(P=.01, q=0.1\).](image-url)

Table 2

<table>
<thead>
<tr>
<th>(m)</th>
<th>(DT=0) (the firm is not first and alone) %</th>
<th>(DT=1) (the firm is first and alone) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 ((n=10,000))</td>
<td>76.1</td>
<td>23.9</td>
</tr>
<tr>
<td>4 ((n=10,000))</td>
<td>83.1</td>
<td>16.9</td>
</tr>
<tr>
<td>5 ((n=10,000))</td>
<td>86.8</td>
<td>13.2</td>
</tr>
<tr>
<td>6 ((n=10,000))</td>
<td>89.6</td>
<td>10.4</td>
</tr>
<tr>
<td>7 ((n=10,000))</td>
<td>91.3</td>
<td>8.7</td>
</tr>
<tr>
<td>8 ((n=10,000))</td>
<td>92.7</td>
<td>7.3</td>
</tr>
<tr>
<td>9 ((n=10,000))</td>
<td>93.7</td>
<td>6.3</td>
</tr>
</tbody>
</table>
By observing the timing of the first discovery, a number of predictors for $dt$ can be defined. A linear regression was performed on $dt$ as a function of $m$, $tm_1$, and $n$ (the percentages of aware agents in the market). Inclusion of the last two predictors is grounded in the simple fact that the greater the number of aware consumers present in the sample, the greater the likelihood of need discovery by any of the competitors. Note that for larger values of $tm_1$, the probability of discovery by any next competitor grows correspondingly. In this regression, $R^2$ was .51 ($P < .001$) and its coefficients are presented in Table 4. Each one of the coefficients was found to have a significant contribution.

Adopting the perspective of the individual firm, the question can be posed in managerial terms, i.e., “is it possible, in a specified situation, for our firm to exclusively discover an emergent need?” To this aim, we performed a logistic regression in which $DT$ was defined as the dependent variable. The results, shown in Tables 5 and 6 indicate that 89% of the cases are correctly predicted with log likelihood of 29,415.6, and all coefficients are significant at $P < .001$ level.

These results may seem counterintuitive at first glance. Why is the probability of exclusive discovery of an emerging need so small when there are so many consumers and so few competitors? The mechanism that explains this concentration in time of discoveries by the competitors in a market can be identified by observing the dynamics of the process. Note that the S-shaped propagation of awareness behavior of the market is, in fact, a “phase transition” phenomenon. At a certain point in the emerging awareness process (when the derivative is at its maximum), the market undergoes an abrupt transition from unawareness to awareness. Discovery by any firm has limited probability until sufficient awareness accumulates, leading to a concentration of discoveries in a bounded time span.

<table>
<thead>
<tr>
<th>$m$</th>
<th>$DT=0$ (the firm is not first and alone) %</th>
<th>$DT=1$ (the firm is first and alone) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 ($n=10,000$)</td>
<td>88.2</td>
<td>11.8</td>
</tr>
<tr>
<td>3 ($n=10,000$)</td>
<td>95.6</td>
<td>4.5</td>
</tr>
<tr>
<td>4 ($n=10,000$)</td>
<td>97.6</td>
<td>2.4</td>
</tr>
<tr>
<td>5 ($n=10,000$)</td>
<td>98.4</td>
<td>1.6</td>
</tr>
<tr>
<td>6 ($n=10,000$)</td>
<td>98.9</td>
<td>1.1</td>
</tr>
<tr>
<td>7 ($n=10,000$)</td>
<td>99.1</td>
<td>0.9</td>
</tr>
<tr>
<td>8 ($n=10,000$)</td>
<td>99.4</td>
<td>0.6</td>
</tr>
<tr>
<td>9 ($n=10,000$)</td>
<td>99.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 3
Distribution of exclusive discovery and completing R&D (three time steps)

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$t$</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-5.49</td>
<td>-193.4</td>
<td>0.000</td>
</tr>
<tr>
<td>$M$</td>
<td>-0.28</td>
<td>102.8</td>
<td>0.000</td>
</tr>
<tr>
<td>$tm_1$</td>
<td>-0.23</td>
<td>215.6</td>
<td>0.000</td>
</tr>
<tr>
<td>Percentage of aware agents in the market</td>
<td>0.08</td>
<td>178.8</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 4
Results of linear regression for $dt$ ($R^2 = .51$, $P < .001$; dependent variable — $dt$)
that is characterized by the generation of a large volume of accessible information in a short period of time. Fig. 3 illustrates this volatility in the discovery status of the competitors by presenting a single simulation of the emerging awareness process and its derivative. The graph denotes the number of discoveries by competitors. If the firm makes its discovery when the derivative is small (low-awareness stage), its probability of being “first and alone” increases. However, due to the low probability of accessing this information through sampling (i.e., market research), this is not expected to be the frequent case. When a discovery is made when the derivative is close to or at its maximum, discoveries of all firms cluster around a limited time span, working against the firm’s aim of achieving an exclusive discovery.

The case in point is that attaining pioneer status and surprising competitors by introducing products or concepts based on the discovery of emergent needs through the implementation of the “listening to the voice of the customer” strategy, has an objectively small probability of success. However, if a firm determines its marketing strategy based on the potential of exploiting pioneering advantages, it is important to provide it the means to estimate its specific probability of success in this endeavor. Naturally, adopting this perspective dictates that the source of information should be based on measures of the surveys itself. We suggest that the firm’s probability of success in attaining pioneer status is a negative function of the following indicators (all can be measured in a survey by the firm):

1. $R_A$ — the ratio of aware agents (in state “1”) to total number of the agents in the sample.
2. $R_q$ — the ratio of agents that discovered the emerging need through word of mouth to total numbers of agents in the sample; larger value of $R_q$ is indicative of a well-developed propagation process.
3. $T_{old}$ — the time that passed since the first agent in the sample became aware of the need under consideration (either by a spontaneous discovery or by word of mouth).

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$t$</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>8.40</td>
<td>10,486.1</td>
<td>0.000</td>
</tr>
<tr>
<td>$M$</td>
<td>−0.54</td>
<td>6333.1</td>
<td>0.000</td>
</tr>
<tr>
<td>$t_{nm}$</td>
<td>−0.079</td>
<td>1018.9</td>
<td>0.000</td>
</tr>
<tr>
<td>Percentage of aware agents in the market</td>
<td>−0.17</td>
<td>11,620.7</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 5
Logistic regression prediction results ($−2 \log \text{likelihood} = 29,415.6$), dependent variable is $DT$

| Observed $DT$= 0 | 64,570 | 2735 | 95.9% |
| Observed $DT$= 1 | 6070 | 6625 | 52.2% |

Overall — 89.0%
4. **$DQ$**—receives the value “1” if the first agent became aware of the need through interaction with another agent, and “0” in the case of a spontaneous discovery.

5. **$m$**—the number of competitors known to the firm.

These measures are a reflection of the dynamics that are described above—the competition, the phase transition type of propagation of awareness, and the parameters

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**Fig. 3.** The affect of the derivative on competitive discovery. The lower graph represents the simulated propagation of awareness, the upper graph depicts the derivative dynamics. The points on the curve represent the discoveries of five firms.

**Table 7**
The classification of the discriminant analysis

<table>
<thead>
<tr>
<th></th>
<th>$DT=0$</th>
<th>$DT=1$</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed $DT=0$</td>
<td>64,988</td>
<td>2062</td>
<td>96.9%</td>
</tr>
<tr>
<td>Observed $DT=1$</td>
<td>6876</td>
<td>6074</td>
<td>46.9%</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td><strong>88.8%</strong></td>
</tr>
</tbody>
</table>
that were used in the linear regression and cannot be measured in the survey (with the exception of $m$).

The results of discriminant analysis performed based on the predictors above are presented in Tables 7 and 8. For the cases that the firm fails to be the first to discover the need, the discriminant analysis correctly classified 96.9% of the cases. This result significantly improves a guess that can be based on the fact that in 83% of the cases, $DT=0$ (thus setting the average probability for an exclusive discovery as 17%). This result, however, is not symmetric—for $DT=1$, only 46.9% of the cases are correctly classified, suggesting that more careful testing should be applied. If the model suggests that a firm may be the first to discover the emerging need, and if pioneering is a crucial aspect of the product launch, a firm may try to assess some of the predictors more accurately to allow a more reliable prediction. Additional information about the competitors’ strategies may also contribute to the evaluation of the probability for pioneering, allowing for a reduction in the uncertainty regarding their intentions.

3. Conclusions and discussion

It is not always clear whether being a “first mover” is an advantage or a disadvantage for a specific firm’s strategy [17,22,23,47]. A follower advantage may be free riding, or even gain a “gateway for a new entry” due to technology discontinuity. However, the exclusive discovery of an emerging need is a commendable achievement and a necessary step toward a possible decision to take advantage of the opportunity to control market share through pioneering status.

Although recognizing the crucial role of market research in new product design and forecasting success, we argue that in some situations caution should be applied. Roughly, market research for eliciting information about new needs can be classified into two types: (1) methods to address regular consumers and explore their needs and wants (e.g., focus groups, in-depth interviews, etc.), and (2) finding a unique type of consumers who may know something in advance about future needs. In the framework of the first class of techniques, we have shown that by eliciting information from consumers, a firm operating in a market with few competitors may discover an emerging need when the gradient of the awareness propagation process is large, i.e., it is more than probable that at least one other competitor may discover the same need at the same time. Observing the saturation zone in Fig. 2, we
conclude that despite the potential of consumer-based market research of eliciting an idea that addresses a real market need, this discovery is less likely to lead to a truly new innovative product idea (as a greater number of competitors are simultaneously in the process of its discovery). In contrast, an idea generated at the beginning of the S-curve (the low awareness zone) is more likely to surprise competitors and the market. Indeed, a number of researchers have recently noted the limitations of market research techniques in contributing constructively to new product ideation [48,49]. In particular, Durgee, O’Connor and Veryzer have noted that many wants lie below the surface and that current product users are unable to express wants and needs for nonexisting products. Referring to the common method of asking buyers to describe problems with current products [2], they noted that big leaps to genuinely new product ideas may not be revealed using this technique, when respondents describe problems in terms of current products. Similarly, Griffin [50] expressed doubts about the ability of consumers to predict products worthy of development by the firm or the details and features of the future innovative products. More generally, Griffin claims that consumers cannot provide reliable information about anything with which they are unfamiliar or have no personal experience.

However, those studies reflect only one aspect of this state of affairs. We posit that even in the absence of these effects, the collective dynamics of the market dictate a situation in which pioneering is not likely to be initiated based on market-elicited information. More precisely, the dominant factor is the demonstrated propagation of awareness process, while the reported weakness of the consumer is merely representative of the fact that the phase transition of awareness to the emerging need has not occurred. Our study reinforces arguments that point to the limitations imposed on market research in the context of new need discovery, by recommending the use of caution when a genuinely new product concept is desired. It is our contention that when all competitors rely on market-based information, the probability is increased that other competitors are concurrently developing a product addressing exactly the same need. The underlying reason for this state of affairs is the “phase transition”-based dynamics of awareness propagation. The propagation of an emerging need may thus be divided into two typical zones of process: (1) low awareness — when the density of awareness is too low to allow extraction of needs via sampling, and (2) saturation zone — when the probability that another competitor will identify the same need is sufficiently large to deny pioneer status. Transition from low awareness to saturation occurs when a threshold of aggregate awareness is crossed.

Our propositions are also supported by evidence of radical innovations that were not the results of market research. A few examples are: Sony Walkman, in which Akio Morita introduced a product no one wanted at the beginning; 3M “Post-It notes” that failed in test marketing; cola drinks that were developed to cure hangover headaches.

It may be important for firms planning on the “pioneer advantage” to assess the probability of identifying adjacent players competing in the market. In the event that a strategic decision to be “first and alone” has been made, a firm should attend to the odds of a competitor discovering the same need. Our analysis shows that these odds can be estimated by measurable attributes collected during market surveys. By estimating the proportion of aware consumers in the sample, the time elapsed since awareness was created, the proportions
of spontaneous discoveries and word-of-mouth discoveries of the total sample, and the sample size, a firm could estimate the degree of exclusivity it will attain in respect of the discovery of the need, in addition to the idea’s value in terms of potential pioneer advantage.

As mentioned earlier, not all market research and exploration techniques will yield this situation. There are alternative methods aimed at achieving exclusive discovery of an emergent need based on information that is invariant to market awareness, but nonetheless reflects future demands. One way to forecast the performance of innovations is the “lead users” approach developed by Von Hippel [51,52], which analyzes information elicited from a specific class of users. More precisely, Von Hippel indicates that new needs should not be discovered by market research but rather by exploring “lead users” (who, most of the time, are solving their personal problems without realizing the potential for commercialization). Using both approaches (lead users and the more traditional approach) can increase the prediction power of the model about the odds that the discovered need has not yet been discovered by any competitor.

Another approach, which relies on product-based information (rather than market based), is the Creativity Templates approach for new product ideation reported in Goldenberg, Mazursky, and Solomon [53] (see its implication for technological innovation in [12]). This approach allows for the generation of novel concepts within predefined closures in a structured manner [54]. Finally, morphological analysis also, in a sense, utilizes product-based information rather than relying on market current dynamics (see [55]).

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References


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