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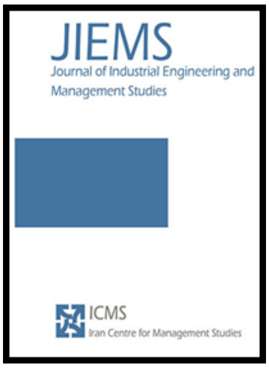

Revenue management and seller pricing decisions in retail industry: An agent-based model

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Abstract

Retailers commonly offer discounts to encourage consumers to purchase more products thereby increasing retailers' revenues. This article focuses on modeling the seller pricing decisions by using agent-based approach when the price, as a tool of revenue management, decreases. Considering the seller as an agent who uses price changes to maximize its total revenues, the objective of this research is to find the proper seller's decision about the rate of discount on products in 3 different scenarios. In the first scenario, all products' price elasticity of demand are the same and the products have relatively elastic demand. In the second scenario, all goods have the same price elasticity of demand and have relatively inelastic demands. The third scenario presents a combination of the first and the second scenarios in which the price elasticity of demand of products are different and goods with elastic and inelastic demand are placed next to each other. Also, all goods in each scenario are substitutes. In the first scenario, reducing the price causes the downward trend in rate of profit even though the discount could increase the revenue. In the second scenario, the agent behaves differently which offering the discount does not increase the revenue. In the third scenario, the products' discount increases the revenue with a slope less than the first scenario. Also, the discount for all products doesn't cause income growth. Therefore, some goods without any discount remain in shelf. Consequently, the proposed model in this research shows the proper rate of discount on each product in different product layouts.

Keywords: Pricing in retail industry; Revenue increasing; Agent-Based modeling.

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1. Introduction

Retail industry is a major contributor to the GDP of developed countries. A recent report by Deloitte suggests that the total revenue of the top *250* world retailers in 2015 was 4.31 trillion dollars. Also, the 2017 revenue of Walmart, the largest retailer in the world, was 488 billion dollars topping the Fortune 500 list. Huge turnover and income make retail industry very attractive for investors.

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On the other hand, the increasing number of retail stores makes the market more competitive and complicated. In such an environment retailers rely on a variety of strategies such as revenue management to increase their revenues.

The effective retail management includes management of limited available capacity for selling the right product category by considering the development of the current and future market. An important scale to measure effectiveness and efficiency of a retailer is the average of sale per each square meter per unit of time. (Araman and Caldentey, 2009). So, Retailers try to offer discounts as a revenue management tool to encourage consumers to buy more products and increase efficiency and total revenues of themselves. In addition, the retailers have greater autonomy to make decision about final price. The power of retailer pricing decisions directly influence on the profits of manufacturers (Haghighat, et al., 2008) . So selecting a good pricing decision and offering a right Price promotions can be considering as core competency of retailers (Bogomolova et al., 2015). Price is always directly linked to profitability and cost efficiency of a company. Therefore, the decision on the discount rate that determine the final price of products is an important decision of retail managers. Finding the proper discount rate is always a complex process and depends on pricing strategy of the retailer. The pricing strategy is informed by different factors such as customers' perception of price, value creation for the customers, the money which is paid for a specific product, competitors' position in the market, and pricing goals of companies (Monroe, 2003) (Hinterhuber, 2014) (Toni et al., 2017).

The right choice of price leads to success and increase revenue and profitability for the company and the wrong choice of price leads to the losses for the company. According to Schindler (2011), pricing is a crucial driver of profitability and it is an essential tool for revenue management. Applying revenue management helps retailers to increase their revenue and buying products in right time. The revenue management is selling the right product, with the proper price, at the appropriate time, to the target customer (Kimes, 2004). According to revenue management definition Choosing proper price and use price changing for increasing demand and income is main tool of retailer in applying revenue management. Pricing directly related to discount rate in revenue management. Although the final price decision is key task of retail industry, retailers prefer to use simple experimental procedures and instructions like finishing price with 9 instead of utilizing optimal price drawn from price optimization system. (Kunz and Crone 2015). These procedures can lead to limitations in achieving optimal price. In this research, we propose a model that can be used easily which supports the seller's pricing decision in the different categories of goods and shows the final price of products when applying revenue management. Also, revenue changes which influence seller's decision about proper discount rates of products are analyzed.

Prior researches have not proposed any pricing decision support model that can be used in various conditions to increase the revenue of retailers. Consequently, the literature is largely silent about the seller's decision when faced with different product categories. Retailers choose different layouts for their available products based on cross price elasticity of demand and price elasticity of demand of those products. In this study, attempts are made to examine revenue and profit changes when a discount is offered by the seller in different scenarios and to find proper discount rates to maximize revenue as the retailer makes pricing decisions.

2. Literature review

As a core competency of firms, revenue management is tool and tactic for optimizing revenue and using maximum capacity of companies. Applying revenue management techniques dates back to late 60s when airlines tried to increase their revenue by offering different discounts to encourage consumers to buy empty seats (Hosseinalifam, 2014). Talluri and Ryzin (2004) Considered revenue management as complementary of supply chain. Sanchez and Satir (2005) Defined revenue management as comprehensive and systematical approach.

Farias (2007) Added using optimized of selling mechanism in revenue management definition. Beck et al. (2013) Considered revenue management as a major factor in marketing and branding strategies. Guerriero, Miglionico, and Olivito (2014) Proposed problem of making decision about using revenue management. Table 1. Shows, Prior researches on revenue management.

Table 1. Previous Researches on revenue management

Authors	Years	Research Method	Tools	Research Goal
Sheryl E. Kimes, Jochen Wirtz	2016	Qualitative	Survey	Pricing and Customer Behavior
Cindy Yoonjoung Heo	2017	Quantitative	Mathematical Modeling	pricing and Measuring performance
Sheryl E Kimes	2016	Qualitative	Review Article	Measuring performance
Yunfei Wang, Ioana C. Bilegan	2016	Quantitative	Dynamic Programming	Pricing
Graziano Abrate, Giampaolo Viglia	2016	Quantitative	Mathematical Modeling	pricing and Measuring performance
Jean X. Zhang, Huangxin Wang	2017	Quantitative	Meta Heuristic Algorithm	-
Beatriz Brito, Maria Antonia	2017	Qualitative	Review Article	Measuring Performance
Bjorn Arenoe, Jean-Pierre I. van der Rest, PaulKattuman	2015	Quantitative	Game Theory	Pricing
Timo P.kunz, Sven F.Crone, Joern Meissner	2016	Quantitative	Mathematical Modeling	Measuring Performance
Nizar Zaarour, Emanuel Melachrinoudis, Marius M.Solomon	2016	Quantitative	Mathematical Modeling	Demand Control
Taiga Saito, Akihiko Takahashi, Noriaki Koide, Yu Ichifuji	2019	Quantitative	Mathematical Modeling	Estimate customer's choice behaviors
Nursen Aydin, S. Ilker Birbil	2018	Quantitative	Dynamic Programing	Capacity Management
Arne K.Strauss, Robert Klein, Claudius Steinhardt	2018	Qualitative	Review Article	Choice-based Revenue Management
This research	**2019**	**Quantitative**	**Agent-Based Model**	**Finding Appropriate discount rate**

Retailing is defined as “the art of understanding behavioral changes and demand of end customers through various methods, offering propositions to resolve needs rooted in fast changes of the environment and rapid delivery of the product to customers.” (Tekin and Erol 2016). An important aspect of this definition is the propositions offered by the retailer that are desirable for customers. Finding products with the right price is an important factor in customer purchase decisions.

Revenue management can be defined as systematic approach which focuses on selling appropriate products to proper customers in the right time with good price, as well as, using a collection of tactics and strategies to use maximum capacity of selling mechanism for increasing revenues and decreasing the risk of spoiling products. Also, it can be a useful strategy for retailers who want to increase their sales revenues. Therefore, retailers try to offer discounts to satisfy their needs. In this article, we attempt to examine agent-based behavior to determine the right discount rates to increase revenues and satisfy customers that try to find proper price of products throughout different scenarios.

Bitran and Wadhwa (1996) worked on an optimal dynamic pricing in selling seasonal products for specific times and inventory levels. Chatwin (2000) investigated on the continuous time treatment of a storage problem. In this study, the price of a specific number of perishable products, which have a short lifetime and must be sold before their expiry date, was determined. Bitran and Caldentey (2003) studied dynamic pricing policies with respect to revenue management. In their research, the adaption of perishable products with price-sensitive demands in a limited time is considered as the problem. The retailer forms the resources into various products and offers a list of end products to the end customers. They have studied the method by which the list can be produced and the capacity to be allocated to each product and finally determine the price to maximize the revenue. Araman and Caldentey (2009)offered a model for dynamic pricing of unperishable products. In their model, the retailers were supposed to offer unperishable products to customers who are sensitive to price and whose demand features are not clear. They noted that the retailers must control their products' prices continuously and use all the information such as price and sales history. They learn about the demand features as time passes. Den Boer (2015) studied the emergence of dynamic pricing and reviewed the current and future research in dynamic pricing as well. This study investigated the integration of dynamic pricing and machine learning which has received a lot of attention in recent years. As proposed in this research, machine learning can be used in future research and retail industry which can reduce many deviations in the complexity of systems.

Fisher, Gallino and Li (2017) studied competition-based dynamic pricing. Their Research offered and proposed the best price response when retailers track the competitor's price changes. Ghose and Tran (2009) created a model for calculating the competitive price using the neural network to increase a vendor's revenue.

Grewal et al. (2011) reviewed the models and the outcomes of pricing research in the retail industry. They divided pervious researches into three parts: first, studies that aim to investigate each product's promotion, second, those which focuse on pricing models and product promotion, and third, the impact of product promotion design on customer's decision in the stores and sales trend. Shankar et al. (2011) examined targeted customers as buyers and attempted to find win-win-win solutions for interaction challenges between buyers, retailers, and producers in retail industry. Grewal et al. (2012) analyzed strategic pricing based on the value in the retail industry. They examined the changes in global markets like economic downturn and the emergence of new technologies and their role in changing customer behavior. They studied customer perception that is influenced by the value that retailers propose, which is affected by environmental changes and technological progress. In fact, the goal of their research was to understand the effects of technological progress and economic changes on consumer behavior. It was noted that pricing in retail industry must change based on changes in customer behavior and their perceived value. Mace (2012) studied the use of nine-ending pricing in grocery industry. The research showed that nine-ending pricing method can increase the sales of small brand and cheaper products and can decrease the sale of premium brands. Guari (2013) used random bounding analysis to measure and compare the inefficiencies among various pricing strategies based on the type of retailing. He collected data from 2500 stores within 50 chains and achieved 28.59 percent of inefficiency. In the meantime, Walmart and Kroger had the lowest inefficiency with 2.81 and 3.06 percent, respectively. Also, it was indicated that retailers can reduce the volume of sale space, number of cashiers, and number of employees without any effects on the level of outcome.

Li and Sexton (2013) suggested three strategies for pricing in grocery industry instead of markup strategy. They stated that pricing strategy of retailers not only affects themselves but also influences supplier revenue. Watson, Wood and Fernie (2014) offered a new reactionary model which can help retailers to choose their pricing method. Authors have interviewed with pricing managers of food retailing stores and attempted to understand how they make decisions about products' price. The results indicate that the managers used typical and simple methods for pricing rather than complex methods. Pricing rules, attitudes toward risk of price change, decision-makers' knowledge, complexity, and uncertainty of the results are considered as factors that influence reactionary model. Ghoniem et al. (2016) examined pricing and optimal layout of various categories of complementary goods in retiling. Each category included a number of substitute goods. The relationship between categories was based on cross-sell standards for increasing sales. This research shows that reduction of sales and revenue of the retailer is not related to supplementary sales standards. Niles et al. (2013) focused on using revenue management elements for decreasing cost and developing online retail services. They found that revenue management can be useful in managing demand and decreasing cost of service which online retailers deliver for customer. Tang and Yin (2007) represented two types of responsible and irresponsible pricing in their research. They considered pricing as a tool for the retailer to control suppliers' uncertainty. Research indicated that if responsible pricing is used, the retailer's profit and revenue will increase.

Zhao, Tang and Wei (2012) studied the pricing method of substitute products in fuzzy environments. Substitute products pricing method in a supply chain with a manufacturer and two competitor retailers were examined. Finally, in their research, they offered a strategy for pricing with fuzzy theory and game theory in fuzzy environments. Zhao and Wang (2015) considered retailer's service level in pricing strategy. . In a fuzzy environment service cost, production cost, and customer demand were linked together. Finally, they proposed the pricing strategy that considers retailers' service. In fact, the two studies focused on pricing in an uncertain environment. Tsao (2015) focused on how retailers react to the efforts of manufactures' product promotions under supply uncertainty. This research suggests that although suppliers always attempt to encourage retailers to share the costs of product promotion and support product promotion plan to increase sales, retailers in most cases are not interested in taking part in promotion plan because their profit reduces, unless pricing takes place by the retailers. Harrison and Bonnie (2016) used the basic theory of prisoners' dilemma game model and empirical price concentration model together to show the quasi-collusive behavior among retailers. Huang and Ke (2017) studied pricing in an uncertain environment. Game theory and uncertainty theory were used to solve the problem. Finally, the research indicated if sales cost is high, consumers will find cheaper products in retailers which have high bargaining power.

A number of research gaps are identified in the previous research that was reviewed in this article. First, previous research focused on level of stock inventory and expired time for retail products. (Chatwin, 2000), (Bitran and Wadhaw, 1996), (Wood and Fernie, 2014), (Bitran and Caldentey, 2003), (Ghose and Tran, 2009). These lines of research used revenue management and price reduction as a tool of revenue management to increase the demand of products with imminent expiration dates. None of these articles examined increasing revenue of retailers from the perspective of the seller. Second, previous research focused on managing order and demand with pricing. (Kunz and Crone, 2015), (Niels et al., 2013), (Watson, Wood and Fernie, 2014) . (Ghose and Tran, 2009). This stream of research tries to solve the demand managing problem and they do not say anything about the proper price and discount rate to reach maximum revenue. Third, previous research has focused on using different methods such as game theory to develop pricing methods. (Grewal et al. 2012), (Zhao Tang and Wei, 2012), (Watson, et al., 2014), (Gauri, 2013), (Zhao and Wang, 2015, (Den boer, 2015). None of these articles consider seller as an agent which has the ability to make decisions and find the best discount rate to reach maximum revenue and use agent-based method.

In the previous research, different types of relationships between suppliers and retailers are studied and they didn't mention the conditions in which relationships between available products in a retail store are different. In this article, the seller pricing decisions about selecting proper discount rate for increasing revenue in different existing conditions between goods of a particular category in the retail store is examined.

3. Expressing the model

In this section, the model and activities diagram are proposed and described.

3.1. Conceptual model

In the proposed conceptual model, the seller is known as an intelligent agent who has complete control over goods' prices. Like all agent-based models, agent attempts to recognize and interact with the environment. The agent uses price changes based on the discount rate to encourage customers to buy more products and increase the revenue. The model attempts to increase company's revenue by reducing price and find proper discount rate to achieve maximum revenue. In the following conceptual model, the agent always tries to increase its revenue in an environment that substitute products are laid out next to each other. However, there are limitations and boundaries in achieving its goal. Boundaries are created for different reasons such as limitation in offering discounts due to restriction of products' margins, limitations in supplying products for customers because of warehouse, and storage capacity. First the agent with output of environment which are cross price elasticity of demand and price elasticity of demand, determines the scenario. Second the agent begins the sale process based on the price of the goods. In fact, achieved revenue from goods sold with the initial price is considered as the first state by the agent and he keeps this information in the database. In each level, the agent tries to increase its revenue. It starts to reduce his prices and offers discounts to consumers. In reality, by offering the first discount, price and demand change and, as a result, revenue also changes. In this case, the outcome resulted from the second state is calculated. If revenue increases, the agent will get a score and the new revenue is recorded in the database. In the same way, the agent continues its action and learning process. Finally, when the agent cannot achieve higher revenue in later actions, the model will stop and the final price will be extracted. In order to better understand the agent's behavior, we examine the model in different scenarios in which the agent behaves differently.

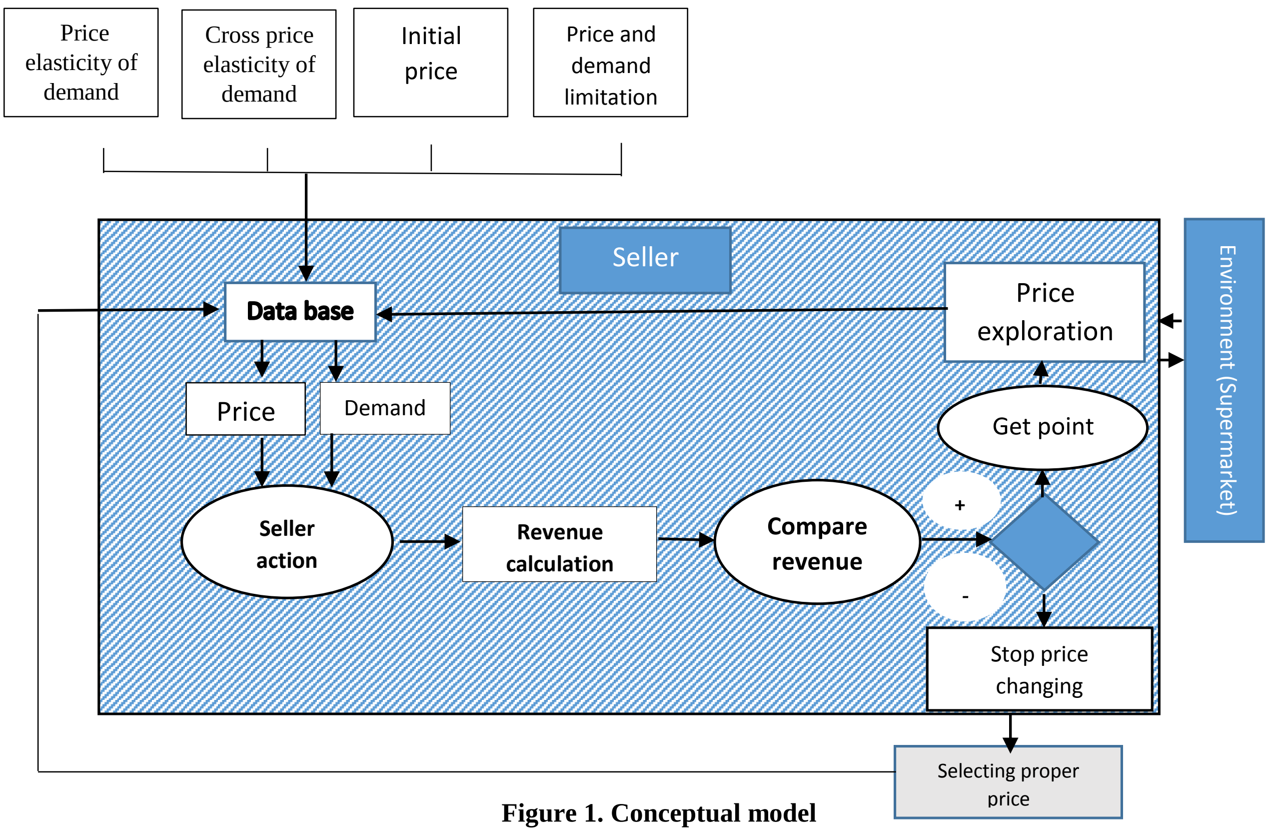

Figure 1. Conceptual model

3.2. Activity diagram

Activity Diagram is used to represent related activities and data flow between them in a system.

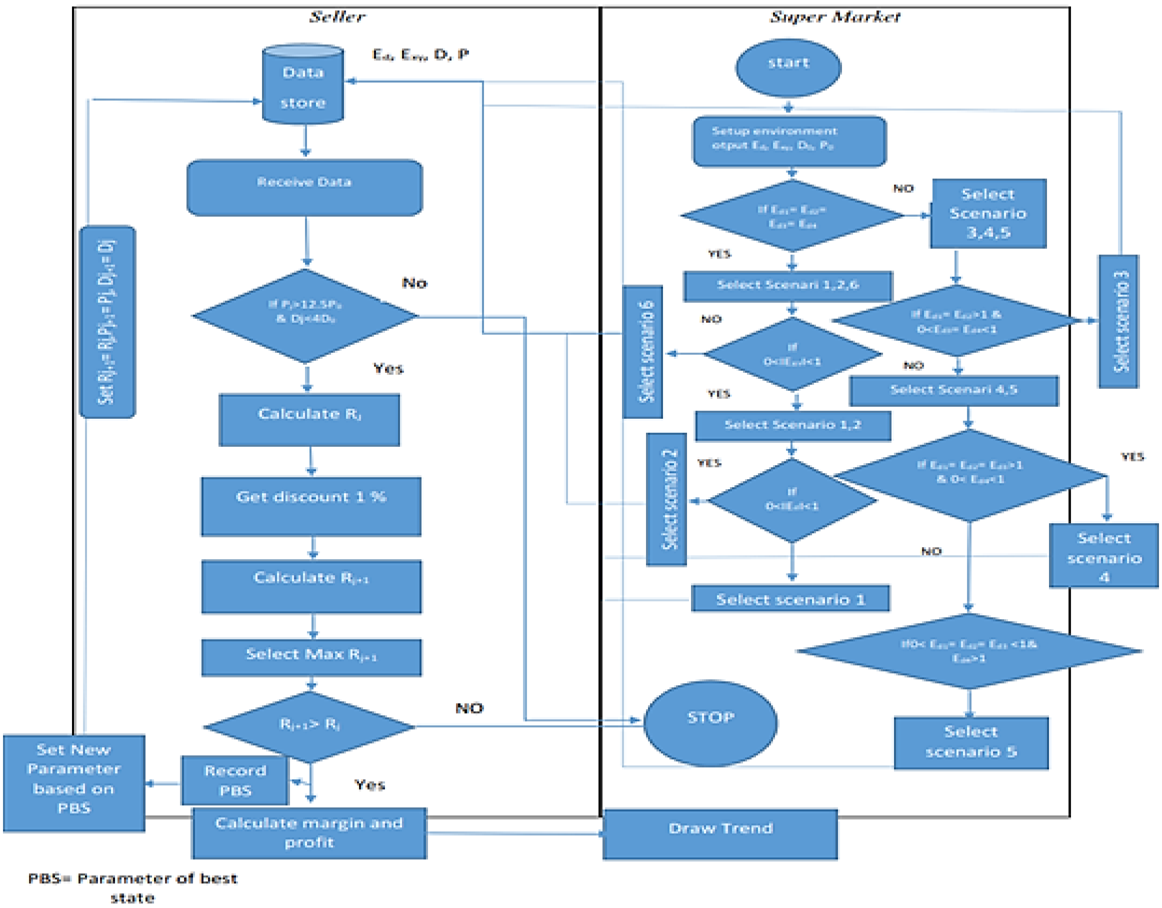

Figure 2. Activity diagram

3.3. Environment

The agent is in interaction with the environment and uses its information for analysis. The information which the agent gets from the environment is useful in the learning process and later actions of the agent. All the behaviors of the agent (seller) take part in the store. The store has the following traits:

3.3.1. Storehouse

Inventory limitation is determined by the environment. Because of constriction in inventory space, the demand that stores can support is limited. In this model the maximum of demand that seller can save in its storehouse depends on initial demand and is equal to $D_{MAX}=4D_0$

3.3.2. Product characters

In the supermarket, products are specified with some characters such as brand, margin limitation, and usage. In this model, products are categorized by cross price elasticity of demand and price elasticity of demand

3.3.3. Margin limitation

Margin is related to the cost of selling products to supermarket and initial price of goods. In this research, the margin is equal to 12.5 percent of initial consumer price and is determined by the environment. The discount rate cannot be more than 12.5 percent.

3.3.4. Initial price

The initial price is pre-determined and marked with the price tag. In fact, the initial price is determined by the environment for the agent. The initial price is indicated as P_0 . Different goods' initial prices are considered the same if they are in one product classification and do not have a special privilege over each other.

3.3.5. Initial demand

Initial demand is also determined by the environment. Since the environment is the store, there are constraints in supply and distribution of demand for the seller.

3.4. The agent

The agent in this research is the seller. In reality, the seller attempts to create the most value for itself through changing the price. Price reduction and checking model boundaries are two important agent actions. Also, the agent examines the consequences of each action and compares them with previous actions results and makes decisions to do future actions based on them. The operating range depends on the model boundaries.

3. 4. 1. Agent's goal

The agent's goal is using price reduction to find proper discount rate to get maximum revenue.

3. 4. 2. Agent's action

The agent decrease the price of each product step by step. In each step the agent calculates the revenue of selling products with the new price. The agent continues its action if revenue is increased.

3.4.3. Assumption

We hold three assumptions about the seller and products:

1. Products have margin limitation. So the agent has constraints in price reduction. In this research the margin equals to 12.5 percent. The agent cannot sell products below 12.5 percent of initial price.
2. The seller has the limitation in supplying demand. It can keep fourfold of initial demand in its warehouse.

The agent has 4 SKUs in each product category.

3.4.4. What is the agent's behavior?

The agent chooses the goods, examines the environment, gets input from the environment, and examines the price changes and calculates and compers consequences of price changing.

3.4.5. The consequences

The final consequence of each action is the revenue from the sale of goods with determined discount rate. The agent records the consequence in the database and continues price changes and compares new consequences with the database until the revenue increases. Consequence is denoted as R_{total} and is calculated as follows:

$$R_i = P_iD_i \quad (1)$$

$$R_{total} = R_i + R_{i-1} + R_{i-2} + R_{i-3} + \ldots\ldots = \Sigma R_i = \Sigma P_iD_i \quad (2)$$

$$DIS_R = \alpha \quad (3)$$

$$P_i = \alpha^i P_0 \quad (4)$$

$$R_{total} = \Sigma P_iD_i = \Sigma\, \alpha^i P_0D_i \quad (5)$$

$$dR/dt > 0 \quad (6)$$

3.4.6. Agent learning method

Agent uses reinforcement learning.

$$Q\,(St,Rt) \longleftarrow Q\,(St,Rt) + \alpha t\,(St,Rt) \times [R(St) + \gamma \max Q\,(St+1,Rt+1) - Q\,(St,Rt)] \quad (7)$$

In this formula $Q\ (S_t, R_t)$ shows the initial state of the agent. $\alpha_t\ (S_t, R_t)$ is learning rate which shows the grade that the agent uses new data. In this research after each data upgrade, price and demand are changed. So the learning rate is equal to 1. $R(S_t)$ is reward and in this article the reward is equal to 1. γ is discount factor that equals to 0 because in this research the seller only considers current reward. And $Q\ (S_{t+1}, R_{t+1})$ is the state after the agent action.

4. Implementation of the model and analysis

The model is run in three different scenarios that present different layouts of products next to each other in the store. Each scenario has different parameters which affect the consequences of agent actions. This article examines the effects of discount on the revenue and tries to find proper discount rates to achieve maximum revenue by running this model in each scenario. The data is collected from a database of hi mart chain store. Sales Data of a period of one years is used for this research. In the current research, an agent-based method is used to simulate the seller's behavior. For a better examination of the agent's behavior, the model is examined in three different scenarios. The difference between each scenario is in cross price elasticity of demand and price elasticity of demand. Python used for coding the model.

4.1. Scenario 1

In Table 2, the characteristics of products that distinguish the first scenario from others are showed:

Table 2. Characteristics of goods in scenario 1

$E^2_{d1} = E_{d2} = E_{d3} = E_{d4}$
$\lvert E^1_{xy} \rvert > 0$
$E_d > 1$

Results of running model in scenario 1:

Figure 3. Revenue and Profit if E_d=|15|

Table 3. Agent action and Revenue Changing

Characteristics	$\|E_d\|$=15
Agent Action	10
Minimum Revenue	4548060
Maximum Revenue	16424347
Amount of Revenue Changing	11876287
Percentage of Revenue increasing	261%+
Percentage of profit increasing	1.2%+
Revenue Trend	Positive
Profit Trend	Fluctuate

Figures 4 and 5 show the maximum number of actions of the agent in $1<|E_d|<20$ to reach maximum revenue. Each agent action means a 1% discount on the product Therefore, the number of agent actions equal to discount rate.

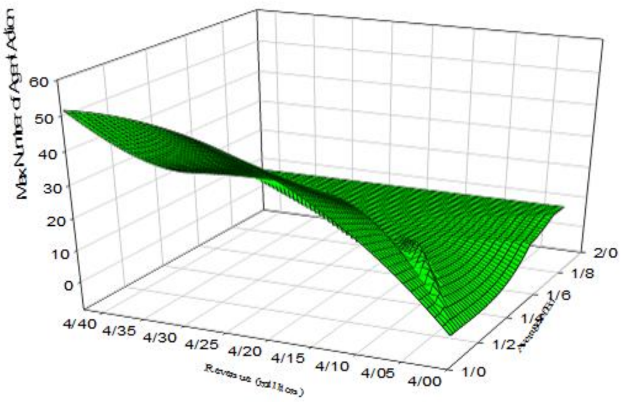

Figure 4. Revenue in max number of agent action when $1<|E_d|<2$

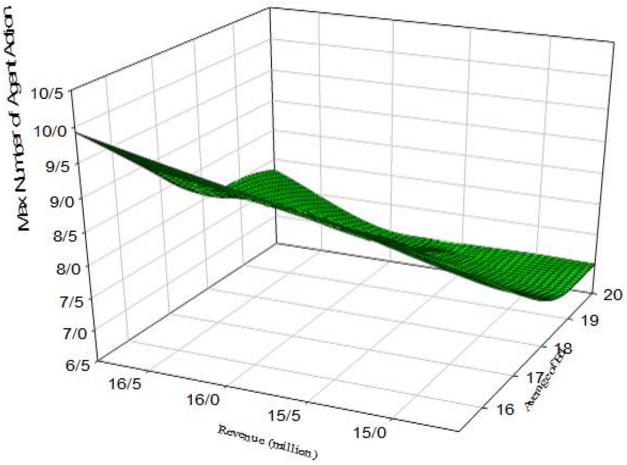

Figure 5. Revenue in max number of agent action when 15<|E_d|<20

Figures 4 and 5 show that discount in the condition which goods have relatively inelastic demand is not a very effective way to increase the revenue and it even reduces the derivative (slope) of the profit curve. The seller calculates the consequence of each state after each action and the agent continues its action even when the revenue has grown gradually, therefore, the price reduction is continued to reach to the boundary of the model. Also the maximum number of agent actions, which means the discount rate, to reach maximum revenue in different value of E_d are shown in Figures 4 and 5. When Ed is close to 1 the agent does only one action but when value of Ed is more than 1.03, the agent continues its action until reaches the margin boundary in 13th action. In the situation that $15<|Ed|<20$, the agent actions stop in step 7, 8, or 9 because it reaches to demand boundary. Table 4 shows the proper discount rate of different products with different values of Ed in the first scenario.

Table 4. Proper discount rate

Different State of scenario 1	Discount of product number 1	Discount of product number 2	Discount of product number 3	Discount of product number 4
|Ed|=1.5	12.5%	12.5%	12.5%	12.5%
|Ed|=7	12.5%	12.5%	12.5%	12.5%
|Ed|=15	10.47%	10.47%	10.47%	10.47%
|Ed|=17.5	8.65%	8.65%	8.65%	8.65%
|Ed|=20	7.73%	7.73%	7.73%	7.73%

4.2. Scenario 2

As shown in Table 5, absolute value of price elasticity of demand in the second scenario is lower than 1.

Table 5. Characteristics of goods in scenario 2

$E_{d1}= E_{d2}= E_{d3}= E_{d4}$
$1>\|E_d\|>0$
$E_{xy}>0$

Results of running model in scenario 2:

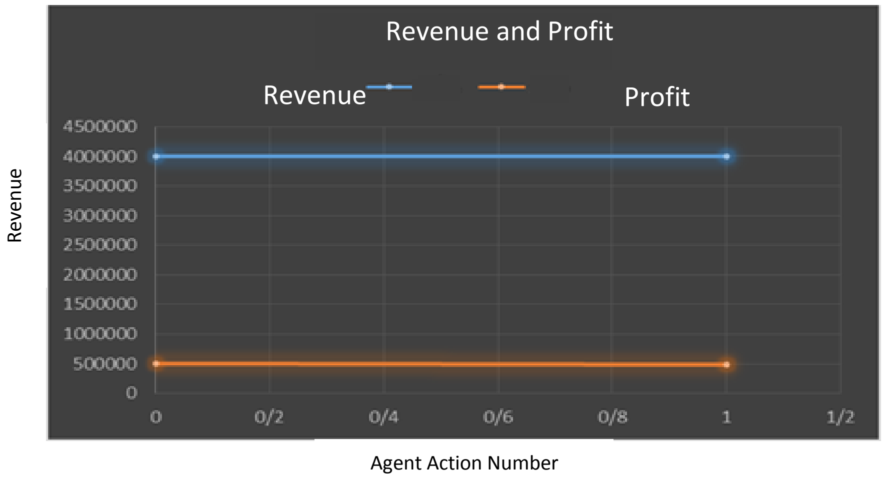

Figure 6. Revenue and Profit if 1>|Ed|>0

Table 5 shows the agent action number and revenue and profit trend in scenario 2.

Table 5. Agent action and Revenue Changing

Characteristics	$\|E_d\|=0.5$
Agent Action	1
Minimum Revenue	3994800
Maximum Revenue	4000000
Amount of Revenue Changing	-5200
Percentage of Revenue increasing	-0.13%
Percentage of profit increasing	-2.2%
Revenue Trend	Negative
Profit Trend	Negative

Figures 7 shows the maximum number of agent actions in 1>|Ed|>0 to achieve maximum revenue.

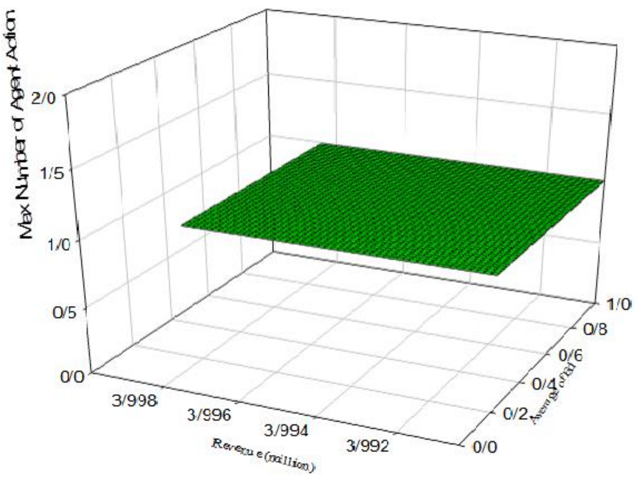

Fig.7 Revenue in max number of agent action when 1>|Ed|>0

Price reduction and its relation to revenue trend is one of the most important challenges in retailing. As shown in Figure 7, the agent in the second scenario does not continue its action after the second one because it cannot achieve better outcomes in future actions. Also Figure 7 has shown that the maximum number of actions of the agent in the second scenario is 1. After the first step the agent stops to decrease the price. Running model in the second scenario shows that price reduction and discounting do not lead to an increase in revenue and profit and it can even have negative influences on them. Table 6 shows the proper discount rate to reach maximum revenue in different absolute values of Ed between 0 and 1 in scenario 2.

Table 6. Proper discount rate

Different State of scenario 2	Discount of product number 1	Discount of product number 2	Discount of product number 3	Discount of product number 4
$\lvert Ed \rvert=0.5$	0%	0%	0%	0%
$0<\lvert Ed \rvert<1$	0%	0%	0%	0%

4.3. Scenario 3

As presented in Table 7, the difference of this scenario with other scenarios is the type of goods which are placed next to each other in the shelf of the retailer.

Table 7. Characteristics of goods in scenario 3

$E_{d1} = E_{d2} > E_{d3} = E_{d4}$
$1 > \lvert E_{3d}, E_{4d} \rvert > 0, \lvert E_{d1} = E_{d2} \rvert > 1$
$E_{xy} > 0$

Results of running model in scenario 3

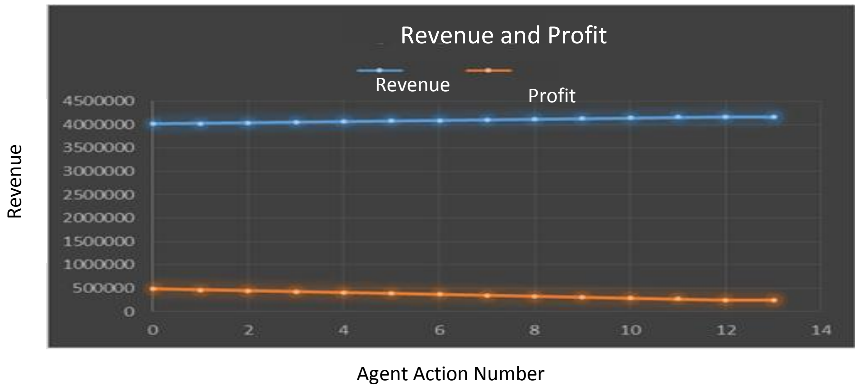

Figure 8. Revenue and profit if $\lvert E_d \rvert$=1.8, 0.8

Table 8. Agent action and revenue changing

Characteristics	$\|E_d\|$=1.8,0.8
Agent Action	13
Minimum Revenue	4025409
Maximum Revenue	4173204
Amount of Revenue Changing	147795
Percentage of Revenue increasing	3.6%+
Percentage of profit increasing	47.6%-
Revenue Trend	Positive
Profit Trend	Negative

Figures 9, and 10 show the maximum action of agent in 1>$|E_{3d}$, $E_{4d}|$ >0, $|E_{d1}= E_{d2}|$>1 to reach maximum revenue.

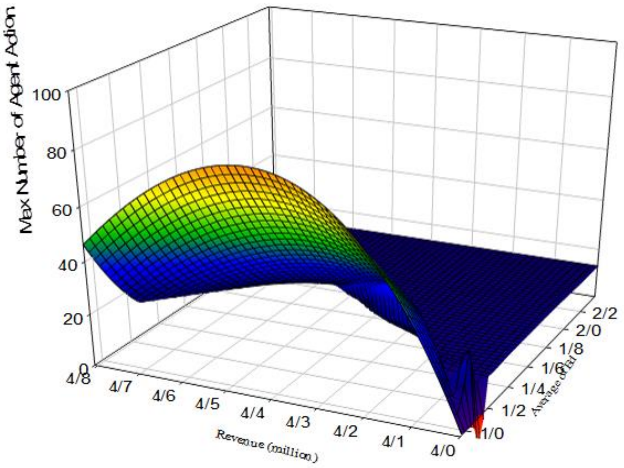

Figure 9. Revenue in max number of agent action when 1<$|E_{d1,2}|$<3, 0<$|E_{d3,4}|$<1

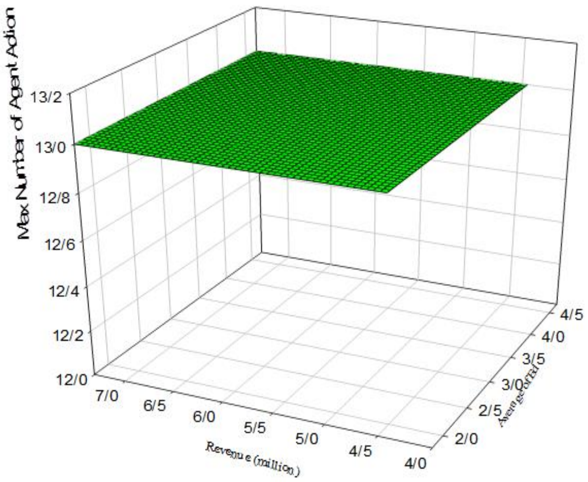

Figure 10. Revenue in max number of agent action when 7<$|E_{d1,2}|$<9, 0<$|E_{d3,4}|$<1

In this scenario, like the first scenario, the agent continues its actions to achieve higher revenue. As shown in Figures 9 and 10, under conditions that price elasticity of demand is growing discount leads to more revenue. Also in higher price elasticity of demand, the derivative (slope) of profit is reduced at a lower rate. In reality, the agent continues its actions until it gets to the boundary of the model. Table 9 shows the proper discount rate for reaching maximum revenue in different absolute values of Ed. In this scenario $|Ed_{1,2}|$ is more than 1 and $|Ed_{3,4}|$ are between 0 and 1.

Table 9. Proper discount rate

Different State of scenario 3	**Discount of product number 1**	**Discount of product number 2**	**Discount of product number 3**	**Discount of product number 4**
$\|E_d\|=1.8,0.8$	12.5%	12.5%	0%	0%
$\|E_d\|=8,0.8$	12.5%	12.5%	0%	0%
$\|E_d\|=14,0.8$	12.5%	12.5%	0%	0%
$1<E_1d,E_2d<1$ $0<E_3d,E_4d<1$	0%	0%	0%	0%
$1<\|E_1d,E_2d\|<3$ $0<\|E_3d,E_4d\|<1$	12.5%	12.5%	0%	0%
$7<\|E_1d,E_2d\|<9$ $0<\|E_3d,E_4d\|<1$	12.5%	12.5%	0%	0%
$13<\|E_1d,E_2d\|<15$ $0<\|E_3d,E_4d\|<1$	12.5%	12.5%	0%	0%

5. Conclusion

Previous research on pricing and finding proper discount rate to increase the revenue in the retailing industry is divided into three categories: first, the research that uses dynamic pricing and tries to achieve an optimal price for different existent goods in the retailing store to offer a solution for high inventory level of perishable products problem. The behavior of the seller and the effect of substitute goods on each other have not been considered in these studies. Second, the research which presents pricing models in retailing using different methods such as games theories, neural network, non-linear programming, and statistical method. None of this research articles uses the agent-based model. Also, the agent's decisional behavior is not considered in these studies. Third, the research which investigates the effects of different relationships between suppliers and retailer on products' price. In these studies pricing is not done based on the relationship between existent goods in the store. The literature review reveals that the seller's decisional behavior when it wants to use price reduction as a tool of revenue management for increasing revenue in different layouts of products has not been investigated in previous research. In this article, the model is presented to examine seller's decisional behavior when changing price to increase revenue. Also, the model can be used to find proper discount rates for products to achieve maximum revenue. The agent-based theory is utilized in this article. The model is implemented and examined in three different scenarios. Scenarios vary based on the price sensitivity level of goods and the level of effects of substituted goods to each other. In the first scenario all products' price elasticity of demand are same and they have relatively elastic demands. In the second scenario, all goods have same price elasticity of demand and have relatively inelastic demands. The third scenario presents the combination of the first and second scenarios which the price elasticity of demand of products are different and goods with elastic and inelastic demands are laid out next to each other. The seller action is offering discount and after each action the consequences which are the new total revenue are calculated and recorded in the database. If the revenue doesn't increase, it stops its action.

The model is implemented to determine the maximum amount of discount rate which the seller can offer to achieve maximum revenue. Python is used for coding. The model was implemented in three different scenarios and different results were achieved.
In the first and third scenarios, reducing the price causes the downward trend in rate of profit even though the discount could increase the revenue. In addition, the number of agent's actions based on the amount of each elasticity in the first and third scenarios are different. The rate of discount on the product and final price in each scenario is different due to the number of each agent actions. In the second scenario, the agent shows a completely different behavior which does not result in an increase in the revenue by offering the discount.
In order to measure the validity of the agent-based models, different approaches can be utilized. One of the most common approaches is testing the boundary conditions. In this model profit margin is assumed to be 12.5 percent. Discount rates in the range of 0 to 12.5 percent must be offered. If the discount is higher than 12.5 percent, the model will stop. In fact, the agent doesn't take any action and always keeps the previous price. This indicates that the model operates correctly in the price margin boundary points. Another method used to test the validity of the model is the reproduction of the behavior. In this model, the type of the behavior resulted from the action of the agent in model is somehow similar to the behavior in reality after the behavior of the agent is investigate and compared to the behavior is taken place in reality. This indicates the model validity.
The research outcomes show the difference of discount effects on revenue growth in different layouts of products in retail industry. Also the research indicates the proper rate of discount on different products to achieve maximum revenue in retail industry.

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