APPLYING THE CONSUMAT MODEL TO FLOOD MANAGEMENT POLICIES

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ABSTRACT

The number and severity of weather related catastrophes is increasing, possibly due to climate changes and changes in land use. Economic losses from these catastrophes are escalating, mainly as a result of concentration of assets and population in high-risk areas. How to deal with these economic liabilities in a fair way at the level of the individual property owners is the focus of our research.

As a case study we choose the second largest river in Hungary, the Tisza, which flows through one of the poorest agricultural regions of Europe, and where large areas are repeatedly struck by floods. The Hungarian government is experiencing huge costs for flood mitigation measures and for economical compensation to the victims. The use of a simulation model for evaluating alternative flood management policies is a natural choice, since it is impossible to predict the time, the location and the magnitude of a flood; historical data is of limited use when looking at the outcome of future policies. The simulation model (Brouwers 2002) shows the economic outcome for the various stakeholders (the individual property owner, the insurance companies, and the central government). The behavior of the river and the financial consequences are simulated on a year-by-year basis.

In the research reported upon, we have extended the simulation model by using the Consumat approach to model the individual property owners. We compare the results with respect to wealth distribution in the case of Consumat agents and simple (non-Consumat) agents.

It is shown that in the Consumat case, the system is more dynamic and seems more realistic. We plan to further investigate these effects and hope to obtain real world data on insurance distributions to verify the outcomes.

INTRODUCTION

There are strong indications that humans are gradually but definitely changing the climate of the earth. Emissions from fossil fuels and greenhouse gasses are altering the atmosphere, leading to an uncertain future of global warming (Jepma and Munasinghe 1998). A possible correlation between the climate change and the frequency and severity of natural disasters can be seen. When the number of catastrophes is increasing the financial losses escalates as well. During the period 1988 - 1997 major natural catastrophes cost the worlds economies US$ 700 billion (Munich Reinsurance Company 1998). The raise cannot be explained by the higher frequency of catastrophes alone. An increased concentration of populations and vulnerable assets in high-risk zones is said to be the main reason to the rise of economic damages (Loster 1999). A key

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problem for policy makers is to identify ways to improve resilience and to protect society effectively against the increasing risk. Questions of accountability and liability for preventing and absorbing the financial losses are on the political agenda in most countries.

For the current article we want to focus upon the distribution of wealth to see if the floods, that only effect part of the basin, has disproportional effects upon the income and wealth of just a few agents. For this we use the Gini coefficient (Gini 1912). As part of the continuous development of the model, we implemented an agent-based model based upon the Consumat approach (Jansen and Jager 1999, Jager 2000). Below we will in more detail describe the case and the Consumat approach. Following this we describe the simulation model. After this we present the simulation results and finally the conclusions and future research are discussed.

THE UPPER TISZA CASE

Hungary is a country where as much as 20 per cent of its 93,000 square meters of territory are at risk for flooding. The Upper Tisza region is one of the largest, natural riverside systems in Central Europe. Both international and Hungarian studies indicate that floods are becoming higher and more frequent, probably as a result of global warming and land-use changes.

The Tisza is the second largest river in Hungary. The part of the Tisza called Upper Tisza stretches to the county of Szabolcs-Szatmár-Bereg. There is no extensive lake system in the Carpathian Mountains, resulting in a large contrast between the maximum and minimum level of water. The lack of lakes is also the explanation to the three annual floods in the Tisza. The first flood occurs in early spring, the second in early summer, and the third in the autumn. Apart from the minor or moderate annual floods, extreme floods occur every 10 – 12 year. During the last years the large floods appear to have become more frequent, large floods occurred in: 1970 (levee breaches), 1993, 1995, 1998, 1999, 2000, and 2001 (dike burst).

Within an international research project (from Austria: IIASA, from Sweden: Department of Computer and Systems Sciences - Stockholm University/KTH, and the Hungarian Academy of Sciences) a case study was performed to identify flood management strategies that were acceptable to the involved stakeholders. The stakeholders involved in the project were the water management bureaus, the insurance companies, the municipalities (represented trough the mayors), catastrophe management organizations, and environmentalist NGO's. To be able to test different flood management policies, a small basin was modeled. During the final stakeholder workshop, which took place in September 2002, the stakeholders used the computer model as a tool for discussing and evaluating different policy alternatives.

The basin of study is located in a poor area where the population is dependent on agriculture. Still, the income from agriculture is not sufficient to support the local population. The intention to shift part of the economical responsibility from the government to the individual property owners is a challenging task to accomplish, as most people are too poor to be able to buy insurance. A flood can be very rewarding for those with insurance however; due to current practice of double-compensating the victims, some property owners receive compensation from both government and insurer.

In the flood model, which was used in the Tisza-project, the property owner agents were not modeled as decision-making agents. It was assumed that all property owners who could afford insurance would buy it. The extended model presented here is a first step in the direction of making the model more realistic.

THE CONSUMAT APPROACH

Wander Jager (Jager 2000) and Marco Jansen developed the Consumat approach. It is a model of human behavior with a focus on consumer behavior. It combines in an elegant way many of the leading psychological theories, such as theories about human needs, motivational processes, social comparison theory, social learning theory, theory of reasoned action, etc. The theories mentioned all explain parts of human behavior but lack the generality to take all circumstances into account, thus rendering them less useful for an overall view. To rectify this, Jansen and Jager set out to develop a meta-theory, which in its turn became the Consumat model.

The driving forces at the macro and the micro level determine the environmental setting for the Consumat behavior. The micro level is formed by the individual Consumats, have needs which may more or less satisfied, have opportunities to consume, and have various abilities to consume the opportunities. Furthermore, Consumats have a certain degree of uncertainty. Depending on the combinations satisfied/not satisfied and certain/uncertain, the Consumats are engaged in four different cognitive processes: repetition, deliberation, imitation and social comparison. When a Consumat is both certain and satisfied, it has of course no reason to change its behavior, thus repetition is the strategy chosen. An uncertain but satisfied Consumat has a reason to change its behavior. In this case the cognitive process chosen is imitation of its neighbors. An unsatisfied but certain Consumat on the other hand will deliberate. The final strategy is to consult the social network, the strategy chosen by uncertain and unsatisfied Consumats.

SIMULATION STUDIES

The simulation experiments are performed on the flood simulation model introduced above, used for investigating the effects of various different flood risk management strategies. The flood model has been used in a study about flood mitigation and loss sharing in northeastern Hungary, in the Upper Tisza region (see Brouwers 2002 for a detailed description). Most of the data used in these agent-based social simulations are real data from the Palad–Csecsei basin; in some cases real data were not available (e.g., a geographically explicit income distribution) in which case we used fictive but realistic data.

The flood model simulates flood failures in the Palad–Csecsei basin. A flood failure occurs when a levee breaks, the flood overtops the levee, or when the water finds its way under the levee. The reason for restricting the simulations to flood failures is that insurance companies compensate damages caused by failures, but not damages caused by ground water related floods.

Nine different flood failure scenarios are implemented in the model. This is based on the assumption that the flood can be of three different magnitudes, and that a failure can occur at three different locations. The financial damages are estimated for all flooded private properties for the nine failure scenarios. Even with a hydrological model, it is impossible to model when and where a levee failure will occur. This uncertainty is made explicit in the stochastic variables Magnitude and Failure. For each simulation year the stochastic variables are assigned new random values. Magnitude tells if there will be a 100-year flood, a 150-year flood, a 1000-year flood, or no flood at all. The probabilities for these events are: 1/100, 1/150, 1/ 1000, and 1-(1/100 + 1/150 + 1/1000). The second variable Failure tells if the flood will cause a levee failure at one of the three locations.

For each simulated year, the financial consequences for the property owner agents are computed. If there was a flood failure the simulated year, the Catastrophe module calculates what land areas (cells in the grid) are inundated, and by how deep water. The Palad-Csecsei basin is geographically represented in form of a grid, in which every cell represents an area of 10 square meters. There are 1551*1551 cells in the grid. Only private properties are considered in these experiments, so all other cells are filtered out. If a flood failure occurred the simulated year, the Catastrophe module is consulted. The financial damages are calculated for each inundated cell. The losses for an individual property owner depend on the prevailing loss-sharing policies. In some countries the government compensates the victims to 100 per cent, while other countries are more restrictive. In addition, the property owner can buy flood insurance. The wealth of all property owner agents is updated in the agent module every year, after consulting the policy module to find the current loss-sharing strategies.

Description of Agent Decision Making Model

As described above, we have two different types of agents that we compare. The first type of agents have a simple decision making model. This means that if an agent has enough financial means to buy insurance, it does. The other model is based upon the Consumat approach described above. Thus agents have the following alternatives:

1. Agent is satisfied and certain: Repetition

2. Agent is satisfied but uncertain: Imitate neighbors (if more than 2 neighbors are insured, the agent will also buy insurance)

3. Agent is not satisfied but is certain on flood risk: Deliberate (change strategy if the agent can afford to buy insurance)

4. Agent is not satisfied and is uncertain on flood risk: Imitates Social Network (goes with the majority in its network)

Agent satisfaction is coupled to the financial means an agent has. An agent is satisfied if its wealth is larger than the agent's satisfaction threshold and if its wealth is larger than last year. The uncertainty of an agent is coupled to its risk profile and the number of years that has passed since the last flood failure occurred. In the section on simulation setup all functions are specified.

Simulation Setups

General assumptions:

- Income = random distribution with mean 36 900 * 12
  12 * average monthly income (which is 36 900 Hungarian Forints, statistics from 1998) using a normal distribution
- Flood frequency = 4
  As statistical records do not reflect last decades' increased flooding, the return period for floods has been decreased. Flood frequency 4 means that the probability for a 100-year flood to occur is: 1/100 * 4
- Premium size for insurance = 0.02 per cent of the property value
  The size of the insurance premium does not reflect the underlying flood-risk; it is based on the property value alone. This corresponds with existing premium prizing in Hungary
- Penetration rate = 0.6
  The fraction of property owners who carry flood insurance (bundled with property insurance). The average penetration rate for property insurance in Hungary is 60 per cent
- Expenses = 0.9
  The figure 0.9 is just estimation, however, the area that is simulated is a very poor area. Thus 90 percent of an agents year income is spend on direct expenses.
- Content Threshold = 10.000 HUF
  This figure corresponds roughly to 1/3 of a monthly income, an agent who has less money to spend (for an entire year) is not content

- Flood Compensation from Government = 0.5
  This figure shows the trend to reduce compensation from government; it used to be much higher (90 – 100 per cent of damages).
- Flood Compensation from Insurer = 0.8
  For the property owners with insurance contract, the insurance companies compensate a fraction of the damages. The size of the fraction can be decided by using different coverage, or deductibles. For simplicity, we are assuming that the companies deduct 20 per cent of the damages and only compensate to 80 per cent

Social assumptions:

- Minimum number of contacts in social network = 2
- Maximum number of contacts in social network = 50
- Number of Social Nodes = 10
- Probability for a property owner to know a social node = 0.9
- Number of neighbors = 5

Simulation assumptions:

- Time period that is simulated = 30 years
- Number of property owner agents = 2580
- Series of simulations = 2
- One series of 9 * 30 years with Consumat model for decision making on insurance
- One series of 5 * 30 years with simple model for decision making on insurance
- Wealth transformation function for property agents (an agent can not have a negative wealth in these experiments)
- No flood failure occurred this year:
  - Wealth year n = max (0, Wealth year n –1 + Income * (1-expenses) – Insurance premiums)
- A Flood failure did occur this year:
  - Wealth year n = max (0, Wealth year n –1 + Income * (1-expenses) – Insurance premiums – Flood Damages + Gov Compensation + Insurance Compensation)
- Risk function
  - Risk for flooding = RiskValue - log2 (Number of years since last flood)

  If the risk is higher than zero, a flood is expected. The risk values are randomly distributed between zero and five. A risk value of zero means that the agent will never expect a flood since the risk function is always below zero. A risk value of 5 means the agent will always expect a flood even if it has not occurred within the last 30 years (which is the maximum number of years in the simulation).

The Gini coefficient

The Gini coefficient is the most used measure for inequality. We used the Gini coefficient to analyze the results of the different simulation settings with respect to the distribution of wealth within the agent population. Since we do not have the corresponding data for the real population, we are only interested in trends.

SIMULATION RESULTS

The simulations were run only a couple of times to obtain a feeling for the possible results. The base model, where agents buy insurance when they can afford it proved to produce a rather static society. Less and less agents bought insurance since most of the uncertain agents were those who suffered from floods while their neighbors did not and most of time did not buy any insurance. The results for the five runs of this model are depicted in figure 1.

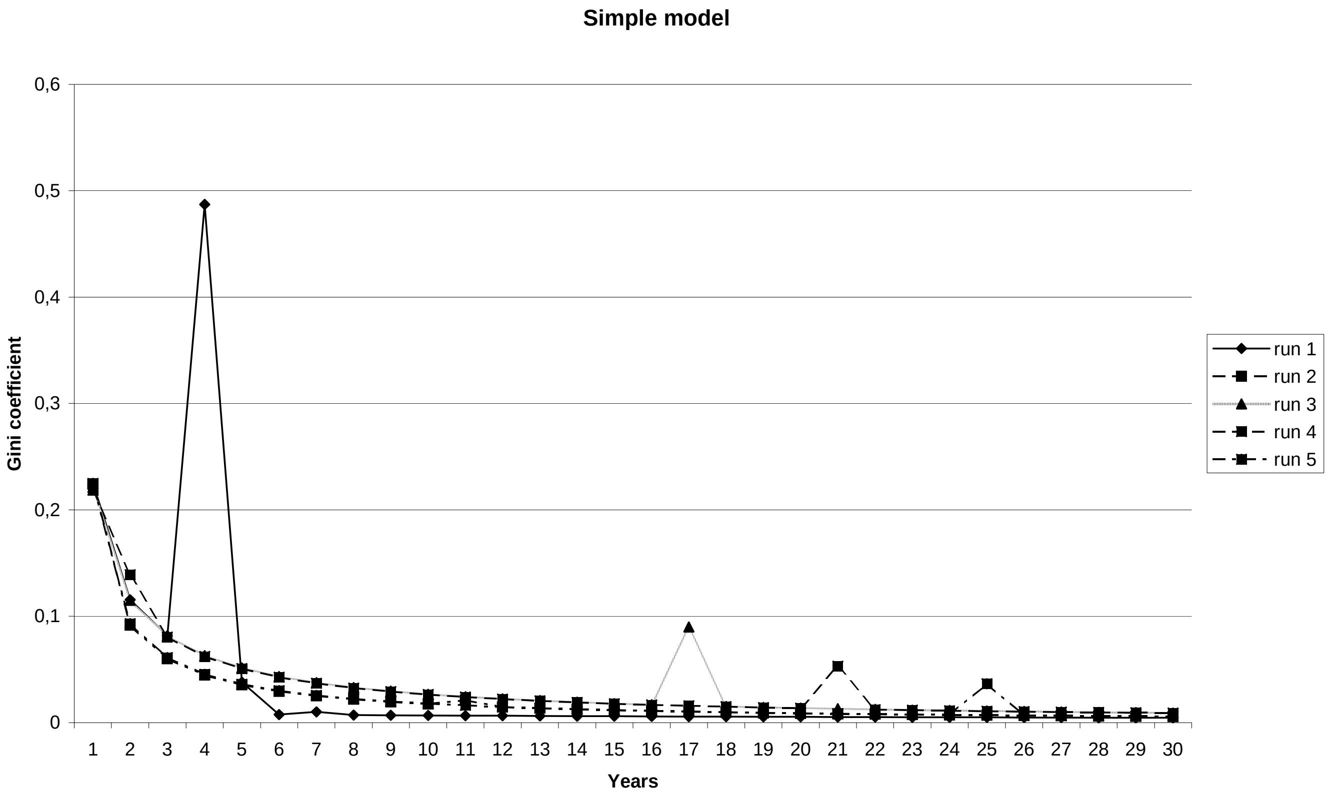

Figure 1: Gini coefficient for the base case simulations

The Consumat based simulations on the other hand show a more dynamic, one might even say chaotic society. Most floods resulted in changes in insurance buying behavior and in a skewer wealth distribution. The results are depicted in figure 2.

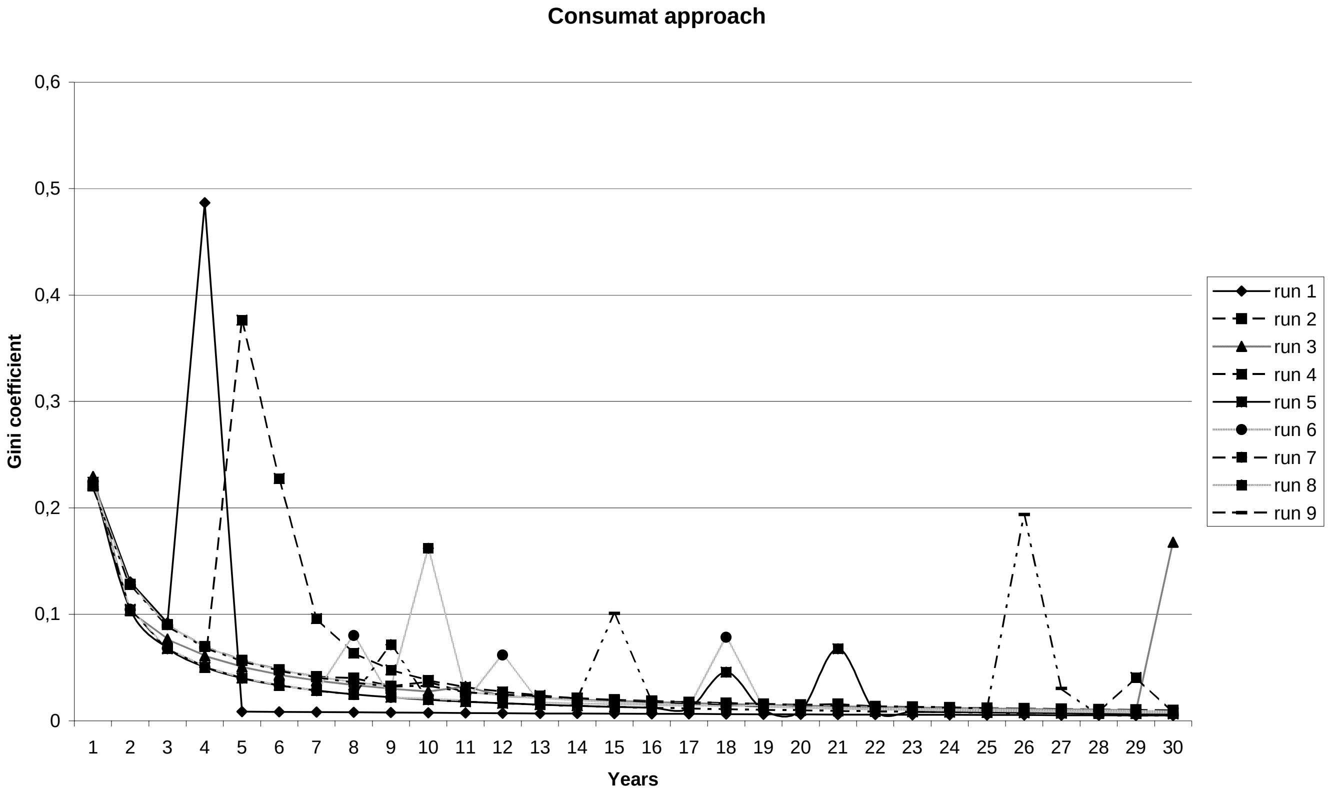

Figure 2: Gini coefficient for the Consumat-based simulations.

DISCUSSION AND FUTURE RESEARCH

The extension of the model has proven successful, since the results are more in line to the real world. Even if the Gini coefficient values are not in the range usually found in a whole society, in our case most inhabitants are very poor and have about the same amount of money to spend. We plan to further investigate these by on the one hand approach insurance companies to try and get access to their statistics, and on the other hand by interviewing a representative selection of the inhabitants in the studied basin to investigate their social network and decision making procedures.

ACKNOWLEDGEMENTS

The authors wish to thank Wander Jager and Marco Jansen for inspiring discussions and clarification of the Consumat approach. This work was in part sponsored by VINNOVA through the project Software agent technology for Ambient Intelligent Systems, part of the “Nätverksbaserad programvaruteknik” program.

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