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INCORPORATING RETAILERS INTO NEW PRODUCT DIFFUSION MODEL: AN AGENT-BASED SIMULATION APPROACH

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ABSTRACT

The prediction of the results of introducing a new product into the market, is one of the vital issues facing the organization's executives before investing in marketing activities. The impact of various factors on the market as well as the specific characteristics of the market, depending on the region and its product type, has made it difficult to predict market behavior. In Iran retailers are effective players especially in FMCG market. The purpose of this paper is to suggest a model to the marketing managers to predict the result of their new product lunch to market considering their special market attributes in Iran. Agent-based modeling, as a tool for modeling complicated systems, can be helpful for simulating real-world conditions. In present paper, agent-based modeling is used to model the market for agents, including manufacturers, retailers and consumers with particular profit functions. The introduction over a three-year period of a new soft drink in the Iranian market is considered as a case study. The results show that paying attention to the needs of retailers and consumers simultaneously, and changing policies based on long-term profitability, create success in the new product diffusion process. The analysis of a competitive environment and the role of retailers in market and also repeat purchase behavior of consumers is instructive. These can provide valuable pointers for marketing managers to customize the model to their special market and product.

Keywords: *Agent-Based Modeling, New Product Launch, New Product Diffusion, Competitive Market, Retailers, Repeat Purchase.*

INTRODUCTION

Innovations have become an indispensable factor for securing the long-term success of enterprises (Tseng, 2008). However, the multiple factors often affect the success of the innovation diffusion process, which entails high costs for organizations, such that the failure of the diffusion process may sometimes terminate an organization's life. Therefore, it may be vital to anticipate the results of the diffusion of innovation for organizations before introducing their new products to the market.

Innovation diffusion is the process by which an innovation is communicated over time among the participants in a social system (Rogers, 1962). Diffusion models as a tool for predicting the results of innovation diffusion have been based largely on the model suggested by (Bass, 1969). These are usually cumulative models with a macro-level approach to systems, and their

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development is based on differential equations. These models try to provide simple and overall approximations of systems in the future. Even though these models do
Not account for the heterogeneity of consumers and details of their decision rules and interactions, but the most problem of these models is that the Bass model requires as inputs two of the most important events that managers would like to predict (Chandrasekaran et al., 2007).

In recent years, simultaneous changes in agent-based modeling and the ability to process large volumes of data make it possible to focus on the details of and diversity in social networks. In agent-based modeling based on a bottom-up approach, the interactions between components and the impact of these interactions on the overall system behavior can also be modeled. Agent-based diffusion models in the field of marketing have mainly been developed since 2000 and provide an appropriate basis for managers to make more accurate decisions. In most practical studies, the basic assumption is that innovations are available to consumers as soon as the diffusion process begins, and the role of intermediary agents such as distributers and retailers in the product diffusion network is considered less. Also, less attention is paid to the competitive environment, and the impact of changes on continuing consumer behavior after the primary acceptance of innovations.

The present paper attempts to (i) investigate a competitive environment with two brand owners (manufacturers) (ii) considers the important role of retailers as intermediary players in the market, with rational and profit-seeking decision rules, (iii) and also considers repeat purchase behavior of consumers who continue comparing products before each purchase even when they have previously accepted and used theme.

Continuing the research on new product diffusion process modeling based on agent-based modeling, the present study focuses on fast-moving consumer goods (FMCG), especially on carbonated drinks in the market of Tehran as a retailer based and price sensitive market in FMCG goods.

The rest of the paper is organized as follows: Section 2 reviews the existing literature and the research gaps. Section 3 describes the case study. The structure and components of the model and the procedures and parameters of the simulation process are described in section 4. In section 5 we examine the reliability and validity of the model and in Section 6 the policies are introduced and results of implementation of policies are shown. Finally, the conclusion and recommendations for future research are discussed in section 7.

LITERATURE REVIEW

The term “diffusion” embraces concepts such as contagion, mimicry, social learning, and organized dissemination Strang and Soule (1998). Diffusion research is an interdisciplinary field with roots in anthropology, sociology, geography, political science, economics, and marketing Kiesling et al. (2012). Ryan and Gross (1943) were the originators of the diffusion paradigm. They found that social contacts, social interaction, and interpersonal communication had an important influence on the adoption of new behaviors Valente and Rogers (1995). Early efforts to mathematically model the spread of a new product in a marketplace were rooted in analogies from models of epidemics, biology and ecology (Mahajan and Muller, 1979). Along these lines, Fourt and Woodlock (1960) developed a simple penetration model to forecast sales of new grocery products. Other studies proposed

similar models, but the most influential contribution to date was made by Bass (1969). He specified that an individual's probability of adopting a new product depends linearly on two forces: One that is not related to previous adopters and is represented by the parameter of external influence (traditionally denoted as *p*, e.g., advertising and mass media); and one that is related to the number of previous adopters, the parameter of internal influence (denoted as *q*, e.g. word of mouth - WOM) (Goldenberg et al., 2000). Since then many studies have done based on Bass model. Meade and Islam (2006) reviewed the wealth of these studies from a forecasting perspective and concluded that, in spite of the efforts of many authors, few research questions have been fully resolved. They emphasized that research should include forecasting new product diffusion with little or no data and focus on forecasting future behavior instead of estimating the future using past behavior. In the last two decades, many efforts have been made to eliminate the constraints on aggregate models based on the Boss model. Agent-based models, which differ fundamentally from both aggregate differential equations and aggregate simulation approaches such as system dynamics (Milling, 1996), are believed to overcome the problem because of their individual-based modeling approach.

The bottom-up modeling approach can easily incorporate micro-level diversity in adoption, bounded rationality, imperfect information, and individual heterogeneity in terms of attributes, behavior, and linkages in social networks (Kiesling et al., 2012).

Agent-based modeling analyzes and implements simple rules of interaction between members. The possibility of combining the effects of these interactions at the macro level enables analysts to model the complexities of social realities, including interactions in the new product diffusion process.

The literature on agent-based models of innovation diffusion is divided into two major streams: theoretical insights and practical applications.

In the field of theoretical findings, research has mainly been carried out in three areas (Kiesling et al., 2012): the impact of consumer heterogeneity on innovation diffusion (Alkemade and Castaldi, 2005; Goldenberg et al., 2000; Delre et al., 2010) the role of social influence in diffusion processes (Delre et al., 2007; Bohlmann et al., 2010; Xiao and Han, 2016) and the effect of promotional marketing strategies on diffusion processes (Delre et al., 2007; Moldovan and Goldenberg, 2004; Goldenberg et al., 2001).

In the field of practical applications, many studies have been done since 2000 that have had a strong influence in the operational use of agent-based models by managers and decision-makers in marketing: In primary studies, such as Berger (2001), the impact of various policies on simulated models with one product is investigated in a non-competitive environment. In subsequent years, attention gradually moved toward the impact of competitive environments in the agent-based models have been seen in (Günther et al., 2011; Kim et al., 2011; Fazeli and Jadbabaie, 2012). Fazeli and Jadbabaie (2012) proposed a game theoretic analysis of a strategic model of competitive contagion and product adoption in social networks. Of course, in this model, the main players are consumers, not innovation owners, who are in fact the main policymakers and competitors in the market.

Paying attention to a subject neglected in research, repeat purchases in competitive environments in (Summer et al., 2015) simulating the Diffusion of Competing Multi-generation Technologies in Günther and Stummer (2018) and multi-channel choice behavior

in Sonderegger-Wakolbinger and Stummer (2015), as the latest effort to fill the gaps in literature are considered.

The major players in the market, apart from manufacturers and consumers, are retailers. These players have been noticed in few studies, such as (Heppenstal et al., 2006; Kaufmann et al., 2009; Sturley et al., 2018). Of course, in their proposed models, retailers as agents have no decision-making power or heterogeneity, and they only have a role in determining retail prices. This is despite the fact that retailers are the main factors in the market, and while they compete to attract more consumers, they also have significant role in determining the availability of products and innovation diffusion. Therefore, they must be entered into diffusion process modeling as important and independent agents. In the past, and in research by Jones and Ritz (1991) that was a development of Bass model and did not use agent-based modeling tools, the role of retailers was also considered. That research models the role of retailers, as a precondition (intermediary) of consumer's access to new products.

A review of the literature and existing research gaps show the need to develop a model that considers competitive environments with active manufacturers as the main policy makers in market, independent retailers with special profit functions as active agents, repetition of purchase after initial acceptance and the impact of distribution costs in the profit function as important issues in reality. In the present paper, retailers and repeat purchase and the impact of distribution cost are considered.

CASE STUDY

This model utilizes the case study of fast-moving consumer goods (FMCG), specifically carbonated drinks. One type of FMGC goods was selected for use in the proposed model for a number of reasons: the extreme role of retailers in the distribution of these products; short repurchase period of the products; high rates of infidelity of consumers to the brands of these products; the possibility of studying competitive policies; and the availability of actual data to evaluate the validity and reliability of the model.

According to statistics from the Majles (Iranian parleman) Research Center, Iranians imbibe 33 liters per capita of carbonated drinks. Based on an average of 3.5 people per family, that means consumption equal to 1 small can or bottle per day for each family. Generalizing the average of country to Tehran and considering that the major shares of carbonated drink market in Tehran is for one brand, the consumption parameter of the model is set. From now on the major brand will be called the old brand and its manufacturer as the marketing policy maker is called old manufacturer. The new product that start competing to main brand when diffusion process starts, is called new brand and its manufacturer as new manufacturer, makes related marketing policies in model.

Results of our field research in Tehran shows that in case of carbonated drink when the quality of products are similar, price play the major role affecting consumer behavior and the power of loyalty in our field research is 0.34. The power of brand loyalty (POL) is calculated as the ratio between price of the new brand and the price of the old brand that the consumer chooses new brand if the ratio be equal or less. Results of field research also shows that when the ratio is between POL and 1, probable of new brand selection can be calculated from linear probability distribution function will be described in formula 2.

MODEL

In the proposed model, consumers are agents embedded in a social network communicating to each other and purchasing from their neighbor retailers. Retailers are agents having communication to their neighbor retailers with the ability to make decisions to purchase from manufacturers and determine retailer price based on their own benefits function.

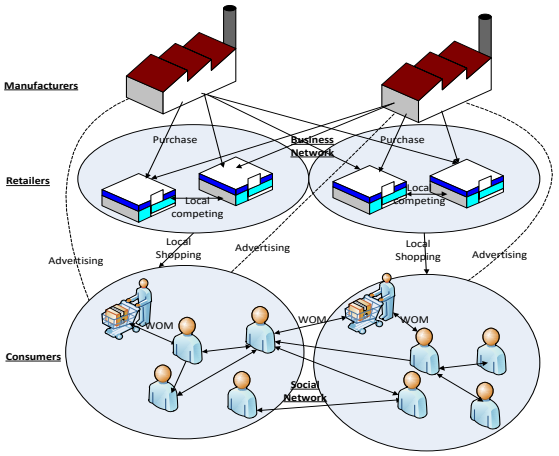

Figure 1: Model Framework

The diffusion process begins with the arrival of a new product to the market while consumers are purchasing the main brand from retailers and retailers from manufacturers. Consumers accept the new product under the influence of external variables (advertising) and internal variables (word of mouth) at a specified rate. Consumers may change retailers because they overcharge compared with their neighboring retailers and also they decide which brand to buy based on formula 2.

Retailers also periodically determine prices for products based on their previous profit and the lowest prices of neighboring retailers in the market. In this process they try to simultaneously increase their profit and consumers. In the following sections, the agents, network structure, diffusion process, pricing process, purchasing process and policies of manufacturers will be described.

Agents

- Products: In the proposed model, the products are fast-moving consumer goods (FMCG), specifically carbonated drinks. The practical data on new product distribution is extracted from an existing database archived transactions of a distribution company in Iran for 3 years from the beginning of a carbonated drink lunch. This information presents the amount of purchase by retailers of new and main brands and also changes happen in price.
- Consumers: Households in 22 districts of Tehran whose population is determined based on the 2011 census and based on population and income levels are different.
- Retailers: Business owners who purchase goods from manufacturers or distributors and sell them to end consumers. In Iran, in the case of FMCGs and in terms of the magnitude and diversity of goods, these can be grouped into five types. These retailers also have independent business and their product selection criteria are profit margin,

volume of sales, and the distribution network Miremadi and Faghani (2012). In each area, based on population and income levels, the number and types of retailers are different; these differences are applied in the model. Each type of retailer-agent has a different attraction coefficient for probable consumer attraction.

- Manufacturers: They are the brand owners and main policymakers in the model. They apply their policies and change marketing factors, especially wholesale prices in this model, to increase market share and profitability. It is assumed that a manufacturer exists first, and all consumers have been purchasing the product from it. Starting the process of diffusion, a new product enters the market and takes a part of the market share of the primary product, so the main manufacturer is forced to react.

Network

The social network is in operation for a period of 10,000 days, equivalent to almost 27 years, before the diffusion process begins, based on the model described by Albert and Barabási (2000).

A common property of many large networks is that the vertex connectivity follow a scale-free power-law distribution. This feature is found to be a consequence of the two generic mechanisms that networks expand continuously by the addition of new vertices, and new vertices attach preferentially to already well connected vertices. A model based on these two ingredients reproduces the observed stationary scale free distributions (Barabási et al., 1999). The network of consumer relationships in our model is constructed by a preferred and gradual approach, which is consistent with the principles of making pseudo realistic models.

With the completion of the consumer-consumer network, the construction of the consumer - retailer is created in this way: Consumers in each area are connected to retailers from the same area based on the determined possibility of attracting consumers for each retail type.

Later, when the diffusion process is run, each retailer who is one of the three available retailers for any one consumer, is periodically evaluated. If there is a better retail price, the retailer may to be replaced. This algorithm leads to the creation of a network in which the right to choose the best retailer is given to the consumer and simultaneously leads retailers to compete to attract more customers.

Now, assuming that the entire network is shaped and all the consumers are buying the main brand, the diffusion process of the new brand in the network can begin.

Diffusion and acceptance process

- The probability of acceptance by each consumer *(i)* in period *(t)* is calculated as follows: (Amini et al., 2012).

$$p(i,t) = 1 - (1-p)\prod_j (1-q_j) \qquad (1)$$

- In the above formula, p is the probability for consumer (i) that is influenced by external advertisement, and q is the probability of consumer (i) that is influenced by word of mouth of accepted consumers (j). These values are enter into proposed model based on the amounts specified in Sultan et al. (1990): p=0.03, q=0.4. Later, verification tests on results show that the implementation of the model with these parameter values are robust, and they are matched to the real data.

- In the process of acceptance, only individuals who consume the product can have an impact on other individuals. So, not only they should first accept the new product, but also, based on the model described by Jones (1991), the product should exist in one of their retail centers, and they should buy the product from the retailer at least once.

Consumer buying process from retailer

As mentioned, the retailers who are selected by a consumer are determined in each period of the model, so that the consumer can go to one of the retailers that are in the consumer's home region in each period. Assuming that the consumer knows there is a new brand of product (adoption process is complete), the price of the new brand is lower than the main brand, and the new brand is available in stores, the new brand is selected by consumer by the following probability formula called brand selection probabilistic function in the present paper:

$$P(\text{New Brand Selection}) = (\text{Old rp} - \text{New rp}) / (\text{Old rp} - \text{POL})$$

Where Old rp >= New rp

Else P (New Brand Selection) = 0; (2)

P (Old Brand Selection) = 1 - P (New Brand Selection); (3)

Where "Old rp" and "New rp" are the retailer prices of the main brand and new brand respectively, and "POL" is consumer power of loyalty to the main brand.

Retailer pricing process

- The manufacturers can only determine wholesale prices, which are the sale prices of the products to the retailers by the manufacturers. Wholesale prices are determined based on policies set by manufacturers.
- The retail price in this paper is determined by each retailer in model and it is based on an algorithm referred to in (Heppenstal et al., 2006) as Pricing Algorithm:
  - If the profit is rising, continue implementing the last price change;
  - If the profit is falling, increase the price.
  - If this does not work, decrease the price.
  - If the profit is constant (within a defined tolerance), keep the price constant.

  The above requirements are periodically implemented by the retailers and appropriate decisions are made. The retailers also periodically check other retailers' prices and set the price close to the lowest region price based on a defined algorithm in model.

Retailer buying process from manufacturers

Each manufacturer's sales agent visits the assigned retailers to sell his products in a specific period. The retailers determine the share of each brand for their shelves based on the income derived from each brand. This income is affected by the (i) consumer purchases and (ii) the retailer's profit margin. When manufacturers' sales agents come, retailers order amount of product based on share of space for each brand excluding the brand inventory in shelf.

Policies

It is assumed that each manufacturer can change the value of marketing parameters such as the wholesale price, the proposed retail price, the amount and coverage area of advertising, the product distribution areas, and the visiting period to retailers to increase market share and

profits. To simplify policymaking, only the prices are changed in different policies; other parameters are set at constant values. In the first step of policymaking, the initial wholesale and retail prices are set and the results are checked. It should be noted that the retail prices of both brands are changed by retailers during the model implementation; the values set at the beginning of model implementation are only the initial values suggested by the manufacturers and have no control on retail price changes. Also, none of the manufacturers are able to change the values of the model parameters during the model implementation.

MODEL TEST

The large number of independent and effective agents, complex and local interactions between agents, the impact of time in simulation result, and the dynamics in the system are some properties of our problem. Rand and Rust (2011) explain that exhibition of these properties in problem, confirm that ABM is not only an appropriate solution for the problem but also is one of very few approaches that will work.

In the following sections, the validation and verification test of our agent based model are explained which are designed based on the methods proposed by Rand and Rust (2011).

Verification:

Two experts compared the code with the model plan and verified the validity of the proposed model. In addition, corner case, sampled case, specific scenario, and relative value testing were carried out; the results confirmed the validity of the model.

Validation:

Validation is the process of determining how well the implemented model corresponds to reality. Four steps were taken to ensure rigor in validation:

1. Micro-face validation: Experts in the field of FMCG approved utilization of the Pricing Algorithm introduced by Heppenstall et al. (2006) when manufacturer and retailer face with a change in profit and sales. The retailers' behavior in the purchasing process, Consumer buying process from retailer and Retailer pricing process were also approved.
2. Macro-face validation: the behavior of factors such as purchase and sale levels, wholesales price and retailer price and also market share of the brands were evaluated. The difference between estimated factors and their real values was compared using the Theil-Sen method and the cumulative behavior pattern of the model was confirmed.
3. Empirical input validation: The accuracy of input data such as population, price and costs, and their adaptation to the real data were confirmed.
4. Empirical output validation: Total sales were evaluated as one of the main outputs where input data were adapted to the corresponding real data.
5. Cross-model validation: It was performed by comparing our results to the modified bass model formulated by Jones and Ritz (1991) because of incorporating distribution into classic bass model as we done in part of our model. We fitted the model to the average diffusion curve using nonlinear least squares. We find that the modified Bass model fits the simulation output reasonably well ($R2 = 0.63$) and conclude that the simulation does indeed reproduce the stylized facts embodied in the modified Bass model.

MODEL IMPLEMENTATION

After verification and validation of the model, its parameters were set based on four policies and the model was run. In these policies, the wholesale price and retail price of the main brand were fixed, and these prices for the new brand in each policy were set differently. Parameter values and results were as follows:

Fixed parameter values in pricing policies:

- Model implementation period: equal to 1,000 days
- Impact of advertising: p=0.03
- Effect of WOM: q=0.4
- Period of change in the retail price: 45 days
- Period of retailer change by customer: 15 days
- Sales visits period for the main product and new product: 15-day period with a delay of 3 days
- Period and type of advertising: television advertising for the new product for 30 days from the beginning of model implementation
- Advertising cost per day: 300 million rials
- Product distribution to retailer: distribution in all regions and to all retailers is done from the beginning of the simulation for both products
- Distribution cost for each customer: 50,000 rials
- Loyalty power of main product: set at 0.34.

Table 1 shows the names of the policies and the values of the variables in policy development.

Table1: Policy values

Main brand			New brand			Policy name	Policy number
Retail price	Wholesale price	Cost price	Retail price	Wholesale price	Cost price		
10	8.5	4	8	6.5	4	Balance price	1
10	8.5	4	8	7.5	4	Regardless of retailers' profit	2
10	8.5	4	7	6.5	4	Attention to consumers	3
10	8.5	4	8	5.5	4	Decrease profit and attention to retailers	4

NOTE: Values shown in thousands of Rial

Figures 2 to 5 present the cumulative monthly (30-day period) results of the simulation for each policy by displaying profit and sales for each product.

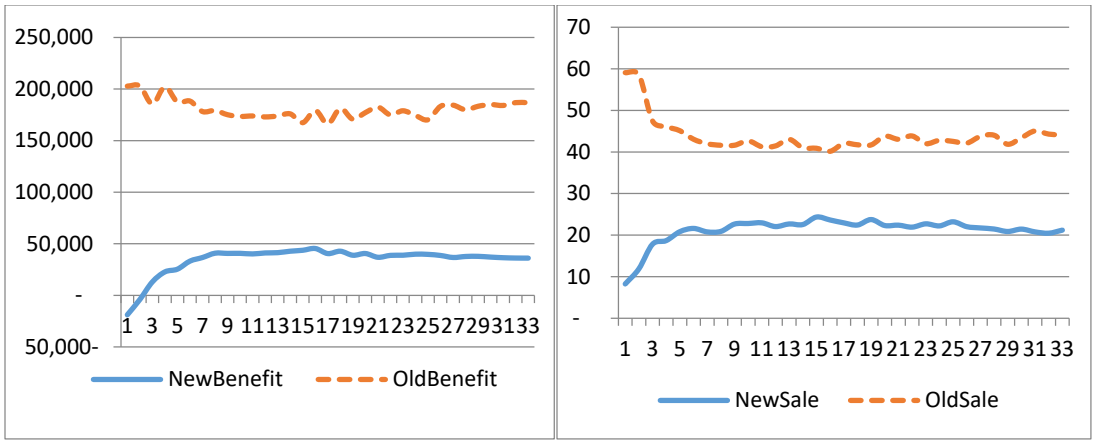

Figure2: Profit and sales for policy 1 (balance price)

NOTE: Profit: millions of rial; sales: millions of cans.

The balanced policy considers both the retailers' profit and consumers' sensitivity to price. The simulation results show that the new brand achieves suitable and constant profit in the long term.

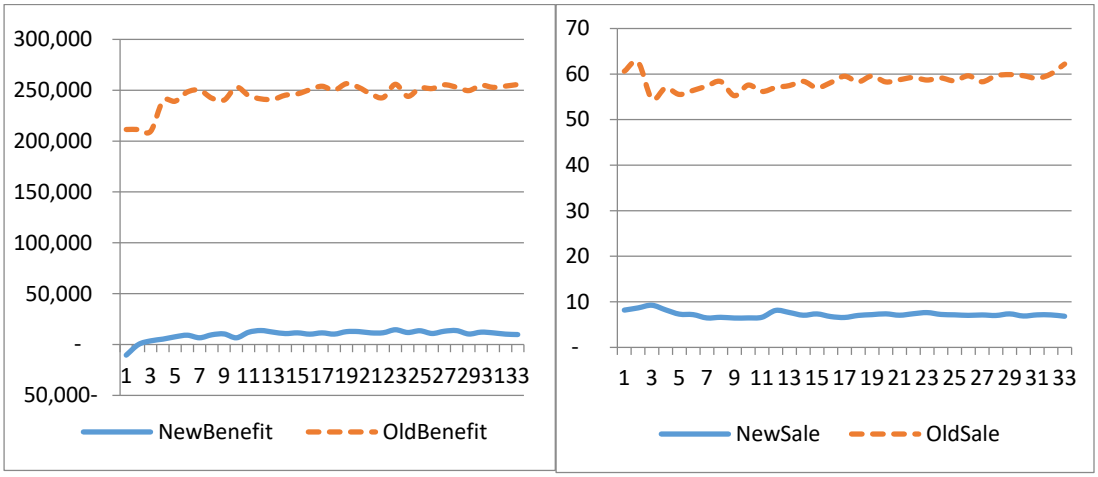

Figure 3: Profit and sales for policy 2 (regardless of the retailer's profit)

NOTE: Profit: millions of rials; sales: millions of cans.

This is an expediency policy under which the new manufacturer tries to allocate part of the retailers' profit to itself. In this case, because of a high wholesale price and low profit for the retailers, retailers avoid allocating adequate space to the product in their self until the retail price increases enough to achieve optimum profit. As a result, although the new manufacturer uses advertising to provide enough information to consumers to increase the population of adopters and assign the right retail price for consumers, lack of access to the new brand for consumers leads new manufacturer to don't achieve a high market share and appropriate profit.

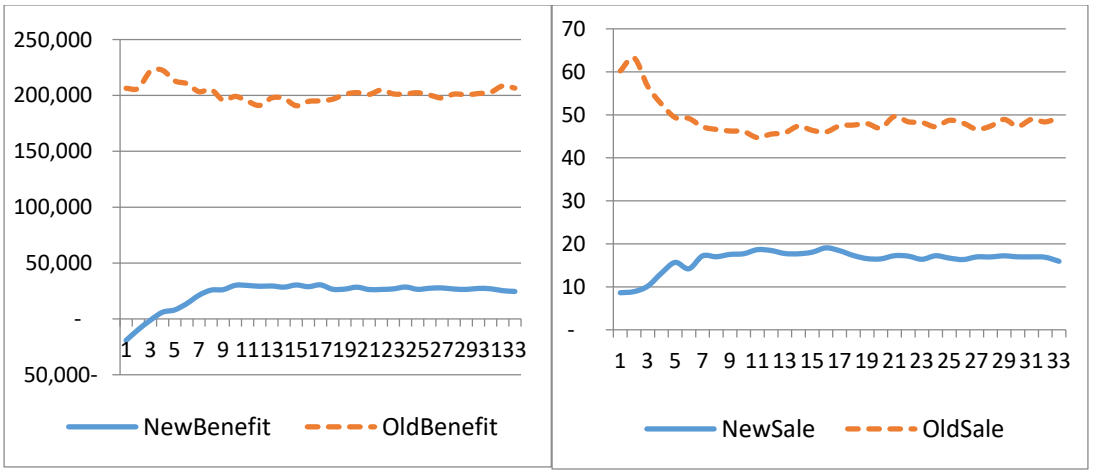

Figure 4: Profit and sales for policy 3 (attention to consumers)

NOTE: Profit: millions of rials; sales: millions of cans.

This is a policy of high interest to consumers, in which the primary retail price set by the manufacturer is decreased to attract the attention of consumers. But it can be seen that retailers gradually increase the retail price because of their low profit and possibility of retail price increment. In fact, retailer price reduction has a negative effect on retailers' profit and their purchase amount in the initial steps of the diffusion process which leads to lack of enough inventory of the new brand on retailer shelves. In the other words, despite enough investment in advertising by the manufacturer, there is no product to be bought by adopters and the total profit of the new manufacturer is lower in policy 3 compared to policy 1.

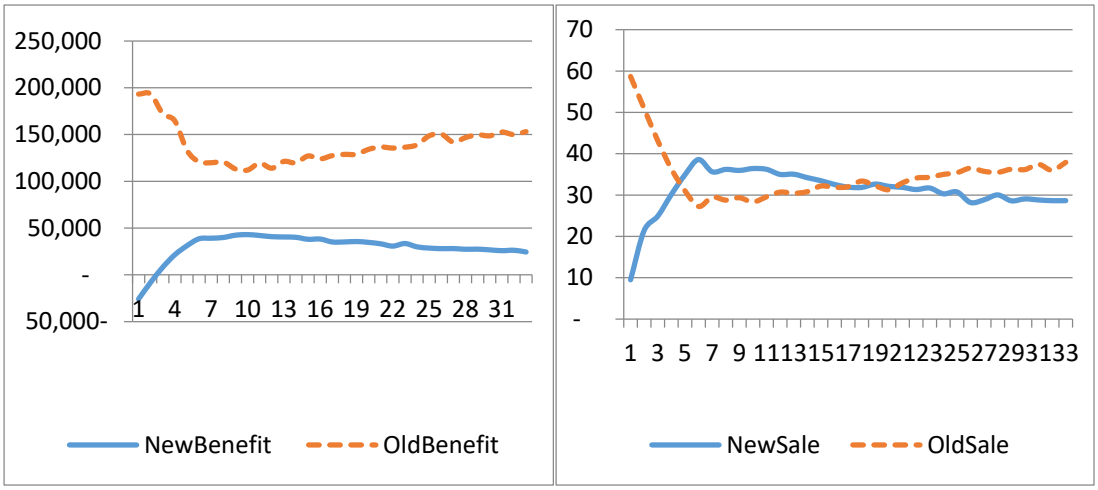

Figure 5: Profit and sales for policy 4 (decrease profit and attention to retailer)

NOTE: Profit: millions of rials; sales: millions of cans.

In this policy, the main attention is on the retailers. The new manufacturer reduces its profit by keeping a low wholesale price which causes an increment in retailers' profit, and determine a rational initial retail price for consumers. In this case, due to the high incentive of retailers and consumers to buy the new brand, seizing market share happens more quickly than in the other policies, and the new product gets 50% of the market share. However, because of, decline in the wholesale price and the reduction of profit for each product for the manufacturer, despite

increment in sales amount, the total profit achieved doesn't increase and is equal to first policy. This despite the fact that if the sales amount decrease as happened later, the risk of losing the benefit will be higher.

CONCLUSION

The current paper tried to examine some subjects to which previous researchers have not paid enough attention. This includes competitive environments, the effective role of retailers in the diffusion process, and repeat purchases after initial innovation acceptance. To cover these gaps, an agent-based model was proposed, considering decision agents in markets. These agents included: consumers, who make decisions to stay loyal to brands and retailers in their shopping; Retailers, who have their own profit-based decision rules for repurchasing and pricing the products they sell and compete with each other to attract more consumers; and manufacturers, who have specific decision rules in competition with others to gain more market share and profit. After the construction of a communication network among consumers, and based on the principles of preferred models and communication networks between retailers and consumers based on neighborhoods, the model was run for 1,000 periods and the behavior of consumers and retailers were simulated and evaluated. The results show that for accurate prediction of the results of introducing new products into the market, in addition to paying attention to the principles of initial diffusion and the role of media advertising and word-of-mouth, it is also necessary to consider the behavior of the main players in the market during the time after diffusion and in the repeat purchase process. Also, decisions about whether to implement any changes should take into consideration the fact that the effect of changes in the market is not linear, but is the result of decisions made by different people at different levels. The aim of the present paper was to find the best policy for a manufacturer who wants to launch a new brand into the market when there is a similar brand already in the market. The results show that in the diffusion process, disregarding retailers is problematic, and also paying attention only to consumers can be catastrophic. For a successful new brand launch, depending on the competitors' price and situation, the benefits to retailers and consumers should be considered simultaneously.

The present paper discusses only the effect of wholesale price changes by manufacturers. Future research could consider other factors such as timing and amounts and coverage regions of media advertising. In addition, in the present paper, the target areas for product distribution by manufacturers, sales visit periods, and product shipment to retailer costs were assumed to be constant, which could take into consideration in implementing a policy in the proposed and similar models. Finally, it is suggested that this model be developed for more players in a game between manufacturers.

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