A business simulation game with an agent-based deliberative model of consumer behaviour

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Abstract. We present an agent-based business simulation game where the marketplace is simulated as an evolving system of autonomous interacting deliberative agents acting as utility maximizers. Consumers are explicitly modelled as deliberative agents with concrete beliefs, intentions and desires who act to accomplish their purchase plans. Simple codification rules at the level of the utility functions of the agents allow the emergence of complex behaviour which illustrate fundamental concepts from economics such as the law of demand, diminishing returns, effects of price and income changes and substitution and complementary effects. The game was tested experimentally, with our results proving to be encouraging, with the majority of the participants considering they were able to understand the results of the simulation. The high levels of agreement on this subject were closely related to the high degree of information provided by the agent-based model of consumer behaviour which allowed the disclosure of information, both at the micro and macro levels of complexity, without however, hindering the strategic value of the game.

Keywords: Agent-based modelling, business simulation game, consumer behaviour, learning processes

1 Introduction

The problem of modelling the marketplace is perhaps the most central and unavoidable issue of a business simulation game. In fact, the algorithms responsible for calculating market and firm level demand have been considered the most complex and important algorithms of a business simulation game [1]. Its importance follows from the fact that the ability of a firm to capture market share from other firms forms the essence of a business simulation game. The complexity

of the algorithms comes from the fact that a considerable number of variables, such as price, advertising and sales staff expenditures, as well as their intricate interactions, must be taken into account when modelling demand.

Since Goosen [2] first proposed a generalized algorithm for a business simulation game, several modelling paradigms such as the equation-based [3], interpolation-based and statistical-based [4] approaches have been studied as techniques to simulate demand in business simulation games and much effort has been devoted to enhance the flexibility and validity of the proposed models. A paradigm not yet extensively applied to the modelling of consumer behaviour in business simulation games is the agent-based modelling technique [5] whose benefits can been captured in three characteristics: emergent phenomena, natural description of a system and flexibility [6]. These properties may contribute to solve some of the dilemmas of modelling demand in business simulation games.

To promote the further comprehension of the mechanics of business simulation games a number of authors such as Machuca et al. [7], Grossler et al. [8], Alessi [9] and Kopainsky et al. [10] have advanced arguments in favour of the provision of more information and disclosure of the system's structure. With the agent-based approach this is feasible without hindering the strategic value of the game since the agent-based technique provides a natural description of the system and captures its macro behaviour as emergent phenomena. Moreover, complex phenomena can emerge from the simplest set of rules defined at the level of the individual entities of the system. Hence, the use of this technique may also contribute to the upward trend in complexity of business simulation games reported by Faria et al. [11].

Given the not yet extensively explored possibilities of the agent-based approach, we present in this article a business simulation game with an agent-based model of consumer behaviour. In the following sections we review the previous demand models of business simulation games. We proceed to a description of our agent-based model of consumer behaviour and prototype game as well of our experimental findings. We conclude with a reflection on our work.

2 Background

The following approaches have been used to model demand in business simulation games:

- Equation-based: mathematical functions model industry and firm demand.
- Interpolation based: an interpolation method derives the graphics of industry and firm demand functions.
- Statistical: the proportion of consumers which consume a given product is measured using purchase probability distributions.
- Agent-based: the complexity of the marketplace is captured using a bottom-up approach, modelling the behavioural rules of each consumer.

2.1 Equation-based models

An equation-based model consists of two functions:

1. A function of market demand (Q) calculated from the average values of demand determinants such as price (P), advertising and promotion variables (M) and product quality variables (R):

$$Q = f(P, M, R) \tag{1}$$

2. A function of firm level demand (q_i) used to calculate the weight of each firm (w_i) when allocating market share:

$$q_i = w_i Q \tag{2}$$

$$w_i = g(P_i, M_i, R_i) \tag{3}$$

The equation-based approach uses a set of equations to express the complex relationships which occur between the consumers in a marketplace. It is therefore understandable the difficulties faced by authors while attempting to capture the intricacies of a real dynamic marketplace in a single set of mathematical equations.

2.2 Interpolation approach

Goosen and Kusel [12] recognized that to try to find a single general flexible demand equation for modelling market and firm demand was an intricate task. Therefore, the authors proposed a method of implementing self-designed functions. Their proposed method has however, a number of limitations. First, the method does not prescribe the nature of the self-designed functions. Consequently, this approach does not solve the underlying problem of finding a flexible demand function. Furthermore, the designer has the burden of identifying all the relevant points in the modelled functional relationships. Modelling interactivity effects is also not straightforward as Gold [13] showed.

2.3 Statistical approach

Carvalho [14] proposed another approach to model market demand. The author disagreed with the fact that the previous models were mostly based on input decisions, not modelling explicitly the crucial element of a demand model: the consumer itself. Accordingly, Carvalho proposed a model of market demand based on the equimarginal principle using the gamma probability distribution to simulate the preferences of the consumers. Carvalho's model allows a more explicit modelling of consumers given that the probability distribution parameters can be changed to reflect changes in the consumers' incomes, tastes and market dimension. However, as Gold and Pray [15] noted, it is difficult to select and modify the distribution parameter values.

2.4 Agent-based approach

In the general area of agent-based models of consumer behaviour, a number of models have been proposed [16–18]. These models are however, not suited to be models of business simulation games since their primary purpose is to explain particular economic phenomena such as the decoy effect[3] [18], or the lock-in effect[4] [17, 16]. In contrast, we aim to develop a demand model able to simulate general concepts from economics such as the law of demand, diminishing marginal returns and other phenomena such as substitution and complementary effects.

3 Model

Our proposed model of consumer behaviour is based on the deliberative Beliefs, Desires and Intentions (BDI) architecture [19], perhaps the best known and most studied model of practical reasoning agents. The BDI architecture provides a simple and efficient psychological framework for modelling the behaviour of agents acting under incomplete or incorrect information in their environments.

In our reasoning architecture the internal state of the consumer consists of the following elements (illustrated in Figure 1):

Beliefs represent the information the consumer holds about the current state of the world, that is, the marketplace, and its internal state. Two types of beliefs can be identified:
- Belief in the availability of a particular product.
- Belief that given the available budget (I) the consumer is able to purchase products.

Desires represent the goals of the consumer. For instance, the consumer can have the desire to consume an additional unit of a given product.

Intentions representing the possible courses of action. Purchase intentions are generated during the reasoning process of the consumer, each for a possible bundle of products.

The reasoning process of a consumer consists in the following steps:

Step 1 The consumer verifies if the desire to consume goods is a current goal. In the affirmative case, the reasoning process proceeds to step 2. Otherwise, the reasoning process proceeds to step 5.

[3] The decoy effect can be defined as a phenomenon whereby consumers will tend to have a specific change in preference between two options when also presented with a third option which is asymmetrically dominated.

[4] The phenomenon of lock-in occurs when the consumer becomes dependent on a supplier for products and services, unable to switch to another supplier without substantial switching costs.

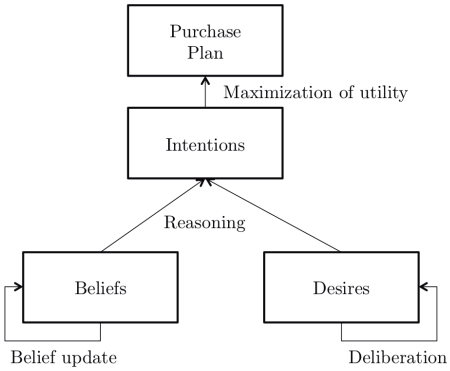

Fig. 1: The rationality elements of the BDI architecture of a consumer.

Step 2 For each affordable combination of goods the consumer generates a purchase intention. This generation of intentions is supported by the current beliefs of the consumer in the availability of products at the market and its belief in his own economic capabilities.

Step 3 The consumer selects from the list of purchase intentions a preferred intention according to the maximization of an utility function. In case of identical utility values, a random factor is used to decide. The following utility function can be used to simulate the preferences of the consumer:

$$U(x_1, ..., x_n) = \sum_{j=1}^{x_1} b_1(j) + ... + \sum_{j=1}^{x_n} b_n(j) \tag{4}$$

$$x_1 p_1 + x_2 p_2 + ... + x_n p_n \leq I \tag{5}$$

where $x_1, x_2, ..., x_n$ *represent the quantities of distinct products* $1, 2, ..., n$ *which can be purchased at prices* $p_1, p_2, ..., p_n$ *for a consumer with a budget* I*.*

Step 4 The consumer attempts to accomplish his preferred purchase intention as an effective purchase plan.

Step 5 The consumer updates his beliefs and desires.

4 Game

Our proposed agent-based model of consumer behaviour was implemented in a concrete business simulation game to further analyse the educational possibilities

Fig. 2: Game interface: A) panel of decisions, B) simulation panel and C) panel of information of firms, suppliers and consumers.

provided by the model. The developed business simulation game models the following entities (refer to Figure 2):

Firms represents the participants. Each participant acts as a firm and manages a retail store where the participant can purchase and sell a number of different products to the final consumer. In each round, participants have to decide on two fundamental topics: (a) quantity of each product to purchase and (b) selling price of products at the store. The performance of firms is evaluated according to their profit.

Products represents the goods sold by firms to the final customer. Each product has an associated purchase cost and is characterized by a type and a quality measured in a scale from zero to one. The type defines the quantity in average a consumer requires of that product according to his available budget. The quality defines his preference over other products.

Consumers represents the virtual agents of the game. Each consumer decides which products to purchase and attempts to accomplish his purchase intentions. Consumers attempt to accomplish their intentions sequentially according to a random arrangement in each round of the game. The intentions of consumers to purchase a particular product from a specific firm are represented by their movement from their houses to the firm and the accomplishment of such intentions are expressed through graphical changes of state (see Figure 3).

Participants are requested to submit their decisions during each round of the game which ends after all participants have submitted their decisions. After the submission of all decisions the processing of the decisions unfolds and the results are returned to the participants who can then simulate the marketplace in virtual time.

In the majority of the existing business simulation games results are presented to the participants managing the firms in a static manner through the use of spreadsheets. In our game, the results of a round, are not the outcome of an equation, emerging instead from the complex interaction of several agents during a period of time. Consequently, at the end of a round participants can analyse in virtual time the alteration of several indicators of performance of firms such as quantities bought, quantities sold, stock and current cash and visualize the interconnected behaviour of consumers. This execution can be rerun several times providing the participants with the possibility to revisit the simulation to acquire new learning perspectives.

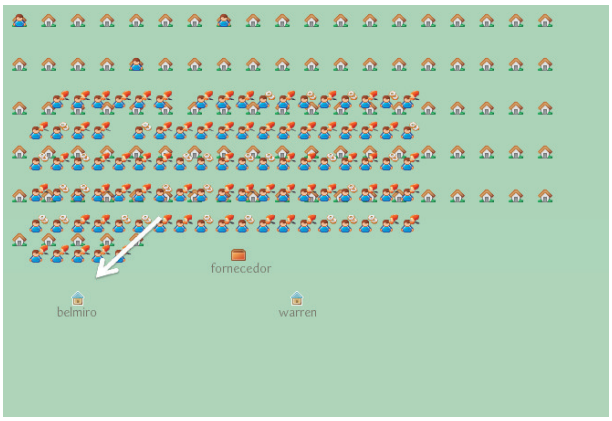

Fig. 3: Movements of consumers as displays of purchase intentions.

5 Experimental results

Table 1: Results of evaluation of "I understood the results".

Classification	Exercise A	Exercise B
Agree	85%	15%
Somewhat agree	11%	18%
Neutral	4%	33%
Somewhat disagree	0%	30%
Disagree	0%	4%

Our prototype was tested experimentally with a total of 27 volunteers, between the ages of 22 and 35 from an applied sciences background. Each participant was subject to two different exercises: exercise A where they were able to

Table 2: Results of evaluation of "The information was useful".

Classification	Exercise A	Exercise B
Agree	48%	34%
Somewhat agree	41%	22%
Neutral	11%	22%
Somewhat disagree	0%	22%
Disagree	0%	0%

play the complete game and exercise B with same game where the participants were only provided with the final outcomes (cash, stock and quantities sold) of their decisions at the end of each round, as it is standard in business simulation games. In both exercises participants played the game in pairs during five rounds. The order in which the participants performed the two exercises varied. No formal debriefing session was planned at the end of each exercise.

The results (refer to Table 1) revealed high levels of agreement (96%) when the participants where asked if they understood the results of the game in exercise A. However, in exercise B, the responses of the participants varied, revealing a low level of agreement, with 34% of the respondents stating they were not able to understand the results of the game. In terms of understandability of the results, all participants rated exercise A with a higher (85.1%) or equal (14.8%) grade than exercise B.

A Spearman's correlation analysis showed a strong correlation ($\rho = 0.677, p = 0.005$) between the perceived usefulness of information and comprehension in exercise A. In exercise B, no strong correlation between these two variables was registered.

6 Conclusion

We presented an agent-based model of consumer behaviour for a business simulation game. The model is based in concepts from artificial intelligence and is consistent with neoclassical economics. The model captures the complexity of the fundamental concepts of introductory economic courses and provides a natural description of economic phenomena. The law of demand, diminishing marginal utility, effects of income and price, independent goods, complementary, substitution and advertising effects can be simulated seemingly by a mere modification of the agents' utility functions.

A business simulation game was designed having as its demand model the proposed agent-based model. In the development of the game, attention was directed to the creation of an informative interface which took advantage of the descriptive potential of the model. Our experimental results suggest that the game was more straightforward to understand than a game with no informative elements. Hence, strong evidence exists supporting the premise that information concerning the behaviour of the individual consumers, available due to the

application of agent-based modelling, plays an important role in enhancing the understanding of the participants of the game.

We believe that our theoretical and experimental results form a strong case for the use of the agent-based technique to model consumer behaviour in business simulation games.

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