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"Food Risk Communication and Consumers' Trust in the Food Supply Chain"

TRUST

QLK1-CT-2002-02343

Simulating Food Risk Communication Strategies and Trust Diffusion: A Multi Agent Approach

EAAE Seminar Copenhagen 2005, Paper 3

by

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Abstract

Our motivation is lying on the questions "How does a food scare and information of a food scare influence the buying decision of one single agent and the changes in the aggregate demand?" and "How can we evaluate effective risk communication strategies?". Since we investigate a society of consumers which do have their own decision functions, we can observe how new information could influence the behaviour of each consumer and more interesting the aggregate changes in the demand by creating a population of agents. This multi agent simulation can be used to investigate how different information releases and decision functions influence the aggregate demand. The agents get information from the networks in which they are present. Then this information will be processed, the trust regarding the food item under investigation will be updated and taken into account for the own decision. Our intention is to measure how different risk communication strategies influence the aggregate demand. For this purpose we use a multi agent method in order to follow a bottom up approach where each agent acts individually. The interaction between the agents leads to an emergence of an aggregate demand that comes from the bottom up. Each agent follows its internal updating and decision algorithms so that on the aggregate level the demand changes according to the outcomes of the interaction and its related updating processes. After the communication phases the aggregation of the outcomes of each agent shows the result of the information strategy that was selected. In this way we can test and investigate different risk communication strategies and evaluate these information policies, i.e. the benefits of a risk communication strategy can be evaluated with this multi agent approach.

Keywords: Multi-agent simulation, consumer response, information diffusion, risk communication.

Introduction

The relation between trust, information and demand is a research field, which has been investigated in many different ways. Our approach is to use an agent based simulation model.[1] We want to investigate how heterogeneous interacting agents process information and change attitude and trust by communicating with related agents.
We concentrate on two kinds of behaviour. One is to get information from the networks in which the agent is present. The agent processes this information. The other is to see how related agents behave in terms of deciding on consuming a food item or not and to take this behaviour into account for the own decision.
Our intention is to measure how different information strategies influence the aggregate demand. For this purpose we use a multi-agent method in order to follow a bottom up approach where each agent acts individually. The interaction between the agents leads to an emergence of an aggregate demand that comes from the bottom up. Each agent follows its internal updating and decision algorithms so that on the aggregate level the demand changes according to the outcomes of the interaction and its related updating processes. After the communication phases the aggregation of the outcomes of each agent shows the result of the information strategy that was selected.

1. The theoretical framework of the simulation model[2]

The multi agent simulation software is designed to model the diffusion of trust in food safety information and its impact on demand in the environment of a food safety incidence. Hence, it offers the opportunity to illustrate the variability of trust in the course of time and can provide valuable information about recovery process of trust and the time that has to elapse before pre-incidence sales are obtained, again.
As depicted in figure 1, the simulation software comprises three interdependent spheres. These are firstly a set of *n* individual consumers who more or less frequently decide upon to conduct of not the behaviour in question. These decisions are based on a general decision framework within the Theory of Planned Behaviour (TPB) considering the special features of the agent's affiliation to a consumer group, the current state of the agent's information about food safety and risk, and the corresponding trust in food chain actors. Secondly, the *n* individual consumers are summarised into a demographic network and into social networks in which they exchange information about food safety issues. Finally, a set of *m* media agents that supplies the consumers' network with either positive or negative information about the food under investigation is introduced. The impact of information on the consumers is assumed to depend on the former's addressees, their position within the network, and the media's trustworthiness represented by the specific network weight of the information source (the media agent), apparently.

[1] This work belongs to a project of the European Union. "Food Risk Communication and Consumers' Trust in the Food Supply Chain". TRUST - QLK1-CT-2002-02343.
http://www.trust.unifi.it/
[2] See 1st Progress Report – R1, p. A 43 – A 49.

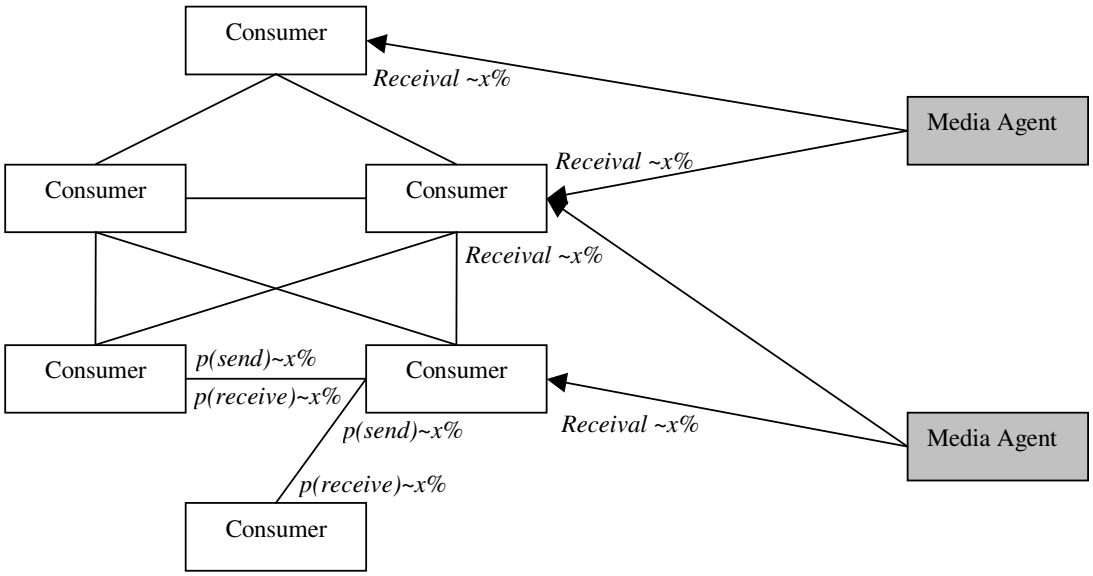

Figure 1: The Distribution of Food Safety Information within the Demographic Network and the Social Networks

As previously mentioned, the main objective of working package five is a *simulation model* which adequately reflects the *diffusion of trust* and its *impact on demand*. In the network part of the model it is determined which consumers receive new information about the risk and safety of the investigated food.
The task of the consumer agents is to transfer this information to trust and ultimately to a buying decision. Hence, these artificial agents must have been constructed in a way that they are able to transfer food risk and safety information into purchase decisions. As the transformation process certainly varies from person to person the artificial consumer agents had to be modelled that they correspond in their structural and behavioural characteristics to different consumer segments.

2. The model

The modelling starts with the construction of an economy which consists of an initial population of agents. There are primary agents like consumers and there are auxiliary agents which often represent different social and model environmental objects, e.g. media agents.
First the initial state of the economy has to be specified, i.e. the agents will be equipped with their initial attributes. These attributes are type characteristics, internal behavioural norms and internal information about themselves and other agents like the network connections.
The development of the economy happens in time by interaction and updating of internal states of the agents, i.e. updating the trust value for a specific good or supplier. The simulation model adequately reflects the development of trust respectively distrust within a population of consumer agents after a food safety incident happened.

2.1 The networks and the information sources

The model consists of several networks which serve as information sources for the agents (SAGGAU and PATELLI, 2004, 2f). We have decided to implement decentralized and centralized networks. Both types of networks serve as information sources for the agents. The decentralized networks are social networks which again are several networks like the demographic network or

friend's networks. These networks are endogenous, i.e. the information processing is endogenous whereas the centralized networks are exogenous. They spread the information from one single information source via the population of agents.
An initial population of consumer agents found the basis for the simulation. They are connected to the networks. They communicate information about the safety of food and their trust regarding this food item.
We differentiate two respectively three kinds of social networks. Each network serves as an information source for the agents. The networks are differentiated by unique identifiers so that the information sources are well known to the agents.
In the demographic network each agent of the population finds its place in a family structure. The demographic network consists of three generations: the grandparent generation, the parent generation and the children generation. The agents are consistently assigned to this network, i.e. the family relations are kept, and there are no inconsistent states (see figure 2).
The demographic network can be varied by changing three parameters: the population size, the average number of offspring in the second generation and the average number of offspring in the third generation.

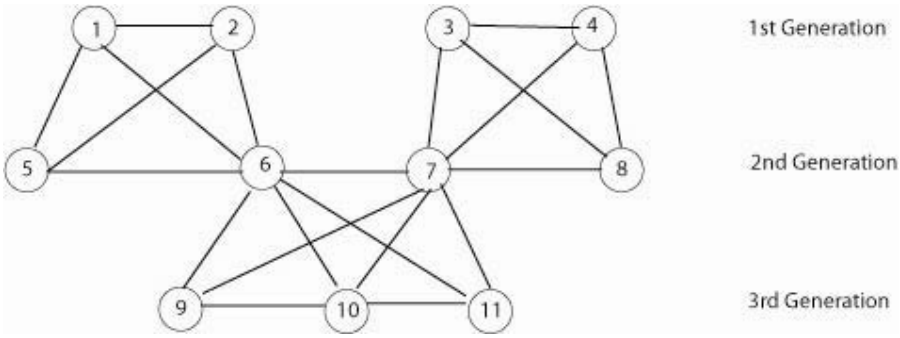

Figure 2: Demographic network

The population size determines the size of the adjacency matrix which will be used as the connections matrix. This connections matrix is quadratic and the size corresponds to the number of agents in the population. This matrix will initially be filled with zeros. The zeros change to one when the generations will be upset and only if the connections are determined. During this phase the initial parameters for the agents will be set.
The size of the first generation results from the quotient of the population divided by the product of the average number of the 2nd and 3rd generation. The size of the second generation is the product of the first generation and the average number of children per family in the second generation while the size of the third generation is the result of the subtraction of the population size minus the size of the first generation and minus the size of the second generation.
The "marriage" in the first generation will be done by an algorithm which overwrites the zeros in the connections matrix by a one if two partners are found. In the next step another algorithm generates the offspring of the first generation and connects this second generation with the first generation.
The marriage in the second generation is a little bit more complicated because it has to be excluded that there are no brothers and sisters marrying each other. Finally the grandchildren have to be included into the family structure, i.e. the third generation will be assigned to the second generation.
All these connections will be done in one adjacency matrix by overwriting the zeros by ones. In this way the demographic network will be set up, in parallel the agents will be initialised and assigned to the network.

Besides a family network each agent can also be part of a friend's network. These are random networks that are not determined like the family network, i.e. each agent randomly receives a variable number of links which connects him to agents that are no family members. The members of these social networks are again the members of the agent population, which already form the family (demographic) network. The connection to other agents can be chosen differently. It's possible to choose between different distributions of the links to the friends.
The uniform distribution for example sets up a connection matrix where the number of connections results from the product of the average connections and the population size. An algorithm then sets up the connections matrix according to the uniform distribution. Figure 3 shows a possible structure of this network.

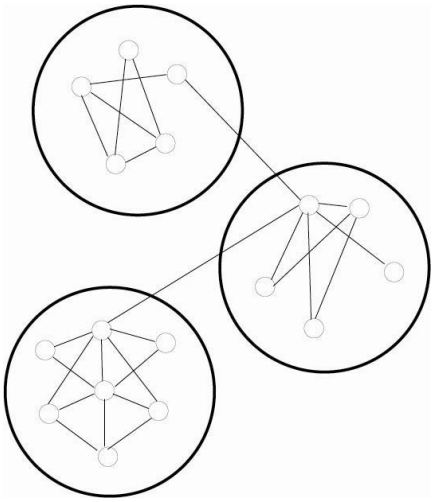

Figure 3: Social networks

Agents can be related in groups respectively clusters, where the nodes or agents are interconnected in a bidirectional way. Some agents have links to agents which are outside of the cluster but again in another cluster. In this way the friend's networks can be created.
Colleague's networks are technically similar, but they have a different weight in the information processing of the single agent, depending on the weight of the network. Both of these networks have a unique identifier so that the agents exactly know where their information comes from.
The centralized networks can be the shops, the media, the government etc.(see figure 4).

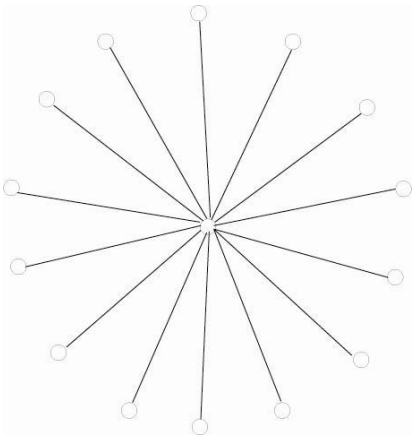

Figure 4: Centralized networks

We differentiate between global centralized and segment centralized networks. In the global centralized networks everybody receives a message which is released by these information sources. Whereas the segment centralized networks are just segment specific and segment exclusive. The social networks are fully decentralised, i.e. only the members of the single social networks will be informed. The intensity of the information received from the different networks is also different, depending on the information type, the information source (the weight of the network) and other environmental influences. Media agents are newspapers, television, internet and radio. Television and Internet are global centralized networks whereas newspapers and radio can be either global or local or segmented depending on the definition respectively the declaration by the user.
The structure of the centralized network is different from the other networks. One reason is that it is responsible for the initial information release which will be diffused via the agent population and processed by each agent. Since we look at information which is related to food scares we have to consider negative and positive information. Bounded rationality is an aspect which has to be taken into account when looking at consumers which have to take decisions. The Prospect Theory of KAHNEMAN and TVERSKY (1979) refers to that issue. Consumers evaluate negative information relative to a reference point higher than positive information, i.e. negative information has a higher weight than positive information. This point has to be taken into account with respect to information releases by centralized information sources.
Each centralized network also has a unique identifier. The information release distribution is a time related distribution – one iteration is one day.
The user can chose between different media sources. Depending on the media source the data from the survey will be loaded into the text field. For these global media sources (they reach everybody) the data will be the same but of course different for the different media sources.
The segment centralized networks refer to specific segments of the population. The data analysis of the Trust-survey (CAVICCHI et al. 2005) identified three segments: “Trusters”, “Mixed-trusters” and “Non-Trusters”. For these three segments a cross country comparison was made, i.e. the five EU-countries (United Kingdom, Italy, Netherlands, France and Germany) have different sizes of the segments.
The population of consumer agents will be assigned to the segments according to the respective percentage distribution. The simulation starts to assign the agents of the population to the first segment then to the second segment on so on. If for example the percentage number for the first segment is 50 and the percentage number for the second segment is 51 then there are just two segments, i.e. the first segment with 50 % of the population and the second segment with the remaining 50 % of the population, the rest will be cut. And even if the other text fields are filled with number they won’t be applied, i.e. if the hundred percent is assigned then the population is also fully assigned to the segments.

2.2 The agents

“An agent is a system that tries to fulfil a set of goals in a complex, dynamic environment. An agent is situated in the environment: it can sense the environment through its sensors and act upon the environment using its actuators.” (MAES 1994, 2).
Starting point is an agent who maximizes his expected utility (BOECKER and HANF 2000). It is assumed that his purchase decision depends on four parameters: the utility from a safe unit of a certain product (U_X^+), the subjective probability to purchase a hazardous unit of that product (P_G)[3], the subjectively presumed disutility from consuming a hazardous unit of that product (U_X^-), and the ex-

[3] With $P_G = P_J$ P(G|A) + (1-P_J) P(G|B) and $P(G|A) < P(G|B)$ and $P(G|A) + P(G|B) < 1$.

pected utility from consuming a substitute which is perceived to be safe (U_Y). He only buys and consumes the product if its expected utility under consideration of the possible disutility is higher than the expected utility of the substitute ($U_Y < U_X^+$).
Further, the artificial consumer agent responds to information about risk and safety of the product. Every piece of positive or negative information changes the subjective probability that he relates to purchasing a hazardous unit of this product. For this updating of the prior subjective probability, the Bayesian updating is employed. Updating (trust) mechanism *(revised trust in supplier J)*:

– Negative Information:

$$P_{PJ} = \frac{P_J P(G \mid A)}{P_J P(G \mid A) + (1 - P_J) P(G \mid B)} \tag{1}$$

– Positive Information:

$$P_{PJ} = \frac{P_J (1 - P(G \mid A))}{P_J (1 - P(G \mid A)) + (1 - P_J)(1 - P(G \mid B))} \tag{2}$$

Each agent is part in at least one network, the demographic network, but can also be part in other networks. The agent is registered in the networks where it belongs to. It can go through the networks and ask for information. Additional to the basic model there is the possibility to “see” how other agents behave in risky situations, i.e. the trust value can be communicated which is a proxy for the demand. The third step is optional.
The agents have internal updating algorithms. These algorithms aim at the information on the one hand side and at the decisions taken by the related agents in the networks on the other hand side. In each step of the simulation run the basic agents' internal step method will be invoked. This method goes through the list of related agents, looks up what the trust value is, evaluates it and it also goes through the list of information sources in order to get information and to update its own information state.

One Iteration/Day:
Step 1 - Information Collection and Processing:
The agents collect in each time step information from their neighbours, i.e. from the decentralized information sources and also the agents collect information from the centralized information sources (media, government, shops, ...) (see figure 5).

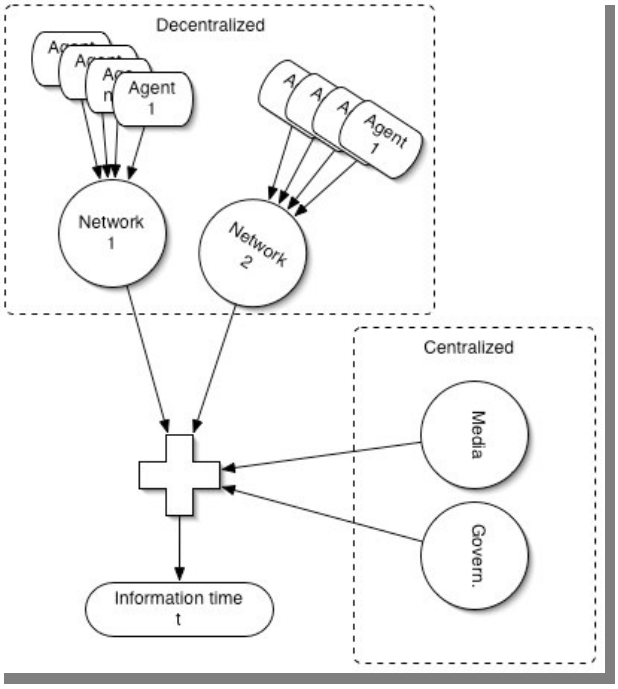

Figure 5: Information collection

Step 2 - Bayesian Updating:
After the information collection the agents update their P_J according to Bayesian updating (see above). The old P_J enters into the equation and revises P_J which then again is the next value which enters in the following updating and so on.
Step 3 - Trust Communication (P_J):
The third step is that the agents collect the P_J s from their related agents and aggregate the value according to an aggregation rule (mean, max, min) (see figure 6).

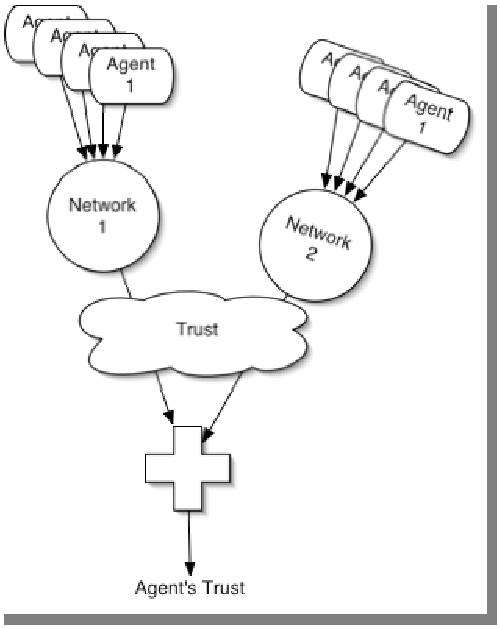

Figure 6: Trust collection

The model offers the possibility to assign different trust values to the four identified consumer segments. Together with the standard deviations of the segmented trust value the system assigns to the single agents normal distributed trust values around the mean value of the respective segment

3. Micro data of the simulation model

The information sources are different. One has to differentiate between the type of the network, the media source (credibility and influence) and the intensity of the information release and the range of the information release. Information sources in centralized networks like media have far more influence regarding these aspects than a single information source in a single social network.
The SPARTA model which is derived from the TPB is based on the socio-economic differences across the population dependent on classification of trust in information. It produced a five information categories based on a principal component analysis which are (1) trust in media information; (2) trust in food chain actors; (3) trust in public authorities; (4) trust in independent organisations and (5) trust in alternative sources[4]. The segmentation analysis on the Trust survey data is based on a further extension of the SPARTA model. It categorises consumers into three distinct 'trust groups' (1) Non-trusters; (2) Mixed trusters (those that are neither particularly trustful nor distrustful); and (3) Trusters. These segments are implemented in the simulation software and can be addressed by segment specific information sources.

3.1 Aggregation rule for getting weights

The weight of the network can be interpreted as a placeholder for the importance of this information source for the agents, i.e. the higher the weight is, the higher is the influence of this information source regarding the trust building of the agent. Radio has for example can have a higher weight than a local newspaper. The Centralized information source can also be a shopkeeper; in this case the empirical data from the survey regarding trust of different information sources plays a crucial role, i.e. if the butcher is more trustful than the newspaper, then this weight value should be higher for the shopkeeper agent (e.g. Media 2).
The aggregation rule for getting weights is related to the collection of information values from the information sources. Each agent updates its information status randomly in the time horizon of the simulation run. The updating of the information status must result in the aggregation of only one information value. Based on this information value, i.e. positive or negative information value, the trust value *Pj* will be updated according to Bayesian updating – more trust or less trust compared to the previous trust value. For this reason, i.e. forming a unique opinion (*newInfoValue*) based on the information values which came from the information sources, the agent has to aggregate and weight the information values of the information sources: Each information source *i* (family, friends, media etc.) has its own information status and a network weight and are registered in the connection list of the respective agent. Both values will be asked by the updating agent. The information values and the network weights will then be multiplied and summarized ($\sum_i (inFoValues_i * weight_i)$). Additionally the network weights will be summarized ($\sum_i (weight_i)$). Finally the new information value (*newInfoValue*) will be computed (see equation 3):

[4] See Lobb et al. (2005), p. 11.

$$newInfoValue = \frac{\sum_i (inFoValues_i * weight_i)}{\sum_i (weight_i)} \quad (3)$$

The trust value will then be revised based on *newInfoValue*, i.e. if *newInfoValue* < 0 then the trust value will be decreased and vice versa.

3.2 Intensity of information releases

The simulation software works with numerical values hence the information regarding the safety of food has to be a numerical value. The reason for this technical issue lies in the nature of the decision for the agent when to increase the trust value or when to decrease the trust value: there are two equations for the Bayesian updating; the decision criterion between these forms of the revision of trust is based on the updated and aggregated information value. The range for the information values released by the centralized media agents on the one hand side (exogenously) and the agents in the networks on the other hand side (endogenously) is between -1 for negative information and 1 for positive information. These are the highest values for both directions. The lesser the values for both directions or say the absolute value, the lesser is the intensity of the information release. This is a second kind of weighting besides the weighting of the information source.
The intensity of the information can also be set explicitly. If a Centralized information source like the shopkeeper should release information then the intensity of the information is probably less than information release from the television, e.g. for positive information – shopkeeper 0.5 and television 0.8 or another example within the same centralized information source like the television: 0.6 for the news reportage at the prime time and 0.3 for the news reportage in the afternoon.
With this variety of information release possibilities there can be predefined empirical information distributions and there can also be produced information strategies which can be tested with respect to the aggregate demand.

4. Information strategies (information policies)

One question in the beginning was which impact does different information strategies have on the aggregate demand, i.e. is it possible to evaluate risk communication strategies? Since we investigate food scares and the corresponding changes in the demand, we focus on information strategies starting with negative information releases regarding the food item under investigation followed by positive information releases by stakeholders using the media to spread information.
The distribution of the information releases by the centralized media can be chosen by the user of the simulation. Consider an example where centralized media agents spread negative information over the network respectively the population in the sense of observing a product failure regarding the food item under investigation, so that each agent receives this negative information signal. When time goes on, here the iterations of the communications steps, the intensity of the information release decreases. It follows an exponential distribution. In a certain point in time, we call it breakpoint, the information release changes from negative to positive information, e.g. it was discovered that the food is safe. It also follows an exponential distribution, beginning with a high intensity and decreasing intensity when time continues (see figure 7).
The information release strategy was selected and parameterised by the user and is visualised by the simulation in an output graph.

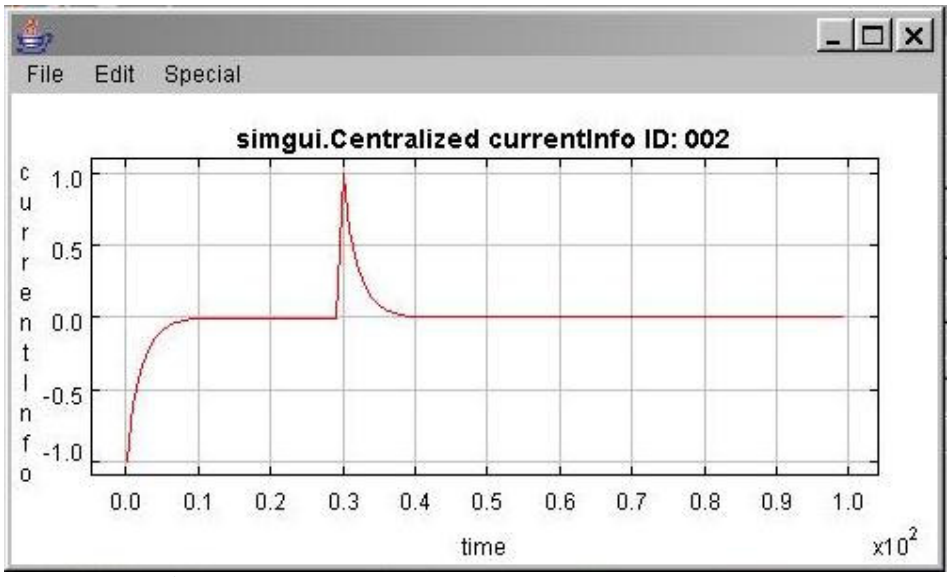

Figure 7: Information release strategy by one media agent

This information release distribution starts with an intensity of -1, i.e. a very strong negative news reportage regarding a food scare. The time scale is the x-value times 10^2, e.g. $0.1*10^2=10$ which means at 0.1 on the x-axis the information value (intensity) at day 10 can be derived from the y-axis. In this example at day 10 this information source respectively the centralized media agent does not longer report about this food safety issue whether negative nor positive. At day 30 (set by the user in the inversion text field) this media agent reports that the food under investigation is safe, i.e. positive information again with strong information intensity (may it be in the television at prime time). The agents update their own trust value based on the new information and if selected also on the basis of the aggregated trust of its related agents.
The consumer agents update their trust value from time to time randomly; they are equipped with the starting parameters heterogeneously. In the example above there was an initial population of 100 agents which are represented each by a single coloured line.
On the aggregated level the development of the average trust value of the population emerge by taking the new information release into account on the micro level and communicating and updating accordingly (see figure 8).

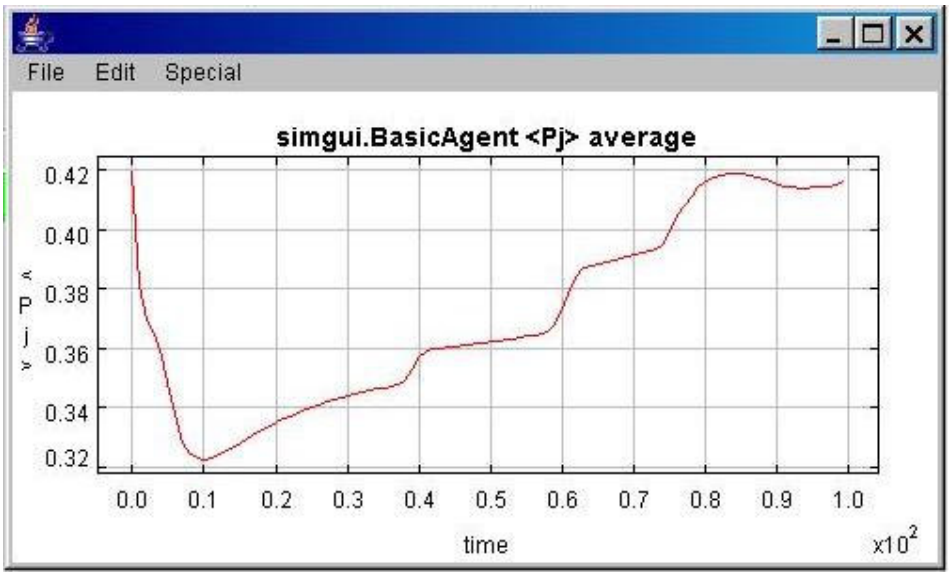

Figure 8: Aggregated (mean) trust

This double exponential distribution of information releases is just one possibility, there may be others. The user of the simulation can implement self created information distributions and can also test information strategies by directing specific consumer segments with information policies.

4.1 Varying information strategies

Varying the breakpoint, the intensity and other parameters leads to different information strategies. These information strategies have different implications for the aggregate demand. The agents communicate about the new information and behave according to their internal processing mechanisms. The result emerges from the bottom up via the communication and the actions of the agents. It is planned to test different information strategies (risk communication strategies) with respect to the aggregate demand. We want to investigate how the different information strategies influence the dynamics of the system and the outcome.
Segment specific information policies can be applied. The segments receive global information by global media but can also be addressed by segment specific centralized information sources or campaigns.

4.2 Evaluating information strategies

Several simulation runs under controlled conditions have to be done in order to evaluate the different information strategies. We are now in the testing phase. The results will be discussed later on when we have tested the model in all areas. The idea is to evaluate risk communication strategies in cooperation with Partner 1. The model provides a tool to economically assess risk communication strategies with the corresponding consumption behavior and market outcome. A cost-effectiveness analysis of different risk communication procedures will be done within the Trust-project. A quantitative monetary measure of benefits will be provided by the outcome of the alternative communication strategies using the simulation model. WP6 has done the policy simulation analysis.

5. Testing risk communication strategies

Risk communication strategies will be formulated in scenarios which should be tested. Depending on the form of the risk communication strategy, i.e. the duration of strategies, the segments addressed, the selected media etc., the recovery of the trust respectively the demand can be the measure for the effectiveness of the risk communication strategy.
In the general sensitivity analysis two information distribution scenarios are tested: double exponential and exponential distribution by media objects. The consumer population is divided in three segments: “Trusters”, “Mixed-trusters” and “Non-trusters”. These segments vary from country to country. In the general sensitivity analysis there is no country scenario selected instead the information scenarios are tested according to different duration of the simulations runs (10, 20, 30, 50 and 100 days).
The simulation testing is combined with a sensitivity analysis from a general point of view so that the results can be seen as reliable. The impact of positive and negative information should be analysed first, i.e. what does the simulation produce when only negative information is available (but whose intensity decreases in time) and second what impact has positive information on the trust building in the time after negative information was released by the media. The comparison of these aspects gives insights into the impact of the general mechanisms which influence the trust building. A general sensitivity analysis can identify the boundaries and the threshold parameter values which are important to improve risk communication strategies.

5.1 Exponential distribution – no risk communication

In this section there will analysed the case when only negative information are released by the media. It is to mention that the intensity of the negative information decreases over time. A practical and empirical reason for this distribution is the fact that a theme loses its interest for the media and the population when time continues. Another reason is that other topics become more interesting for the public and the media, e.g. a shock like the 9/11-incident.
This simulation scenario was performed for different duration: from 10 to 100 days. Each of these simulations was run 50 times; the mean recovery rate is displayed in the following table:

Table1: Simulation results for exponential distribution – no risk communication

Run no.		Starting Pj (all)	End Pj (all)	End Pj Segm1	End Pj Segm2	End Pj Segm3
10	Recovery rate:	0.99	0.329720696	0.776385002	0.154760683	0.012712395
20	Recovery rate:	0.99	0.370884193	0.801667046	0.230528358	0.032052672
30	Recovery rate:	0.99	0.39992159	0.787959537	0.306999906	0.055619285
50	Recovery rate:	0.99	0.487149466	0.808435869	0.478176465	0.122783831
100	Recovery rate:	0.99	0.57954298	0.865073769	0.634467592	0.182345013

Source: Saggau

Each agent of the population is equipped with a Pj-value of 0.99, i.e. nearly full trust. After 10 days the overall trust went down respectively recovery to 0.33, the mean Pj-value for the trust segment is 0.78, for the mixed-trust segment 0.15 and for the non-trusters 0.01. The picture changes after 100 days: the overall trust recovered to 0.58, the mean Pj-value for the trusters is 0.87, for the mixed-trusters 0.64 and for the non-trusters 0.18, i.e. even this segment recovers a little bit.

The heterogeneity of the agents and the network structure leads in each simulation run to slight changes in the results but the standard deviation in each run is very small, so that the mean result is reliable (see appendix A.3).

5.2 Double exponential distribution – with positive counter information

The previous information distribution just released negative information and even then the trust recovered after a breakpoint approximately to the starting conditions. In this section there will be analysed how positive information influences the recovery of the trust. Positive information can be for example the introduction of a quick test to check whether cows are infected by BSE or news like "it's forbidden to process risky parts of the cow" or "the prohibition of feeding meat and bone meal" and especially advertisement campaigns.
Each testing scenario is also performed a 50 times; this allows identifying the boundaries of the results and the validity of the simulation.
This simulation scenario was also performed for different durations: from 10 to 100 days. Each of these simulations was run 50 times; the mean recovery rate is displayed in the following table:

Table 2: Simulation results for exponential distribution – no risk communication

Run no.		Starting Pj (all)	End Pj (all)	End Pj Segm1	End Pj Segm2	End Pj Segm3
10	Recovery rate:	0.99	0.333790422	0.787127609	0.158287578	0.009597319
20	Recovery rate:	0.99	0.359640692	0.783520616	0.214486303	0.0344609
30	Recovery rate:	0.99	0.40285626	0.798587169	0.300713581	0.06033666
50	Recovery rate:	0.99	0.490865946	0.820338863	0.475152773	0.124812911
100	Recovery rate:	0.99	0.638671925	1	0.665654242	0.173858622

Source: Saggau

Each agent of the population is equipped with a Pj-value of 0.99, i.e. nearly full trust. After 10 days the overall trust went down respectively recovery to 0.33, the mean Pj-value for the trust segment is 0.79, for the mixed-trust segment 0.16 and for the non-trusters 0.01. Here also the picture changes after 100 days: the overall trust recovered to 0.64, the mean Pj-value for the trusters is 1, i.e. the trust in this segment fully recovered, for the mixed-trusters 0.67 and for the non-trusters 0.18, i.e. even this segment recovers a little bit.
This information scenario and the results of the simulation runs indicate that positive information has a significant influence on the recovery of the trust. Especially the trusters segment can be positively influenced. Positive information seems to support the recovery in time, i.e. it leads to a faster recovery than without positive information.

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Annexes