Modelling consumer behaviour

Jager, Wander

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Document Version
Publisher's PDF, also known as Version of record

Publication date: 2000

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

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Summary

Introduction (Chapter 1)
Human existence cannot be separated from the natural environment humans live in. People are constantly interacting with their environment to maintain and improve their living conditions. This interaction with natural systems supports the existence and viability of societies and cultures. However, often people consume natural resources at a rate that endangers their existence and viability on the long run. Whereas this led to societies collapsing in the past (e.g., Ponting, 1993), during the last decades awareness has grown that the environmental impacts of our current socio-economic system not only affect the regional or national level, but also affect the world as a whole. These global changes, such as global warming, the thinning of the stratospheric ozone layer and large-scale deforestation, seriously jeopardise basic existential conditions. The critical question in understanding environmental problems is why many people so frequently over-exploit and damage natural resources, thereby endangering their own (future) living conditions, whereas other people use the same type of natural resources with moderation to preserve them. The commons dilemma is excellently suited for studying the behavioural factors and processes that determine when and why people tend to overexploit common resources, or exploit them in a sustainable manner. This monograph is aimed at presenting an integrative perspective on these factors and processes. To do so, we developed a multi-theoretical meta-model of behaviour. This meta-model will be formalised in a computer simulation model, which provides a tool to study processes of resource use and consumption.

The commons dilemma (Chapter 2)
Many studies in the commons dilemma paradigm have been performed to study the factors that affect people's harvesting behaviour from a collective resource. Chapter 2 discusses the commons dilemma paradigm, and states that four dilemmas can be recognised in the environmental commons dilemma. First, the everyday benefit–risk dilemma relates the benefits of behaviour to the associated risks. Second, the temporal dilemma relates positive outcomes now to possible negative outcomes in the future. Third, the spatial dilemma relates local outcomes to more general outcomes, such as the quality of the seas and forest areas. Fourth, the social dilemma relates personal outcomes to outcomes for the collective. Next, an inventory is provided of the factors at the group and individual level that have experimentally been found to affect harvesting behaviour, such as uncertainty, number of people involved and social norms. However, experimental research is often limited in comparison to real commons dilemmas because of the limited time-scale of experiments (typically less than an hour), the small number of people involved and the insignificance of the experimental outcomes for the daily lives of the subjects. Computer simulation models offer a tool to overcome these limitations.

A methodology of modelling (Chapter 3)
Chapter 3 is focussed on the methodologies used in scientific simulation models. First, attention is given to the roles metaphors play in scientific modelling of natural systems, and their applicability. For example, to what extent is an equation-based model of a natural system valid, and for which purposes may it be used? Next, the modelling paradigms
associated to certain metaphors are shortly presented. These paradigms involve multiple regression models, stochastic simulation models, rational-actor optimisation, system dynamics and agent-based models. All mathematical models share a general biased starting point by assuming that the world is not only knowable by a rational process of observation and reflection, but is also assumed to be controllable. This holds in different degrees for various modelling approaches. For example, multiple regression models are assuming a much larger controllability than e.g. models of adaptive systems using genetic algorithms. Because these differences stem from different (implicit) assumptions of how the real world system works, these various modelling approaches seem to fit the concept of paradigm. Because our ‘consumat approach’ entails an agent-based model, a separate section is devoted to the conceptual tools used in this modelling paradigm. These tools involve genetic algorithms, cellular automata and artificial intelligence. The chapter concludes with a section on the application of models.

Simulation models in the social sciences (Chapter 4)
Chapter 4 provides an overview of historic developments and current issues in the use of simulation models in the social sciences. Regarding the commons dilemma, two main directions can be distinguished in the application of simulation models. First, several researchers have tried to increase the realism of natural resource systems by developing computer simulations of complex natural systems (e.g., fish-stocks). Such simulations provide a tool to study the behaviour of people in more realistic yet controllable situations, thereby compressing long-term processes into short-term experimental simulation sessions. Second, several researchers have developed simulations of behaviour itself, formalising agents via algorithms that represent certain decision processes. This approach allows for testing different algorithms against each other, and to evaluate these in terms of the sustainability of the resulting behaviour. Moreover, this approach in principle allows for experimentation with far-reaching outcomes, such as famines when a food resource is being over-harvested, and the ‘death’ of unsuccessful agents.

However, while many different behavioural factors and processes guide the harvesting behaviour of real people, such as human needs, abilities, habitual behaviour and social imitation, it appears that the ‘psychological lay-out’ of agent rules is usually quite poor, or based on only a single theory of behaviour. To improve the ‘behavioural richness’ of simulation models, we need a multi-theoretical meta-model of human behaviour as a guiding framework for the development of agent rules.

A conceptual meta-model of human behaviour (Chapter 5)
The consumat approach is based on a conceptual meta-model that integrates various theories that are relevant for understanding consumer behaviour. This model is graphically depicted in Figure 1. As can be seen in Figure 1, the consumat model consists of different parts. On the left side the macro-level driving factors of consumer behaviour are represented. These macro-level factors involve the natural environment, (involving natural resources), and the human environment, which involves technology, economy, demography, institutions and culture.
On the right side of Figure 1 the micro-level of the individual consumer is modelled. The driving factors of consumer behaviour reside in the available opportunities for consumption, the actor’s abilities, needs, level of need satisfaction and uncertainty, and the opportunity consumption of similar others. These driving forces determine which cognitive processing type the consumer will engage in. When an actor is not satisfied but certain, he/she is most likely to engage in (individually reasoned) deliberation so as to find more satisfying and feasible consumption opportunities. When the actor is not satisfied and uncertain, he/she is most likely to engage in (socially reasoned) social comparison, elaborating on the possible outcomes of imitating the consumptive behaviour of other actors with about the same abilities. When an actor is satisfied and certain, he/she will simply (individually automated) repeat the previous behaviour. Frequent repetition is the cognitive basis of habitual behaviour. Finally, when an actor is satisfied but uncertain, he/she will be most likely to (socially automated) imitate the behaviour of other actors with about the same abilities. Under cognitive processing the actor uses the information available in his/her mental map (memory). Only when the actor engages in reasoned processing (deliberation or social comparison), the actor will store new information in his/her mental map. Figure 1 also reflects that the opportunity consumption following from the cognitive process is aggregated across all actors and affects the macro-level driving factors of behaviour.

Policy measures aimed at changing consumptive behaviour are affecting the driving factors of behaviour either at the macro-level (e.g., economic climate) or at the micro-level (e.g., personal abilities). The conceptual model appears to be suitable to understand the principles behind dynamical processes of consumption such as herd behaviour and habit formation.
Formalising the conceptual model (Chapter 6)

This chapter first deals with the level of detail that is required in the agent rules. The agent rules must be simple enough for the results of simulation runs to be clearly interpretable, but not so simple that mundane realism is lost.

The subsequent parts of the chapter describe how various agent rules are formalised on the basis of the conceptual model of Chapter 5. The agents are called 'consumats', and formalisation of several interacting consumats yields a multi-agent simulation model.

The driving forces at the collective (macro-) and the individual (micro-) level determine the environmental setting for consumat behaviour. The collective level refers to the world consumats are living in. The individual level refers to the consumats themselves, which are equipped with various needs that may be more or less satisfied, and which have various abilities for consumption. Consumats are confronted with different opportunities, which, when consumed, may contribute to their level of need satisfaction. Furthermore, consumats have a certain degree of uncertainty, depending on the difference between expected and actual outcomes of their behaviour.

Consumats may engage in different cognitive processes while deciding how to behave, depending on their level of need satisfaction and their degree of uncertainty (cf. Chapter 5). Consumats having a low level of need satisfaction and a low degree of uncertainty are assumed to deliberate, that is: to determine the consequences of all possible decisions given a fixed time-horizon, in order to maximise their level of need satisfaction. Consumats having a low level of need satisfaction and a high degree of uncertainty are assumed to engage in social comparison. This implies comparison of their own previous behaviour with the previous behaviour of consumats having about similar abilities, and selecting the behaviour yielding a maximal level of need satisfaction. When consumats have a high level of need satisfaction, but are also highly uncertain, they will imitate the behaviour of other similar consumats. Finally, consumats having a high level of need satisfaction and a low level of uncertainty simply repeat their previous behaviour.

A mental map is formalised which serves as a memory to store information on abilities and opportunities, and on characteristics of other agents. Only when consumats engage in reasoned behaviour (deliberation and social comparison) they will update the information in their mental map. Otherwise they will stick to the (possibly outdated) information they obtained in the past.

After consumption of opportunities, the consumat will obtain a new level of need satisfaction and uncertainty, which affect its cognitive processing during the next time step. Moreover, consumption (of the self and other consumats) may cause changes in personal abilities, available opportunities and the world they ‘live’ in, which will affect consumption in succeeding time steps.

Consumats in a commons dilemma (Chapter 7)

In a first series of experiments we investigate how consumats perform in a simple resource management task (Jager, Janssen & Vlek, 1999). We are particularly interested in the effects of uncertainty and satisfaction on the harvesting behaviour of simulated agents. Existing research with real subjects managing a resource revealed that an increase in uncertainty caused people to increase their harvesting (Wit & Wilke, 1998; Hine & Gifford, 1996; Rapoport et al., 1992; Messick et al., 1988).
The simulation experiments reveal three different effects of uncertainty: the optimism-effect, the imitation-effect, and the adaptation-effect, respectively. The optimism-effect holds that deliberating consumats, when confronted with a positive fluctuation in the resource growth, will have too optimistic expectations regarding the future resource size, and hence engage in over-harvesting. This over-harvesting yields high outcomes (on the short run), and as a consequence the consumats may become satisfied and engage in repetition (over-harvesting habit), without perceiving a possible future depletion.

The imitation-effect implies that consumats, when uncertain and satisfied, are likely to imitate the behaviour of other consumats, even when this behaviour is less optimal than one’s own previous behaviour. The adaptation-effect holds that when consumats engage in social processing, they are considering the behaviour of other consumats and (when engaging in social comparison) their own previous behaviour, and hence they do not discover new opportunities for behaviour. As a consequence, the consumats are not capable of adapting their behaviour to changing circumstances, such as a serious depletion of the resource. These three effects are all process-effects, that is, they describe the process that leads towards a certain outcome.

The minimal level of need satisfaction of a consumat appears to be an important behaviour-determining factor. If the actual level of need satisfaction drops below the critical level, the consumats start processing in a reasoned manner. Consequently, a consumat with a high aspiration level is hard to satisfy and thus will frequently engage in reasoned processing. Consumats engaging more often in reasoned processing reach a more sustainable use in case of a relatively accessible resource. This yields the somewhat contradictory effect that consumats which are the most easily to satisfy, are also the ones that are most likely to deplete a resource, due to their easy engagement in an over-harvesting habit. For a less accessible resource the effect turns around, showing that the tendency of easy-to-satisfy consumats to engage in habitual behaviour causes them to develop an under-harvesting habit. We conclude that a higher aspiration level for need satisfaction results in more frequent reasoned behaviour, thereby decreasing the likelihood of over-harvesting and of under-harvesting. These experiments demonstrate that the consumat approach is capable of replicating existing empirical effects, and adding to the explanation of these effects.

The lock-in of consumption patterns (Chapter 8)

Lock-in denotes a phenomenon of dominating technologies or consumer goods in a certain market. Such lock-ins of consumptive patterns cannot always be explained by superior characteristics of the good or technology in question. Previous (economic) studies mainly used probabilistic models to study lock-in effects. We experimented with the consumats to identify relevant processes of lock-in dynamics of consumption patterns. In these experiments, the consumats were equipped with four different needs: identity, personal taste, leisure and subsistence, respectively. Identity is satisfied better if more neighbouring consumats consume the same product. Personal taste implies that consumats can have their own initial preference for a product. Leisure implies that the cheaper the product becomes, the more time remains available for leisure. The price of a product depends on its market share; the more a product is sold, the cheaper it becomes due to learning-by-doing in the production process. Subsistence is related to the level of pollution associated with the products. Important to realise is that not only the product
characteristics affect the need-satisfying capacity of a product, but also whether other consumats consume the product.

In the simulation experiment nine hundred consumats in a checkerboard space of 30 times 30 cells are confronted with two similar products. The product choice of a particular consumat is visualised by the colour of the cell. At the start of the simulation, consumption is random, thus a scattered pattern can be observed in the checkerboard. However, after some time a certain pattern emerges, demonstrating that the consumats are changing their behaviour. Two types of lock-in are observed, namely, a local lock-in and a global lock-in. The local lock-in implies that groups of consumats emerge that consume the same product. Whereas the market-share of both products may remain the same, the spatial distribution may change drastically. This local lock-in is more likely to occur when consumats’ need for identity plays an important role.

The global lock-in relates to price effects and occurs only if individual preferences are not significantly weighted during cognitive processing. In this case we observe that one of the two products will conquer a market-share of 100%. These experiments demonstrate that the consumat-approach is fruitful for exploring the behavioural dynamics that underlie processes of product lock-in.

Formalising the consumat in an ecological-economic model (Chapter 9)
Many ecological-economic models formalise consumer behaviour following the rational-actor approach towards optimisation. We are interested in how the introduction of the behavioural consumat rules may affect the behaviour of a group of agents managing a micro-world. Therefore we place the consumats in an ‘micro-world’ called “Lakeland” (De Greef & De Vries, 1991). Lakeland consists of two natural resources: a fish-stock in a lake and a gold mine. The lake is being modelled as a simple ecological system of fish and shrimps. We place 16 consumats in Lakeland, and these consumats catch fish from the lake to supply their need for food. Moreover, they may also export fish, and the associated income can be spent on assets such as luxury goods. Import of fish is also allowed. If the gold mine is assumed to be open, consumats may also dig for gold. The money earned by mining can be spent on (imported) fish and on luxurious assets. The pollution caused by mining is reducing the carrying capacity of the lake for the fish and shrimp populations. The consumats have to decide on how they allocate their time on leisure, fishing and mining. They are equipped with certain abilities for fishing and mining, and they want to satisfy their four needs: leisure, identity, subsistence and personal taste. We assume that the satisfaction of the leisure-need relates to the share of the time spent on leisure. The identity-need is satisfied by the relative amount of money the consumat owns in comparison to consumats with similar abilities. The subsistence-need relates to the consumption of food. Personal taste is assumed to be related to the absolute amount of money the consumat owns, which can be spent on whatever assets the consumat prefers.

Three important results were found, respectively pointing at the relevance of using a multi-agent simulation approach in modelling behaviour, the importance of different behavioural strategies (repetition, deliberation, social-comparison and imitation), and the role of agent diversity.

First of all, it appeared that 16 consumats that were exclusively engaging in deliberation (homo economicus), were not capable of using the fish-stock in a sustainable manner, because of the social dilemma trap. Each individual consumat, having only a marginal effect on the total fish-stock, ‘thinks’ that the depletion of the resource is
inevitable because it assumes that the other consumats do not change their behaviour. Consequently, all consumats try to maximise their outcomes, catching what they can for as long as there is still fish. This situation resembles a sort of a self-fulfilling prophecy, as the fish-stock depletes because the consumats expect it to deplete.

Using a consumat that could employ all four behavioural strategies (*homo psychologicus*) introduced new behavioural dynamics in the simulation model, such as habitual behaviour and imitation effects. This caused, for example, that the transition from a fishing to a mining society followed a smooth path and caused the consumats to spend more time mining (causing pollution) than in case of the *homo economicus*.

Finally, it appeared that introducing diversity in the consumats by equipping them with different fishing and mining abilities caused a further smoothing of the transition towards a mining society. In comparison to the situation where all consumats had equal abilities, we observed that after the transition for the *homo psychologicus* the time spent fishing rose, whereas for the *homo economicus* the time spent fishing and mining fell. Apparently much more research is needed to investigate how diversity in consumer abilities may affect the management of natural resources.

The current experiments show that it is possible and fruitful to introduce psychological models into ecological-economic models, thereby including relevant behavioural dynamics into ecological economic models.

**The general applicability of the consumat approach for behaviour simulation (Chapter 10)**

The concluding chapter first discusses the advantages and disadvantages of the consumat approach. The advantages reside in the multi-theoretical perspective on behaviour and behaviour change, which allows incorporating more realistic dynamics in simulation-based research. The disadvantages reside in the fact that a formalisation of the consumat approach for a specific (empirical) domain may require a lot of research effort, and results are difficult to validate against empirical data.

A prospect is sketched for the validation of simulation research employing the consumat approach. Here it is also suggested that empirical and simulation research should be used conjointly in exploring research questions regarding behavioural dynamics.

We finally discuss some possible applications of the consumat approach. Three main issues of possible application are distinguished. First, the study of fundamental behavioural dynamics is proposed, such as social value orientations in resource dilemmas, behaviour in ‘give-some’ dilemmas and market dynamics. Second, it is proposed to further experiment with simulated human behaviour in integrated models of complex systems. This would also allow to formalise ‘quality-of-life’ in integrated models, and to diagnose relevant behavioural dynamics of well-defined issues. Third, the consumat approach may be used as a tool to study how policy makers manage complex systems that involve human behaviour. For example, it would be worthwhile to develop a relatively simple model that clearly demonstrates effects of habitual behaviour, the trickling down of new types of behaviour, and the occurrence of herd behaviour. Such a model would allow both to study and to train policy makers’ decision making regarding strategies to change consumer behaviours.