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Cellular automata modeling of resistance to innovations: Effects and solutions

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Abstract

It has long been accepted that word-of-mouth (w-o-m) communications play a key role in new product adoption and much interest has been directed to the positive impact of interpersonal communications on new product dissemination and adoption. Limited attention, however, has been given to the adverse effect of negative w-o-m and consumers' resistance to change, primarily since these negative forces are less visible, leaving no traces in sales data. In this paper, we explore how resistance may shrink market size. In light of the covert nature of negative w-o-m, we use cellular automata modeling to simulate and gain insights into possible resistance scenarios and their implications. We found that, once resistance is enrolled, advertising provides no more than a limited compensating effect, and positive opinion leaders have only low impact on market growth. In a second study, we explore an approach that undermines the effect of resistance leaders through the direct activation of positive opinion leaders prior to the initiation of unfocused marketing efforts.

Keywords: Innovation; Word-of-mouth; Opinion leaders; Resistance; Cellular automata

1. Introduction

In the 1960s, Scott Paper launched its first paper dresses for girls, selling over half a million items. The paper industry could not have been more excited: As ideas of disposable

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clothing for business trips and special occasions spread, expectations of a new paper era mounted. The failure was, however, as sudden as the surprising takeoff, and paper clothes disappeared from the market, never to resurface [1].

Why did this, and other seemingly successful products, fail, after a promising start? Can this pattern of failure be attributed to negative word-of-mouth (w-o-m) generated by a small group of resisting consumers, which created a market bias against the novel innovation? Perhaps, even more important on a practical level, are marketers able to eradicate resistance of this kind, or its effects?

Cases in which consumer resistance causes product failures are not difficult to recognize, yet resistance is also prevalent in successful innovations. In such cases, resistance primarily inhibits the diffusion process and may even reduce market potential. Indeed, in her study of successful innovations in the dental industry, Leonard-Barton [2] found that, although more than 70% of dentists tried or adopted a specific innovation, over 20% rejected its use completely, at the advice of experts.

It is accepted that interactions between consumers in the market, or *internal forces* (i.e., w-o-m, imitation, etc.), drive new product growth and constitute a prime force that governs product success [3–6]. Nevertheless, empirically charted data of actual consumer behavior during an adoption process are sparse, and most available data are based on aggregate sales [7,8]. Consequently, field data on actual resistance and negative w-o-m in product introductions are similarly unavailable.

In the literature, there is no qualitative distinction between negative w-o-m and positive w-o-m, conceptualized as driving the growth process (e.g., see Refs. [3,4,9]). There is, however, some evidence indicating that negative interactions are more dominant, associated with higher recall, and have a higher diffusion rate [10,11]. If this view of two internal counterforces (positive and negative w-o-m) is correct, new products face a dynamics of competition between two growth processes. Both processes are ignited by the same trigger—the *external force* (i.e., marketing efforts).

The present research was designed to uncover the underlying influence of what are herein referred to as *resistance leaders*—opinion leaders who hold negative opinions about a product and show resistance to product adoption. These resistant leaders disseminate negative w-o-m and initiate a contagious resistance process, which is invisible by nature and eludes capture by sales data.

The complexity modeling approach was found appropriate to explore the covert and intricate nature of the resistance phenomenon. We show and quantify how such kernels of resistance significantly reduce the market of a new product, and suggest means to control the destructive effects of this covert process.

2. Background: the source of resistance

Following diffusion theory [5,12], new product adoption is viewed as a process consisting of two forces: (a) the external force, which consists of marketing efforts (e.g., advertising, sales promotion, etc.), and (b) the internal force, comprised of interactions among consumers (e.g., w-o-m, imitation, externalities, etc.). It is argued that external forces are crucial for a successful launch and takeoff. Beyond that stage, their effectiveness is reduced, as internal dynamics becomes the main force propelling growth (see Refs. [5,7,13]). Consistent with the literature, and for the sake of convenience, we herein refer to all internal force elements (w-o-m, imitation, externalities, etc.) as w-o-m.

2.1. Positive w-o-m

When an idea is perceived as new, individuals will seek information to evaluate its expected utility and consequences. W-o-m and other interpersonal communications occur among individuals who have already adopted the idea, on one hand, and other individuals in the market, on the other. Both information holders and seekers may initiate a communications interaction: Some people desire to influence the purchase behavior of others, while others seek advice when considering a new product [14].

Although marketing efforts are a cost-effective way to create awareness of an innovation, interpersonal communications are sometimes perceived as a more credible source of information, having more impact on an individual's willingness to adopt [5,10,15]. In fact, studies have shown that w-o-m is the most influential factor affecting attitudes towards purchase decisions: It is argued to be two to seven times more effective than personal selling or advertising in newspapers, magazines, or the radio [16].

2.2. Negative w-o-m

Marketing literature pays little attention to the negative form of w-o-m. Roots of negative w-o-m may range from dissatisfaction with a specific product to a generalized opposition to change. Resistance to change often occurs because people are reluctant to abandon the familiar and are suspicious of the unfamiliar [17]; however, Mukherjee and Hoyer [18] attribute such resistance to the need to acquire new skills that is sometimes associated with product complexity (see also Ref. [19]).

Dissatisfaction with a new product usually arises from inadequate performance relative to expectations. However, dissatisfaction may occur on the basis of the advertising message or pricing [20], even in the absence of any trial use or purchase. Dissatisfaction may lead to one (or more) of three possible responses: (1) "exit" or discontinuation of purchase, (2) "voice" or complaint to the manufacturer, and (3) negative w-o-m to friends and acquaintances [11,21–23].

Herr et al. [10] found that negative information offsets the effect of positive w-o-m. It seems that consumers place more weight on negative information, which is perceived as more informative [6,11,21]. Further, in some cases, negative w-o-m is disseminated more rapidly.

Indeed, if the interaction between positive and negative w-o-m is more complex than a simple rivalry of forces, counterintuitive results may ensue. Such complexity was recognized by Midgley [9], who presented a first attempt to incorporate negative w-o-m in a diffusion model, using differential equations to express complex behavior and calculate market rejection rates. Mahajan et al. [4] demonstrated how, in some cases of negative w-o-m, the marketer's best policy is to limit advertising, while Kalish and Lilien [24] found that an early introduction of an underdeveloped product may generate negative feedback, resulting in an undersized market.

2.3. Opinion leaders

Individuals who render advice and information about new products and influence the attitudes or behaviors of others are defined as *opinion leaders* [5]. Opinion leaders have been described as the "most influential people" in a social network, individuals with the highest number of followers [25], "role models" who determine behavioral change [26], and individuals who are linked to a relatively larger number of distinct social networks [27].

Although opinion leaders are not formal leaders, their characteristics cause others to listen to them, seek their advice, and imitate their behavior [5]. Their influence derives from their persuasiveness and from their association with multiple social networks.

Opinion leaders are perceived as having greater product knowledge and familiarity with the product category, as a result of their extensive exposure to all forms of external communications [5,27]. They are more innovative and have a higher socio-economic status, higher educational attainment, and greater public individuation [27–29]. Despite several attempts to profile opinion leaders, it is interesting to note that there has been no evidence of generalized opinion leadership: The trait tends to vary by type of product and situation [28]. However, there is consistent support of the view that opinion leaders maintain a central position in the social system, with the ability and desire to provide advice and information about new products.

By influencing attitude and behavioral changes of members of their social networks, and by initializing information dissemination outside their immediate social group, opinion leaders play a crucial role in determining the fate of new products or technologies. What happens if opinion leaders are engaged in spreading a negative attitude towards an innovation?

2.4. Resistance leaders

According to Rogers [5], opinion leaders either *lead the diffusion* of an innovation, or *oppose the change* implied in the adoption process (see also Ref. [30], in which opinion leaders are described as possible obstacles to product adoption). In such cases, opinion leaders spread negative information and *inhibit* the adoption of the innovation. Indeed, studies have found that the individuals who tend to spread negative w-o-m are similar in their traits to opinion leaders: They have stronger social ties and higher socio-economic status, and they are more active in formal organizations and social groups [21–23,31].

Recalling that expertise is one trait of opinion leadership (see Ref. [2]), the findings of Moreau et al. [32] may offer another cause underlying opinion leaders' resistance to adoption. They found that, in a case of radical innovation, experts are more reluctant to adopt compared to novices. It is plausible to assume that resistance leaders may be experts who form a resistant attitude at a very early stage of product introduction, and generate negative w-o-m.

On the other hand, studies have found that the flow of information is bilateral: from opinion leaders to their followers, and vice versa [27,29]. Thus, information is shared by all members and their contacts, but opinion leaders have more contacts with whom they share their information. Hence, resistance may be a result of exposure to marketing efforts, positive w-o-m, or negative w-o-m, or any combination of all three.

The present paper explores the influence of resistance leaders on the growth of new products and innovations. We specifically discuss the following questions:

1. How do resistance leaders affect the market?
2. What role do other consumers play in the presence of opinion and resistance leaders?
3. How can marketers offset or contain the effect of resistance leaders?

3. Complexity modeling

Complex systems are generally defined as systems that consist of a large number of interacting individuals or entities, ultimately generating aggregate behavior, visible on a large scale [33]. Although the interactions in many such adaptive systems may be simple in themselves, the large scale of the systems at work allows the emergence of patterns that are otherwise hard to predict, hard to track empirically, and often almost impossible to analyze analytically.

Various disciplines, including physics, biology, and ecology, have developed theories and methods to investigate how complex systems evolve. Attention has also been drawn to the analysis of complex systems in the social sciences, which recognize the inherent complexity of numerous systems such as organizations [34,35], and markets [7,26,36,37].

The strength of complex system studies stems from its ability to link microsocial and macrosocial phenomena, capturing the underlying details of visible yet unexplained behavior (e.g., see Ref. [38]). In addition, unlike diffusion models based on past data, micro-representation models can be used at product launch to forecast future sales [36,39].

A convenient method that allows for inferring macrocollective behavior from micro-representations is *cellular automata* modeling (see Refs. [37,40]). The model employed in the present study is an extension of the cellular automata model.

A general cellular automata model is composed of an array of cells, each having a discrete value (0 and 1, in this example) representing the state of each individual. The transition from 0 to 1 is governed by two probabilistic rules: (1) an external influence that may impact all cells, and (2) interactions among cells. The external influence may represent marketing efforts, and the interactions among cells may correspond to internal effects. The model is solved computationally by running a stochastic process, in which each individual's probability of adoption (i.e., the transition from 0 to 1) is determined, at each period, by the two forces described.

3.1. Model of resistance leaders dynamics

In the present study, we use a model, based on findings drawn from diffusion literature, which extends the cellular automata model described above in three ways:

1. Consumers (represented by cells) can interact with consumers who are not their adjacent neighbors (Midgley [9] explains why communication networks are more random than expected).
2. Rather than a single homogeneous market, consumers in our model may belong to one of three groups: opinion leaders, resistance leaders, or main market (ordinary) consumers. The difference between the two types of leaders, on one hand, and the main market, on the other, is expressed by the number and intensity of the social ties they maintain: Leaders interact with more individuals, and their interactions have more influence [5,25–27].
3. Consumers (in all groups) may be in one of three states (uninformed, adopters, and resisters), rather than two possible states (adopters and nonadopters).

Consequently, uninformed consumers do not spread w-o-m, adopters spread positive w-o-m, while resisters spread negative w-o-m. These implications are grounded in the literature [4,9].

In order to increase the validity of the model, an empirical study was conducted. Forty-nine individuals were asked to rate their attitude, purchase intention, and w-o-m intentions with respect to four new products. The products were chosen to generate both positive and negative w-o-m (computer USB disk, air-powered car, dental implant cell phone, and a video recording of a television show). To eliminate a potential influence of existing w-o-m, all products were in a prelaunch state.

Attitude was measured on a seven-point scale (1 = *not at all* to 7 = *very much*), using four items (α=.94). Spread of positive and negative w-o-m was measured by two items each (α=.82 and 0.79, respectively), on a seven-point (1 = *disagree* to 7 = *agree*) scale. A single item using the same scale measured purchase intentions.

Study results showed that subjects expressing high purchase intention (as opposed to low purchase intention, implying product rejection) rated the innovation more favorably ($\bar{X}_{\text{adopters}} = 6.2$, $\bar{X}_{\text{rejecters}} = 2.9$, $t(77) = -9.3$, $P < .001$) and showed a significant stronger intention to spread positive w-o-m ($\bar{X}_{\text{adopters}} = 5.2$, $\bar{X}_{\text{rejecters}} = 1.7$, $t(77) = -13.8$, $P < .001$). Subjects who rejected the innovation showed significantly stronger intention to spread negative w-o-m ($\bar{X}_{\text{adopters}} = 1.4$, $\bar{X}_{\text{rejecters}} = 3.05$, $t(77) = 3.2$, $P < .002$).

3.2. Flow of influences

We employed our model to simulate a new product adoption process. In the initial stage of the simulation, all consumers are in an "uninformed" state. Consumers become either adopters or resisters after having been affected by internal or external forces, denoted by the following parameters:

1. The probability to be affected by the advertising message (α).
2. The probability to be affected by positive w-o-m imparted by an ordinary consumer (β_p).
3. The probability to be affected by negative w-o-m imparted by an ordinary consumer (β_n).
4. The probability to be affected by positive w-o-m imparted by an opinion leader (β_{OL}).
5. The probability to be affected by negative w-o-m imparted by a resistance leader (β_{RL}).

In addition, the following parameters determine the percent of opinion and resistance leaders in the market at the beginning of the simulation:

6. Percent of opinion leaders in the market (π_{OL}).
7. Percent of resistance leaders in the market (π_{RL}).

The model flow is based on the following transition rules (the flow diagram is illustrated in Fig. 1).

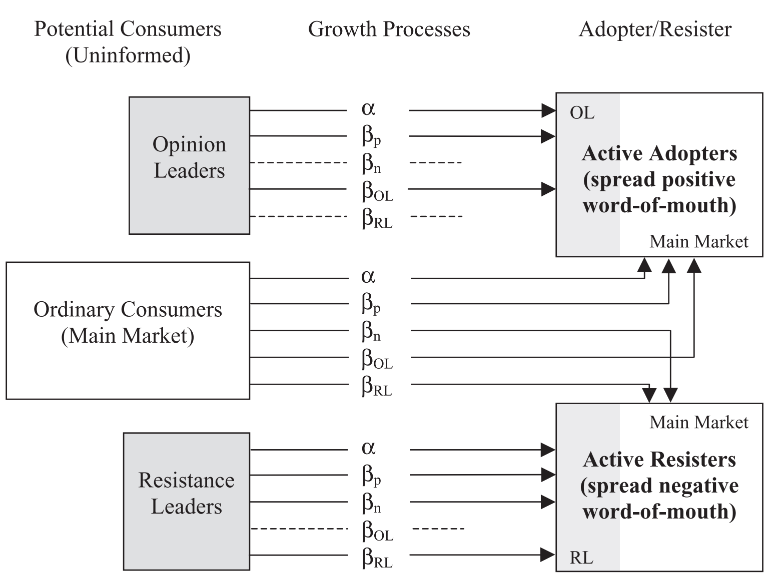

Fig. 1. Model flow diagram. This diagram represents the consumer groups and the growth processes affecting them. Opinion leaders (OL) and resistance leaders (RL) are marked in gray. Sizes of each group correspond to their relative distribution in the market. Five forces affect the market: advertising (α) and four w-o-m effects: main market's positive and negative, opinion leaders' and resistance leaders' (β_p, β_n, β_{OL}, and β_{RL}, respectively). These forces affect each group differently and drive adoption or resistance, consequently disseminating positive and negative w-o-m, respectively.

Adoption occurs, at a certain probability, as a result of positive w-o-m or advertising, while rejection occurs as a result of negative w-o-m. These are rather acceptable axioms taken from diffusion theory (e.g., Refs. [4,9]).

Once exposed to product-related knowledge, main market consumers may either adopt or reject the innovation (at specified probabilities). Opinion leaders, however, may only adopt the innovation, while resistance leaders may only reject it. This persistent character of the leaders is based on the findings that resistance to change is a stable disposition (e.g., Refs. [41,42]). Note also the findings of Leonard-Barton [2], in her study of dental experts, that although negative opinion leaders were completely integrated into the profession, none had ever tried the innovation, which they rejected completely. Moreover, both positive and negative opinion leaders found reasons to support their views and undermine opposing viewpoints.

We therefore treat opinion and resistance leaders as two distinct, stable groups, which, although influencing and influenced by main market consumers, have no mutual interaction effects. Moreover, since both leader groups are small compared to the main market, any mutual effects among opinion and resistance leaders would be negligible. This parameter is therefore set at zero.

The model also assumes that resistance leaders are activated by negative w-o-m, or by positive information such as advertising or positive w-o-m. As this characteristic of the model is not a straightforward implication of the literature, additional justification is required.

We therefore conducted a second study to confirm the validity of this assumption. Participants in this study recounted how they actually chose to adopt or reject new products that had previously achieved extensive market penetration (i.e., DVD player, satellite television, and digital cable television; $n = 118$). Resistance leaders were defined as individuals who rejected the innovation and reported communication with more than five friends. Of the nine individuals so identified, eight (89%) rejected the innovation despite having been exposed to positive w-o-m or advertising; one resistance leader even claimed that advertising was the actual cause of his rejection. These findings are consistent with Smith and Vogt [19], who claimed that negative w-o-m could be a result of product attributes, dissatisfaction, or even advertising.

This study also supported the model flows and assumption through the following finding:

Positive and negative information was found to arrive from friends (w-o-m) more than from marketing efforts (Cochran's $Q_{\text{positive}} = 9$, $Q_{\text{negative}} = 18.9$, $P < .005$). In addition, it was found that the number of friends spreading positive w-o-m is higher than the number of friends disseminating negative w-o-m ($t = 6.43$, $P < .001$). Altogether, both w-o-m and marketing efforts prompt positive information in significantly higher levels than negative information (Cochran's $Q_{\text{w-o-m}} = 15.1$, $Q_{\text{promotions}} = 25.9$, $P < .001$).

It was also found that opinions leaders and resistance leaders indeed behave in a similar way when exposed to internal and external forces; the difference between these groups was not significant. Finally, none of the opinion leaders reported to develop negative opinion when exposed to advertising (as opposed to 11% of resistance leaders).

Opinion leaders, by definition, adopt the innovation, implying that they are impervious to negative w-o-m originating from ordinary consumers. This is a conservative assumption: Allowing negative w-o-m to convert opinion leaders to resistance leaders will increase the effects of resistance. This assumption is also plausible since ordinary consumers' negative w-o-m is smaller and has a significant delay.

3.3. Model equations and solution

The model was formulated and solved computationally through a simulation (see Refs. [43,44]), in which the procedural rules are defined as probabilities for each event. The simulation is terminated when the number of uninformed individuals is less than 5% of the population, which is an acceptable procedure that allows for reduction of simulation time.

The probability equations (procedural rules) for our cellular automata model are defined as follows:

The probability of an opinion leader to adopt at time t is:

$$P_{\mathrm{OL}}(t) = (1 - (1 - \alpha)(1 - \beta_{\mathrm{OL}})^{\mathrm{OL}}(1 - \beta_{\mathrm{p}})^{\mathrm{adopt}}) \tag{1}$$

where "OL" denotes the number of opinion leaders in the "adopter" state at time t, and "adopt" denotes the number of ordinary consumers in the "adopter" state at time t.

The probability of a resistance leader to resist at time t is:

$$P_{\mathrm{RL}}(t) = (1 - (1 - \alpha)(1 - \beta_{\mathrm{RL}})^{\mathrm{RL}}(1 - \beta_{n})^{\mathrm{resist}}(1 - \beta_{\mathrm{p}})^{\mathrm{adopt}}) \tag{2}$$

where RL denotes the number of resistance leaders in the "resister" state at time t, "resist" denotes the number of ordinary consumers in the "resister" state at time t, and "adopt" denotes the number of ordinary consumers in the "adopter" state at time t.

The formula for the probability of an ordinary consumer to adopt at time t is similar to the probability for an opinion leader:

$$P_{\mathrm{adopt}}(t) = (1 - (1 - \alpha)(1 - \beta_{\mathrm{OL}})^{\mathrm{OL}}(1 - \beta_{\mathrm{p}})^{\mathrm{adopt}}) \tag{3}$$

The probability of an ordinary consumer to resist at time t is different from the probability for a resistance leader, since ordinary consumers adopt the innovation as a result of exposure to positive w-o-m or advertising, and reject the innovation when exposed to negative w-o-m. Note that this probability reflects the basic asymmetry of the model (i.e., ordinary consumers are not negatively affected by advertising). This asymmetry is relevant for successful product adoptions:

$$P_{\mathrm{resist}}(t) = (1 - (1 - \beta_{\mathrm{RL}})^{\mathrm{RL}}(1 - \beta_{\mathrm{n}})^{\mathrm{resist}}) \tag{4}$$

where "RL" denotes the number of resistance leaders in the "resister" state at time t, and "resist" denotes the number of ordinary consumers in the "resister" state at time t.

Since an ordinary consumer may either adopt or reject at time t, there is a theoretical probability of simultaneous adoption and rejection. This probability was divided relatively between the two probabilities (to adopt and to reject). The probability to remain uninformed remains unchanged.

4. Study 1: investigating the role of resistance leaders

The purpose of this study was to understand the detrimental effect of resistance leaders on product growth and development. In this study, we employed a cellular automata model representing 2500 individuals in a social system. In each simulation, a small percent of these individuals was designated as opinion leaders or resistance leaders. The remainder functioned as "ordinary consumers." Marketing efforts and internal processes of positive and negative w-o-m were modeled according to the discussion above.

4.1. Method

A computer model for this study was programmed in the C++ language. In each simulation, the population was divided into opinion leaders, resistance leaders, and ordinary consumers, and all members of the population were in an "uninformed" state. For each period, the status change of each consumer was calculated on the basis of the probability (Eqs. (1)–(4)) described above. For each parameter, we substituted values from ranges consistent with previous studies [7,45], performing a total of five manipulations for each parameter excluding advertising, which was manipulated on seven levels. All combinations were considered in a full factorial design to produce a total of 109,375 simulations of market development processes.

The ranges of the parameters were as follows:

(1) Effect of advertising message (α)	0.001–0.01
(2) Effect of positive w-o-m by ordinary consumers (β_p)	0.00007–0.00035
(3) Effect of negative w-o-m by ordinary consumers (β_n)	0.00007–0.00035
(4) Effect of positive w-o-m by opinion leaders (β_{OL})	0.0008–0.004
(5) Effect of negative w-o-m by resistance leaders (β_{RL})	0.0008–0.004
(6) Percent of opinion leaders in the social system (π_{OL})	0.004–0.01
(7) Percent of resistance leaders in the social system (π_{RL})	0.004–0.01

Adopting a conservative approach, the same probabilities were used for both positive and negative w-o-m, although research has found that negative w-o-m may have a stronger effect [10,11]. Regression analysis was performed with the market size as the dependent variable, and the seven independent variables.

4.2. Results

Table 1 summarizes the results of the regression analysis (all coefficients are standardized). Below we discuss the main results:

> Resistance leaders will reduce sales significantly, as a function of both their relative number and the strength of their social influence. The compensating force of opinion leaders is insufficient to overcome this dynamics.

Table 1
Study 1—impact on market size

	Market size	t
(1) Advertising effect	0.14	17.68
(2) Advertising effect^2	– 0.05	– 6.32
(3) Ordinary positive w-o-m effect	1.82	186.55
(4) Ordinary positive w-o-m effect^2	– 1.25	– 128.06
(5) Ordinary negative w-o-m effect	– 0.29	– 157.53
(6) OL positive w-o-m effect	0.07	35.38
(7) RL negative w-o-m effect	– 0.26	– 137.69
(8) Number of OL	0.04	23.88
(9) Number of RL	– 0.19	– 104.21
Adjusted R^2	.62	

Based on 109,375 simulations. All variables are significant at the $P<.001$ level. OLS parameters are standardized. The dependent variable is the size of the market at the end of the simulation. OL and RL denote opinion leaders and resistance leaders, respectively.

As hypothesized, negative w-o-m disseminated by resistance leaders significantly undermines market growth (Table 1, rows 7 and 9). The more prolific and influential these resistance leaders are, the smaller the eventual market.

Note that, on average, 20% of the market rejected the innovation, while 76% adopted it (another 4% remained uninformed). Leonard-Barton [2] also found that about 20% of dentists rejected a dental innovation, while over 70% tried or adopted the same innovation.

Perhaps surprisingly, disproving popular wisdom, when resistance leaders operated in the market, *opinion leaders were found to have the least influence on innovation adoption and ultimate market size* (influence of resistance leaders is four times greater than that of opinion leaders). Market size was hardly affected by any increase in the force of opinion leaders' influence, or their percentage of the total population (Table 1, rows 6 and 8).[1] The reason lies in an asymmetry of the process: As positive w-o-m relies on several channels of dissemination, eliminating one channel—opinion leaders—will have no more than a marginal effect on positive w-o-m. Eliminating resistance leaders, on the other hand, will actually shut down the process of negative w-o-m promulgation.

To gain further understanding of the small magnitude of opinion leaders' effect on market size, four short simulations were performed[2] on populations comprised of: (1) ordinary consumers and opinion leaders only; (2) ordinary consumers and resistance leaders only; (3) ordinary consumers only; and (4) ordinary consumers, opinion leaders, and resistance leaders. The simulations were tested and results for each time period were noted (see Fig. 2 for an illustration of these simulations).

[1] An increase in opinion leaders' w-o-m (in the ranges tested) increases the market by 4%; the same increase of resistance leaders' negative w-o-m shrinks the market by more than 16%.

[2] In these simulations, advertising and ordinary consumers' w-o-m parameters remained constant on average effect (based on the ranges tested), while only opinion and resistance leaders effects were manipulated.

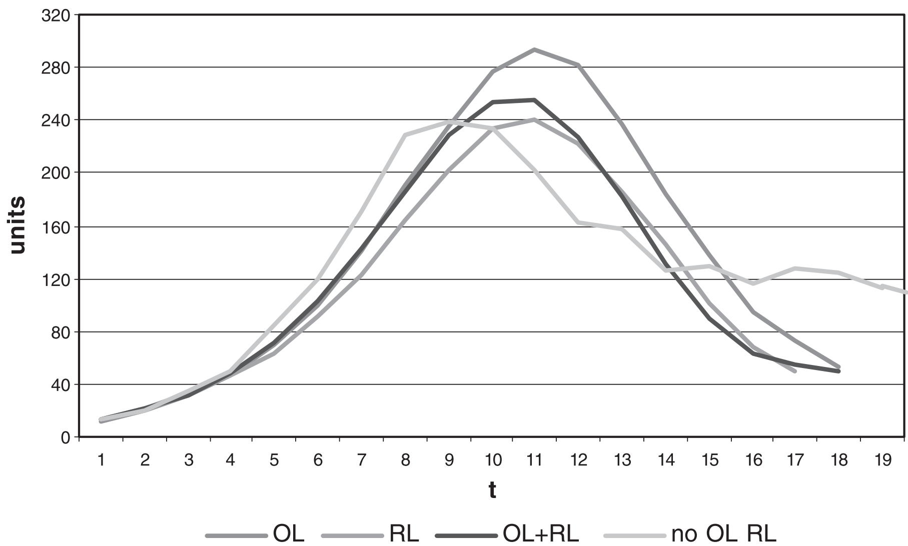

Fig. 2. Market growth simulations comparison. A comparison of four simulations (ordinary consumers and advertising are kept on an average level in all simulations): a market comprised exclusively of ordinary consumers; a market containing opinion leaders; a market containing resistance leaders; and a market containing ordinary consumers, opinion leaders, and resistance leaders. Note that markets with no opinion or resistance leaders continue until $t = 38$.

In simulations on populations comprised of opinion leaders and ordinary consumers, or only ordinary consumers, the market grows to its maximum potential size (defined as 95% of the market). When the population is comprised of opinion leaders and ordinary consumers, the market reaches its full potential in less than half the time required by a market comprised exclusively of ordinary consumers (although the chart ended at $t = 19$, the latter simulation continued until $t = 38$).

In a population comprised of resistance leaders (and ordinary consumers), a proportion of all ordinary consumers is affected, resulting in a 17% decrease in the total number of adopters, compared to its maximum potential. In fact, although the market appears to evolve as quickly in populations comprised of either leader type, the market is much smaller in the case of resistance leaders and therefore less time is required to reach its potential. Posteriori examination of the process may suggest a rapidly evolving market, while in practice, increased rejection causes the market to contract.

The combination of both opinion leaders and resistance leaders in a simulation mitigates both effects—the market is 14% smaller than its maximum potential. Resistance leaders' contracting impact on the market is only partially offset by the effect of opinion leaders. In fact, opinion leaders' positive w-o-m recaptures a mere 3% of the total market potential, compared to a population comprised solely of resistance leaders. Thus, in the presence of resistance leaders, opinion leaders provide marginal assistance to market growth.

Advertising efficiency is limited.

Surprisingly, advertising had a small and nonlinear effect on market size (Table 1, rows 1 and 2) that may even decrease market size at high levels. Intuitively, more advertising attracts more consumers to consider the adoption of the innovation. However, advertising also activates the market's resistance leaders, who (like opinion leaders) are highly attentive to advertising and are well connected [5,27]. Thus, they are more affected by the external force and increase the effect of the negative internal force.

Ordinary consumers' positive w-o-m effect is the most influential factor affecting market size. This effect is much stronger than the negative w-o-m effect[3] (Table 1, rows 3 and 5). However, the positive w-o-m effect is nonlinear[4] (Table 1, rows 3 and 4) and, similar to advertising, activates resistance leaders at high levels.

4.3. Conclusions

Previous studies have examined the crucial contribution of opinion leaders and (positive) w-o-m on new product adoption, under the assumption that advertising is vital when launching the innovation less essential to its diffusion. In this study, we attempted to understand the dynamics underlying the innovation adoption process by adding resistance leaders and negative w-o-m to a model of market growth. We have demonstrated that not only do resistance leaders significantly reduce the ultimate market size, their very existence may completely negate the positive effect of the opinion leaders. Study 2 was designed to explore the means of reducing the detrimental effect of resistance leaders on market growth and size.

5. Study 2: restraining resistance leaders

The following study utilizes the main advantage of cellular automata and complexity modeling. A series of scenarios was developed using sets of parameters that correspond to different marketing strategies. Each scenario simulation creates a "would-be world" (see Ref. [43]) that allows for evaluation of the outcomes of each strategy. In this way, different concepts can be tested, and an optimal strategy can be chosen, even if the process itself is latent in nature.

One possible solution to counteract resistance leaders' inhibition of opinion leaders' contribution to market growth is granting an advantage to opinion leaders. Advance activation of opinion leaders may enhance their impact before resistance leaders are able to erode the market.

[3] Increasing positive w-o-m influence (in the ranges tested) will increase market size by 31%. Corresponding increase of negative w-o-m effect will decrease the market by 18%.

[4] No significant nonlinearities or interactions were found, excluding those reported in Table 1.

5.1. Method

In a second design of 109,375 simulations with the same values as above, we preactivated 10 opinion leaders at time 0 (prior to the activation of advertising). This group constituted between 40% and 100% of the total opinion leader group in any simulation.

To fully understand the results of these two studies, we performed three separate analyses: first, a comparison of the final market size in the two designs; second, regression analysis using the two designs for a total of 218,750 simulations, including a dummy variable reflecting the existence of preactivated opinion leaders; and three, a comparison of the various effects between the two studies.

5.2. Results

In general, market size increases when opinion leaders are preactivated.

Activating opinion leaders prior to the initiation of advertising efforts increases the ultimate market size by 13%, from 1903 to 2147 ($t = -134.5$, $P < .001$), and may offset the negative effect generated by resistance leaders.

Table 2 presents the standardized coefficients of Study 2. The standardized coefficients of the combination of the two studies appear to be an average of Study 1 (Table 1) and Study 2 (Table 2). However, if we refer to the early activation of opinion leaders as a dummy variable, a standardized coefficient of .22 is obtained, which becomes the second most important of market growth effects, following ordinary consumers' w-o-m.

Opinion leaders' w-o-m, which had a minor effect in the first study, becomes the third most important factor (equal in impact, yet opposite in direction, to resistance leaders' negative w-o-m). Note that preactivation of opinion leaders moderated all w-o-m effects, compared to the results of Study 1. In the previous study, positive and negative w-o-m of ordinary consumers increased the market by 31% and diminished it by 18%, respectively, whereas in

Table 2
Study 2—impact of preactivated opinion leaders on market size

	Market size	t
(1) Advertising effect	−0.06	−6.98
(2) Advertising effect^2	0.05	5.99
(3) Ordinary positive w-o-m effect	1.63	170.40
(4) Ordinary positive w-o-m effect^2	−1.09	−114.24
(5) Ordinary negative w-o-m effect	−0.23	−125.63
(6) OL positive w-o-m effect	0.28	150.01
(7) RL negative w-o-m effect	−0.30	−161.88
(8) Number of OL	0.04	22.77
(9) Number of RL	−0.21	−113.50
Adjusted R^2	.62	

Based on 109,375 simulations. All variables are significant at the $P < .001$ level. OLS parameters are standardized. Same variables and ranges were used as in Study 1 (Table 1), but 10 of the opinion leaders (40–100%) were activated at time 0. OL and RL denote opinion leaders and resistance leaders, respectively.

Table 3
A comparison of effects in Studies 1 and 2

	Study 1	Study 2
Market size	1903	2147
Percent of market	76%	86%
Ordinary positive w-o-m effect	+ 31%	+ 19%
Ordinary negative w-o-m effect	– 18%	– 8%
OL positive w-o-m effect	+ 4%	+ 10%
RL negative w-o-m effect	– 16%	– 10%

The table shows the change in market size as a result of increasing the w-o-m effects, in simulations excluding opinion leaders' preactivation (Study 1) and including opinion leaders' preactivation (Study 2).

the preactivation condition (this study), their influence was 19% and 8%, respectively. Opinion leaders increase the market by 10% compared to the previous result of 4%, while resistance leaders decrease it by 10%, compared to 16% (see Table 3 for a summary of the results of Studies 1 and 2).

5.3. Conclusions

The second study was designed to identify a possible method of mitigating negative w-o-m and the destructive effect of resistance leaders on market development. When opinion leaders were activated in advance of unfocused advertising messages, market size increased significantly. In this condition, opinion leaders' positive w-o-m had a stronger effect, while the impact of w-o-m by resistance leaders and ordinary consumers had weaker effects. Preactivation of opinion leaders was also recommended by Dye [46], who claimed that the development of a self-generating demand requires marketers to recognize opinion leaders and persuade them to adopt the product.

6. Discussion and implications

The present paper examined the effects of resistance leaders and the negative w-o-m they enroll against the adoption of innovations. Because this process is both complex and covert in nature, and its consequences are not directly reflected in sales data, a complexity approach was employed.

Innovations may suffer from the adverse consequences of kernels of opposition, which proliferate concurrently with the adoption process and diminish ultimate market size. In the case of successful products, the process of resistance may be invisible, but it causes irreparable damage to market size, which opinion leaders are unable to rectify. In this situation, increasing marketing efforts has no more than a limited effect, as it concurrently activates both opinion leaders and resistance leaders. This may explain why Jeffrey P. Bezos, founder and chief executive of Amazon.com, found that advertising does not "justify its spending." As a result, Amazon.com currently has limited all advertising and relies more heavily on w-o-m [47].

Study 2 demonstrated one method to mitigate the destructive effect on market growth. Opinion leaders may recapture the market, if they come into play in advance of unfocused marketing efforts (e.g., advertising).

These results have several managerial implications for the introduction of innovations to the market. Firms may benefit if they are able to identify and activate opinion leaders at an early stage of the launch, to encourage positive w-o-m, and to discourage negative w-o-m. In such cases, the relevance of direct marketing may increase. Identifying opinion leaders is not, however, a simple task. Although opinion leaders may have several discriminating attributes that facilitate their identification, these attributes are not conclusive and may differ by innovation domain [5,14,27,28].

As difficult as it may be to identify opinion leaders, it is even more difficult to prevent the emergence of opposition to new innovations. Resistance to adoption may occur when an innovation deviates from accepted social norms, which threatens opinion leaders' status, or when an innovation requires new knowledge acquisition, which threatens opinion leaders' expertise [2,5,18].

These obstacles to new product adoption imply that future research should address the traits and behaviors of opinion leaders to understand how resistance can be reduced, either by supporting opinion leaders' expertise status, or by increasing market acceptance through stimulation of positive w-o-m [48].

The results of the present study are subject to the limitations of the model. The model uses several facilitating assumptions (see also Refs. [3,4]). For example, we ignored groups that do not engage in w-o-m at all, as well as the effects of networks. Furthermore, it may be more realistic to assume that even in the preactivation condition, opinion leaders enroll in the adoption process in a more sequential form, rather than as a group. Since a simulated model is unable to imitate a real market in all its aspects, additional studies are needed to confirm these results and develop more specific strategies.

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