Integration of the Decoy Effect in an Agent-Based-Model Simulation of Insurance Consumer Behavior

Aurelija Ulbinaitė [1+], Marija Kučinskienė [1] and Yannick Le Moullec [2]

[1] Business Department, Vilnius University, Lithuania

[2] Technology Platforms Section, Department of Electronic Systems, Aalborg University, Denmark

Abstract. The need for increased competitiveness in marketing calls for new analysis and decision methods and tools. This paper describes an agent-based-model simulation of the decoy effect for studying consumer behaviour towards insurance service products. We propose a model that takes both the price-quality tradeoffs of the insurance services (including the decoy) and the influence of the social network of the consumers. The model is integrated in our existing agent-based-model framework for the study of insurance consumer behaviour. Experimental results show that the proposed model and its implementation constitute a first step for simulating the decoy effect and for identifying the best price-quality trade-off of the decoy when promoting insurance services against each other.

Keywords: consumer behaviour, agent-based-model, decoy effect, insurance services, competitiveness

1. Introduction

1.1. Agent-Based-Modelling for insurance consumer behavior

As in many financial sectors, the insurance industry is faced with increasing internationalisation and globalisation, and thus with increased competition. Moreover, phenomena such as the ageing population or the tremendous opportunities in emerging markets in developing countries (e.g., Brazil, Russia, India, China, and Asia in general) further complicate insurance entrepreneurship. This makes that insurance companies face major challenges and have to continuously innovate, i.e., i) invent and provide new products and services that match the evolving demands of their customers and ii) improve their competitiveness by means of advanced marketing strategies and techniques, efficient distribution channels, heterogeneous alliances (e.g., the Bank Insurance Model, a.k.a. Bancassurance), etc.

This means that insurance companies need to understand, among other things, the salient relations of their customers to insurance services, i.e., how they perceive threats and risks, the need for financial and psychological security, and how they compare and evaluate alternatives, and decide to (or not to) purchase insurance service products. This type of knowledge is not trivial to obtain and requires detailed and thorough analysis of information about consumer awareness, attitude, expectations, i.e., consumer behaviour with respect to insurance services. The modelling, analysis, exploration, and prediction of consumer behaviour can advantageously rely on and benefit from contemporary financial computing which is a technological enabler that makes it possible to develop advanced methods and supporting software tools that can help the insurance sector. A specific financial computing approach that builds upon Agent-Based Modelling (ABM) is Agent-Based-Model Simulation (ABMS).

The literature contains several examples of successful application of ABMS to various economic and financial applications [1], including consumer behaviour modelling [2][3]. In previous work [4], we have proposed a framework which applies ABM to consumer purchase decision making with respect to insurance

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[+] Corresponding author. Tel.: +370 5 2366152; fax: +370 5 2366127
  E-mail address: aurelija.ulbinaite@ef.stud.vu.lt

services. In that framework, population members are modelled by acting agents who mimic potential and already existing insurance service users. Agent-based consumers are characterised by their socio-demographic features that include overall experience, education, family nest status, purchasing power, and owned property. The agent-based consumers interact with each other by means of social networks and they evolve in an environment where they get influenced by factors such as mortality rate, diseases and other accidents as well as their own and surrounding insurance culture. In turn, the agent-based consumers shape their motivations towards insurance products, i.e., they accumulate experience, improve their understanding and knowledge of such products, and over time their perception of the need for security evolves and so does their consideration of the usefulness of insurance services. All this leads to the purchase decision-making and subsequent actions (evaluation and possible renewal of insurance alternatives). In this paper, we augment our existing framework with an extension for modelling and simulating the so-called decoy effect in the context of insurance consumer behaviour.

1.2. The decoy effect

Generally speaking, the decoy effect, also known as the asymmetric dominance effect, occurs when "an asymmetrically dominated alternative is dominated by one item in the set but not by another. Adding such an alternative to a choice set can increase the probability of choosing the item that dominates it" [5]. From a consumer behaviour point of view, this means that when faced with one product entirely dominated by another one and partially dominated by yet another one, the percentage of consumers inclined towards the entirely dominating product will increase. In practice, the asymmetrically dominated option can be used as a decoy with the purpose of increasing the sales of one of the two other options. It has been shown that the decoy effect can have a significant impact on consumer purchase decision [6]. ABMS that takes the decoy effect on consumer behaviour into account has been investigated in e.g., [7]; however, and to the best of our knowledge, there is no published work that considers the specific relation between the decoy effect and insurance consumer behaviour. The contributions presented in what follows are i) an insurance consumer behaviour model that includes the decoy effect and ii) an extension to our existing simulation framework that enables its simulation and evaluation.

2. Proposed Model

In this section, we briefly present the essential points of our existing framework and then detail the model underlying the decoy effect extension. As can be seen in Figure 1, the insurance purchase decision is influenced by two groups of factors: perception of need for insurance and perception of affordability. The first group is composed of parameters such as insurance culture, influence of network, social status, perception of need for security, etc. The second group is composed of the purchasing power (income, expenditures). The model includes a feedback loop so as to reflect the impact of the consumer's experience with the service on his future decisions. The entire list of parameters and their respective weighting factors can be found in [4]. The model that we use for the decoy effect is inspired by that of [7] and is specifically adapted to insurance services and our existing framework. In our model, all insurance service alternatives (including the decoy one) are characterized by two parameters: price and quality. We define price as the combined price paid for i) the service premium and ii) the related deductible (excess) share. We define quality as the number of insurable risks and the expectable amount of their respective financial compensation. Price and quality examples can be found in Section 4.

In our model, the effect of the decoy depends on two factors. The first factor is the respective price-quality ratios of the services (A, B) and of the decoy (D). Assuming that the difference between A and B in terms of price-quality ratio is relatively small, consumers will tend to prefer the service of which the price-quality ratio is closest to that of the average ratio of all products. By choosing the right price-quality ratio of the decoy, it is possible for the marketer to make that the average of A, B, and D is closer to either A or B (see Figure 2), and therefore increase the sales of a specific service. Note that here price and quality values are normalized to their respective maxima. The second factor is related to the social network of the consumers. As suggested in [7], the sociological interactions among consumers account for a significant part of the decoy effect. In our model, we separate its impacts in two: impact on the decision to buy an insurance

service in general, and impact on the decision to select and purchase a specific service. It is the latter which is considered for the decoy effect. Figure 1 shows how these two factors are added to our existing framework; the specific insurance service purchase decision is summarized by Equations 1 to 3.

$$\text{Distance A to Average} = \sqrt{|Price'A - Average'\,Price|^2 + |Quality'\,A - Average'\,Quality|^2} \quad (1)$$

$$\text{Distance B to Average} = \sqrt{|Price'B - Average'\,Price|^2 + |Quality'\,B - Average'\,Quality|^2} \quad (2)$$

$$if \left(\begin{array}{c} (Distance\ B\ to\ Average\ <\ Distance\ A\ to\ Average) \\ and\ (NbNeighbors\ >\ NbNeighborsThreshold) \end{array} \right), \quad (3) \\ then\ select\ B, else\ select\ A$$

where Price'A/B and Average' Price are the normalized prices of A/B and normalized average price over A, B, D, respectively and where Quality'A/B and Average' Quality are the normalized qualities of A/B and normalized average quality over A, B, D, respectively.
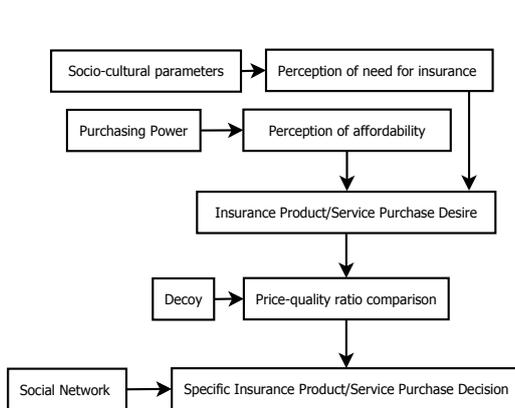

Figure 1. Proposed model of insurance consumer behavior including the decoy effect. The five uppermost boxes are detailed in [4]. The four lower ones are modeling the decoy extension: the effect of the decoy depends on both the price-quality trade-offs of the decoy and service alternatives as well as on the influence of the social network of consumers.
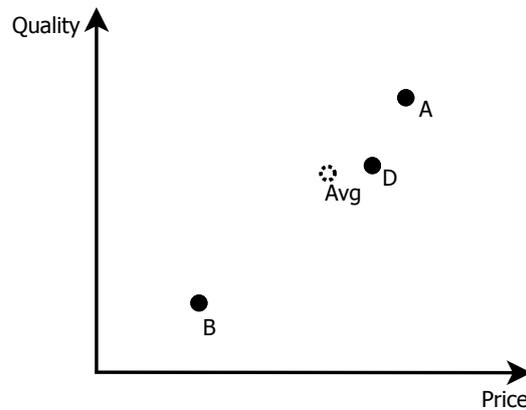

Figure 2. Choosing the right price-quality ratio of the decoy D makes it possible to get the average AVG closer to either

The proposed extension has been implemented in our existing framework [4], programmed with NetLogo [8]. With the initial version of the framework it is possible to calculate how and to which extent certain behavioural changes can affect the consumers' average insurance service purchasing decision. Since our framework has been designed in a modular and flexible way, adding the decoy effect extension is quite straightforward. Thus, the updated framework can now be used to explore and evaluate the effect of decoys on consumers insurance purchasing decisions. Figure 3 shows a simplified Unified Modeling Language (UML) representation of the implementation. Here agents (turtles in Netlogo) represent the Consumers which are part of the overall Population. The population is divided in four classes, implemented by means of breeds: Poors, MiddleClassLowers, MiddleClassUppers, and Riches. The socio-cultural and purchasing power factors (detailed in [4]) are parameterised and implemented in Population and Consumers. The decoy model presented in Section 2 is added to the behaviour of the agents representing the consumers, in the CalculateDecisionToBuy procedure. The price-quality trade-offs for services A, B, and for the decoy are calculated as indicated in Equations 1 and 2. The size of the social network of a consumer depends on the number of neighbours present in the adjacent cells (patches in Netlogo); this is implemented by means of the count turtles in-radius command. The price and quality of services A, B, and of the decoy are also parameterised and inherited from Services, part of the Pool of Services. A screenshot of the Graphical User Interface (GUI) of the implementation can be seen in Figure 4. The GUI enables the user to vary the values of all parameters, either before starting a simulation or on the fly. The parameters related to the decoy effect extension are i) the price and quality of services A, B, and of the decoy and ii) the radius in which neighbours are counted and the corresponding threshold value. In order to run series of experiments and to

have better control over the parameter variations, we use the Behavior Space tool of Netlogo to automate the simulation and reporting processes, as in the example presented in the next section.

4. Experimental Results

In order to experiment with the proposed model, we have used data from a real-life case, namely those of the insurance options proposed by a country-specific branch of a major car rental company (of which the name is not given here for neutrality purpose). As can been seen in Table I, the company proposes two options, Collision Damage Waiver and Super Collision Damage Waiver, which are used as services B and A in our model, respectively. The price-quality trade-off of each option depends on the ratio between the premium paid for the service and the deductible (excess) paid in case the service is actually used. In this example, the price parameter for each service is defined as the premium paid for each option. Defining the quality parameter is less straightforward and could be manifold as it depends on the coverage amounts and conditions of each service; however, for illustration purpose we define quality as the average value of the vehicles of each category minus the deductible (excess). The corresponding price-quality trade-offs (and their normalized values) are shown in Table II.
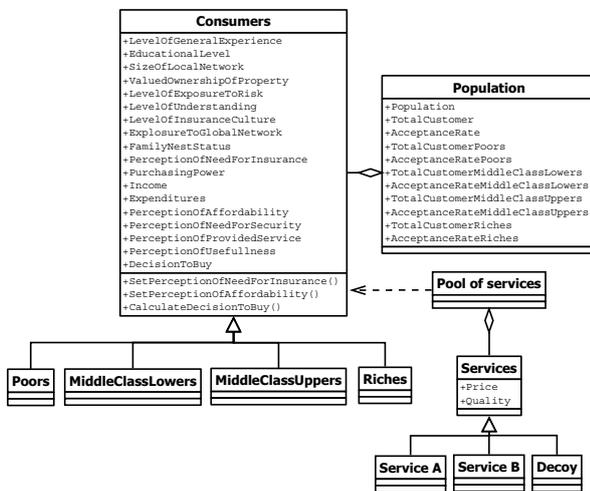

Figure 3. Simplified UML representation of the implementation. The decoy effect model is added to the *CalculateDecisionToBuy* procedure.
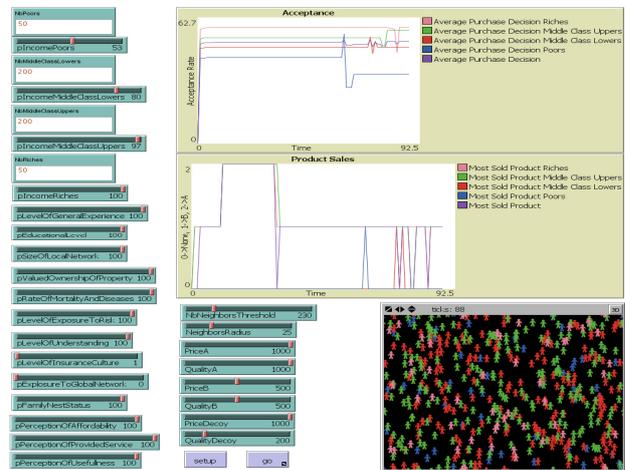

Figure 4. Screenshot of the GUI of the implementation. The individual parameters can be changed manually on the fly for direct observation of their impact, or through the *Behavior Space* tool of Netlogo for automated, thorough experiments.

Table I. Premiums and deductibles of two insurance options for several vehicle categories

Insurance options	Premium and Deductible (units)	Vehicle category		
		A-F	G-L, N	M, O
Collision Damage Waiver	Premium (Euros/day)	15	19	22
	Deductible/ Excess (Euros)	1000	1500	2000
Super Collision Damage Waiver	Premium (Euros/day)	21.5	26.5	31.5
	Deductible/ Excess (Euros)	0	0	600

Table II. Price-quality trade-offs of the two insurance options listed in Table I

Insurance options	Price-Quality trade-off	Vehicle category		
		A-F	G-L, N	M,O
Collision Damage Waiver (service B)	Price	15	19	22
	Normalized price (%)	47.6	60.3	69.8
	Quality	11000	16500	23000
	Normalized quality (%)	45	67.6	94.2
Super Collision Damage Waiver (service A)	Price	21.5	26.5	31.5
	Normalized price (%)	68.2	84.1	100
	Quality	12000	18000	24400
	Normalized quality (%)	49.1	73.7	100

In what follows we present the results of two experiments. The purpose of the first experiment is to evaluate how the introduction of a decoy service impacts the insurance purchase decision of the consumers. The population is composed of four categories, Poors (50 individuals), MiddleClassLowers (200 individuals), MiddleClassUppers (200 individuals), Riches (50 individuals). As our goal is to observe the effect of the decoy effect only, we start by varying the price and quality of the decoy (0 to 100, step=1); all the other parameters are fixed and set to 100% (except network threshold, set to 0%): all consumers behave equally. As they all have maximum income and since the threshold is set to 0, we make sure that they will buy an insurance service; thus the experiment shows which service they will buy depending on the price-quality of the decoy only. In the second experiment we also modify the value of certain socio-cultural parameters to evaluate their impact on the decoy effect. In particular we vary the radius and threshold of the social network and we set different income levels for the four consumer categories: price and quality of the decoy (0 to 100, step=1), radius (1 to 6, step=1), Poors (70%), MiddleClassLowers (80%), MiddleClassUppers (90%), Riches (100%). The results of the first and the second experiments are shown in Figures 5 and 6, respectively, and discussed in what follows.

The results of the first experience illustrate the basic effect of modifying the price-quality trade-off of the decoy; the Pareto-like points show the price-quality combinations that should not be exceeded in order to promote Service B (CDW) or that should be exceeded to promote Service A. The extreme (price, quality) cases are (67,1) and (47,100), or after de-normalising the values, (21.1 euros/day, 244 euros) and (14.8 euros/day, 24400 euros), respectively. In the second experiment, not all consumers behave equally. They do not all buy the same product (shown by the varying size of the points in Figure 6); moreover, the individual insurance purchase preference is not only influenced by the price-quality trade-off of the decoy but also by the density of the social network of the consumers. As can be observed, gradually increasing the radius, i.e., the social interactions among consumers, makes that they tend to buy service A (SCDW) more often when the price-quality trade-off of the decoy is high; this is especially visible when the radius is equal to or larger than four.

All simulations have been carried out with a standard PC with a 2.8 GHz microprocessor and 4 GB RAM. The first experiment took ca. 3 minutes with 1 thread and ca. 0.75 minute with 8 threads. The second one took ca. 20 and 4 minutes, respectively. Memory usage peaked at 580 MB. This shows that the computational requirement for the framework is moderate and that it can benefit, to a certain extent, from a parallel processing architecture and the threaded execution supported by Netlogo's Behavior Space.
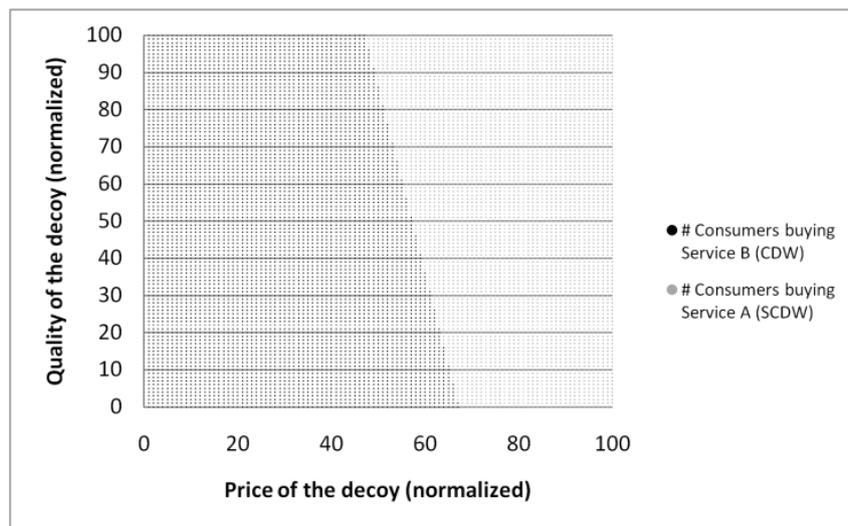

Figure 5. Number of consumers buying service B (CDW) and service A (SCDW) as a function of the price and quality of the decoy. In this experiment, all consumers are set equal and thus behave equally, as denoted by the constant size of the points.
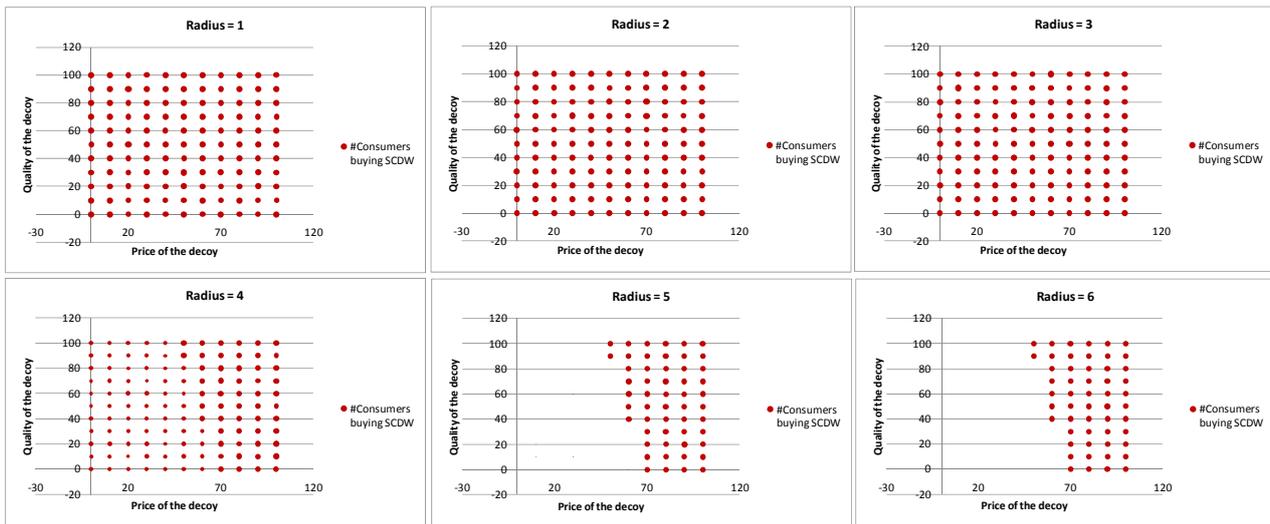
Figure 6. Number of consumers buying service A (SCDW) as a function of the price and quality of the decoy for several network radius. Increasing the radius makes that consumers tend to buy this service more often when the price-quality trade-off of the decoy is high.

5. Concluding Remarks

The competitiveness of the financial industry, including that of the insurance sector, increasingly relies on financial computing. Our overall research effort is concerned with ABM for simulating, analysing and understanding consumer behaviour with respect to insurance services. In this paper we have presented an extension to our existing framework for the exploration and evaluation of the decoy effect on consumers who consider the purchase of insurance services. Experimental results show that the proposed model and its implementation can support such activities. Using real-life data we have illustrated how the effect of the price-quality trade-off of the decoy and that of the density of the social network of the consumers influence their behaviour. The results have also shown that the computational requirements are quite reasonable for a moderate-size problem. Future work includes refining the current model of the decoy effect; for example, it would be valuable to calibrate and compare several models for a large set of cases so as to construct a more universal and robust solution by fine-tuning the individual parameters of the model.

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