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CONSUMER DEMAND FOR SUSTAINABLE VERSUS LOW-COST FOOD PRODUCTS: AN AGENT-BASED MODELLING APPROACH

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KEYWORDS

Sustainable food systems, Agent-based modelling, Simulation, Consumer choice, Product price.

ABSTRACT

This paper introduces a first agent-based modelling attempt to food system simulation. It aims to capture the balance of supply and demand for sustainable versus low-cost food products. It contributes in modelling consumer choice and more specifically understanding the tensions between price and sustainability.

INTRODUCTION

With global population reaching 9bn by 2050 and significant environmental challenges, there is an increasing need to increase sustainability of the food chain. Although consumers demand more sustainable products, price is often driving consumer choice (Hoek *et al.*, 2016; Asioli *et al.*, 2017). Sustainable products are typically at a higher cost leaving them to a competitive disadvantage. There has been a lot of effort in understanding and modelling consumer choice and more specifically understanding the tensions between price and sustainability. A range of theoretical frameworks have been proposed (Ho *et al.*, 2006; Asioli *et al.*, 2017). Higher prices of sustainable products do not only involve higher costs of raw materials but also costs of production as they tend to be specialized small scale production units. It would be of interest to explore a scenario where by adoption of sustainable products from consumers costs are reduced.

Agent-based models (ABMs) offer a way of taking into account actor heterogeneity, social interaction and interdependence, adaptation, and decision-making at different levels. In land use-related environmental science, they have affirmed as a way to capture complex characteristics of socio-ecological systems (Epstein and Axtell 1996, Berger 2001, Parker *et al.* 2003, Mathiews *et al.* 2007, Rammel *et al.* 2007, An 2012, Filatova *et al.* 2013). In this family of ABM works, ecology and geography predominate (Grimm 1999, Parker *et al.* 2003, Verburg and Veldkamp 2005, Castella *et al.* 2005, Railsback *et al.* 2006). However social sciences are also present in such ABM approaches to assess and explain the complexity of human decision-making processes and behaviors (Schelling 1971, Epstein and Axtell 1996, Simon 1997, Janssen *et al.* 2000, Janssen and Ostrom 2006, Robinson *et al.* 2007).

In food science, historically based on process-oriented studies, ABMs are absent from the range of models used to approach food quality and, as a more recent concern, food sustainability. Recent studies related to multi-agent systems applied to the agri-food sector are those based on the argumentation theory (Bourguet *et al.* 2013, Thomopoulos *et al.* 2015, Thomopoulos and Paturel 2017), some of them coupled with system dynamics simulation (Thomopoulos *et al.* 2017). Social issues are deeply involved in food system sustainability. Consumer demand, environmental awareness, willingness to pay, acceptability of products, spreading of new food habits, are key compounds to analyze the system. Therefore, there is a pressing need and a real challenge to take into account food-related social behaviors and integrate them in decision making.

In this paper, a first ABM attempt to food system simulation is proposed. It aims to model the balance

of supply and demand for sustainable versus low-cost food products. More specifically we aim to understand the dynamics of adoption of a certain product (namely sustainable vs low-price) including the scenario of changing price with an increase of consumption.

METHODS

Agent-based modelling

Agent-based models are computational models used to simulate the actions and interactions of autonomous agents, individual or collective, in order to assess their effects on the system as a whole. They attempt to reproduce and predict the emergence of complex phenomena induced from the micro-scale of systems to a macro-scale. Their principle is that simple local behavioral rules generate complex global behavior. An overview of their early history can be found in Samuelson (2000) and more recent developments in Samuelson and Macal (2006).

The CORMAS platform

The CORMAS platform (<http://cormas.cirad.fr/>) used for the model construction was specially developed by CIRAD for simulating natural resource management and is oriented towards the representation of interactions between stakeholders about resource use. In CORMAS, entities are categorized into three types: spatial entities describing the space at different aggregation levels, passive entities, which are objects that can be manipulated by social agents, and social entities which can make decisions, move, and interact with other agents.

Our hypotheses

- A cognitive theory of food perceptions and needs, explained in the following scenario description.
- 3 triggers for sustainable/low-price product demand: (i) environmental crises; (ii) neighborhood effect; (iii) low-price attractiveness.

Scenario description

The system we intend to model is a country made of a population of N citizens. Two products are sold in this country: low-cost products, which have a constant and low price, and sustainable products,

whose price is initially higher but may vary in time. Each citizen is characterized by: (i) a constant level of need for sustainability regarding food (environment preservation, ethics, health, etc.); (ii) a variable level of perception of sustainable products. Depending on these two levels, citizens have a behavior regarding their food product demand, either sustainable if their perception exceeds their needs, or low-cost if their needs exceed their perception. Moreover, each citizen has some resistance to change.

Environmental crises break out with a given frequency. Then all citizens get the information, all the more since they are close to the crisis event. Their perception of sustainable products may be impacted. Each citizen also communicates with his/her direct neighbors and may change his/her diet depending on theirs. Finally, citizens are influenced by low-price attractiveness.

The objective of the simulation model is to provide a view of the evolution of both food behaviors and product prices in time. Initial parameters subject to stochasticity are the distribution of need and perception levels in the population, with respect to some initial proportions of sustainable and low-cost buyers.

RESULTS

Conceptual model

Figure 1 displays the UML class diagram associated with the simulation model.

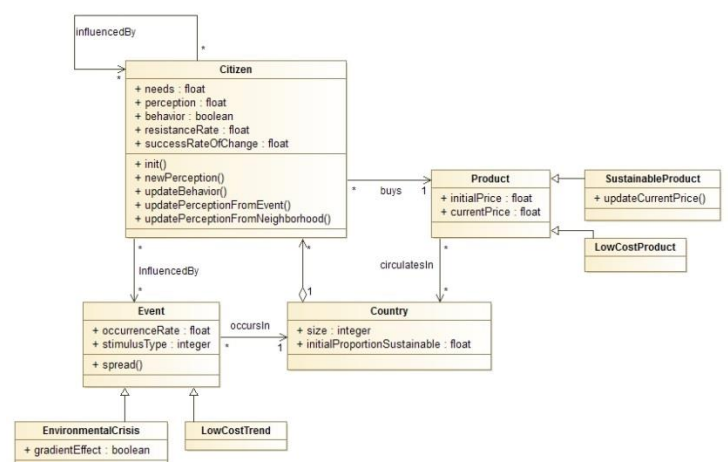


Figure 1: Class diagram

Modelling choices for price-related variables

In this scenario and for simplicity we selected a linear decrease of price with the volume of sales/consumers.

- Price function for the sustainable product: linear function of the number of buyers, from the initial price of the sustainable product when the number of buyers is reduced (e.g. 5% as an initialization), to the low-cost product price if the whole population buys the sustainable product.
- Feedback influence of price on consumer perception: linear function from 'no effect' when the price of sustainable products is high (initial situation) to 'total effect' when the price of sustainable products decreases to the level of low-cost products.
When a consumer's perception surpasses this consumer's needs for sustainable products, this consumer becomes a sustainable buyer, which participates in reducing the price of sustainable products.

Simulation results

Figure 2 displays a running simulation. Each step has been calibrated to correspond to about one month, so that the whole simulation corresponds to 15 to 20 years approximately. The associated evolutions of the volumes of sales and of product prices are given in the graphs of Figure 3.

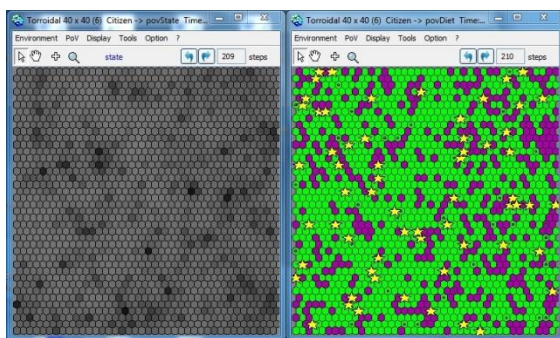


Figure 2: A running simulation. The left part shows consumer perceptions of sustainable products (the darker, the higher). The right side displays resulting consumer behaviors, green for sustainable buyers, purple for low-cost buyers. The yellow stars materialize the occurrence of an environmental crisis which tends to increase people's perceptions of sustainable products, all the more since the crisis localization is close.

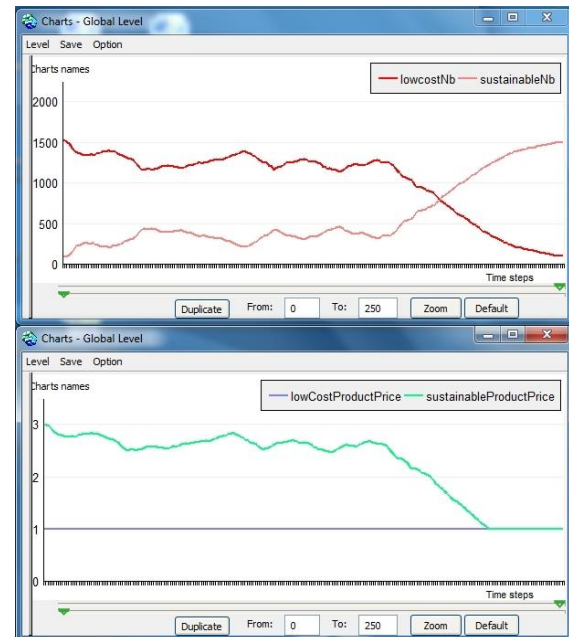


Figure 3: In the top part, evolution of the number of low-cost buyers (in red) and of sustainable buyers (in pink). In the bottom, evolution of the prices of the sustainable product (in green) and of the low-cost product (in blue).

DISCUSSION

We can see in this simulation, after some initial period of oscillations, a decrease of the price of the sustainable product until it reaches the low product price, jointly with a decrease of low-price buyers and an increase of sustainable buyers.

We showed that this result is depending on the ratio between environmental crisis frequency and low-price attractiveness. The latter is represented in our model as the ratio between the initial sustainable price and the initial low-product price (which remains constant). This is illustrated in Figure 4.

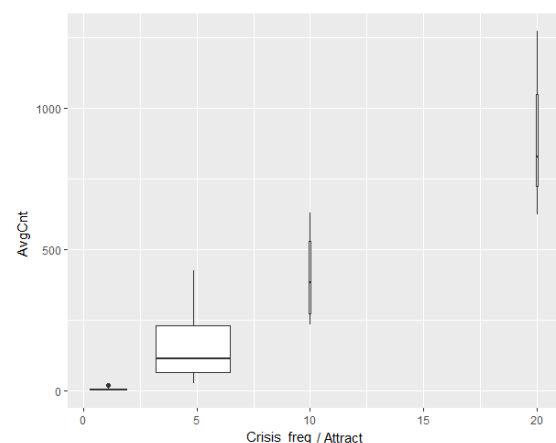


Figure 4: Sensitivity analysis shows that a stability in the simulation results obtained is reached for a given ratio between environmental crisis frequency and low-price attractiveness. This ratio seems to be close to the ratio between the initial product prices (sustainable price/low-cost price).

CONCLUSION

The overall work demonstrates the potential to develop an ABM to predict the dynamics of change of a food chain. Environmental crisis has led to adoption of sustainable products from consumers. We also evaluated the effect of a reduction of product price with an increasing volume. After a certain period where oscillations in the number of adopters of sustainable products occurred and once a critical mass of consumers was adopted we observed that the number of adopters increased dramatically. The above results indicate that there is the potential of extending the reach of sustainable products by reaching a critical mass. An interesting issue to further investigate is how the public opinion is formed in case of environmental crisis, including situations where the assumptions that the whole population is well informed and the news reliable do not hold.

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BIOGRAPHIES

Rallou THOMOPOULOS is INRA Research Scientist in Montpellier and permanent member of the GraphIK lab at INRIA. She has dual skills in computer science and the agri-food sector. Her research topics are in knowledge representation and decision support, focused on argumentation systems and complemented by simulation approaches. She was a Guest Research Scientist at Laval University (Canada) in 2015-2016 and previously Assistant Professor at AgroParisTech.

Serafim BAKALIS has expertise in processing, transport phenomena and modelling of processes occurring in digestion and in general in use of consumer products. Prof. Bakalis has recently moved to the University of Nottigham to establish a group in Food Process Engineering. Prof. Bakalis has published over 100 papers and 150 conference publications.