Agent Based Marketing: An Inspiring Review

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Abstract

Agent-based modelling is a premising approach that enable researchers to construct artificial worlds where agents ranging from passive world features to active decision makers who have believes and interact, learn, adapt to environment in accordance with their believes which can change over time. In this artificial world, openness to the interactions which occur between agents and/or with their physical environments lead agents to be adaptive (learning) and create a complex adaptive system. Having bottom-up approach, agent-based models (ABMs) offer many advantages for researchers who study complex systems in social sciences. As a complex system involving consumer behaviors Marketing is one the fields where ABMs are used widely. Use of ABMs in Marketing enable researchers to study micro foundations of macro marketing structures. In this study, current application areas of ABMs into Marketing such as diffusion of information, inter-firm relations, marketing mix models etc are explored as literature review. New inspiring fields in Marketing for ABM are introduced that will give insights for future researches.

Key words: Agent based modeling, marketing

Introduction

Models which neglect interactions has suffered from understanding the real life dynamics. In fact, economics, finance, marketing and others are consist of complex adaptive systems where agents ranging from physical entities to individuals, firms, banks, governments and countries interact each other and with their environment and comprise a dynamic world.

Tesfatsion (2006) defines a system to be complex if it is composed of interacting units and it exhibits emergent properties.¹ Rather than analytical models, decrease in cost of computational modelling encourages the researchers to understand the complex systems and Agent-based models, shortly ABMs, are well suited for examining how complex systems change over time (Rand et al. 2011).

Empirical and statistical modellings enable future predictions, but due to cost of consumer behavior experiments and impossibility of examining the effects on a large scale, these models do not cover much theory of consumer behaviours. Instead, using ABMs approach in Marketing allows the researchers to model firms and consumers based upon strong theories of behavior. In addition, validation of results against empirical data and therefore predictions becomes easier with ABMs (Rand et al. 2011).

¹ Properties arising from the interactions of the units that are not properties of the individual units themselves (See more on Tesfatsion 2006)
Agent-Based Modelling

Historically, the birth of the agent-based model as a model for social systems can be primarily attributed to a computer scientist, Craig Reynolds. He tried to model the reality of lively biological agents, known as artificial life, a term coined by Christopher Langton. In 1996 Joshua M. Epstein and Robert Axtell developed the first large scale agent model, the Sugarscape, to simulate and explore the role of social phenomenon such as seasonal migrations, pollution, sexual reproduction, combat, transmission of disease and even culture (Castiglione 2009).

Agent-based models create artificial worlds where agents have beliefs and interact, learn, adapt to environment in accordance with their beliefs which can change over time.

Agent-based modeling (shortly ABM) is the computational modeling of systems as collections of autonomous interacting entities (“agents”) with encapsulated functionality that operate within a computational world (Borill et al. 2011).

Various social phenomena have been investigated using ABMs that are not easily modeled using other approaches. ABMs began largely as the set of ideas, techniques, and tools for implementing computational models of complex adaptive systems. ABMs can explicitly model the complexity arising from individual actions and interactions that exist in the real world. These models explicitly consider the role of people’s behavior and interactions through social networks as they affect the spread of infectious diseases (Macal et al. 2010).

According to Macal et al. (2010, p.152) a typical agent-based model has three elements:

1. A set of agents, their attributes and behaviors.
3. The agents’ environment: Agents interact with their environment in addition to other agents.

As an important type of simulation in the social sciences, Agent-based models are used as an alternative to other tools. According to Axtell (2000), ABMs are useful when numerical realizations are relevant and when a model has no complete or verifiable mathematical solution.

ABMs show common properties such as heterogeneity, interactions (or local interactions), bounded rationality, emergence of self-organization, evolution, micro foundation and bottom-up approach. In ABMs, every individual that may differ from one another by wealth, preferences, memories, decision rules, social network, locations, genetics and culture is explicitly represented. Some or all individuals may adapt or change endogenously over time (Epstein 2006). Social systems consist of heterogeneous communicating entities (interacting agents) in an evolving network of relationships (Borill et al. 2011). In this network, interactions are occurred both between an agent himself/herself and his/her environment and among agents.

Each individual can be modeled differently from others. Having different buying habits, budget and demographic properties, most consumers have different local networks and level of innovation. Thus heterogeneity arises the benefit of ABM. In case of homogeneity, other models, i.e. system dynamics modelling may be more useful since they use similar agents and seek to capture the change in time (Rand

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2 An “agent” is basically someone who acts on someone else’s behalf. Usually, the agent refers to a human. In the computer world, an agent most often refers to a software program that acts on a user’s behalf. For example, the agent collects and analyzes information, draws conclusions, makes recommendations, and performs transactions (See more Serenko et al. 2002)
et al. 2011). Midgley et al. (2007) discusses that heterogeneity is the essence of ABMs since heterogeneity in existing econometric models mainly lead to impractical simplifications and equations with intractable solutions.

Works using simulation are getting widely placed in social science. There are three types of simulation: discrete event simulation, system dynamics and finally agent-based simulation. Macal and North distinguish the ABM from other two technics with its two features: modeling heterogeneity of agents and the emergence of self-organization. Flake (1998) defines the self-organization as “the process by which autonomous agents interact in such a way as to create global order”. The author finds self-organized states in chemical soups, gene regulation systems, super-organisms, animal collectives, and economic systems, and other types of phenomena. Here, emergence does not refers to simply sum. According to Axelrod (2003), since many interacting agents exists with few or no control, the emergent properties of an ABM are then the result of "bottom-up" processes, rather than "top-down" direction. Due to these bottom-up or ground-up processes aggregate patterns are derived from a large number of individual decisions instead of modelling those patterns (Rand et al. 2011).

Evolution is another feature faced in ABMs. Agent-Based Simulations become far more interesting and realistic when evolution is introduced (Mistry 2003). According to the author, many forms of evolution can occur. Adapting new strategies, agents may change their behaviors; running simulation may generate new agents with better strategies and competitive power or microstructures (e.g. rules) in the simulation can change over time.

Traditional or neoclassical view uses rationality approach which assumes people can access perfect information, instantly use the information by which they maximize their utilities. Dissatisfaction with rational agents is important motivation for ABMs as need for heterogeneity, hence these models are modelled as bounded rational with adaptive behaviors.

Macro structures are comprised of micro foundation in ABMs. However, statistical regularities at the aggregate level are characterized by emerging properties which do not show up at the microscopic level (Gatti 2008) and high-level systems may possess new and different properties than the low-level systems on which they are based (Stiglitz et al. 2011). According to Rand et al. (2011) instead of requiring macro dynamics knowledge, modelling micro rules of behavior and then measuring the emergent macro-level results are the power of ABMs.

**ABM Research Areas**

Extensive ABM research is widespread in economics. Borrill et al. (2011,) range ABM research areas as agricultural and environmental economics, automated markets, business and management, electricity markets, financial economics, industrial organization, labor markets, macroeconomics, political economy, and economic network formation. Within the social sciences emergence of collective behavior, evolution

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3 An organized state without design (See more Flake 1998).
4 An example of emergent properties can be those that are not inherent in the individual components (See more Howitt 2006)
5 Although mainstream economics and standard finance theory have grounded on rationality and rational agents, critiques have risen after importance given to bounded rationality, adaptive and evolutionary processes, non-linearity, etc. Contrary to standard theory, behavioral finance and one of its implementation tools, namely agent-based models, have gained momentum in recent years by giving much importance to the psychology and behaviors rather than rationality.
of cooperation and trust, innovation, institutional design, learning, norms, social influence, and social network formation are the field that ABMs are used according to authors.

Tesfatsion (2003) summarizes the topics in ACE researches by roughly dividing into eight research areas: learning and the embodied mind, evolution of behavioral norms, bottom-up modeling of market processes, formation of economic networks, modeling of organizations, design of computational agents for automated markets, parallel experiments with real and computational agents, and building ACE computational laboratories.

Financial markets are also suitable for ABMs. Asset pricing behaviors including exchange rate determination, explanation of bubbles, crash and stylized facts have been focus of interest. LeBaron (2000), LeBaron (2006) and Hommes (2006) give details about agent-based models used in finance. LeBaron (2006) states the appeal for ABMs as the key debates in finance about market efficiency and rationality, puzzles in financial time series, plenty of data, approximation possibility through return and wealth performance, and strong connections to relevant experimental results.

**Critiques to ABM**

In some points ABM insufficiates. Since it is an alternative tool there are not few critiques to the models. In a nutshell, some ABMs’ disadvantages are as follow: modelling of agents, need for strong programming skill (Mistry 2003), dependence to the initial conditions (Tesfatsion 2003; Assenza et al. 2007), validation problems (LeBaron et al. 2008). Since insufficiency of standardized agent-based modelling methods, top marketing journals do not publish much (Rand et al. 2011).

ABM enable heterogeneity in modelling of agents. According to Rand et al. (2011), the benefit of using ABM increases in case of heterogeneity. However, different psychological status and beliefs are not easily modelled. This becomes difficulty for the researchers. Zhang et al. (2007) state this situation as “… a challenge to researchers and practitioners is how to use psychographic data to model consumer purchase decision-making as well as dynamically emergent phenomena in markets” (p. 912).

Validation is the most complicated and hardest step in modelling and ABM can have problems special to itself. According to LeBaron et al. (2008), one problem involves degrees of freedom. ACE models often contain many parameters, and the claim is that the clever researcher can match any desired empirical feature using these degrees of freedom. Another problem is that the properties of many ACE models are currently not well understood and not well motivated by observed human behavior. The authors believe that these models can be modeled commonly by connecting agent-level behavior to experiments with real people, i.e. laboratory experiments. In addition to laboratory data comparisons, another direct and obvious empirical validation test for an ACE model is to replicate empirical features at many levels and at multiple time scales.

**ABM in Marketing**

Marketing is also one of those fields where ABM is taken place to simulate complex systems. Zhang et al. (2007) considers outlets, large supermarkets and manufacturing systems as complex systems. Thus, ABM can be applied to many Marketing research areas. Schenk et al. (2007) explains the importance of ABM as follow: “Consumer attitudes and behavior are changing rapidly toward more individuality and more
diversity. Agent-based simulations are currently the most promising tool to address these challenges on the level of modelling”. Since computational methods will become more powerful and be easily practiced as time goes on, some standard procedures are required to implement ABM for those who are unfamiliar with it. Rand et al. (2011) underline the importance of conducting standard guidelines. They use an agent-based model to replicate the Bass Model of the diffusion of innovations by proposing a guideline for ABM development.

The purchase decision making process and the interactions among consumers based on this process generate market dynamics. Mathematical and statistical techniques are used to model consumer’s socio-demographic and behavioral data. In addition to this psychographic data such as attitudes, opinions, lifestyles or personal values are vital in purchase decision making (Zhang et al., 2007)

Garcia et al. (2007) draw attention to the validation issues and they aim to give right a definition of validation for agent-based models in marketing research and present a calibration model based on conjoint analysis that enable agent-based marketing simulation with real-world data. The authors give importance to macro level validation as well as micro level and therefore, use conjoint data collection method to validate the agent-based model.

Starting individual level and capturing complex emergent dynamics are also relevant in diffusion research (Kiesling et al., 2011).

Roozmand et al. (2011) believe that presentation of an ABM for the consumer’s decision making process which is the closest to the real consumer’s decision is most important thing for the researchers. Hence, the authors pay attention to human factors affecting consumer behaviors.

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Data</th>
<th>Model</th>
<th>Content</th>
<th>Discussion</th>
</tr>
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<tbody>
<tr>
<td>Garcia et al. (2007)</td>
<td>2225 leading edge wine consumers from US, Australia, and New Zealand</td>
<td>Diffusion modelling of screw caps closures among wine consumers</td>
<td>Use of alliance between wine producers in order to produce wines with screw caps closures. A strategy of coopetition as an instrument to diffuse the Stelvin amongst resistant consumers in New Zealand wine industry. Agents: Consumers and wineries Closure type, types of wine, origin of wine</td>
<td>Alliance of too few wineries do not cause the necessary impact to the market Alliance of too many wineries decrease the profits of those in the membership due to supply exceeding demand</td>
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<tr>
<td>Rand and Rust (2011)</td>
<td></td>
<td>Model of Consumer adaption-a version of the Bass Model</td>
<td>In the original Bass Model the likelihood of agents’ adopting due to mass media (p) and due to word-of-mouth (q) effects and number of agents (m) are the main inputs. In addition in this model, interaction of agents</td>
<td>Within consumer adaption, agents often make decisions to purchase a product based on previous recommendations from their social network.</td>
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</tbody>
</table>
Roozmand et al. (2011) introduced 11 European countries data on car buying motives from European Media and Marketing Survey (EMS) 1999 Data on Power Distance from Hofstede’s National Culture Theory ABM toolkit: Repast Simphony (Computational) Based on MASQ meta-model (Conceptual) R software to generate input data for some agents Decision making based on; - Power distance dimension of Hofstede’s national culture model - 3 Personality Traits Extroversion, Openness and Agreeableness (McCrae and Costa (1992)’s Five Factor model of personality) - Human needs Social Status Social Responsibility Consider culture and personality and its role on need recognition and different stages of consumer decision making process Further Analysis of other dimensions of culture (individualism, masculinity, uncertainty avoidance, etc.)

Also in other marketing topics ABM are used for the diffusion of innovation (Garcia et al. 2007; Goldenberg et al. 2009; Kiesling et al. 2011; Rahmandad et al. 2008); Retail location decisions (Heppenstall et al. 2006; North et al. 2010); Inter-firm relationships, strategy and competition (Hill et al. 2009; Wilkinson et al. 2002); Marketing mix models (North et al., 2010); Purchase decision making process (Roozmand et al. 2011; Zhang et al. 2007).

**Conclusion**

In summary, ABM is a useful and developing tool to create complex dynamic world. In marketing applications ABM enable the researchers to create a large number of heterogeneous consumer, retailer or producer agents and to conduct artificial markets. In these markets, interactions are occured between agents and their environments. Their adaptions to the market structures help agents change their strategies in case of different situations. These interaction and adoption lead to emergence of macro results similar to real life.

Since ABM is a technique that gets benefit from simulation and need programming skills, dramatic developments in software technology will be key to problems arising from modelling of behaviors and validation issues. These developments will also decrease the costs of modelling.

In ABM in marketing studies retailers and/or manufacturers (producers) are assumed as fully informed of each other’s proposal instantly or behaviors in advance although consumers become aware of offers by any marketing channel. In real, no players in the markets are fully informed of others’ proposal, normally. Thus, as a further research, retailers and manufacturers can be modelled as they have limited information about others’ offers. These make memories and decision rules of agents and the way to evaluate the alternatives to change. Behavioral models may help the researchers to conduct such rules. As another thing, agents can make their purchasing decisions getting benefit from social network (world of mouth, viral marketing…) in addition to ads, in-store promotion or other channels.


Bibliography


