MODELLING ADVERTISING AND PRODUCTION STRATEGIES USING CELLULAR AUTOMATA

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Abstract

In this paper we describe a simulation approach to explore different advertising strategies in a heterogeneous consumer market. The main focus is to model the dynamic of two competing advertising channels and their dynamic advertising effects. Here one advertising channel effects all consumers at the same time representing traditional large-area advertising instruments like broadcasting or print media, and the second represents the dispersion of post-purchase information in the customers' social circle - called word-of-mouth advertising. Here a model of an artificial consumer market has been used to provide an experimental environment for the simulation and optimization task - modelling typical stylized facts of software business. So the stylized facts are modeled using a hybrid approach of combining a continuous process described by an ordinary differential equation linked with discrete update processes of cellular automata. The stability of the model is shown by comparing a homogeneous and a heterogenous market scenario. Additionally the amount of exaggeration of the product features has been varied to figure out the influence of the resulting dissatisfaction to sales and profit of the companies. This fact is related to product development decisions and production processes. It is shown that some exaggeration generates a higher outcome, but due to the word-of-mouth effects too much exaggeration destroys the market at all.

Keywords: Artificial consumer market, Cellular Automata, Advertising strategies

Presenting Author's Biography

Jürgen Wöckl studied "Physics and Economics" and received a doctoral degree in mathematics at the Technical University of Vienna (Institute of Analysis and Scientific Computing, Prof. Breitenecker). Since his participation in a research program at the University of Economics called "Adaptive Information Systems and Modelling in Economics and Management" and funded by the Austrian Science Foundation (FWF) - his interests are focused on mathematical modelling and simulation in economics. Since 2006 he is assistant professor at the Vienna University of Economics and Business Administration (Institute for Production Management, Prof. Taudes).

1 Introduction

Considering different businesses there is wide range of marketing strategies the companies can focus on - related to the products and the structure of their business. In some businesses the products and their features are in the center of the consumers interest and the advertising claim is geared to the attributes forming a preferably attractive USP. Other products are mainly driven by pure advertising as the features of the product are hardly accessible and appraisable. Depending to the business and the product category the post-purchase satisfaction of the consumers depends either on the product image driven by pure advertising or purely on the mensureable product features or on both. So in many businesses the post-purchase satisfaction of the consumer is highly related to the gap between the pre-purchase advertising claim - which triggered the purchase - and the first-hand evaluation of the product features after the purchase. Here a big gap and the resulting high level of dissatisfaction additionally triggers a propagation of the gap under the circle of friends. Generally the aim of the companies is to optimize this gap due to advertising should trigger the purchase even if the product doesn't exactly achieve the needs of the consumer but should avoid dissatisfaction due to the resulting negative recommendations.
Picking one business highly related to the focused gap between advertising claim and product features this study refers to the software business. The software business is very complex and not like other businesses. There are many examples of how software companies differ from traditional manufacturing and service industries. To cite some examples, in software business the production cost of one copy or one thousand copies are about the same, the gross profit margins for the products are up to 99 percent and the company structure reaches from production companies over hybrid to pure service companies ([3]). Also software products are mostly very complex with a high-dimensional attribute space and therefore hard to evaluate for the customer. Even the needs of the customers are unclear and usual fuzzy. So the needs of the consumers are highly driven by advertising influenced by the expectancies of the customers' social circle and their post-purchase evaluation of the software product. All this qualities of software leads to some main strategies used in software business, namely bundling, heavy marketing, using locking and network effect. The strategy of bundling extracts substantially higher profits by offering bundles of information goods than by offering the same goods separately. In the literature many papers quoting criteria for the optimal design and pricing of bundles can be found (see e.g. [1]). The properties and attributes of software products are not easily ascertainable and appraisable by the user and even the need of some features of the software are quite ambiguous. Therefore a heavy marketing campaign is necessary to boost the consumers product awareness and to stimulate the demand. A relevant quality of software products is the so called locking effect. A costumer buying a specific software product spends some time and money for training and to get the necessary operating experience. Therefore the consumer is locked to this software for some time, thus a chance costs many resources. So software companies are impelled to sell as much licenses as possible - on the on hand to gain directly by the sales revenues and on the other hand by a strong binding of the consumer to their product for a longer time - frequently over several release cycles of the product. Additionally the network effect supports this strategy since software products provide a strong economy of scale. The more consumers are using a software, the more valueable it is for a costumer. This is supported by faster release cycles driven by the requirements of the use community and by the higher revenues of the software company enabling faster development processes ([4], [8], [3]).All these effects cause the seduction to overstate the products' features in the advertising claim - to call the widespread exaggeration of software companies - to make the consumers buying their products. Additionally to the advertising claim which is important to drive the economy of scale effects, the word-of-mouth communication between the consumers is crucial. The companies' task is the fine tuning of the advertising strategy driving the demand using sugarcoated advertising claims but paying attention not to initiate negative word-of-mouth effects.

This study models this advertising-driven market added by local word-of-mouth communication to exchange post-purchase experience among the costumers. So it deals with a fusion of two methodological approaches used to describe two main effects of advertising impact - the effect of large-area advertising instruments modeled using ordinary differential equations (ODEs) and the effect of post-purchase word-of-mouth effects modeled using cellular automata (CA). The ideas of the artificial consumer market ([2], [7]) have been adopted to this issue. In the next section, first the ideas and concepts of the original ACM and later on the model adoptions to enable the fusion of the ODE and the CA approach will be presented.

2 Modeling the Artificial Consumer Market

Structurally the artificial consumer market is made up of a constant number of consumers represented by the cells of a cellular automata. The position of the cells in the population lattice of the cellular automata represents a local position of the consumer. Additionally to the local position each consumer has a set of internal states. Especially each consumer has an individual aspiration point of attributes which the preferred product should possess. Generally different sized segments can be assumed each representing a group of consumers with similar aspiration points and different products are established in the market competing for a market share in this artificial market. In this environment it's assumed that each firm just provides one product and therefore the profit of the firm equals the price times sales of its product reduced by the budget spent for advertising. This assumption can be made without any limitation to

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the model as firms providing two products can be handled as two separated firms but finally aggregating their profit.

The choice process of a artificial consumer depends on the consumer's knowledge about the products offered at the market and the attitude he gained by comparing his aspiration point to the perceived attributes of the products - induced by their advertising claims. Additionally the variables price and budget are influencing the evolvement of the attitude of a consumer regarding to a product (see equ. 1). Initially ($t_0 = 0$) no consumer knows anything about the products and the firms on the market, and their choices cannot be made rationally - in the sense of choosing a product best fullfilling their aspirations. Primary through the advertising the consumers get information about the products and their attributes and so they are able to choose the best fitting product. This evolvement of the attitude is formulated with an ODE (equ. 1). After the purchase of the supposed best fitting product the consumer gains additional information about the gap between his pre-purchase brand knowledge induced just by advertising and his own post-purchase satisfaction. Additionally in each periode each consumer gets post-purchase information of his neighbors - even about products not bought by himself - and provides his own post-purchase information to his next neighbors - (word-of-mouth advertising). This word-of-mouth process is modeled using a BGK-LBM cellular automata (Bhatnagar, Gross, Krook - Lattice Boltzmann Model). So each consumer forms his own brand information based on continuous advertising and its own purchase experiences. The success of each firm/product depends on the price, the real and advertised attributes and the advertising budget invested. Generally these variables has to be optimized by all firms in the market.

In the following the functionality and the associated model equations used in this study merging the traditional ACM with the cellular automata approach is presented, short ACM-CA. The advertising impact of wide-area advertising is modeled using differential equations as mentioned above - and the local effects of post-purchase word-of-mouth effects are described by the cellular automata. Due to the CA automata is a discrete system with a discrete state space of quantities and time and the ODEs represent a continuous system, the resulting model has to deal with the resulting hybrid system.

3 Definition of the continuous system using ODEs

Following the continuous ACM ([7],[9]) the differential equation modelling the evolvement of the attitudes att_{ijk} of a consumer i regarding to the attribute k of product j is defined as:

$$\frac{d\,att_{ijk}(t)}{dt} = \frac{claim_{jk}}{\lambda_i\ price_j^*}\left[aif(budget_j)\,(1 - att_{ijk}(t))\right] \tag{1}$$

In this equation $claim_{jk}$ indicates the advertising claim for wide-area advertising communicated by the firms j regarding the attributes k of their product and the parameter λ_i describes the price sensibility of the consumer i. Additionally $aif(budget_j)$ indicates the advertising impact function depending to the advertising budget of product j, $price_j^*$ refer the relative price of product j and the utilities uti_{ij} are measured by the weighted Euclidean distance between the consumers' attitude and aspiration point:

$$aif(budget_j) = e^{\alpha - \frac{\beta}{budget_j}}$$

$$price_j^* = \frac{price_j}{\frac{1}{J}\sum_{j=1}^{J}(price_j)}$$

$$uti_{ij} = \frac{max(distance_{ij})}{distance_{ij}}.$$

4 Design of the Cellular Automata

The design of the cellular automata environment is done object-oriented and has been implemented in Python. The lattice has a dimension of 40x50 cells and the neighborhood of the cells has been defined as 'hexagonal', which provides stable solutions. In each generation of the CA the differential equation is solved numerically updating the attitude of the consumer evolving by the impact of the wide-area advertising. The update rule of the CA describes the information flow between consumers sharing their post-purchase satisfaction. At each discrete update-periode of the CA each consumer chooses the best-fitting product, which enables a correction of his pre-purchase attitude by comparing it with the perceived real attributes/features f_{ijk} by:

$$\Delta att_{ijk} = att_{ijk}^{t+1} - att_{ijk}^{t} = \frac{f_{ijk} - att_{ijk}^{t}}{2}$$

$$\Rightarrow att_{ijk}^{t+1} = \frac{f_{ijk} + att_{ijk}^{t}}{2}.$$

The firms' target is to optimize their profit, especially the strategic decision between promoting real features or using claims optimized to the segments.

5 Design of the study

The experimental setting assumes different levels of overstating the product features - or three levels of exaggeration and compares a homogeneous and a heterogenous market setting. The lattice of the CA defines the entire market and each cell represents an individual consumer i. Concerning the need for a manageable and

significant experimental design in this study just one firm/product has been assumed to exist in the market and just one dimension of the k-dim. attribute/feature space has been observed. The consumers' attitude evolvement in time is described by the ordinary differential equation (ODE) solved in each generation of the cellular automata. Initially the price of the product is set constant for the hole market and therefore without loss of generality it has been assumed as 1 ($price_1 = 1$). The following parameters are set as follows: budget ($budget_1 = 1000$), level of the aspirations ($asp_{i1} = 1$), claim for the observed attribute ($claim_{11} = 1$) and real feature ($f_{i11} = 1$). To set different levels of exaggeration the advertising claim has been varied between 0.8 and 2.2 - means from a understatement to a exaggeration concerning the product feature.

A distribution of the aspiration patterns of the consumers have been assumed to generate a heterogeneous initial setting consumer market. In detail this stylized fact has been modeled by splitting up the market into two segments with different price sensibilities. Additionally this study distinguish two cases - first a homogeneous case where all consumer of a specific segment have the same price sensibility and therefore the segment are well separated - and second a heterogeneous case where the price sensibility of the consumers in each segment is normal distributed to adjust a segment overlapping.

In detail the parameter λ_i of the consumer has set to one for the first segment ($\lambda_i = 1$), but with the probability of $p = 0.03$ the consumer is assumed to be less price sensible and so a member of the second segment ($\lambda_i = 0.5$). So 3% of the population are assumed to be 'early adopters' willing to pay double of the price of the common consumer. This assumptions and the resulting random initial state of the aspiration patterns cause a stochastic component in the model influencing the evolvement of the attitude of a specific consumer. In the homogeneous case all consumer of the first segment have a common price sensibility as mentioned just before, in the heterogeneous case the price sensibilities of each segment are assumed as normal distributed with a variance of 0.05 - so $N(1, 0.05)$ for the main segment and $N(0.5, 0.05)$ for the segment of 'early adopters'. The comparison between the homogeneous and the heterogenous case shows the stability of the model and makes the resulting stylized facts comprehensible. Further it has been assumed that each consumer may buy one product in each periode, but there is no force - the consumer can decide to buy or not to buy. The choice process is modeled using a threshold function. If the attitude reaches a certain level of the aspiration level ξ, the consumer decides to buy the product. The choice process is modeled as:

$$\textit{choose product j, if } att_{ijk} \xi\ asp_{ik}$$

which means that in this setting the consumer buy if their attitude cross the threshold of $\xi = 0.8$ (because of the assumption $asp_{i1} = 1$). Finally, the initial conditions, the choice rules and the resulting different evolvement speed of the two costumer groups regarding the different price sensibility (λ_i) cause the 'early adopters' to buy the products earlier than the common consumer. The consumer which buy the product are able to obtain an individual evaluation comparing the advertised attributes with the real product features. Here it is assumed that the advertising has been exaggerated and that the consumers are dissatisfied ($f_{i11} = 1 \ > att_{i11}$). The update rules of the cellular automata generate a local dispersion of the post-purchase experience among the neighborhood communicating the dissatisfaction and lowering the attitudes of the adjacent consumers.

6 Results

In this section the results are presented demonstrating the designated stylized facts. Especially some plots of the states of the cellular automata and the evolvement of the attitudes are provided to give some insights in the dynamics of the model. As mentioned above some consumer are less price sensible than the others and so their attitude rises faster. This triggers an early choice decision. This first purchaser are also called 'early adopters'. Due to the features of the products are not fulfilling the consumers' aspirations the dissatisfaction rises after the purchase. The word-of-mouth advertising modeled by the cellular automata communicates the post-purchase experience to the neighbors also lowering their attitudes regarding the product.

The following figures show the states of the cellular automata and the attitudes for the homogeneous case (figure 1) and the heterogeneous case (figure 2) after 100 and 150 calculated generations. The evolvement and the dynamic of the model can be seen. The attitudes rise depending the price sensibility. Due to the model settings just assuming two different sensibility levels, there are just two attitude states. The 'early adopters' are dissatisfied after their first purchase and communicate the dissatisfaction to their neighborhood. The cell states of the cellular automata show the dispersion of the dissatisfaction to the adjacent costumers lowering their advertising driven attitudes.

The results show the interaction of the two advertising strategies. The formation of local areas of dissatisfaction triggered by the word-of-mouth communication among the consumer can be seen clearly. The word-of-mouth process has also a relevant impact in the case of software business - triggering the disposition to buy among the consumer in their social circle. Figure (3 - left) shows the evolvement of the decision process of time. In the homogeneous case all the 'early adopters' purchase in the same time periode, even when their common attitude rises the threshold (ξ). In the heterogeneous case the choices of the 'early adopters' segment are distributed over time. Comparing the homogeneous and the heterogeneous case the stylized facts

are related. The Figure (3 - right) shows the result of the optimization task. It shows that the optimal advertising claim is at 1.3 - thus higher than the true feature value. This implies that here an overstated advertising claim (=exaggeration) generates more choices and therefore more profit than telling the true. But there is a limit as exaggerating too much results in no choices at all. Especially if the dissatisfaction among the 'early adopters' caused by the exaggerating is too high, the early nevertheless start buying in early periods, but the high degree of dissatisfaction brandy by the word-of-mouth process, blocks all future choices of the entire market. This result can also be found in real markets of software business. The optimal choice of the marketing claim is important in such markets driven by advertising. Especially if the product attributes are not easily appraisable by the costumer, the advertising claim is the first trigger of choice and thus important for the marketing strategy of such products. Therefore an exaggeration in advertising gains more sales and more profit - but the word-of-mouth process among the costumers is a dangerous limitation - able to destroy the hole reputation of the software product.

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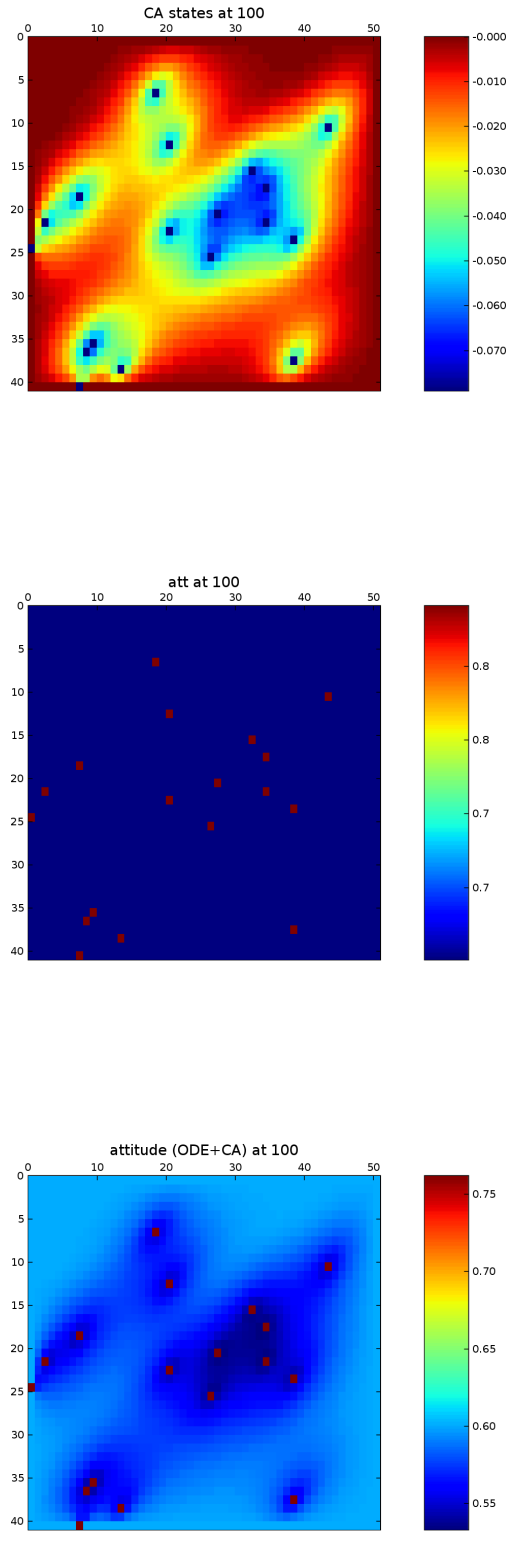

Fig. 1 Advertising driven attitudes, CA states and total attitudes at time 100 and 150 (homogeneous case)

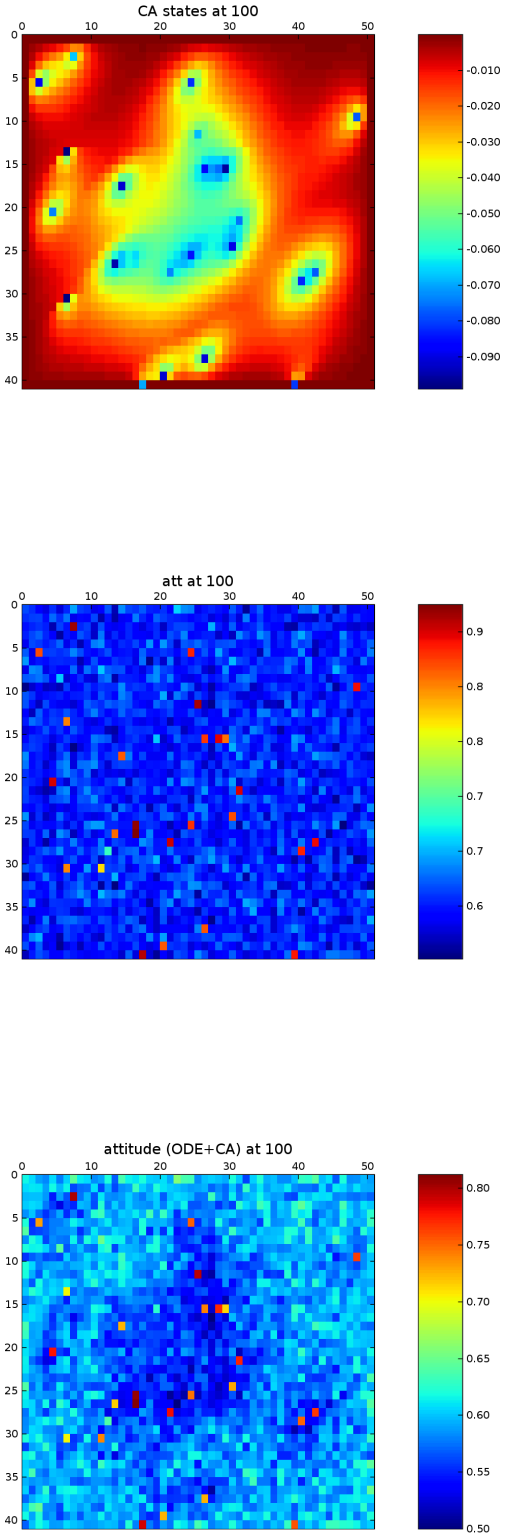

Fig. 2 Advertising driven attitudes, CA states and total attitudes at time 100 and 150 (heterogeneous case)

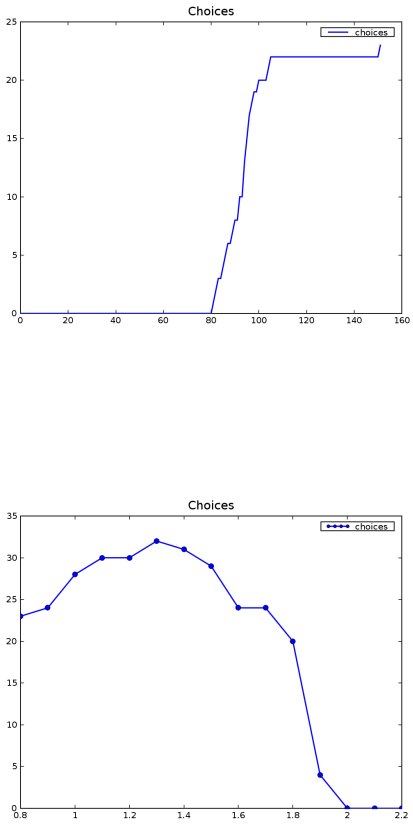

Fig. 3 Evolvement of the choice process of the heterogeneous consumer market (left) and the objective function of the optimization of exaggeration (varying the advertising claim from 0.8 to 2.2; choices at time 150) (right)

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