How Social Unrest Started Innovations in a Food Supply Chain

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Abstract: Transitions leading to sociotechnical innovations in food supply chains have been described in dramaturgical analyses on the basis of newspaper articles and parliamentary records. The time scale of the transitions driven by aroused public opinion on issues such as animal welfare, is typically a decade. Actors are primary producers (farmers), other supply chain parties, authorities, NGOs voicing particular opinions, political parties, and consumers. In this article, their interactions and reactions to external events are modelled in an agent-based simulation based on opinion dynamics. The purposes of the simulation are (1) to validate that hypothetical relations derived from the dramaturgical analysis indeed lead to the emergence of the observed transitions, and (2) to study how the system could have developed under different behaviours or a different course of external events. Simulation results and a sensitivity analysis are discussed.

Keywords: sociotechnical innovation, opinion dynamics, content analysis, food supply chain, dramaturgical analysis

Introduction

- 1.1 This article proposes an agent-based simulation of public debate on food issues and the resulting changes in food production, under pressure of public opinion. The purpose of the simulation is to partially validate hypotheses about the processes leading to the changes, and to generate counterfactual data. The work is inspired by analyses of public debates on social responsibility aspects of food production.
- 1.2 In the years 2001-2007, public debates on animal welfare in livestock production were staged by the Animal Protection Society in the Netherlands (Buurma 2010; Buurma et al. 2016). In 2001-2002, they called upon the government to support the marketing of organic meat and to introduce animal welfare regulations. In 2002-2004, they started consumer campaigns in newspapers, supermarkets and fast-food restaurants. More activist NGOs entered the stage and increased the pressure. In 2005-2007, the Animal Protection Society started an initiative for an intermediate segment between the conventional and organic segments in the meat market. They introduced the "Better Life" label for animal-friendly produced meat and eggs. The initiative got support from specific feed suppliers, farmer groups, slaughterhouses and retailers. Innovations in housing and production systems took place, and new products were taken to the consumer market under the "Better Life" label.
- 1.3 The debates studied in this work entailed long-lasting controversies between the involved actors. Eventually the debates resulted in innovations in the food supply chain. In that sense, the debates can be understood as constructive processes. The current understanding of transitions towards increased social responsibility in food production and consumption tends to be limited to a macro-level identification and characterisation of a handful of phases or stages in food innovation processes, based on, for instance, Loorbach & Rotmans (2006), who discerned phases of pre-development, take-off, acceleration, and stabilisation in transition processes, and Geels & Schot (2007), who, taking a multi-level approach, described how innovations on the niche-level (bottom level) and external influences from the sociotechnical landscape level (top level) can lead to breakthroughs on the sociotechnical level (in between). A deeper understanding of the dynamics behind these transitions, and in particular of the movement from one stage to the next, requires a micro-level analysis of who voices what, when and how in the public debate.

- 1.4 Stakeholder theory was applied to model the positions of the stakeholders engaged in the debates. Freeman (1984) described stakeholder theory as an approach that identifies and models the groups which are stakeholders of a corporation, and described and recommended methods by which management can give due regard to the interests of those groups. Winn & Keller (2001) presented a case study where they modelled a multi-stakeholder decision process in the StarKist Corporation that adapted their Tuna sourcing strategy under public opinion pressure. The present study focuses on the public debate on food issues, without putting value chain corporations a priori in the leading role. The research is embedded in theory of how innovations spread in societies and the forces that drive these transitions (Geels (2002, 2005); Geels & Schot (2007)) rather than in stakeholder theory. Buurma et al. (2012) presents an overview of literature on the transition theories on which this research builds.
- 1.5 The stakeholders and their interests are identified from content analyses and dramaturgical analyses showing the succession of events, issues and reactions in the course of time, based on publicly available documents: articles in national newspapers and professional journals, and questions in Parliament. Babbie (2007) defined content analysis as "*the study of recorded human communications, such as books, websites, paintings and laws*". Lasswell (1948) formulated the core questions of content analysis as: "*Who says what, to whom, why, to what extent and with what effect?*". These questions represent the aim of the analyses of the public debates. It requires a systematic approach to analyse hundreds of documents. Hajer (2005) introduced dramaturgical analysis as a systematic framework to analyse such processes. Dramaturgical analysis considers the public debate as a theatre performance with scripting (story lines and actors), setting (locations and discourses), staging (parties involved), and plots (crucial moments). In the present research, dramaturgical analysis was used to identify events, conditions, and actors having a critical role in turning points in the debates. In addition to the dramaturgical analyses, content-based media analyses were conducted by tagging newspaper articles with discrete speech acts of specified actors groups at specific moments to identify trends in the topics of the discourse. As a result of the analyses, the process is visualised in a flow chart model, implicitly showing "*who and what really counts*" in stakeholder salience (Mitchell et al. 1997): power of stakeholders, legitimacy of their relationships and urgency of their claims.
- 1.6 The present paper proposes an agent-based simulation based on the interactions identified in the analyses. Multi-agent systems offer a natural paradigm to model social processes with diverse, interacting, agents. They allow for diversity of the agents and of their interaction patterns. Agents may not only be diverse with respect to their preferences and decision functions, but also with respect to susceptibility to influences from other agents. Moss (2002) argued that adaptive agent models of markets with agents that reason and are socially embedded have the same statistical signatures as real markets, and that these models offer unique opportunities for validation on the basis of domain expertise and qualitative data. As Moss further argued, adaptive agent modelling is an effective method when embedded in a wider policy analysis procedure.
- 1.7 Simulations of social responsibility in supply chains tend to model internal dynamics and the behaviours of particular actors in the chains. Abdelkafi & Täuscher (2016) proposed a system dynamics model of value creation for a firm, customers, and the environment, based on dynamic cognitive models of firm manager and customers; however, they only described a conceptual model and presented no simulation results. Bichraoui et al. (2013) proposed an agent-based simulation that modelled economic, environmental, and social responsibility aspects of regional cooperation in agricultural processing industries; they did not include the primary producers' and consumers' ends of the supply chain. Verwaart & van den Broek (2015) simulated the economic and sustainability performance of different governance regimes for food supply chains, but did not explicitly model the demand drivers for sustainable products. On the consumer end of supply chains, Schwarz & Ernst (2009) introduced an approach to account for heterogeneity of consumer populations in agent-based simulations of innovation diffusion, based on a segmentation widely used in market research, and Krejci et al. (2016) simulated the role of pro-social considerations in consumer decisions on purchasing through a food hub with the consumers' choices are based on given preferences; both did not include forces that change preferences in their models. A detailed agent-based simulation of alternative fuel production and consumption was proposed by van Vliet et al. (2010); their model includes consumer preferences and simulates preference changes based on consumer network interactions. Simulations by van Eck et al. (2011) have demonstrated the importance of opinion leaders in such networks. Assuming an increasing weight of ethical considerations in consumers' decisions, Handayati et al. (2015) propose a simulation of value co-creation of new, ethically inspired, brands by supply chain partners; they model the response, not the drivers. Okada (2011) modelled a firm's benefits from social responsibility activities in an agent-based simulation with workers, consumers, and shareholders as agents affecting the firm's social responsibility behaviours. The work reported in the present paper complements this work. It models how external social forces can initiate a shift towards social responsibility in food supply chains.

Issue	2005	2006	2007	2008	2009	2010	2011	2012	Total
Welfare standards	3	4				3	1		11
Welfare criteria	1	4				1		2	8
Housing systems	5	11	36	1	5	5	1	3	67
Intermediate segment			3	5	7	23	13	11	62
Meat quality/taste		1	2			2	3	7	15
Total	9	20	41	6	12	34	18	23	163

Table 1: Number of references in newspaper articles on specific aspects of animal welfare of pigs, mentioning the Animal Protection Society, classified into issues and years

- 1.8** A well-established application of agent-based modelling is the simulation of opinion dynamics. Deffuant et al. (2000) proposed an agent-based simulation in which opinions were represented by a continuous variable x on the interval $[0, 1]$. In this simulation, agents meet at random and then exchange opinions, provided that the difference between their opinion is less than some threshold d . When two agents meet between (discrete) times $t - 1$ and t , and at time $t - 1$ have different opinions x_{t-1} and x'_{t-1} , respectively, their opinions at time t are updated as follows:

$$x_t = \begin{cases} x_{t-1} + m(x'_{t-1} - x_{t-1}) & \text{if } |x'_{t-1} - x_{t-1}| < d \\ x_{t-1} & \text{if } |x'_{t-1} - x_{t-1}| \geq d \end{cases} \quad (1)$$

with $d > 0$ and $0 \leq m \leq 0.5$. One can think of d as an agent's openness to others' opinions or uncertainty about its own opinion; m determines the pace of convergence when an agent is open to the opinion of the other agent.

- 1.9** In the research reported here, data resulting from the discourse analyses are input to an agent-based simulation of opinion dynamics. The hypothesis is that the agent-based simulation can be applied to partially validate the outcomes from the dramaturgical analyses, showing that the assumed relations and interactions indeed cause the observed patterns of transition, and that these patterns do not emerge if the assumptions are changed.
- 1.10** The following sections summarise the results of the dramaturgical analysis (Section 2), describe the agent-based simulation (Section 3), analyse the simulation's emerging patterns and sensitivity to parameter variations (Section 4), and draw conclusions about validity and applicability of the simulation (Section 5).

An animal-welfare case

- 2.1** The agent-based simulation proposed in this article is informed by the debate on animal welfare in pork production in the Netherlands in the period 2005-2012. That period saw many campaigns, activities and efforts of various actors to address and reduce animal suffering in pork production. Several animal welfare NGOs took part in the debates. Two were the most prominent and played a central role in triggering a system innovation in the pork sector: a traditional, moderate NGO (the Animal Protection Society) and an activist NGO (in Dutch named "Varkens In Nood" - translated to English: "Pigs In Distress"). They raised different issues and used different types of means and discourse (Buurma 2010; Buurma et al. 2016).
- 2.2** Two sets of newspaper articles were analysed: articles mentioning the Animal Protection Society and articles mentioning Pigs in Distress. The present section briefly describes the outcomes, which are extensively reported by Buurma et al. (2016). First, the issues raised by the two NGOs are described and compared. The section is concluded by an overview of the dynamics of social pressure and innovations.

Animal Protection Society's issues

- 2.3** Table 1 shows the number of articles about selected issues related to the Animal Protection Society. In the years 2005-2012, the Animal Protection Society put much effort in the development of an animal-friendly housing system and in the development of an intermediate animal-welfare label for a segment in the market between conventional and organic pork. The process started with an exchange of trends, opinions and responsibilities with regard to welfare standards between a retail company, the Pig Farmers' Union and social scientists in

Issue	2005	2006	2007	2008	2009	2010	2011	2012	Total
Organic			4	1					5
Less meat	1		5		8	1			15
Meat prices		1	6	7	3	6	3		26
Meat marker					31	4		26	61
Intermediate segment						11	7	2	20
Total	1	1	15	8	42	22	10	28	127

Table 2: Number of references in newspaper articles on animal welfare of pigs mentioning Pigs in Distress, targeting consumers and retailers, classified into issues and years

2005/2006. In reaction to this diverging exchange, the Animal Protection Society together with the Pig Farmers' Union decided to define the basic needs of pigs and translate them into welfare criteria.

- 2.4** Starting from the welfare criteria, researchers and representatives of both the Pig Farmers' Union and the Animal Protection Society designed an animal-friendly housing system. In 2006/2007, the technical results received broad attention in the news media. In 2009/2010, the researchers admitted that the costs were 10-15% higher than in the conventional system. At the same time, pig farmers told in newspaper articles that they needed compensation for the costs of distraction material, straw and additional labour.
- 2.5** The higher costs and the invisibility of animal-friendly produced pork in the market were reason for the Animal Protection Society to develop the intermediate animal-welfare label ("Better Life" label). The Better Life label was developed (2008/2009) and introduced (2010/2011) in close cooperation with slaughterhouses and retail chains. Through the introduction of the Better Life label pig farmers with animal-friendly production were able to get a price premium for their investments in animal welfare. The development of the intermediate animal-welfare label was followed by requests of retail chains for improvement of meat quality/taste.

Pigs In Distress's issues

- 2.6** Table 2 shows the issues brought forward by Pigs In Distress, targeting consumers and retailers. In 2007 and 2009, culinary journalists, together with Pigs in Distress, argued in favour of buying organic meat and buying less meat. They argued that animal welfare in organic production was much better than in regular production and, later on in the discourse, that high levels of meat consumption were harmful to human health and to the environment. In addition, Pigs in Distress explained to citizens and consumers that low meat prices constrain farmers' investments in animal welfare and blamed retail chains for unethical behaviour by offering regular meat at record low prices. Their statements were supported by experiences of pig farmers and findings of researchers and experts. Retail companies replied that the buying behaviour of the consumers forced them to decrease the prices.
- 2.7** In the second part of the period, Pigs in Distress introduced the so-called "Meat Marker". The "Meat Marker" shows the consumer how different types of meat and protein products score in terms of animal welfare and environmental impact. The first version (2009) was a small card showing the scores of 18 types of meat on animal welfare and environmental impact. The second version (2012) was a smartphone app enabling consumers to scan the barcodes of 16,000 meat products in supermarket shelves and to see the animal-welfare quality and the environmental impact of these products. Moreover, Pigs in Distress supported the activities of the Animal Protection Society and challenged retail chains to start selling Better Life meat and thus reduce animal suffering and get a better reputation.
- 2.8** Apart from challenging consumers and retailers to make a shift to animal-friendly produced meat, Pigs in Distress also denounced various abuses in the pork production chain. Table 3 shows the issues targeting pig farmers, livestock transporters and slaughterhouses. The main issues (in terms of number of references) of Pigs in Distress targeting the pork production chain in 2005-2012 were anaesthesia in slaughterhouses, transportation of livestock, castration of piglets, and animal suffering.
- 2.9** The issue of anaesthesia in slaughterhouses was raised for the first time during the elections campaign in 2006. The issue then focused on the best method for anaesthesia (CO₂ or electric shock) and inspection by the Food Safety Authority. In 2009, the issue was raised for the second time. The attention then went to animal suffering caused by CO₂. Pigs in Distress showed videos with shocking scenes of anaesthesia with CO₂ in slaughterhouses. The Minister of Agriculture explained in parliament that the slaughterhouses met the EU regulations.
- 2.10** Transportation of livestock was raised in 2007. Focus was on violation of the regulations by transport companies. Pigs in Distress showed shocking scenes (blood on trucks) of livestock transports. Politicians asked for

Issue	2005	2006	2007	2008	2009	2010	2011	2012	Total
Housing		1	6	1	1			1	10
Anaesthesia		14		2	19				35
Transportation		1	12	5	10	1		1	30
Castration				6	11	11		4	32
Animal suffering		3		3	5	1	1	11	24
Total		19	18	17	46	13	1	17	131

Table 3: Number of references in newspaper articles on animal welfare of pigs mentioning Pigs in Distress, targeting the pork production chain, classified into issues and years

better inspection procedures. In 2009, the issue returned again because of transport companies breaking the regulations. Pigs in Distress disclosed a secret report of the Food Inspection Authority on violations of transport regulations and intimidation of inspectors. Transport companies replied that most animal transports complied with the regulations. Politicians again asked for better inspection procedures.

- 2.11** In 2008, castration of piglets became an issue for Pigs in Distress. They took out a summons against two retail chains in order to stop the sales of meat of castrated pigs. The retailers replied that castration was to be stopped in 2015 and that, in the meantime, castrations would take place under anaesthesia. In 2009, Pigs in Distress revealed research results showing that anaesthesia was twenty times more stressful than castration itself. This finding fuelled the discussion on castration. In this environment the Animal Protection Society succeeded to strike a deal in January 2010 with the retail and the pig farmers to stop selling meat of castrated pigs by January 2011.
- 2.12** In 2007, the national government issued a policy position on animal welfare, including a report on discomfort issues in livestock husbandry. The resulting debate in parliament included criticism (and a plea for a ban) on circus animals and attention for living conditions of pets. In 2012, Pigs in Distress continued the debate on health problems of pigs (pneumonia) and measures to avoid tail biting (tail docking). A new issue was started in 2012 with the observation that animals in the meat industry are considered and treated as 'things' instead of being living creatures.

Animal Protection Society versus Pigs in Distress

- 2.13** There is little overlap in the issues raised by the moderate and the activist NGOs. Furthermore, the overlap in parties addressed was small. The moderate Animal Protection Society was mainly involved in issues targeting primary producers and processing/retail. The activist Pigs in Distress was mainly involved in issues targeting consumers/citizens and processing/retail. Thus, the two NGOs focused on different levels in the value chain. While the Animal Protection Society focused on the production end of the supply chain, Pigs in Distress focused on the consumer end. Furthermore, there was little overlap in approach. The moderate Animal Protection Society mostly tried to create feasible solutions. The activist Pigs in Distress was more inclined to denounce existing behaviours or practices and pushed consumers in the direction of buying less meat and campaigned against record low meat prices. An exception was the introduction of the "Meat Marker" with which Pigs in Distress tried to create a solution for the effects of meat consumption, such as animal suffering and environmental impact.
- 2.14** The differences raise the question whether the activist NGO and the moderate NGO were antagonists or complemented each other's role. The content analysis revealed examples and evidence that the differences in issues, target groups and approach resulted in complementary pressures on different stakeholders, which eventually brought the transition about. One example was mentioned in the description of the debate on castration of pigs: the Animal Protection Society struck a deal with the retailers, after Pigs in Distress had fuelled the debate.

Dynamics of pressure and change

- 2.15** Figure 1 depicts the sequence of activities and stakeholders involved in the shift from low-cost production and marketing of pork to animal-friendly production and marketing, showing "*who and what really counts*" in this process, after Mitchell et al. (1997). It starts with normative pressure (red arrow, bottom right) created by activist NGOs publishing confronting reports or observing disappointing trends. This normative pressure is pumped into the heart of the triangle, where the moderate NGOs have a central position between knowledge partners,

Figure 1: The dynamics of societal pressure and innovations

primary producers and value chain partners. The moderate NGOs consult knowledge partners (researchers and pioneers) to develop solutions such as housing systems.

- 2.16** The normative pressure generated by the activist NGOs moves on to the primary producers and via consumer behaviour to retail companies and their suppliers. The activity of various partners is coordinated through the gear wheels of a process in which the most relevant actors are involved. This coordination process includes negotiations and striking deals. Such deals (e.g. between Animal Protection Society, retail companies and Pig Farmers' Union) result in new production systems and market segments, enabling (1) primary producers to sell pigs kept according to animal-welfare standards, (2) retail companies and slaughterhouses to source the responsibly produced pigs, and (3) consumers to buy pork, meeting social responsibility standards.
- 2.17** The dynamics depicted in Figure 1 represents a lengthy process of activities of NGOs and knowledge partners to build normative pressure, to develop innovative solutions, and to influence buying behaviour before the value chain partners started to move. This finding supports the concept of stakeholder salience: stakeholders have to become powerful, to present reasonable solutions, and to create social unrest among consumers before value chain partners feel urgency to move. The case described in the present paper contrasts with the StarKist case described by Winn & Keller (2001), where the fishing fleet was driven out of business. In the present case the involvement of all stakeholders (NGOs, knowledge partners, primary producers and value chain partners) resulted in a solution without losers.

Agent-based simulation of the transitions

- 3.1** The following subsections describe the agent-based simulation following the updated ODD protocol (Grimm et al. 2010; Polhill 2010).

Purpose

- 3.2** The first purpose of the simulation is to contribute to the validation of hypotheses about micro-level processes and stakeholder interactions leading to observed sociotechnical innovations in food supply chains. The second purpose is to provide counterfactual evidence to enhance understanding of alternative outcomes, assuming that different external events would have occurred or that actors would have behaved differently.

Entities, state variables and scales

- 3.3** Four classes of actors are discerned in the simulation:

- Consumers,

- Supply chain parties (in the simulation represented by retail companies),
- Primary producers (farmers),
- NGOs (producers' and animal-welfare organisations).

3.4 All agents have a position on the opinion scale x ranging from 0 (preference for cost minimisation) to 1 (preference for social responsibility, e.g., animal welfare maximisation). For the simulation we assume that all agents, except the animal-welfare NGOs, are initially positioned at $x_0 = 0$.

3.5 In order to represent diversity of the actors, the first three classes are segmented into subclasses discerned by Hessing-Couvret & Reuling (2002), van Tulder et al. (2009), and de Lauwere et al. (2002), respectively (see Table 4). Hessing-Couvret & Reuling (2002) described a segmentation of the Dutch population which is widely used in opinion polls and market research. For the purpose of supply chain research van Tulder et al. (2009) proposed a typology of companies in the Dutch retail sector. The segmentation of the Dutch farmers' population by de Lauwere et al. (2002) is used in research on Dutch agricultural entrepreneurship. These publications present prevalence frequencies and rankings of the discerned segments on several dimensions. We estimated projections from the dimensional rankings to the scales of the opinion dynamics parameters m and d and discussed the projected values with experts in the respective fields.

3.6 The fourth class of actors is represented by agents voicing particular positions on x . The producers' organisations are initially positioned at $x_0 = 0$ and have a small value of $m > 0$. The activist NGOs are positioned at $x_0 = 1$ with $m = 0$. The moderate NGOs also start at $x_0 = 1$, but have a value of $m > 0$, which allows them to compromise. However, they tend to move back when possible.

3.7 Setting values for d , the problem arises that NGOs tend to be more open to opinions on one particular side of the opinion scale. Hegselmann & Krause (2002) identified different approaches to opinion dynamics. Asymmetric confidence is one of the concepts they described. This concept is adopted to model the opinion dynamics in the present simulation. The mathematics according to Hegselmann & Krause (2002) are

$$x_t = \begin{cases} x_{t-1} + m(x'_{t-1} - x_{t-1}) & \text{if } -d_l < x'_{t-1} - x_{t-1} < d_r \\ x_{t-1} & \text{if } x'_{t-1} - x_{t-1} \leq -d_l \vee x'_{t-1} - x_{t-1} \geq d_r \end{cases} \quad (2)$$

where d_l stands for openness to opinions on the agent's left-hand and d_r for opinions on its right-hand side.

3.8 The moderate animal welfare NGO will be more susceptible to opinions with high values of x , which is represented by assigning a higher value to d_r than to d_l . On the other hand, the producers' organisation is assumed to be more open to opinions with a lower value of x and is assigned a higher value of d_l . The concept of asymmetric confidence is also applied to model the effect of media events that arouse uncertainty among consumers. In the beginning of the simulation, d_l and d_r are assigned symmetric values for consumers, retailers, and producers. For consumers the values of d_l and d_r may be influenced by events reported in the media.

3.9 Table 4 presents the actor types, the number of agents in the simulation and the default parameter settings. The frequencies of the consumer and producer classes are copied from the respective source publications. The other classes are represented by a single agent. For supply chain partners (retailers) and NGOs the values of m , which determine the pace of opinion convergence, are relatively small, because these agents interact more frequently with other agents than consumers and producers do, and they will not change their opinion rapidly on the basis of a single interaction. The producers' organisation in particular has a low value of m , to represent a stable policy and keep the organisation connected with the majority of the producers.

3.10 A time step in the simulations represents 1 week, which matches the actual time scale of the communications between the agents through newspaper articles and periodicals, mostly on weekly opinion pages. A simulation is typically run for ten years; this is the time scale on which the actual transitions emerge.

Process overview and scheduling

3.11 The simulation¹ is implemented in NetLogo (Wilenski 1999), with agents as described in Table 4. The basic processes are the random generation of media events that may arouse consumers' uncertainty and the exchange of opinions by the agents. In addition, some monitoring processes are implemented, for instance to stop the simulation after 10 years and to observe emerging properties at macro level.

3.12 News items in the media may arouse consumers' uncertainty. For instance, images of animals in bad conditions may make consumers more susceptible to opinions with higher values of x , while news about fraud with organic

Agent type	frequency	x_0	m	d_l	d_r
<i>Consumer types, according to Hessing-Couvret & Reuling (2002)</i>					
- Conservatives	16	0	medium	low	low
- Caring	15	0	high	medium	medium
- Balanced	21	0	medium	medium	medium
- Committed	11	0	high	high	high
- Open-minded	7	0	medium	high	high
- Professionals	8	0	low	medium	medium
- Materialists	11	0	low	low	low
- Hedonists	11	0	low	low	low
<i>Producer types, according to de Lauwere et al. (2002)</i>					
- Traditional	22	0	low	low	low
- Economical	14	0	low	low	low
- Balanced	21	0	medium	medium	medium
- Open-minded	18	0	high	high	high
- Professional	25	0	low	high	high
<i>Retail types, according to van Tulder et al. (2009)</i>					
- Inactive	1	0	0	0	0
- Reactive	1	0	0.0001	0.30	0.30
- Active	1	0	0.0001	0.70	0.70
- Proactive	1	0	0.0001	1.00	1.00
<i>NGO types, according to Buurma et al. (2016)</i>					
- Producers' organisation	1	0	0.00001	1.00	0.60
- Animal welfare (activist)	1	1	0	0	0
- Animal welfare (moderate)	1	1	0.0001	0.70	1.00

Table 4: Number of agents in the simulation and default parameter settings for each actor type; x_0 denotes the initial opinion; m , d_l , and d_r are the opinion dynamics parameters; 'high' denotes a uniformly distributed random value on the interval [0.10, 0.15]; 'medium' on [0.05, 0.10]; 'low' on [0, 0.05]; the random values are generated for each agent during the simulation's initialisation

Figure 2: Interactions among agents modelled in the simulation

food may have an adverse effect. This is modelled in the simulation by randomly generated rare events which for one week increase all consumers' values of either d_l or d_r with an arousal factor $a > 1$. The factor a quantifies the arousal of uncertainty by media events. The frequency of the events is typically set to a probability of twice per year for events that increase d_r and once per year for events that increase d_l .

3.13 Interactions occur between consumers and NGOs, among consumers, between consumers and supply chain actors, between supply chain actors and producers, among producers, and in the public debate, as displayed in Figure 2. When the NGOs' positions are far away from groups in the public, they are voices calling in the wilderness. This may be changed by events with emotional impact that get media attention, e.g. an outbreak of a live-stock disease or news about pesticide residues in food. Such events may temporarily increase the consumers'

susceptibility to other opinions (i.e. increase the value of d_l or d_r , typically with an arousal factor $a = 10$).

Design concepts

3.14 This subsection describes the design concepts according to the eleven elements specified by the ODD protocol.

- The *basic principle* of the simulation is opinion dynamics according to equation (2), in a network with generic links between groups of agents (as in Figure 2).
- The most important *emergent property* to be observed is whether shifts in average opinions occur that set the conditions for implementing new production systems and marketing models in the supply chain and uptake of the produce by consumers. Further, shifts in the positions of specific actors that particularly influence the course of events are relevant, as is the time when they occur.
- The *adaptive trait* of all agents is their opinion, which is represented on a scale of 0 (price oriented) to 1 (animal-welfare or social-responsibility oriented).
- The main *objective* of all agents is to share opinions with other agents to a greater or lesser extent. The parameter m determines the pace at which opinions converge when an agent is open to the opinion of another agent.
- The agents have no other *learning* than updating their opinions in interaction with other agents; the extent to which they do so may for consumers depend on uncertainty-arousing news items.
- The actors are simulated by reactive agents that have no goal-directed behaviours based on *predictions*.
- Consumers *sense* news items from the media that are generated from the environment.
- The *interaction* between the agents follows the scheme depicted in Figure 2 and is described in detail under "Submodels".
- The news items arousing the consumers are randomly generated with frequencies that can be set in the user interface. This *stochasticity* may influence the course of events and the emergence of opinion shifts.
- No explicit *collectives* are modelled. Groups of agents may emerge by alignment on particular points on the opinion scale.
- The *observable properties* of the simulation are the positions on the opinions scale of the different agent categories and the consumers' arousal level. Two observables are particularly interesting. First, whether or not and, if so, at which time step a general shift of opinions occurred with a cluster including the moderate NGO, a retailer, and the producers' organisation. Second, the distribution of opinions among the producers, because that must lay the foundation for innovations.

Initialisation

3.15 At setup time the moderate and the activist NGOs are located on the animal welfare oriented end of the opinion scale ($x = 1$). All other agents are located on the price oriented end ($x = 0$). The parameters and numbers of all agents are set according to Table 4. Where the table specifies a range of values for a parameter, the values are generated at random, with new values for each run. Typically 100 consumer agents and 100 producer agents are set up in order to enable sufficient diversity of parameter values in the individual agents, but the numbers can be modified through the user interface. Other agent parameters that can be modified for setup are whether or not an activist NGO is participating, and the values of the moderate NGO's d_l , the producers' organisation's d_r , and the maximal value of d_r of the retailers. Further, the targeted frequencies of randomly generated media events and the arousal factor can be set.

Input data

3.16 The input data from Table4 is included in the simulations' source code.

Submodels

- 3.17** Uncertainty arousal, agents' encounters, and the exchange and updating of opinions are the essential submodels of the simulation.
- 3.18** News items in the media can raise consumers' uncertainty about their current opinion on animal welfare. For instance, items on massive slaughtering of diseased animals, with dramatic pictures, can make consumers more susceptible to NGO campaigns. In terms of equation 2: the value of d_r is increased. On the other hand, items reporting, for instance, fraud with biologically produced meat may make consumers more susceptible to campaigns from traditional farmers, which is similarly modelled as an increase of d_l . The frequencies of such media events are generated at random, with probabilities p_r and p_l , respectively. When such an event occurs, the value of d_r or d_l , respectively, is increased with the arousal factor a for one simulation time step, representing one week. After each week d_r and d_l are reset to their basic values, unless new events occur. The result is that, under influence of media events, shifts in the opinions can occur which would otherwise not have occurred. The frequencies of arousal p_r and p_l and the arousal factor a are set in the user interface.
- 3.19** Five daily interactions per time step of one week are implemented, following Figure 2. First, the consumers update their (possibly aroused) opinions based on NGO's communications and NGOs take notice of the consumers' opinions, then consumers meet one other consumer per day to exchange opinions with, and consumers interact with a retailer. After that, the producers (farmers) exchange opinions with the producers' organisation, with another producer and with a retailer. Finally, the NGOs interact with each other and with one of the retailers. We assume the latter discussions to be more intensive than those with each individual consumer and producer, which is represented by the (arbitrary) factor 100 in the algorithm below. In NetLogo code this is represented as follows:

```
to apply-opinion-dynamics    ; let agents interact and update their opinions
  repeat 5
  [ ask consumers
    [ interact-with one-of ngos
      interact-with one-of other-consumers
      interact-with one-of retailers ]
    ask producers
    [ interact-with one-of ngos with [category = "producers organization"]
      interact-with one-of other-producers
      interact-with one-of retailers ]
    repeat 100 ; (intensive mutual interactions between NGOs and retailers)
    [ ask ngos
      [ interact-with one-of other-ngos
        interact-with one-of retailers] ] ]
end
```

- 3.20** When an agent encounters another agent according to the above algorithm, they exchange and update opinions. In NetLogo code this is implemented as follows: the agent keeps its original opinion in mind, considers the other agent's opinion and updates its own opinion according to equation 2, and then asks the other agent to do the same, based on the first agent's original opinion before updating it:

```
to interact-with [other-agent]
  let my-opinion opinion          ; need to save original opinion
  consider [opinion] of other-agent ; update my opinion
  ask other-agent [consider my-opinion] ; other agent updates its opinion
end
to consider [other-agent-s-opinion] ; mathematics of opinion dynamics
  let difference other-agent-s-opinion - opinion
  if difference > (- d_l) and difference < d_r
  [ set opinion opinion + mu * difference ]
end
```

Simulation results

- 4.1** This section first presents results of a scan of the parameter space and discusses patterns that emerge. Subsequently, experiments and results are described that test the sensitivity to parameter variations in the role of

the activist NGO, combinations of consumer arousal and retail-NGO relationships in the Dutch animal welfare case, the weight of the consumer population, and the role of the producers' organisation.

Scanning the parameter space

- 4.2** The simulation's user interface presents the results as displayed in figure 6 in Appendix A. The view shows the agents' positions on the opinion scale from $x = 0$ (price oriented; left hand side) to $x = 1$ (animal welfare oriented; right hand side). Consumer agents are positioned in the top part of the view; producer agents in the bottom part. Agents representing NGOs and retailers are depicted in the middle layer of the view. In this setting, experiments have been performed to explore the patterns that can emerge from the simulation and the conditions under which they actually do emerge. The simulation runs spanned 10 years with time steps of 1 week.
- 4.3** In order to explore the scenarios that can evolve, a first series of experiments was defined in the NetLogo BehaviourSpace. The main observable from these exploratory simulations is the average opinion of producers at the end of the simulation. We use the average farmers' opinion as an indicator for the possibility of a transition from a cost price oriented supply chain regime to an animal welfare oriented one. In this respect, the diversity of the farmers is less relevant. The main issue is whether there is sufficient willingness among farmers to consider new production systems.
- 4.4** The simulations were run with 100 consumers and 100 producers. These numbers are sufficient to represent diversity of agent parameters in the respective groups. The numbers are not realistic for real-world supply chains, but that is not essential since no actual supply chain transactions are modelled. The simulations ran for 520 weeks, and with "activist" set to TRUE (i.e. the default situation where an activist NGO participates in the simulation), scanning all combinations of the following parameters values:
- event-frequency-right in {0.02, 0.04, 0.06}
 - event-frequency-left in {0.02, 0.04, 0.06}
 - arousal-factor-alpha in {6, 7, 8, 9, 10}
 - d_l-of-moderate-ngo in {0.5, 0.6, 0.7, 0.8}
 - retail-upper-limit-of-d_r in {0.7, 0.8, 0.9, 1.0}
 - d_r-of-producers-org in {0.1, 0.3, 0.5}
- 4.5** This resulted in 2160 runs. The simulations started with the two animal-welfare NGOs positioned at $x = 1$ and all other agents at $x = 0$. Three alternative typical patterns could be observed when running the simulation:
1. no sustained changes in the public opinion occurred;
 2. the opinions changed substantially from price orientation towards animal-welfare orientation;
 3. a slight and slow change in opinions toward animal-welfare orientation occurred.
- 4.6** The patterns are illustrated in Appendix A. The first pattern emerged when there was insufficient arousal. If the arousal factor $a < 7$ or media event frequency on the animal-welfare side was very low, all agents ended on or near their initial positions. With higher values of a and event frequencies of one or several events annually, two other patterns evolved, depending on the randomly generated sequence of events and openness of the agents to other agents' opinions.
- 4.7** The second pattern that emerged was similar to the scenario found in the dramaturgical analysis reported in Section 2. In the simulations, this pattern can only emerge if at least one NGO has exchanged opinions with other agents, since all agents except for the NGOs have an opinion equal to 0 and the NGOs have an opinion equal to 1. However, the agents are initially too far apart. Only when consumers are aroused by media events, they may be open to opinions of the NGOs and shift to the animal-welfare oriented end of the scale. The pro-active retailer follows them. When sufficient consumers and the retailer get within reach of d_l of the moderate NGO, the latter will move toward them (the activist NGO will never change its extreme position). The extent to which this occurs mainly depends on the positions taken by the consumer agents, which in turn depends on the arousal by randomly generated events. If this leads to a situation where opinions of the moderate NGO and a pro-active retailer get close, a turning point in the discourse is reached, where more consumers and the

Figure 3: Scatter plots of the mean producers' opinions at the end of simulations versus the different parameter values in the first series of experiments; red circles represent the runs where a turning point occurred, i.e. runs in which the moderate NGO crossed a point where its distance to the pro-active retailer was less than its distance to the activist NGO; black crosses represent the runs where no turning point occurred

producers' organisation move toward the NGO and the retailer. Then a general shift of opinions can occur where many consumers and producers start moving towards the opinion of the moderate NGO, and other retailers follow. Meanwhile, when consumers are aroused by new events, they become more open to the activist NGO's opinion, move further towards the animal-welfare oriented end, and cause a further shift of the other agents.

4.8 The third pattern emerged if consumers were aroused, but not sufficiently to bring the moderate NGO and the pro-active retailer together to a turning point where a strong cluster of opinions in favour of animal welfare could develop. If the turning point was not reached in a period of arousal, the most aroused consumer agents joined the cluster of agents at the price-oriented end and the moderate NGO joined the activist NGO again. In these runs a only slight shift of the average opinions remained after each arousal.

4.9 The mean producers' opinions observed in the simulations are plotted against the parameter values in Figure 3. As can be seen in the figure, only when a turning point has occurred the average producers' opinions could reach relatively high values. Furthermore the first pattern ("nothing happens") always occurs if arousal factor $a = 6$; for higher values of a the other patterns can also evolve, with the "turning point" pattern becoming more likely when a increases. The uncertainty-arousing event frequencies have their effects on the occurrence of turning points: events on the animal-welfare (right-hand) side are required and increase the likelihood of a turning point; higher left-hand side frequencies can reduce the likelihood. The three graphs in the bottom row show that the third pattern described above ("slight and slow change") can occur under pressure of consumers, but that the main actors must each have some minimal openness to others' opinions for a turning point to occur. Interesting cases for further analysis can be selected using these exploratory results.

4.10 We assume that broad uptake of sociotechnical innovations can follow if the turning point is reached (as in the second pattern) and the moderate NGO has influenced retailers and producers to such extent that they are open to the introduction of animal-friendly production systems and more animal-friendly produced meat can be delivered to the consumer market. In the third pattern, there will be no common ground for such innovations. Therefore further analyses focus on the turning point.

The activist NGO's role

- 4.11** The role of the activist NGO was essential. The set of experiments described above was repeated with "activist" set to FALSE, i.e. no activist NGO took part in the simulations. In all runs with "activist"=FALSE either nothing happened if consumers were not aroused, or all agents ended up on the price oriented end of the opinion scale. Out of 2160 simulations, 11 ended with mean producers' opinion > 0.1 , with a maximum value of 0.16. All of these cases were characterised by a low value of $d_l = 0.5$ for the moderate NGO and high values of arousal factor ($a \geq 9$) and right-hand event frequency ($p_r \geq 0.04$), and for the pro-active retailer $d_r \geq 0.8$. Limited to this part of parameter space, it concerns 11 out of 108 runs. We conclude that the pressure as exercised by the activist NGO is as good as a sine qua non for broad uptake of sociotechnical innovations.

Sensitivity analysis for the Dutch animal-welfare case

- 4.12** Based on the outcomes of the first set of experiments (Figure 3), a second set was specified and performed to test the simulation's sensitivity to parameter variations, in particular with respect to the occurrence of turning points and their effects on innovation uptake. From the results of the first set of experiments, it is clear that no innovations will occur if the producers' organisation does not co-operate. Therefore, its openness d_r is set to 0.6 in this second set. Thirty replications were run for each combination of the following values:
- arousal factor a in {8, 10, 12},
 - the frequency of both right-hand media events in {0.02, 0.05},
 - the frequency of both left-hand media events in {0.02, 0.05},
 - openness to agents who are more price oriented d_l of the moderate NGO in {0.6, 0.8},
 - openness to animal welfare oriented opinions d_r of the proactive retailer in {0.9, 1.0}.
- 4.13** This resulted in a total of 1440 simulation runs, for which the following observable outputs were recorded:
- whether a turning point occurred or not,
 - in runs where a turning point occurred, the time step (week) in which it was reached,
 - the final average producer's opinion as an indicator of the potential innovation uptake.
- 4.14** As an observable output from the simulations, the moment where a turning point is reached is defined as the first time step where the distance between the moderate NGO and the pro-active retailer is less than the distance between the two NGOs. In practice this situation emerges when the moderate NGO's opinion $x < 0.8$.
- 4.15** In the 1440 simulations, the turning point was overcome 894 times. In the cases where this point was overcome, the average opinion of producers was 0.35 with standard deviation 0.13 after 10 years. In the cases where no turning point was reached, the average opinion of producers was 0.047 with standard deviation 0.040. This confirms that the turning point where the opinions of the moderate NGO and supply chain parties converge is an essential event in the discourse to result in innovation uptake.
- 4.16** The results were sensitive to the parameter settings. Table 5 presents the fraction of simulation runs in which turning points occurred, and the resulting average opinion of producers for several parameter values. These data show that a turning point will almost certainly occur and result in a high level of producers' opinions towards animal friendly production, if d_r of the pro-active retailer is set to 1.0 and d_l of the moderate NGO is set to 0.8. If these values are set lower than 0.9 and 0.6, respectively, turning points and sociotechnical innovation uptake are unlikely. The results for the arousal-related settings show that these turning points are unlikely when arousal strength a is set to 8 or less. With $a = 10$ or $a = 12$, turning points are more likely, but high values of producers' opinions largely depend on the event frequency. Higher values of producers' opinions are likely when the right-hand side event frequency $p_r = 0.05$. This information is useful to calibrate parameters for studying new cases. In the context of the simulations we can define:
- a pro-active retailer has $d_r = 1.0$;
 - a moderate NGO has $d_l \geq 0.8$;
 - an arousing course of events has arousal strength $a \geq 10$ and average event frequency $p_r \geq 0.5$.

(a) Fraction of simulations where a turning point occurred					
(a1) - by d_l of moderate NGO and d_r of proactive retailer					
d_r of proactive retailer	d_l of moderate NGO	0.6	0.8	average	
0.9		0.33	0.56	0.45	
1.0		0.59	1.00	0.80	
average		0.46	0.78		
(a2) - by arousal strength (a) and arousal frequency					
right-hand versus left-hand frequency	arousal strength (a)	8	10	12	average
0.02 versus 0.05		0.24	0.36	0.58	0.39
0.02 versus 0.02		0.30	0.58	0.85	0.58
0.05 versus 0.05		0.38	0.74	0.98	0.70
0.05 versus 0.02		0.53	0.92	0.99	0.81
average		0.36	0.65	0.85	
(b) Average opinion of producers at simulation end time					
(b1) - by d_l of moderate NGO and d_r of proactive retailer					
d_r of proactive retailer	d_l of moderate NGO	0.6	0.8	average	
0.9		0.12	0.20	0.16	
1.0		0.22	0.40	0.31	
average		0.17	0.30		
(b2) - by arousal strength (a) and arousal frequency					
right-hand versus left-hand frequency	arousal strength (a)	8	10	12	average
0.02 versus 0.05		0.09	0.12	0.19	0.13
0.02 versus 0.02		0.11	0.18	0.28	0.19
0.05 versus 0.05		0.15	0.29	0.37	0.27
0.05 versus 0.02		0.20	0.37	0.45	0.34
average		0.14	0.24	0.32	

Table 5: Fraction of simulation runs where a turning point occurred (a), and average opinion of producers at simulation end time (b), by d_l of moderate NGO and d_r of proactive retailer (a1 and b1) and by arousal strength a and arousal frequency (a2 and b2); all runs with 100 consumers and 100 producers, activist NGO "ON", and producers' unions' $d_r = 0.6$

Figure 4: Final average opinion of producers by year where the turning point was reached (a) at the end of the simulation and (b) in the week where the turning point was reached (vertical axis: average producers' opinions; horizontal axis: year of the turning point; note that scales on the vertical axes are different)

- 4.17** In all of the 120 simulations according to these conditions, the turning point occurred within five years, in 116 cases within three years. The average final producers' opinion in these 120 simulations was 0.49.
- 4.18** In the 894 simulations where a turning point occurred, the average final opinion of producers was negatively correlated with the week number in which the turning point occurred, with correlation coefficient -0.84. The average final opinions of the producers depended on the year in which the turning point was reached as displayed in Figure 4(a). Figure 4(b) shows that this dependency was not caused by a high value of the average producers' opinion before the turning point: the values of average producers' opinions were low when the turning points occurred. We conclude that the higher values at the end of the simulations were caused by the longer times remaining for opinions to shift more rapidly towards the animal-welfare end when the turning point occurred early, and by the higher levels of arousal which cause early turning points. Furthermore, clusters of consumers who have slightly moved towards more animal-friendly positions (as in Figure 12) are more likely to exist later in the simulation. They can attract some aroused consumers back to their original positions more rapidly than in the beginning of the simulation. As a consequence, the moderate NGO is insufficiently attracted towards the turning point.

The consumer population's weight

- 4.19** All simulations discussed so far were run with 100 consumers and 100 producers. This is not realistic for a real-world supply chain, but these numbers are sufficient to represent the diversity of these actor classes. To test the sensitivity to the numbers of consumers, the simulations were rerun with 1000 consumer agents. This would entail that, in case of arousal, more consumers could get within d_t of the moderate NGO, causing a stronger shift of the NGO's position on the x axis and thus increasing the probability of a turning point. Indeed, rerunning the experiments with 1000 consumers resulted in 1245 turning points out of 1440 runs, versus 894 when ran with 100 consumers. However, the average producers' opinion in runs where a turning point occurred was lower: 0.29 with standard deviation 0.11, versus 0.35 with standard deviation 0.13 with 100 consumers. The greater mass of the 1000 consumers moved slower once the turning point had occurred. The average of producers' opinion for the runs where no turning point occurred (0.049 with standard deviation 0.024) was comparable with the runs with 100 consumers (0.047 with standard deviation 0.040).

The producers' union's role

- 4.20** As can be seen in Figure 3, the producers' opinions remain low when the producers' organisation has a low value of d_r , i.e., if it not open to opinions of agents on the animal-welfare side. In Dutch society, where consensus is highly appreciated, the producers' organisations will usually be more open, as in the case described in Section 2. However, when a producers' organisation would be less open, a situation as depicted in Figure 5 could occur. In this case, a turning point has occurred, but the producers' organisation and most of the producers do not follow. This situation resembles the StarKist case described by Winn & Keller (2001), where the

Figure 5: Example of the outcome of a case where a turning point occurred, but most producers did not follow the retailers due to the low value of d_r of their organisation

food processing company, under pressure from the public opinion, dropped its suppliers, who would not adapt their fishing methods. In 30 simulation runs with these parameter settings, the average producers' opinion at simulation end was 0.037 with standard deviation 0.013, while the average consumers' opinion ended at 0.21 with standard deviation 0.12. We conclude that in the Dutch case described in Section 2, the producers' union's role was essential to mediate between retailers and NGOs and the producers.

Conclusion

- 5.1 This article summarised the outcomes of a dramaturgical analysis of a sociotechnical innovation in a food supply chain, under pressure of public opinion and proposed an agent-based simulation, building on the concept of opinion dynamics. The main purpose of the simulation was to test certain hypotheses about the micro-level processes leading to macro-level changes in the sociotechnical system. When the simulation was run for a period of 10 years with a time step representing 1 week, patterns emerged that are comparable with those observed in the dramaturgical analysis. In that sense, we can conclude that this purpose is served.
- 5.2 Our sensitivity analysis showed that the simulation is most sensitive to the frequency and impact of events arousing consumers' uncertainty about social responsibility aspects of food and the distribution of the NGOs' and retailers' parameters of susceptibility to others' opinions. The shift towards opinions that enable uptake of sociotechnical innovations only emerges if a turning point is reached where a proactive retailer and a moderate NGO can share their opinions and pull the producers and other retailers towards innovation. Such a turning point only occurs in the simulation if activist and moderate NGOs are both participating in the discourse and at least one retailer is open to animal-welfare oriented opinions before actual consumer demand evolves.
- 5.3 The contribution of this research is that it deepens the insights into the processes that drive sociotechnical innovations under societal pressure, by combining the results from dramaturgical analyses and agent-based simulations. The approach is specific for the domain of agriculture and food or other supply chains with a large population of primary producers and consumers, so that the dynamics of both groups can be modelled with opinion dynamics. However, the approach is not limited to the present case; it can be applied for policy making by organisations involved in the response to societal pressure in other agriculture-related cases. Agent-based simulation as proposed in this article can be applied for exploration and ex-ante assessment of interventions.
- 5.4 In the present case, the simulation results revealed that activist NGOs, proactive retailers and open minded producers' organisations are crucial for reaching turning points that enable the uptake of socio-technical inno-

vations. The findings may have important implications for policy makers responsible to create the right conditions for breakthroughs in public controversies. The effectivity of activist NGOs can be increased by providing a legal status allowing them to launch lawsuits against government institutions and/or value chain parties. The chance of having proactive retailers can be increased by maintaining sufficient competition among retailers, which forces them to take distinct positions in the consumer market. A way to make producers' organisations more open minded, is organising stakeholder platforms (gear wheels in Figure 1) in which they can strike deals or make agreements on sustainable production and marketing with moderate NGOs and value chain partners.

- 5.5** For future research, the present simulation provides a basis to include cognitive modelling of the NGOs and supply chain agents. Those parties take positions and communicate deliberately to influence opinions. Their decision making could, for instance, be modelled through the doubt management mechanisms according to Karl E. Weick, as described by Selnes & Termeer (2011). We expect such cognitive modelling to increase the simulation's value for policy support. Also, it is worthwhile to investigate if the simulation can benefit from more realistic models of networks and influences among consumers and producers as applied in work by Delre et al. (2010), van Eck et al. (2011) and Krebs (2016).

Appendix A: Emerging patterns in the simulation

This appendix describes typical patterns that can emerge in the simulation. The concept "attraction" is frequently used in the explanations in this appendix. In terms of opinion dynamics, attraction is to be understood as the influence on an agent's opinion that other agents have when their opinions are within the uncertainty distance d of the first agent.

When the simulation is run for ten years, with time steps of one week, three typical, alternative, patterns can be observed.

1. When consumer arousal by media events is very low, all agents end up on or near their initial positions.
2. When the moderate NGO and a retailer are both attracted by aroused consumers to a point where their uncertainties overlap, they jointly attract other retailers, other consumers, the producers' union and the producers (farmers) towards the animal-welfare orientation.
3. If the moderate NGO is not sufficiently attracted to the other agents and does not join with the retailer, the agent's opinions can shift towards the animal-welfare end of the scale, but to a lesser extent. This pattern emerges if arousal is less than in the previous case or if moderate NGO or retailers have little uncertainty about their opinion.

The following paragraphs discuss these patterns illustrated with screen shots from the user interface. In the user interface, the agents of the different categories are positioned on a horizontal axis representing their opinions with cost price orientation on the left hand side ($x = 0$) and animal-welfare orientation on the other end ($x = 1$). As shown in Figure 6, simulation runs start with the two animal-welfare NGOs positioned at $x = 1$ and all other agents at $x = 0$.

The first pattern emerges if the arousal factor is low (typically if $a < 7$) or media event frequency on the animal-welfare side is very low. Under these conditions, some consumer agents may now and then be aroused, but they are rapidly attracted towards their initial opinions by the other agents. Since it is trivial, we will not further discuss this pattern.

With higher values of a and event frequencies of one or several events annually, the two other patterns can evolve, depending on the randomly generated sequence of events and settings of agent parameters. In this scenario, consumer agents aroused by media events attract the proactive retailer agent to shift towards higher values of x . When sufficient consumers are moving towards the animal-welfare oriented right-hand side, and a retailer follows, the moderate NGO is attracted and shifts to the left. This leads to a situation as depicted in Figure 7.

When some consumers are attracted by NGOs after one or more uncertainty-arousing events, they can in their turn attract other consumers, retailers, and the moderate NGO (the activist NGO will not change its extreme position). If this leads to a situation where uncertainties of the moderate NGO and a pro-active retailer overlap, a turning point in the discourse is reached, where they commonly attract more consumers and the producers' organisation, as in Figure 8.

Figure 6: User interface with agents on their initial positions

Figure 7: Aroused consumer agents attract a retailer and the moderate NGO

If such a turning point in the discourse is reached, a general shift of opinions can occur where many consumers and producers move towards the opinion of the pro-active retailer and the moderate NGO, and other retailers follow. Meanwhile, the activist NGO keeps attracting consumers. In particular it attracts more consumers when uncertainty-arousing events occur, as displayed in Figure 9.

Opinions converge in periods with little arousal by media events, for example as depicted in Figure 10. However, attracted by communications from the activist NGO, the public opinion keeps moving further towards the animal-welfare end of the scale. Figure 11 presents an example of a situation after 10 years.

Figure 8: A turning point in the discourse has occurred where a retailer and an NGO jointly attract other agents

Figure 9: After a turning point is reached, opinions shift towards the animal-welfare end of the scale

Such a pattern only emerges if, under the influence of aroused consumers, a turning point in the discourse occurs where the moderate NGO and a pro-active retailer get sufficiently close to continue the exchange of opinions after the arousal has vanished and jointly attract other agents. Otherwise, the agents move back, attracted by agents who remained on their original positions. The presence of the activist NGO agent is a sine qua non for the latter presence to evolve. This agent continuously attracts aroused consumer agents and pulls the moderate NGO to the right. If there is no NGO agent permanently voicing opinions at $x = 1$, all other agents end up near $x = 0$. Furthermore, the second pattern can only emerge if the proactive retailer agent is open to

Figure 10: Convergence of opinions in periods with little arousal by media events

Figure 11: Example of a situation after 10 years (In this particular example the distribution of consumers' opinions is due to a recent media event on the left-hand side)

animal-welfare opinions (it must have $d_r \geq 0.9$) and if the moderate NGO agent is sufficiently susceptible to other opinions ($d_l > 0.5$).

The third emerging pattern that can occur is one in which the consumer agents are aroused, but not sufficiently to attract the moderate NGO to cross the turning point. In that case, the retailers and producers move only slowly to the right, as is shown in Figure 12.

Figure 12: Example of a situation after 10 years in a case where no turning point has occurred

Notes

¹The NetLogo code is available from <https://www.openabm.org/model/4988>

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