The consumer food market in Italy: a dynamic representation through agent-based modeling

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Abstract

The research aim was the construction of a simulation agent-based model, which reproduces the food market at consumer level in a local context. The model characterizes the behavior of two categories of agents: consumers and food retail shops. The intent of the model is to reproduce the current status of expenditure for food products in a certain territorial context and to investigate how the agents behavior adapts to the changes of the market conditions. The application case concerned the opening of a farmers markets, predicting the positioning of this novel store in the local context and the changes in the consumer habits.

Keywords
agent-based modeling, food market, supply food chain, consumer behavior

Introduction

Agent-based modeling (ABM) is a method of computational simulation, which covers a number of elements, called "agents", defined through a series of software objects. Each agent has own behavioral attributes and other characteristics, which may be different from each other. In this way it is possible to realize populations of heterogeneous agents, which have a variability of behavior. Also, this allows that each agent has a degree of autonomy with respect to other agents and to the environment. The environment itself can be represented by one or more agents and can be defined with geographical characteristics.
The agents of a model interact each other and with the environment; the interaction takes place according to a set of behavior rules dictated by the model; these rules may manifest itself in different ways according to the different values assigned to the internal variables of each agent.
The ABM logic is a bottom-up logic: it reproduces the general phenomena, which emerge in a particular complex system, starting from the definition of the behaviors of the individual entities that make up the system itself (Epstein and Axtell, 1996; Tesfatsion, 2002).
In most environmental and social systems it is evident that there is a relationship between their dynamics and their spatial position; the characterizing events of these systems may vary as a function of the proximity of the agents, or the density, or the possibility to cluster. In order to consider the spatial dynamics, Brown et al. (2005) have illustrated the need for close integration between ABM and Geographic Information Systems (GIS); indeed many of the current ABM software allow this kind of integration.

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A comprehensive and well documented ABM tutorial, which also shows several application examples, has been published by Macal and North (2010).

The ABM and the supply food chain

According to the few studies available, it appears that the supply food chain is an unfrequented area by the ABM scholars, perhaps because it is easier to realize a model in areas, such as manufacturing or financial market, characterized by a higher dynamic than the supply food chain and, therefore, with oscillations more simple to highlight.
Many of the models involved in the agri-food sector reflect a typical point of view of certain modeling applied in this sector, as they are designed to evaluate the large-scale changes induced by the national or supranational policies. They try to provide the public decision-maker with the tools to forecast the effects of agricultural policy decisions. Such models therefore often suffer limitations due to the desire to represent reality too large, with complicated models very difficult to implement.
The following are some of these studies, in order to highlight the different ABM possibilities in the supply food chain.
Berger (2001) presents a multi-agent - cellular automata model aimed at assessing the diffusion of innovations and the changes in resources use (especially the water for irrigation), depending on the different alternatives in agricultural policies. The evaluation was carried out with reference to a great farming area located in Chile and mainly cultivated by campesino families, in the context of the Mercosur international agreement.
Happe et al. (2006), co-authors of the model AgriPoliS (Agricultural Policy Simulator), made an application on the Hohenlohe German district (southwestern Germany). The model assess the effects of the decoupling of aid granted by the European Union on farm structures.
A model that has several similarities with AgriPoliS was developed by Bert et al. (2011) and used to understand the mechanisms that underlie the recent and significant changes in the land use and in the structure of agricultural production in the Argentine Pampas.
Saqalli et al. (2011) developed a model with the aim of better finalizing the policies to support rural development in some areas of Niger. It simulates the behavior of individuals within an environment that mimics the characteristics of villages and the family rules (expecially the genre of the individual and the rank inside the belonging family), with the conditioning that these exert on access to economic activities and production.
Gagliardi et al. (2014) have developed a model to assess the impact of innovation policies in the supply food chain of Puglia Italian region, on the basis of the criteria and guidelines of the regional Rural Development Programme (2007 – 2013).
The aim of the model produced by Dyer and Taylor (2011) is to analyze the effects that the corn price rise has on land use and farm incomes in Mexico. This model reproduces the static general equilibrium of the rural economy of Mexico and in the study was used for an ex-post analysis of the corn price increase that occurred in 2008. The model also investigates the microeconomic aspects that cause the effects at the macro level.
Schenk et al. (2007), with two separate models but very similar in substance, simulated the behavior of consumers shopping at the grocery stores, in one case, and at clothing stores, in the other case. The study examined the inhabitants and the stores of the district which

belongs to the city of Umeå in northern Sweden. Both the models take into account the spatial component, namely the interaction between the consumer and the retail outlets based on mutual geographical position.
Auchincloss et al. (2011)) analyzed with a model the influence that the residential segregation, caused by the income level and the ethnic characteristics, can have on the quality of the diet of people and, consequently, on the occurrence of disorders and diseases. They noted that the segregation causes a prevalence of offering unhealthy food (too high calorie intake and lack of other nutrients) because in areas inhabited mainly by low-income people, the existing stores direct their offering to this type of food, which generally has a lower price; so that, even families who had interest in acquiring better food, often do not find it easily in their area.
Further work in this direction has been published by Widener et al. (2013). This study evaluated the possibility of increasing the consumption of fresh fruits and vegetables in low-income families, by means of some different scenarios for intervention. The model considers the city of Buffalo (USA), which suffered a major socio-economic impoverishment and shows frequent nutrition problems in the low-income population. The model has identified some measures that would improve the situation. It shows that the best solution is a higher spread of the stores like the farmers market or the equipped mobile vehicles, that can increase the availability of fresh vegetables at home, increasing the shopping frequency.

Aim of the model

The aim of the model in this study is to reproduce the current state of the consumers food market in a local context. In this state one can enter some events, such as the opening of new stores and the launch of promotional campaigns, having the opportunity to see how the situation is changed by these events. In the application case the event is the opening of a new farmers market. The model is based on the relationship between consumer and store (Business to Consumer exchanges). It does not deal with the individual food item, but with all the products that make up the consumer food expense, which can be defined as its "food basket". The agents of the model belong to two categories: the consumer and the retail businesses. The implementation of the model has pursued specific goals that can be summarized as follows:

- to reproduce the decision-making process of the consumer, based on a plurality of attributes that interact to define its behavior;
- to implement a process of diffusion of innovations in the market, allowing to play the real dynamics of the process and the changes by these induced;
- to understand the relationships and dynamics on a geographical basis, according to the location of the various agents.

Alongside these specific goals, the model also has some more general objectives, which are:

- to use a methodology of recent and promising development, as the ABM, in the specific context of the studies for the supply food chain, particularly as a means of understanding the complex interactions that exist between actors in the sector, in order to capture the dynamics of the market and check their effects;

- to identify the types of data needed to construct the model, to direct the market researches and data collection, necessary for the design of interventions in the food market similar to the one under study;
- to provide support to find solutions to the known problems of excessive fragmentation of the chain, especially as regards the distribution phase.

Theoretical approach

The agent-based modeling in the economics constitutes, in a sense, the synthesis of a series of theories and socio-economic models, developed in many distinct fields; it summarizes and gives substance to these acquisitions, making them actually operating within the developed model. There are three main theoretical acquisitions implemented in this model, described below.

The consumers food market equilibrium

The consumers food market is characterized, as a whole, by a strong stability, in large part determined by the demand stability and "necessity". In a situation where demand is basically inelastic with respect to price, none of the major players tries to disrupt the market with shocking actions searching to gain further market share, being afraid of possible unforeseen consequences. Small traders, however, are not able to change the behavior of the market leaders and are forced to close or to find a market niche. This situation is characterized, therefore, by an oligopoly of the big operators acting relatively moderate strategies, not to upset the market; it can be considered an example of oligopolistic not collusive Nash equilibrium.

The consumer utility

The consumer has a utilitarian approach when chooses the shop where do the shopping. The consumer, that is, try to maximize his profit by making a weighted evaluation of a set of attributes that he believes important for the selection. While in classical economic theory that choice is considered perfectly rational and based on the availability of all the necessary information to perform it, the latest theories have shown that the choice is only partly rational, since the consumer often acts on the basis of partial information (information asymmetry) or driven by emotion or irrational motivations. Moreover, according to the neo-institutional economic theories, the consumer has transaction costs, that is, the additional costs that occur when making an exchange; in the case of the food shopping such costs may include, for example, the time to be used to reach the point of sale and the one to choose the products inside.

Relations between consumers and diffusion of innovations

Although the food market is less affected than the others by the social influence, word of

mouth is probably the main method by which the consumer acquires information on the shops. The understanding of the word of mouth operation involves the study of human relational networks (social networks); through the analysis of the structural characteristics of social networks it is possible to understand the spread dynamics of the information affecting the consumer. The main characteristics are described below.
The first characteristic of social networks is a *high clustering coefficient*, which can be defined as the consumers tendency to cluster; the high coefficient indicates that people tend to preferentially develop links with members of a group to which they belong, rather than random connections with anyone.
The second detected characteristic is a *small diameter*. This character refers to the finding, experimentally demonstrated (Travers and Milgram, 1969), that whichever couple of members not connected by a link, is connected by a surprisingly small number of links through the other members (the famous *six degrees of separation*).
Finally, a third feature quite recurrent in this type of networks is identified with the expression *scale-free*. In this kind of social networks there are few members with a high number of connections, while the majority of members has few links. This is because the members with most connections have a chance more than proportional to acquire new connections; they are the "opinion leaders".

Methodology

The model agents - Retailers

In the model the term "retailers" means any businesses that sell food directly to consumers, from hypermarkets to peddlers. The parameters that characterize the retailers towards the consumer, and that have been implemented in the model, can be divided into *structural* (objective) and *evocative* (subjective):
structural

- store size,
- type and format,
- general price level,
- service level (product information, opening hours, purchase assistance),
- quality (presence of fresh products or certified, branded, specialized),
- assortment level,
- location and accessibility;

evocative

- store glance,
- feel (pleasantness, decor, colors),
- clientele sympathy.

The model agents – Consumers

In the developed model, the consumer is actually the family, as a unitary subject of the

activities of buying and consuming food. Families have been segmented into many categories, to reflect as closely as possible the behavior and spending capacity of the real population, as measured by the available statistical data, that consider the household income level, the employment status, the number and age of the members.
In the model the basic reference parameter is the average monthly expenditure for food of each family; the immediate result of the model operation is the distribution of this expenditure between the various retailers in the area.
Consumers, in their spending behavior, have two basic capabilities:

- to continuously adapt to market changes, reconsidering their preferences;
- to gather information on retailers and change their preferences; this information arises from two sources: the word of mouth within the consumers social network and the advertising carried out by retailers.

The model deals essentially with the following functions:

- what is the average monthly expenditure of each family-agent for the foods considered,
- how the flow of information on retailers occurs and affects,
- how many and which retailers are selected for each shopping time,
- how the average monthly expenditure is distributed among the visited retailers.

Each family has a list of referenced retailers and, each time, decides which stores to visit for shopping, on the basis of an utility function which considers the price level of each retailer, the distance, the structural and evocative characteristics described above. Each family, according to its behavioral characteristics, for each buying cycle, decides how to divide the food expenditure between the referenced retailers. The list of referenced stores is the subject of ongoing audits and possible changes, according to the influence of the word of mouth and advertising actions.

Model operation and results

The model has an initial setup, where agents (consumers and retailers) are created, each with its own location in the geographic area; the structural and behavioral characteristics which to him belong are assigned to each agent, respecting the statistical frequencies typical of the study area. It is also created the relational network that interconnects the consumers and another that connects them with the referenced stores; at the beginning each family has as referenced retailers the four closer.
After the setup, the model is operated for an indefinite time, observing the evolution of the system. In a first phase of operation only the consumers have a dynamic behavior, because each of them carries out its assessment of the utility of the referenced stores and amends the list thanks the information from other consumers. Instead, retailers have a passive behavior: do not advertise, do not change the prices, or other types of action. By all the purchasing behavior of households in the area is determined a certain distribution of revenues between the various retailers, reproducing a situation of market equilibrium. In particular, the model reproduces a typical Italian distribution of revenues between the different types of food retailers: the largest share of sales held by a few big stores

(supermarkets and hypermarkets), a considerably smaller share held by a large number of traditional small food shops and further lower shares held by other types (self-service shops, hard discount, peddlers, etc.). It is therefore realized a typical oligopolistic non-collusive Nash equilibrium. As long as there are no perturbative actions, the equilibrium remains, with normal oscillations which do not affect the general medium equilibrium.
In this equilibrium situation, as a second phase of operation, the model allows the inclusion of perturbative actions, such as the opening of new stores or the launch of promotional campaigns, allowing to see how the market reacts and the new equilibrium is established.

The application case: the opening of a farmers market

For the purpose of this study, the farmers market (FM) is an interesting application case. Indeed, it allows to test the model by the opening of a new store which belongs to a relatively new distribution type in Italy, which is still the subject of discussions and studies, with the production of data obtained by appropriate statistical methods. Introducing the topic "farmers market" one can tackle more issues of consumer behavior, relating, for example, the reasons and ways of consumption of fresh fruit and vegetables and the ascertainment of the methods by which they are produced. In this case study is considered the monthly expenditure of households to purchase a basket of those food items that are normally found in the Italian farmers market, rather than that relating to the purchase of all food items; thus it is possible to make the comparison between the expense in FM and in other types of retailers on the basis of the same basket of foodstuffs.
The opening of the FM causes a disequilibrium in the market; gradually but increasingly, consumers discover the existence of the new store and visit it for shopping. Thanks to the output of the model it is possible to check the evolution of the performance of the new FM. As time goes by, it is produced a new equilibrium, where one can check the new store positioning (in terms of number, type and origin of the customers and in terms of revenues).
The simulation has been replicated 20 times using the same starting parameters, which included setting up a population of 10,000 families (approximately 23,800 inhabitants, considering the Italian average of 2.38 members per family), in an area where there are about 100 different food retailers of the various types. Every time one farmers market was opened and the simulation has been allowed to proceed until was re-created a new equilibrium in terms of distribution of revenues.
Due to the different location of FM in each replication, the share of sales achieved by the FM was always different, as expected, but with an average of about 40,000 Euros of monthly revenues. This represents 2.5% of the total revenues of the model (that is, the sum of all the stores revenues) and it is compatible with some data collection made in several Italian cities (Filippini and Zucconi, 2009).
The simulation also provided results with respect to the average number of customers per purchase cycle when equilibrium was achieved: on average 584 households (5.8% of the total) have made purchases in the FM.

Conclusions

Compared to the three specific goals, ABM methodology has allowed to realize a model that mimics the decision-making process of the consumer and the diffusion process of innovations in the agri-food market, taking into account the spatial components of these processes, namely the location of the various players. The model has shown that it is able to reproduce some of the real market dynamics, including the division of market share between the various types of food retailers.
The application case, involving the opening of a farmers market, has allowed to test the behavior of the model in a more specific context, analyzing the positioning of the new store in a local market, and observing the evolution of this market.
Compared to the general objectives, the study has actually highlighted the feasibility of the ABM use also in the Italian supply food chain, where the need to consider a large number of variables makes even more attractive the use of this methodology, born precisely to consider a big variety of agents and behaviors. It is clear that being able to take account of all the variables implies a great job of deepening and processing, which was not possible to realize in this study. The work, however, has made it possible to highlight some key issues, which can be considered in any future development. From this perspective the work done can be considered a first step in a long journey.

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