Agent-Based Modeling of Culture's Consequences for Trade

Proefschrift

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Contents

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The project with professors Jan Treur and Catholijn Jonker was about intelligent integration of statistical information from heterogeneous sources. During this project I took their course on multi-agent systems. At the end of the year 2003, doctor Gert Jan Hofstede of Wageningen University asked me to advise a Ph.D. student he was supervising, about a multi-agent simulation. I am grateful for the trust he has put in me, because this is how I got involved in the simulation of the TRUST & TRACING (T&T) game. I thank doctors Sebastiaan Meijer and Dmytro Tykhonov for the fine cooperation and the inspiring discussions we had during the development of the multi-agent simulation, and for their permissions to use our common results as part of this thesis. I also thank them for being willing to accompany me during the defense.

The outcomes of the T&T gaming simulations with human participants proved to depend on the participants' cultural backgrounds. After a discussion on the feasibility of Geert Hofstede's model of culture, my supervisors and I decided to try and model the effects of one of Geert Hofstede's dimensions in the T&T game. This effort resulted in a paper for iTrust 2006. I thank professor Catholijn Jonker and doctor Gert Jan Hofstede for stimulating me to continue that work as a Ph.D. study, for their great support and contributions to the study, and for their critical reflection on my work.

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Part I: Introduction

What is culture? The book by Hofstede, Hofstede, and Minkov (2010) is subtitled "*Software of the Mind*". That suggests that culture is a property of individuals. Yet, the same authors stress that culture is a group property: "*the collective programming of the mind that distinguishes one group of people form another*". It is about 'software of the mind' that is shared by a group, allowing it to function. According to Hofstede (2001) the values associated with a culture are transferred from generation to generation from early childhood on, and remain relatively stable over generations. The values are the basis for norms about how to behave, about how to interpret the world in terms of qualities and threats, and about the salience of relational attributes such as hierarchical relations, common group membership, and trust in strangers.

Kashima (2009) refers to culture as the common ground for joint activities of its members, while these activities "*are in fact the very activities that get their society and culture going. They produce and reproduce the social relationships and cultural resources that enabled these joint activities to begin with*". That approach models culture as a dynamic and situational phenomenon and may explain how, under different circumstances and following different development paths, different cultures can have emerged. It also models the transfer of social norms by performing joint activities. Yet, according to Hofstede, Hofstede, and Minkov (2010) the deep-rooted value systems that are transferred from early childhood on are a persistent element in the programming of the individual's mind.

Culture provides individuals with the semantics for a shared interpretation of the world and the behaviors of others. It also guides the behaviors of individuals and provides them with clues how to express their ideas and emotions so that they will be understood by others. As a collective intelligence that has no physical representation but in the brains of its members, culture is an interesting subject for students of cognition and artificial intelligence. A multi-agent system, where all intelligence is represented in individual agents, can serve as an analogon for the modeling of culture. In a multi-agent system, intelligent software agents can be applied to model the knowledge and behaviors of individuals in a context of interactions and relationships with others, situated in an environment (Phan and Amblard 2007).

A multi-agent simulation can be used to validate a model of individuals' decisions and behaviors. The validated model of culture can subsequently be used to design artificial agents for several purposes, for instance in simulators for training (see, e.g., Silverman et al. 2007) or in affective agents (see, e.g., Payr and Trappl 2004).

This dissertation studies the application of multi-agent modeling as a research tool, to be used in combination with gaming simulation. The work was inspired by a Ph.D. study using gaming simulation for research into the organization of transactions in supply chains (Meijer 2009). The focus of study in the TRUST & TRACING (T&T) game is on trust in a business partner when acquiring or selling commodities with invisible quality. There are five roles in this game: traders (producers, middlemen and retailers), consumers and a tracing agency. Typically there are 4 producers, 4 middlemen, 4 retailers and 8 consumers, to reflect the multiple steps and oligopoly character of most supply networks. The real quality of a commodity is known by producers only. Sellers may deceive buyers with respect to quality, to increase profits. Buyers have either to rely on information provided by sellers (Trust) or to request a formal quality assessment at the Tracing Agency (Trace). This costs a tracing fee for the buyer if the product is what the seller stated (honest). The agency will punish untruthful sellers by a fine. Results of tracing are reported to the requestor only or by public disgrace depending on the game configuration.

The game is played in a group of 12 up to 25 persons Commodities usually flow from producers to middlemen, from middlemen to retailers and from retailers to consumers. Players receive (artificial) money upfront. Producers receive sealed envelopes representing lots of commodities. Each lot is of a certain commodity type (represented by the colour of the envelope) and of either low or high quality (represented by a ticket covered in the envelope). The envelopes may only be opened by the tracing agency, or at the end of the game to count points collected by the consumers (table 1). The player who has collected most points is the winner in the consumer category. In the other categories the player with maximal profit wins.

A multi-agent model has been developed to simulate the T&T game (Tykhonov et al. 2008). That first version of the model does not take culture into account. Experimental results of gaming simulations in different countries and with participants with different cultural backgrounds have shown that culture matters for this game (Meijer 2006 et al.). These findings motivated the development of the model for cultural adaptation of agents, proposed in this dissertation. The findings of Meijer et al. (2006) are in line with a multitude of studies, amply showing that validation of behaviors in experiments with subjects from one culture is no guarantee for the occurrence of similar behaviors in other cultures (Smith et al. 2006). This highlights the relevance of modeling cultural differentiation in multi-agent simulations for cross-cultural research.

The purpose of modeling culture in the present work is not to develop theories about culture, but to explain the differences found in gaming simulations played with subjects from different cultures. Studying the literature about culture, some different approaches are found. First, there is the stream of literature that studies specific cultures by extensive observation and, what Geertz (1973) has called “Thick Description”. Examples of this approach – students of artificial intelligence would call it case-based – can be found in the works of Geertz (1973), Hall (1976), and Lévi-Strauss (1992). Such work can be a solid basis for the modeling of a particular culture.

Another approach is the differential approach practiced by, for instance, Hofstede (2001), House et al. (2004), and Schwartz (1994). In this approach one studies as large a set of groups (usually countries) as possible, aiming to find a set of orthogonal, universally valid, dimensions to discern cultures. The dimensions can, for instance, be discovered by factor analysis of surveys, identifying the relevant questions to measure the scores of groups of people on those dimensions. The scores on the dimensions can then be related to societal phenomena. By its nature, a dimensional approach lends itself for modeling cross-cultural differences.

In this thesis, culture is modeled according to Hofstede’s five-dimensional model of national cultures (Hofstede 2001, Hofstede and Hofstede 2005). Hofstede’s is the most widely used of the dimensional models. It has shown predictive value for many societal phenomena (Hofstede 2001, Smith 2002). In this thesis it is applied to a model of the agents playing the TRUST & TRACING (T&T) game, which is a gaming simulation to study the role of trust in trading relations in a supply chain setting with asymmetric information about product quality. Fig. I displays the structure of the (artificial) agents participating in the simulated T&T game. It is based on concepts of Transaction Cost Economics (TCE) according to Williamson (1998): the ex-ante cost of searching, bargaining, safeguarding and drafting a contract, and the ex-post cost of monitoring and enforcing the contract. Due to bounded rationality, a contract is necessarily incomplete according to TCE, thus offering partners an opportunity to defect in delivery, for instance taking advantage of information asymmetry.

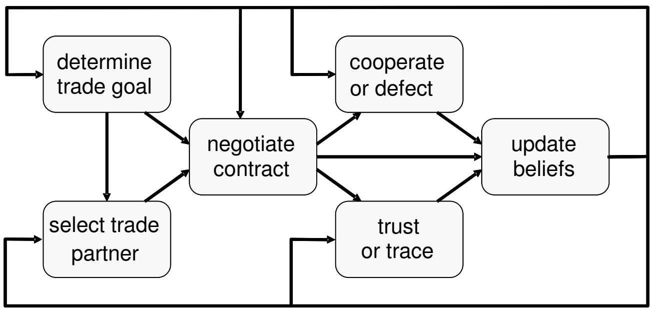

Fig. I. Processes and internal information flows of trading agents

The thesis not only develops a model for cultural adaptation of agent behavior in the T&T game. It also uses this case to address methodological issues related to multi-agent simulation: sensitivity analysis and cross-validation of multi-agent and gaming simulation.

The main research question "how can a model be formulated that adapts universal decision functions to culture according to a theory about the dimensions of culture" entails the following, more specific questions.

1) Given a universal model of human behavior in some domain, can the model of culture's effects be formulated, following an expert systems knowledge acquisition approach?

2) Having formulated the knowledge about the effects of culture on model parameters per dimension, how can a believable model of their joint effect be formulated?

3) How can the sensitivity of such a model be assessed for variation of cultural dimension indices, relational configurations regarding power and group membership, and universal model parameters?

4) Can such a model be applied to fulfill its function as a social sciences research instrument in combination with simulation gaming? This function comprises (Meijer and Verwaart 2005):

   a) Validation of models of behavior induced from game observations

   b) Testing of hypotheses about relations between aggregated outputs and individual agent parameters

   c) Test design: selection of useful configurations for games with humans

The questions are answered by applying Hofstede's five dimensions one by one to an agent-based model of the T&T game, and subsequently integrating the dimension-by-dimension results. An approach to combine the effects is developed, based on the principle of weak disjunction. The agent model is constructed as a composition of models (according to Fig. I) that implement the decision functions. The approach to combine the effects of the individual dimensions is applied to the decision functions implemented in the components.

The choice to use a dimensional model of culture was made because the multi-agent simulation is intended for use in many different cultures and multicultural settings, so a case-based approach would not be feasible. The choice for Hofstede's model was made because it is widely used and validated, because of feasibility of the well-developed concept of Synthetic Cultures (Hofstede and Pedersen 1999, Hofstede et al. 2002) as a support for the dimension-by-dimension modeling, and because of the direct availability of an expert on this model.

The choice to model the effects of the dimensions one by one and to integrate them subsequently was made for two reasons: first it is an approach that follows from the nature of the dimensional approach to study culture and available publications and expertise; second, directly estimating the combined effects of the dimensions on the basis of expertise proved to be too complex for the modeler and for the expert.

Validated – but not culturally differentiated – models and data from the social sciences and artificial intelligence literature are taken as the basis to model the decision functions for partner selection, negotiation, deceit and trust. The choice to model the agents as a composition of validated models from literature and not to develop a specific model for the T&T game was made to reduce the complexity of validation. By using validated models as a basis for the decision functions, the validation of the integrated model can be focused on the composition and the cultural adaptation.

The resulting culture-sensitive model is validated (1) in a sensitivity analysis, (2) by face-validation of simulation results, and (3), as an on-going process, by comparing outputs of gaming simulations and multi-agent simulations.

The main contributions of this work are:

- an approach to model the influence of culture on decision functions in intelligent agents, applying expertise about a dimensional theory of culture dimension by dimension, and integrating the effects of the dimension by weak disjunction;
- the finding that sensitivity of an agent-based simulation must be performed at both individual and aggregated level;
- the idea of the application of micro-games to validate individual components of the process model to reduce the under-determination problem in cross-validation of gaming and multi-agent simulation; however, the validation of this idea remains for future research.

All chapters of this dissertation have been published as separate papers (Chapters 2 through 13) or are submitted for publication (Chapters 1 and 14). For the readability of these papers by themselves, much of the introductory and back-ground material had to be reused. I apologize to the reader of this dissertation for that inconvenience. A compiled list of the literature referenced in the individual chapters is included at the end of this dissertation.

The structure of this dissertation is as follows. Chapter 1 gives an overview of the work and the results. Part II (Chapters 2 and 3) introduces the multi-agent simulation of the T&T game, which is the context of this work. Part III (Chapters 4 through 8) describes expert knowledge based models of the effects of Hofstede's five dimensions one by one. Data that allow for face validation are generated with these models. Part IV (Chapters 9 through 12) integrates the models of the individual dimensions. Chapter 9 describes the integration approach based on weak disjunction of the effects of the individual dimensions. Chapters 10 through 12 present the decision functions for, respectively, partner selection, negotiation, and delivery, trust, and belief updates about potential trading partners. The knowledge about the effects of individual dimensions, acquired in Part III, is applied to these models, using the method described in Chapter 9. Again, data for face validation are presented, and some simulation results are validated against experimental results from the gaming simulation. Part V consists of Chapter 13 – about sensitivity analysis and its relevance for agent-based models, both at the individual and the aggregated level – and Chapter 14 – about cross-validation of gaming and multi-agent simulation. Part VI concludes the thesis with a discussion of the results and a summary of the findings.

1 A Model of Culture in Trading Agents

Abstract Geert Hofstede's five-dimensional framework is widely used in social sciences and management science to characterize cultures. It has been suggested to build culturally consistent agent characters based on his framework. This chapter stresses the relevance of culture and trust for trade, substantiates why a dimensional model offers a good basis for cultural differentiation of agents, and presents an approach to apply Hofstede's model to develop culturally differentiated agents. The approach is based on knowledge acquisition on a dimension-by-dimension basis and a computational method to integrate the acquired knowledge. The approach has been applied to a multi-agent simulation of a trade game. It is instantiated for the processes of partner selection, negotiation, and the interaction between deceit and trust in trade.

Introduction

Great differences in personality may exist between people. On the other hand, all people around the world have their human nature in common. Human nature includes life in society. One can observe groups of people, on scales ranging from clans to nations, living together and having common behaviors that distinguish them from other groups.

Hofstede (2001, p. 9) defines culture as "*the collective programming of the mind that distinguishes one group or category of people from another*". This implies that culture is not an attribute of individual people, unlike personality. It is an attribute of a group that manifests itself through the behaviors of its members.

A shared understanding of the world is essential for social life. From early childhood on the cultural meaning systems are anchored in the minds of people and permanently reinforced and extended by joint activities with other group members. Kashima (2009) concludes that the joint activities members of a culture engage in "*are in fact the very activities that get their society and culture going. They produce and reproduce the social relationships and cultural resources that enabled these joint activities to begin with*" (Kashima 2009).

Groups share value systems and practices – Hofstede refers to rituals, heroes, and symbols as practices. These are transferred from generation to generation. The practices are the observable characteristics of a culture. Over time and under the influence of contacts with other cultures, practices may change far more easily than the value systems that are in the core of a culture (Hofstede 2001).

The present work focuses on the way culture influences trade. The relevance of cultural conflict in trade grows with the current trend of globalization. In a trading situation, culture of the trader manifests itself in four ways. First, culture filters observation. It determines the salience of clues about the acceptability of trade partners and their proposals. Second, culture sets norms for what constitutes an appropriate partner or offer. Third, it sets expectations for the context of the transactions, e.g. the enforceability of regulations and the possible sanctions in case of breach of the rules. Fourth, it sets norms for the kind of action that is appropriate given the other three and, in particular, the difference between the actual and the desired situation.

One of the most prominent, problematic, issues in trade that depend on culture is trust between trade partners (Hofstede et al. 2004, Hofstede 2006). Trust is the aspect of trade where lack of common ground pre-eminently manifests itself. Trust is an important issue in trade, because of the information asymmetries between suppliers and customers, which become more salient in longer supply chains, and because of the inevitable incompleteness of contracts (Williamson 1985, 1998). Many definitions have been given for trust. For the present work a pragmatic definition is used. Customer's trust in a particular supplier is defined as the customer's estimate of the probability that the supplier will deliver as agreed, even if the supplier has the incentive and the opportunity to defect.

Agent-based modeling offers new opportunities to study trust and culture in trade. Agent-based modeling enables the study of emergent phenomena at an aggregated level that originate from the behaviors and interactions of individuals. As such it provides an analogue to culture: culture has no other representation than in the minds of its members. Culture is a form of collective intelligence, physically represented in the brains of individuals, grounded during the common activities where its observable properties emerge. Trade is such a common activity.

Agent-based models can be applied as a research tool in combination with simulation gaming (Tykhonov et al. 2008). Observations in gaming simulations can lead to theorizing about the decision models of participants. These models can be implemented in the multi-agent simulation, in order to validate that the hypothetical models lead to the behavior that was observed in the gaming simulation.

The context of the agent-based model presented in the present paper is the TRUST & TRACING (T&T) game. In runs of this gaming simulation, considerable differences in outcomes are observed across cultures. These observations were the reason to develop this model. Meijer (2009) discusses the validity of the gaming simulation, according to validation aspects as defined by Raser (1969): psychological reality, structural validity, process validity, and predictive validity. The T&T game is an abstract game, not representing or predicting the performance of an actual instance of a real world supply chain. It offers process validity in a laboratory environment, based on psychological reality.

This chapter is structured as follows. The first sections to follow are devoted to related work, including the T&T game, the modeling approach, and the research questions. Then Hofstede's dimensions of culture and their hypothetical effects on the processes in the T&T game are discussed. The last three sections present an integrated model of the five dimensions' joint effect, examples of simulation results, and the conclusion of this work.

Related Work

There is a wealth of literature on trade and culture that so far has not been considered in formalized models of trade. In agent-based economics, individual traders are modeled as intelligent agents cooperating in an artificial trade environment. The agents are modeled to mimic authentic human behavior as closely as possible. In recent papers the differences between such agents are no longer solely attributed to differences in their individual economic situations. Aspects such as personality and attitude are considered as well, see, e.g. (Jager and Mosler 2007). Without considering such aspects, the simulations will not correspond to reality. With respect to formalizing the important influence of cultural background on trade, we only found a few papers. These papers study trade at the macro-level, e.g., (Kónya 2006). That paper presents an equilibrium analysis on the amount countries invest in learning another language and culture and the size and welfare of those countries. Another example is (Bala and Long 2005). That paper presents a formal model of the influence of trade on culture, i.e., the reverse direction of influence as studied in the current paper. Other literature also uses macro-level models, such as the gravity model to study the correlation between culture and trade (Guo 2004).

Kersten (2002) urges the necessity of cultural adaptation of e-Business systems and proposes an architecture that adapts both business logic and user interface. The rationale for adapting systems to user's cultures is given by Kersten et al. (2002), who report significant differences in expectations, perception of the opponent, negotiation process, and outcomes of electronic negotiations across cultures. However, no actual implementations of models of culture in e-Business were found. Blanchard and Frasson (2005) report an application of Hofstede's dimensions in a model to adapt e-Learning systems to the user's culture. Recent research on cultural modeling in agents mostly focus on Embodied Conversational Agents (ECA), including non-verbal behavior like facial expressions, gestures, posture, gazing, and silence in conversations (Payr and Trappl 2004, Rehm et al. 2008). CUBE-G (Rehm et al. 2008a) is based on Hofstede's dimensions and focuses on modeling into virtual characters the processes of first meeting, negotiation, and interaction in case of status difference.

All models discussed so far have in common that they model culture with the purpose to support human decision making or to improve human-computer interaction. The purpose of the model proposed in the present paper is to realistically simulate emergent behavior in multi-agent based simulations for research in the social sciences. The aspects of ECA are of less relevance in this context. Agent behavior may be modeled in a more stylized way. An approach that does so for the purpose of multi-agent simulations is that of Silverman et al. (2006, 2007). They model agents as a composition of biological, personal (personality, culture, emotions), social (relations, trust), and cognitive (decision) modules, completed with modules for perception, memory, and expression. Their approach is a generic structure for modeling the influence of culture on agent behavior – along with factors like stress, emotion, trust, and personality – through Performance Moderator Functions (PMF). It differs from our approach in that it is an environment to implement validated models of culturally differentiated behavior, while our approach aims to develop and validate such models.

The model presented in this paper is based on the TRUST & TRACING (T&T) game (Meijer 2009), a research tool designed to study human behavior in commodity supply chains and networks. The focus of study is on trust in stated quality of commodities. The game is played by a group of 12 up to 25 persons that play roles of producers, middlemen, retailers, or consumers. The goal of producers, middlemen and retailers is to maximize profit. The consumers' goal is to maximize satisfaction. Each player receives (artificial) money. Producers receive envelopes representing lots of commodities. Each lot is of a certain type of product and of either low or high quality. High quality products give more satisfaction points than low quality products. A ticket covered in the envelope (so it is not visible) represents quality. The producers know the quality. Other players have to trust the quality statement of their suppliers, or request a product trace at the cost of some money and some damage to the relations with their suppliers. The game leader acts as a tracing agency and can on request and at the cost of a fee determine product quality. In case of deception the game leader will trace transactions and punish deceivers with a fine and public disgrace.

Modeling approach

One must lean on social sciences literature to model culture. Two main streams of research can be distinguished. First, there is the anthropological approach of "thick description", in which specific cultures are studied by detailed and close observation of behaviors during an extensive time-span. Examples are the works of Lévi-Strauss (1992) and Geertz (1973). Second, there is the comparative approach that tries to identify dimensions on which different cultures can be ordered, aiming to develop a classification system in which cultures can be typed by a small number of qualifications. Examples are the models of culture by Hofstede (2001), Schwarz (2009), Trompenaars (1993) and GLOBE (House et al 2004). The approach of that type of research is to characterize cultures by their indices on a limited number of dimensions. The dimensions and the indices of cultures are typically created by factor analyzing massive surveys with standardized questionnaires in many countries. The value of such dimensions largely depends on the questionnaires used in combination with the sets of respondents that are required. Questionnaire studies will be more reliable predictors of behavior if they are about the desired (for self) than if they are about the desirable (for everyone), and also if they are asked to a broad range of types of respondents as opposed to just one type (e.g., students or managers). The resulting models provide a linear ordering of cultures along each dimension, where implicit norms are hypothesized to be stronger or weaker according to the index on the dimension. As authors of dimensional models stress, these same implicit norms carry over to all relationships in society. In all social situations, they act as filters on perception and on action range. This means that there are no specific values for activity x, e.g. 'trade values', in a dimensional model. It also means that a dimensional model is suited for modeling any process that involves social intercourse, including trade and its sub-activities.

Cultural descriptions of the first type provide rich details about values, norms, symbols, beliefs, rituals, social structure, behavioral patterns, etc., in a particular culture. These will prove very useful for facsimile modeling of specific social systems. The model proposed in the present paper aims to compare the influence of a great diversity of cultures in the standardized environment of a gaming simulation which is by itself an abstraction of social life. For that purpose we need to posit the model at an impartial distance from any single culture. A dimensional model of culture is more suited than a collection of incommensurable rich descriptions. Dimensional models are culture-level abstractions. They do not depict individuals, but average group characteristics, and therefore the agents in our simulation will be iconic for a culture, not specific for any individual.

The work of Hofstede (2001) focuses on differences between national cultures, particularly on differences in value systems across nations. The computational models of the effects of culture proposed in this paper are based on that work. Although other dimensional models of culture could certainly be used for similar purposes, Hofstede's framework was chosen over possible other candidates (such as Hall 1976; House et al. 2004; Schwartz 2009; Trompenaars 1993) for various reasons. First, Hofstede's work is parsimonious and accessible, with only five dimensions compared to GLOBE's 18, and with its 1-to-100 scales. Second, it has a wide scope, compared to Trompenaars', whose dimensions are statistically correlated and can be described as aspects of only individualism and power distance (Smith et al. 1996) or Hall who focused on the dimension of individualism (low-context communication) versus collectivism (high-context communication). Those models miss out on issues related to gender roles, anxiety and Confucian values. Third, it has the greatest empirical base of these studies, with a well-matched sample of 117.000 respondents to the original study plus hundreds of replications during a quarter century that validate the model (Kirkman et al. 2006; Schimmack et al. 2005). Fourth, it is the most widely used. It has survived fashions and hasty storms of criticism (Smith 2006; Sóndergaard 1994). Fifth and most important, it shows continued predictive value for many societal phenomena (Hofstede 2001; Smith 2002).

For the endeavor documented in this paper, not only a model of culture is essential, but also a model of trade. A process model comprising six main processes was elaborated, where possible based on validated models reported in social science or artificial intelligence literature. The six main processes are:

1. trade goal selection (e.g., buy or sell), based on agent role and stock position
2. partner selection, based on the model of Weisbuch et al. (2000)
3. negotiation, based the ABMP architecture (Jonker and Treur 2001)
4. delivery, truthfully or untruthfully according to results from social psychology
5. acceptance of deliveries, and decision to trust or trace, based on dynamic trust
6. belief updates and trust dynamics (Jonker and Treur 1999)

Having decided on a model of trade and a dimensional model of culture, the next step was to model the interaction between the two models. The effects of culture were modeled on a dimension-by-dimension basis, using a classical expert systems knowledge acquisition approach: literature study, expert interviews, formalization and verification of the model, and face validation of results. The results the dimension-by-dimension analysis are described in separate papers per dimension (Hofstede et al. 2006, 2008, 2008a, 2008b, 2009). An overview is given in this chapter in section "Hofstede's dimensions and their effects on trade".

Subsequently, the models for the individual dimensions were integrated on a process-by-process basis, except for the trade goal selection, which is not modeled to depend on culture. The resulting culturally adapted decision models of the agents are described in separate papers (Hofstede et al. 2009a, 2010a, 2010b), as is the computational approach to integration of the dimension-by-dimension expertise (Hofstede et al. 2011). Section "The joint effects of Hofstede's dimensions" presents an overview of the process models and the effects of culture.

The integration into an all-singing, all-dancing model has been verified through a meta-modeling based sensitivity analysis (Burgers et al. 2010).

The model has been implemented in the CORMAS multi-agent environment[1].

Research questions

This work aims to differentiate the behavior of artificial agents that simulate aspects of human behavior, as if the agents had a cultural background. Two assumptions underlie this attempt. The first is that it is possible to define models of agents that share universal, globally valid, properties with human behavior at least in the selected processes of trade. The second is that it is possible to formalize expertise about how culture differentiates these models.

To give an example of the first assumption: to a Western mind negotiation may well be perceived as a sequence of alternating explicit proposals, but would another model fit better to practices in other parts of the world? In this research we do not attempt to answer this kind of questions. We assume that social science literature can provide the modeler with a set of theories of human behavior that have universal coverage for the domain of study and that may have parameters that may be different between cultures.

The main hypothesis of this work is related to the second assumption. This hypothesis is that a composition of universal models of human decision making in a particular domain and a dimensional model of culture can simulate believable differentiation of behavior across cultures. With believable we mean that the behavior simulated by the agents can pass face validation by experts in the cultural differentiation in the domain of application.

The main research question "how can a model be formulated that adapts universal decision functions to culture according to a theory about the dimensions of culture" entails the following, more specific questions.

- Given a universal model of human behavior in some domain, can the model of culture's effects be formulated, following an expert systems knowledge acquisition approach?
- Having formulated the knowledge about the effects of culture on model parameters per dimension, how can a believable model of their joint effect be formulated?
- How can the sensitivity of such a model be assessed for variation of cultural dimension indices, relational configurations regarding power and group membership, and universal model parameters?
- Can such a model be applied to fulfill its function as a social sciences research instrument in combination with simulation gaming? This function comprises (Meijer and Verwaart 2005):
    - Validation of models of behavior induced from game observations

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[1] http://cormas.cirad.fr/indexeng.htm

- Testing of hypotheses about dynamics of aggregated results in relation to parameter changes in individual behavior
- Test design: selection of useful configurations for games with humans

The questions are answered in the context of the T&T game, by applying Hofstede's dimensional theory of culture to three universal domain models, for partner selection, negotiation, and the interaction between deceit and trust.

Hofstede's dimensions and their effects on trade

Hypothetical differences in behavior can be formulated for traders from different cultures on the basis of the works Hofstede (2001) and Hofstede et al. (2010) and observations in the T&T game (Meijer 2009). While in reality, individual behaviors are co-determined by historical, contextual and personality factors, these can be abstracted away in the present study of trends of behavior in groups of people. Before creating an integrated model, the behavioral tendency associated with each dimension will be reviewed. The dimensions in Hofstede's model, to be discussed in the following subsections, are masculinity versus femininity, individualism versus collectivism, power distance, uncertainty avoidance, and long-term versus short-term orientation. Each of the dimensions is briefly characterized and expected distinctions between the extremes are specified, based on the work of Hofstede (2001) and expert consultations.

Masculinity versus femininity

In masculine societies people are expected to place value on measurable performance criteria such as size, speed and quantity. Big is beautiful. Money is good. Rich people are admired. Life is conceptualized as a series of contests and winning is paramount while losing is a disaster. Implicit trust is low; if you get cheated upon it is your own fault and you are a loser. If you do good, you do it in the large. If you commit crimes, they are large, not petty ones.

Feminine societies are the opposite. Winners are at risk of awakening feelings of jealousy. Small is beautiful, implicit trust is high, and cheaters are looked down upon. Yet small-scale cheating occurs a lot because society is permissive and, in the case of small misdemeanors, forgiving. Penalties are mild. Good intentions are more important than good performance.

The meaning of trust across cultures is related to the dimension of masculinity versus femininity. In fact, the statement 'Most people can be trusted' was one of the constituents of the dimension in Hofstede's original research. In feminine cultures, people agree with it more. Since then, many others have investigated the variations of the meaning of the concept across cultures. See e.g. Hofstede et al. (2004) for a discussion of the dynamics of trust and transparency across cultures. Hofstede (2006) distinguishes *intrinsic trust* from *enforceable trust*. Intrinsic trust is trust that accepts vulnerability, while enforceable trust is trust in good performance that is backed up by the option of rewarding and punishing the trustee. To sum it up in a simplified way: the former is what people mean by trust in feminine cultures, and the latter is what people mean by trust in masculine cultures.

Table 1 summarizes expected distinctions reported by Hofstede et al. (2006).

Table 1. Expected behavioral distinctions between traders in the T&T game having masculine versus feminine cultural backgrounds (sources: Hofstede 2001, and expert consultations)

Masculine	Feminine
Deal with anyone	Build relationships
Rapid deals, as many goods as possible	Take time to negotiate, accept small deals
Be a tough negotiator	Show mutual willingness to accommodate
Cheat and expect to be deceived	Trust
Show off with highly valuable goods	Purchase for practical use
Trace and enforce delivery to contract	Avoid notorious deceivers

Individualism versus collectivism

The variation in basic group size and cohesion between societies has been shown by sociologists, e.g., in the distinction between *Gemeinschaft* (community) and *Gesellschaft* (society) that Tönnies introduced as early as 1887 (Tönnies 1963). In a *Gemeinschaft*, people share everything, both material and immaterial, whereas in a *Gesellschaft,* private property and other individual-centered institutions are possible. This variation has been confirmed by social-psychological cross-national studies of practices or values. Triandis (1995) and Hofstede (2001) speak of the distinction between *individualism* and *collectivism*. Minkov (2007) showed that the individualist-collectivist continuum is visible in World Values Survey data (he names it universalism versus exclusionism). This dimension has become the main ingredient of theories about cross-cultural business, e.g., in the work of Trompenaars (1993) who posits a number of dimensions of culture that were shown by Smith et al. (1996) to be correlated with individualism versus collectivism. The relevance of this dimension to the management literature lies in the fact that Anglo countries are at the extreme individualistic end of the scale, so business partners from almost any country are bound to have more collectivistic cultures.

In an individualistic society the various spheres of life, e.g., family, business, and leisure, tend to be separated. To collectivist mindsets, relations are more important than business – and so, business tends to be done among friends and family. The term “in-group” is often used to denote this kind of self-evident unit of social life.

Table 2 summarizes expected distinctions reported by Hofstede et al. (2008a).

Table 2. Expected behavioral distinctions between traders in the T&T game having collectivistic versus individualistic cultural backgrounds (sources: Hofstede 2001, and expert consultations)

Collectivistic	Individualistic
Maintain harmony, avoid confrontation	Speak your mind
Show favor to in-group customers	Treat all customers equally
No business without a personal relation	Task is more important than a good relation
Relations are given	Build and maintain relations actively
Do not terminate negotiations	Terminate if progress is insufficient
Do not show distrust to in-group members	Show distrust as it is
High relational endowment effect*	Low relational endowment effect
Deceive if it does not conflict with group interests	Deceive according to personal morality

* The effects of revealed deceit and showing distrust by tracing deliveries do more damage to relationships in collectivistic than in individualistic societies.

Power Distance

Where the salience of common group memberships for social interaction makes the difference between individualistic and collectivistic societies, the dimension of power distance is about the importance of hierarchy in societies. The dimension runs from egalitarian (*small power distance*, e.g., Anglo, Germanic, and Nordic cultures) to hierarchical (*large power distance*, most other cultures). Hofstede (2001) defines power distance as the extent to which the less powerful accept and expect that power is distributed unequally. In large power distance societies political, economic, and judicial power are interwoven. In small power distance societies a person's power is limited to the purposes of a role and to the situations in which the person plays the role. Table 3 summarizes expected distinctions reported by Hofstede et al. (2009).

Table 3. Expected behavioral distinctions between traders in the T&T game having hierarchical versus egalitarian cultural backgrounds (sources: Hofstede 2001, and expert consultations)

Large power distance (hierarchical)	Small power distance (egalitarian)
Might is right	No privileges and status symbols
Formal speech; acknowledgement	Talk freely in any context
Dictate, obey	Negotiate
Negotiate only in case of equal power	
Prefer equal status partners	Treat all (potential) business partners equally
Avoid more powerful business partners, but show favor when unavoidable	
Be patient and conceding with powerful partners	
Be careful not to deceive more powerful partners	
Do not show distrust to more powerful partners	
No need to distrust less powerful partners	
Trade products of quality according to status	

Uncertainty avoidance

Hofstede (2001, p. 161) defines the uncertainty avoidance dimension of culture as "*the extent to which the members of a culture feel threatened by uncertain or unknown situations*". It is important to realize that this has nothing to do with risk avoidance. Uncertainty avoidance is about fear of situations in which "*anything can happen and one has no idea what*"…"*Uncertainty-avoiding cultures shun ambiguous situations. People in such cultures look for structure in their organizations, institutions, and relationships, which makes events clearly interpretable and predictable. Paradoxically, they are often prepared to engage in risky behavior in order to reduce ambiguities – such as starting a fight with a potential opponent rather than sitting back and waiting*" (Hofstede 2001, p. 148).

People from highly uncertainty avoiding societies or groups do not tolerate ambiguity as to who is a member of their group. They tend to have strict moral criteria as to who fits in: adherents of the same religious subgroup, perhaps, or people from the same region, people with the same profession or status, people who speak their language, people of their gender, or similar clear-cut criteria. Since people from such societies do not easily engage in interactions with others who do not share their most salient group characteristics, trade will often be a within-group activity. Within-group contacts are charged with tokens of loyalty, often through shared ritual that is needed to counteract the stress that people experience.

Societies or groups that are uncertainty tolerant are easy travelers, and will engage in novel activities without needing much time to adjust. Their social interactions tend to be laid-back and they will strike up trade relations with foreigners if the opportunity presents itself.

Table 4 summarizes expected distinctions reported by Hofstede et al. (2008).

Table 4. Expected behavioral distinctions between traders in the T&T game having uncertainty tolerant versus uncertainty avoiding cultural backgrounds (sources: Hofstede 2001, and expert consultations)

Uncertainty tolerant	Uncertainty avoiding
Suppression of emotions	Expression of emotions; strong emotions when deceit is revealed
Willingness to take unknown risks	Only known risks are taken
Openness to innovations	Distrust, strong endowment effect
Tolerance of diversity	Avoid strangers
Comfortable with ambiguity and chaos	Need for clarity and structure
Appeal of novelty and convenience	Appeal of purity, high quality
Relaxed negotiation style	Impatient, time is money
Frequency of deceit depends on relationships	Low deceit threshold toward strangers

Long-Term versus Short-Term Orientation

Behaving as a good, upstanding member of the group is at the core of the lives of all beings that live in social groups (Wilson 2007). Human beings are intensely social and they exemplify the point very well. Ensuring the successful functioning of our social groups is a basic requirement for survival. We spend up to twenty years being taught how to act as virtuous members of society. But how to be virtuous? It turns out that different societies have found different answers to that question. The issue of whether the sources of virtue are to be found in the past and present, or in the future, is one of the basic dimensions of culture found by Hofstede (2001). This fifth dimension, called 'long-term versus short-term orientation' by Hofstede, is very important for trade. Its strong correlation with economic growth across 39 countries in the period 1970-2000 testifies to its relevance for trade (Hofstede and Hofstede 2005, p. 223).

Hofstede (2001, p. 359) gives the following definition of the LTO-dimension: "*Long Term Orientation stands for the fostering of virtues oriented towards future rewards, in particular, perseverance and thrift. Its opposite pole, Short Term Orientation, stands for the fostering of virtues related to the past and the present, in particular, respect for tradition, preservation of 'face', and fulfilling social obligations*". Long-term orientation is correlated with self-effacement. This was found by Minkov (2007) in a meta-analysis of data from the World Values Survey. The individual thinks of itself as a small element within the continuity of life. Hence, learning and developing one's capacities is more important than winning a particular game, or obtaining a particular result. In contrast, short-term orientation correlates with self-enhancing values in which being successful in a game is a desirable thing that will improve one's reputation.

Table 5 summarizes expected distinctions reported by Hofstede et al. (2008b).

Table 5. Expected behavioral distinctions between traders in the T&T game having short-term versus long-term oriented cultural backgrounds (sources: Hofstede 2001, and expert consultations)

Short-term oriented	Long-term oriented
Immediate gratification of needs expected	Deferred gratification of needs accepted
Short-term virtues taught: social consumption	Long-term virtues taught: frugality, perseverance
Spending, top quality demanded, impatient	Saving, investing, patient
The transaction bottom line, quick profits	Building a strong market position
Show off, by trading with high status partners	Invest in long-term relations

The joint effects of Hofstede's dimensions

The preceding section describes how agent behavior in trade is expected to vary across cultures along a single dimension. This approach enables knowledge acquisition. An expert can explain the effects of individual dimensions, but cannot oversee the consequences of varying the indices simultaneously. As was shown by Hofstede et al. (2006, 2008, 2008a, 2008b, 2009), the expertise laid down in narrative form can be formalized into production rules that work in two ways: modify (i.e. either increase or decrease) the values of parameters in decision functions and modify the relevance of some decision functions.

The formal rules can be implemented in agents. In multi-agent simulations results can be generated for different values of the particular cultural index and for different relational configurations (status differences, different in-groups, differences in initial trust etc.). These results can be used for verification of the implementation of the rules, for face validation of results, and even for educational purposes. However, to simulate actual national cultures, all dimensions must be taken into account simultaneously. A computational approach to this integration has been developed (Hofstede et al. 2011). This approach, like the models of the individual dimensions, is based on the adaptation of default parameter values in decision models. The adaptation is made on the basis of the values of "cultural factors". Some dimensions adapt the perceived relevance of relational attributes, such as group membership (in-group versus out-group), status difference, and trust. Cultural factors combine dimension scores and relational attributes (see Table 10 at the end of this chapter). The integrated effect of culture on agent behavior can be modeled as a function h that maps a vector of cultural factors $\vec{f}$ and a vector of default values of model parameters $\vec{x}$ to a vector of culturally adjusted parameters $\vec{x}'$:

$$h\left(\vec{f},\vec{x}\right)=\vec{x}' \ . \qquad (1)$$

The hypothesis of this work entails that, given the set of decision functions, a dimensional theory of culture can be used (a) to identify the cultural factors to be taken into account and (b) to define the mapping h. If this is possible, the agent modeling can benefit from vast bodies of social sciences literature that describe the differentiation of many behaviors along the dimensions of the cultural model.

The computational integration approach is based on the following assumptions.

(1) Given that dimensional models of culture aim to provide for each dimension a linear ordering of the strength of phenomena associated with that dimension, the effect of each cultural factor may be modeled as a strictly monotonic function r_{ijk} that adapts the i-th parameter to the k-th factor associated with the j-th dimension. r_{ijk} can be seen as a member of a set of functions that can be indexed by the labels of cultural factors and parameters as arguments.

(2) As long as there is no further evidence, a first order approach can be taken, i.e., let r_{ijk} adjust x_i proportionally to f_{jk} from its default value in the direction of the extreme values $\varepsilon^{+}_{ijk} > x_i$ and $\varepsilon^{-}_{ijk} < x_i$, with ε^{+}_{ijk} and ε^{-}_{ijk} universal, i.e. not dependent on culture, for a particular domain.

(3) The interaction between decision function parameters does not depend on culture. This assumes that a decision model can be formulated in such a way that any parameter can be modified for culture without taking the values of the other parameters into account. This is not a very restrictive assumption. For instance if a decision function $\Delta(x_i, x_{i'})$ requires parameters $x_i < x_{i'}$, the parameters cannot independently be modified, but they can after substitution: $\Delta(x_i, x_{i'}) = \Delta(x_i, x_i + x_{i''}) = \Delta'(x_i, x_{i''})$, with $x_{i''} > 0$.

(4) The joint decreasing and the joint increasing effect of cultural dimensions can compensate for each other. This expertise is confirmed by expert statements, e.g. (in

cultures with high power distance) “*The powerful dictate the conditions. The less powerful have to accept. In feminine or collectivist cultures the powerful may exercise restraint, …*”.

(5) For the increasing and for the decreasing effects, the effect with maximal influence is dominant: effects in the same direction do not reinforce each other. According to expert knowledge, if several factors influence a parameter in equal direction, it is sufficient for one to be maximal in order to sort maximal effect (disjunctive factor influence, see e.g. “*feminine or collectivist*” under 4. above).

(6) Cultural factors working in the same direction do not reinforce each other. For instance, in Table 2 three factors are identified to have increasing effect on deceit threshold d_b. If two of the factors have effect 0.5 and one has effect 0.2, their joint effect is 0.5; not 0.4 (the average) or another linear combination (see 5. above); not 0.8 (probabilistic) or another product combination.

Under these assumptions, the mapping h can be written as a set of functions g_i, one function for each parameter (Hofstede et al. 2011):

$$g_i\left(\vec{f}, x_i\right) = x_i + \left(\hat{\varepsilon}_i^+ - x_i\right)\max\left\{f_{jk} \mid l_{jk} \in L_i^+\right\} + \left(\hat{\varepsilon}_i^- - x_i\right)\max\left\{f_{jk} \mid l_{jk} \in L_i^-\right\} . \qquad (2)$$

The input to this equation are the (domain-dependent) default, minimal and maximal values of the parameter, and the actual values f_{jk} of the cultural factors labeled l_{jk}. The cultural factors are identified in the dimension-by-dimension knowledge acquisition. L_i+ stands for the set of cultural factors indicated to have increasing effect on x_i and L_i– stands for the set indicated to have decreasing effect.

In order to apply this approach, one needs models for the decisions that the agents make in the simulated processes. The following subsections propose models for the trade processes of partner selection and negotiation in the pre-contract phase of transactions, and deceit and trust in the post-contract or delivery phase.

Partner Selection

The decision model for partner selection (Hofstede et al. 2009a) is based on the reinforcement learning of expected utility proposed by Weisbuch et al. (2000). According to the model of Weisbuch et al., agents select their business partners at random, with probability:

$$P_b = \exp(\beta J_b) / \textstyle\sum_{b'} \exp(\beta J_{b'}) \ , \qquad (3)$$

where J_b represents the preference for business partner b, based on the agent’s belief about the partner’s fairness (defined as experience of utility of previous deals) and affected by the agent’s culture and relationship with the partner. The effects of culture and relationship are computed according to Table 10 (at the end of this paper). If the value of β is high, the agent has a tendency to be loyal to partners with which it has successfully dealt before. If the value of β is low, the agent is likely to display shopping behavior, frequently trying new partners. Weisbuch et al. have validated this model in their research at the Marseille wholesale fish market, where both types of agent behavior prevail: some agents are loyal and some consistently show shopping behavior.

Based on the descriptions of individual dimensions given in the preceding section, the value of β, representing loyalty, is expected to depend on culture: increased to a maximal value in long-term oriented societies, and decreased to a minimal value in uncertainty-avoiding or masculine societies.

For each partner, the agent maintains a belief J'_b about the partner's fairness:

$$J'_b(n) = (1 - \gamma)\, J'_b(n-1) + \gamma\, U_b(n) \quad , \tag{4}$$

where γ represent a learning parameter and $U_b(n)$ the utility of the n-th negotiation result with j; $U_b(n) = 0$ if the negotiation was terminated without agreement. Based on the descriptions given in the preceding section, the value of γ is expected to depend on culture: increased in feminine, decreased in uncertainty avoiding cultures.

If an agent has no negotiation going on, it checks for recently received proposals. It may have recent proposals from several agents simultaneously. From the simultaneous proposers, it selects the agent z that has the maximal acceptability A_z. of all proposers and subsequently decides whether to accept the proposal to negotiate with z or to start new partner search, and propose to a partner selected according to equation (3). This decision is modeled as a Bernoulli variable:

$$p(\text{start negotiation with } z) = A_z \quad ; \tag{5}$$

$$p(\text{start new partner selection}) = 1 - A_z \quad . \tag{6}$$

Acceptability A_b of an agent b is set equal to J_b, but for agents from hierarchical societies the value is modified to express that agents having that cultural background are inclined to accept a higher-ranked proposer even if they do not prefer the partner.

Table 10 (at the end of this chapter) summarizes the cultural factors taken into account to modify the parameters and the variables of the partner selection process, applying equation (2) and using appropriate settings for the default, minimal, and maximal values of these parameters and variables.

Negotiation

The negotiation process (Hofstede et al. 2010a) is modeled according to the ABMP architecture (Jonker and Treur 2001). The similarity of ABMP to human negotiations has been validated (Bosse et al. 2004). The ABMP process is an exchange of bids, starting with a bid by one of the partners. The agents evaluate bids using a utility function.

The agent model uses the utility function proposed by Tykhonov et al. (2008):

$$U = w_{value}V + w_{qual}Q + w_{risk}R \quad , \tag{7}$$

with $0 \le w_{value} \le 1$, $0 \le w_{qual} \le 1$, $0 \le w_{risk} \le 1$, and $w_{value} + w_{qual} + w_{risk} = 1$. The terms of this function represent the economic value of the transaction and the effects of agent's quality preference and risk avoidance, respectively. For a further specification of the computation of the utility function's terms, we refer to Hofstede et al. (2010a).

ABMP is a multi-attribute concession strategy. An agent prepares a bid that is a utility concession to its previous bid. In the present simulation, the agent prepares the first bid by composing an attribute configuration according to its quality preference and risk attitude. After the price is set according to the agent's belief about the market price range for the product (a seller sets the price at the maximal value, a buyer at the minimal value), the utility U_1 of the first bid to be made is computed. In subsequent bids the partners make concessions with respect to the utility of their bid.

Concession factor η and negotiation speed χ are the parameters that govern the concession making. *Concession factor* η, $0 < \eta < 1$, is the fraction of the opening bid's utility that the agent is willing to give in during the negotiation. It determines the minimum utility that is acceptable to an agent, also called the reservation value:

$$U_{\min} = (1 - \eta)U_1 , \tag{8}$$

where $U_{\min}$ represent the reservation value, and U_1 the opening bid's utility.

Negotiation speed χ, $0 < \chi < 1$, is the fraction of difference between the agent's previous bid and the minimum utility that an agent uses to determine the target utility of its next bid:

$$U_{n+1} = U_{\min} + (1 - \chi)(U_n - U_{\min}) , \tag{9}$$

where $U_{\min}$ represent the reservation value, and U_1 the opening bid's utility. In the current simulation a bid is composed by changing the attribute values at random and setting the price to yield the target utility.

After calculation of the utility of a partner's bid and the target utility of its own next bid, the agent decides whether to accept partners bid or not, governed by the utility gap parameter ω.

Acceptable utility gap ω is the maximal difference between own target utility and last partner's bid's utility for which an agent will accept partner's bid.

If the target utility minus the partner's last bid's utility is greater than the acceptable utility gap, the agent does not accept and has to decide about its next action. It can terminate the negotiation for several reasons. First, partner's bid may be interpreted as unrealistic if its utility is too far below the minimum utility. Second, an agent may be dissatisfied by the progress in partner's bids. Third, there may be no more room for a substantial change of attributes to make a bid with the target utility. In the latter case the agent terminates the negotiation. In the first two cases the probability that the agent terminates the negotiation depends on the impatience parameter ι, $0 < \iota < 1$. The agent terminates the negotiation with probability ι if partners bid is considered unrealistic, i.e. less than $(1-\iota)U_{\min}$, or partner makes insufficient concessions, i.e. less than $(1-U_{\min})\iota$ over the last three rounds.

The weight factors in the utility function and the ABMP parameters depend on the negotiation domain and on culture. Table 10 (at the end of this chapter) summarizes the effects of culture for the negotiation process. Equation (2) can be applied to modify the values of weights and parameters, given default, minimal and maximal values for a domain, e.g. the purchase of a supercomputer by a university or transactions in a wholesale food market.

Opportunism and trust

For a simulation of human trust and deceit, a strictly rational model is not sufficient (Hofstede et al 2010b). In intelligent agent research, much attention has been paid to trust. Little research has been published about the simulation of deceit. Some authors modeled deceit as a rational strategy to gain advantage in competitive situations (Castelfranchi et al. 2001, Ward and Hexmoor 2003). A strictly rational approach of deceit neglects the emotional impact that deceit has, not only on the deceived, but also on the deceivers. Feelings of guilt and shame result from deceiving and the extent to which these feelings prevail differs across cultures (Triandis et al. 2001). People have emotional thresholds for deceit that cannot be explained from rational evaluation of cost and benefit, but that are based on morality and cooperative attitudes (Boles et al. 2000, Wirtz and Kum 2004, Steinel and De Dreu 2004). Once deceived, people react to an extent that goes beyond rationality (Boles et al. 2000), especially when they are pro-social rather than selfish (Steinel and De Dreu 2004). In human decision making a model based on *fair trade* prevails over a model of *opportunistic betrayal* (Olekalns and Smith 2009). In addition to psychological factors, rational economic motives can be given for the human inclination to cooperative behavior (Hwang and Burgers 1999).

The decision to deceive depends on opportunity, motive, and attitude. A supplier has an opportunity to deceive if a high quality product has to be delivered and the customer did not require a certificate. A supplier has a motive to deceive if an extra profit can be gained by deceiving, for instance if the customer negotiated a guarantee and the supplier expects the customer to trust the delivery. Whether a supplier actually deceives when opportunity and motive are present, depends on the supplier's threshold toward deceit. The threshold depends on the supplier's morality and may be reinforced by recent penalties or the relationship with the customer. For agents in the TRUST & TRACING game, Hofstede et al (2010b) model the decision to deceive as a Bernoulli variable with probability of deceit

$$p(\text{deceit}) = q\,(1- c)\, m_b\,(1-d_b)\,, \qquad (10)$$

where q represents the quality agreed in the current contract (q=1 for high quality; q=0 for low quality or no opportunity); c=1 if certification has been agreed (no opportunity); c=0 otherwise; m_b represents the supplier's motive or rationale to deceive customer b (m_b =1 if the supplier expects an extra profit from deceit; m_b=0 otherwise); d_b represents on the interval [0, 1] seller's threshold for deceit toward customer b, where d_b=1 represents perfect truthfulness. d_b is influenced by seller's personal traits and values (like risk aversion and morality), power and group relations, and seller's estimate of customer's benevolence, i.e., seller's trust that the customer will accept deliveries without tracing. A more detailed description of the deceit model is given by Hofstede et al. (2010b).

Trust and distrust develop during social interactions. The only sources of information that can be taken into account in the simulation of the Trust and Tracing game are negotiation outcomes and tracing reports, which are relevant in reality as well. Every successful negotiation resulting in a transaction will strengthen partners' trust in each other. However, customers can decide to trace a delivery and this can have its effects on mutual trust. First, if tracing reveals deceit, the customer's trust in the seller will be reduced. Second, the fine and the reputational damage resulting from revealed deceit will reinforce the supplier's honesty. However, reinforced honesty will decay in the course of time. Third, the supplier delivering truthfully may be offended by tracing. To maintain a good relation, customers may exercise restraint to trace. Tracing will always reduce the supplier's belief about customer's benevolence. The following dynamics have to be modeled:

- development of trust and benevolence belief by successful negotiations;
- for customers: reduction of trust in case of revealed deceit;
- for suppliers: reinforcement of honesty in case of revealed deceit;
- for suppliers: decay of reinforced honesty to a base level;
- for suppliers: reduction of benevolence belief in case of tracing.

Jonker and Treur (1999) develop a classification of trust dynamics. The most realistic type for trading situations is slow positive – fast negative: it takes a series of positive experiences to develop trust, but trust can be destroyed by a single betrayal. A consumer's trust in supplier *b* after the *n*-th experience is updated as:

$$\begin{aligned} t_b(n) &= t_b(n\text{-}1) + u^+ (1 - t_b(n\text{-}1)) && \text{if } n^{\text{th}} \text{ experience is positive,} \\ t_b(n) &= t_b(n\text{-}1) - u^- \, t_b(n\text{-}1) && \text{if } n^{\text{th}} \text{ experience is negative,} \\ t_b(n) &= t_b(n\text{-}1) && \text{if } n^{\text{th}} \text{ exp. is neither positive nor negative,} \end{aligned} \tag{11}$$

with $0 < u^+ < u^- < 1$, where $t_b = 1$ represents complete trust and $t_b = 0$ represents complete distrust; a successful negotiation counts as a positive experience; a tracing report revealing deceit counts as negative; all other experiences are considered neither negative nor positive with respect to trust.

A supplier's belief about a customer's benevolence is updated by the same mechanism. A successful negotiation counts as a positive experience. Tracing counts as a negative experience for a supplier, whether it reveals deceit or not. An additional effect of revealed deceit on the supplier's part is that supplier's current honesty $H(n)$ (a personal trait, representing the inclination to deliver truthfully) is reinforced to 1, representing maximal honesty. H will subsequently decay to a base value H_{min} on each interaction, whether it is successful or not, with a decay factor φ.

$$H(n) = H_{min} + \varphi\,(H(n-1) - H_{min})\,, \text{ with } 0 < H_{min} < 1 \text{ and } 0 < \varphi < 1\,. \tag{12}$$

Trust developed according to equation (11) represents an internal state of mind, a belief about a partner. It can be seen as a subjective probability that a partner will not defect even if motive and opportunity are present. According to Castelfranchi and Falcone (1998) trust exists as a state of mind, as a decision, and as a social behavior. Because of the repercussions distrust may have as a social behavior, the decision to trust does not necessarily correspond to trust as a state of mind. The inclination to trust depends on cultural factors. The decision to trust or to trace is modeled in the simulation as a Bernoulli variable, with

$$p(\text{trace}) = T' \, , \qquad (13)$$
$$p(\text{trust}) = 1 - T' \, , \qquad (14)$$

where the culturally adapted inclination to trace T' is computed by applying equation (2) on the base value of $T = q\,(1 - c)\,(1 - t_b)$, using Table 10. Table 10 (at the end of this chapter) summarizes culture's effects on the variables related to trust, deceit, and tracing.

Simulation examples

This section presents some simulation results. The first example confirms that the model is sensitivity to culture and offers face validation at extreme values of Hofstede's indices. The second example illustrates that model outputs are more sensitive to common group membership for agents configured with Japanese settings than for USA settings. Then, sensitivity analysis are presented to confirm that in different cultures, different rules for agent behavior are relevant. The last example validates the feasibility of the model as a research instrument to be used in combination with gaming simulation, aiming to improve models of agent behavior. It uses results of games played in the Netherlands and the USA.

The simulation results should not be interpreted as to give exact quantitative values. The results illustrate stylized facts, such as "common group membership is more relevant in Japan than it is in the USA".

Table 6a presents aggregated outputs of games simulated in an environment where the agents can select a trade partner, negotiate, deceive or deliver truthfully, and update their beliefs. The results show that the ease with which agents reach an agreement, the frequency of negotiation failure, and the quality level depend on culture in a believable way. Table 7 displays the parameter values used.

Much of the literature on cultural difference focuses on individualism versus collectivism and the associated phenomena such as direct versus indirect communication styles. Common group membership determines social relations in collectivistic societies. Group membership is known to be very relevant in Japan (e.g., Hall 1976). The cultures of Japan and the USA differ considerably on individualism versus collectivism, but also on other indices (Hofstede 2001):

- Japan: PDI^*=0.54, IDV^*=0.46, MAS^*=0.95, UAI^*=0.92, LTO^*=0.80;
- USA: PDI^*=0.40, IDV^*=0.91, MAS^*=0.62, UAI^*=0.46, LTO^*=0.29.

It is interesting to see if the influence of group membership emerges in simulations, in spite of the differences on other dimensions. Fig. 1 presents simulation results for Japan and USA, with parameter settings as in Table 7. For the "Japanese" agents, group membership considerably influences the success of negotiations and the trust required for trading high quality products.

Table 6a. Average results of simulated negotiations for cultural stereotypes, with the value for the particular dimension set to either 0.1 or 0.9 and the values for the other dimensions set to 0.5 (8 suppliers; 8 customers; 10 runs of 200 time steps for each configuration; parameter values as in Table 7); data source: Hofstede et al. (2010a)

culture type	*conditions*	*number of transactions*	*% failed negotiations*	*% top quality*
large power distance	all high status	44	57	97
	all low status	50	60	0
	customer higher	77	45	98
	supplier higher	4	92	0
small power distance		72	49	2
uncertainty avoiding	similar partners	29	71	76
	different partners	27	73	87
uncertainty tolerant		49	58	1
individualistic		66	50	1
collectivistic	in-group partners	117	13	61
	out-group partners	39	65	0
masculine		36	71	80
feminine		61	45	0
long-term oriented		55	52	0
short-term oriented	equal status	24	72	95
	diverse status	57	47	91

Table 7. Parameter values used in the simulation runs (w_q': quality preference; w_r': risk aversion; χ: concession factor; η: negotiation speed; ω: acceptable utility gap; ι: impatience)

Type of value	w_q'	w_r'	χ	η	ω	ι
Default value	0.1	0.1	0.7	0.2	0.02	0.3
Maximal value	0.5	0.5	1	0.5	0.1	0.7
Minimal value	0	0	0	0	0	0.1

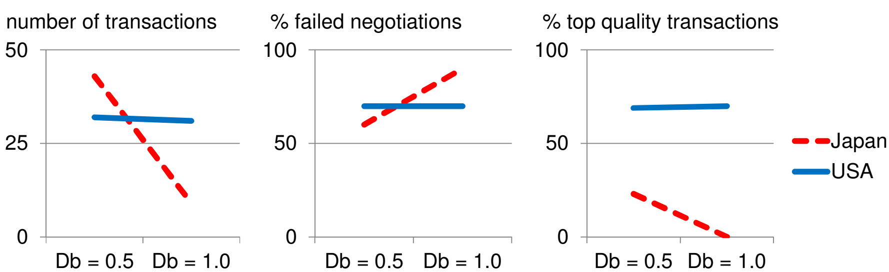

Fig. 1. Simulation results with different settings of group distance between suppliers and customers; data source: Hofstede et al. (2010a)

Trade may run less smoothly between different cultures. Fig. 2 presents simulated results of trade between Japanese and USA agents. The results show that for USA traders in Japan it pays to invest in personal relations in order to reduce group distance. Overcoming distrust is hard for USA traders acting as suppliers to Japanese agents. This phenomenon is not associated with the difference on the IDV index, but with UAI and LTO.

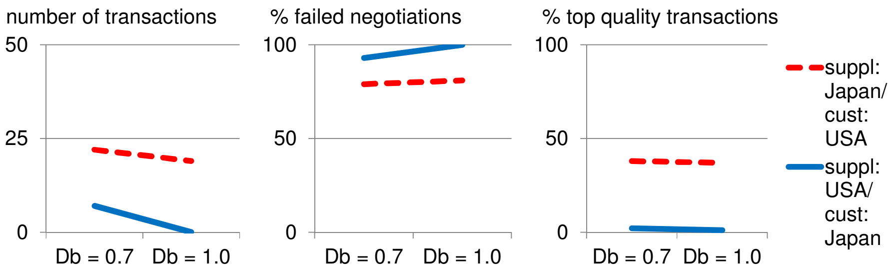

Fig. 2. Simulation results with different settings of group distance between Japanese suppliers and USA customers vice versa; data source: Hofstede et al. (2010a)

The example of Japanese versus USA traders indicates that the salience of parameters may be different across cultures, in combination with trade roles. Burgers et al. (2010) present results of Monte Carlo based sensitivity analyses for the model proposed in the present chapter. Different outputs (e.g., number of transactions, number of certificates) are sensitive to different parameters. Table 8 displays contributions to variance of the number of transactions in a game. The table presents a mean value and shows that considerable differences between countries prevail. It should be noted that the values presented in Table 8 have no actual meaning for simulations results, but they indicate that it depends on culture which parameters should be given most attention to calibrate the model.

Table 8. Mean Top Marginal Variance values (of 62 countries) and data for the countries that have the maximum TMV score for a parameter; source: Burgers et al. 2010

national culture	group distance	mean status	initial trust	partner pref.	conces. factor	negot. speed	quality pref.	risk avoid.
mean (n=62)	4.1	1.0	3.4	1.8	24.8	30.2	0.5	1.6
Indonesia	16.9	0.1	0.2	0.0	11.6	40.9	0.0	0.0
Morocco	0.7	8.7	3.3	4.7	17.5	37.9	0.0	0.0
Hungary	0.0	0.0	11.5	1.9	37.6	1.4	2.4	11.5
Uruguay	4.9	1.7	8.5	5.5	23.4	24.1	0.0	0.0
Netherlands	0.7	0.0	1.6	0.3	46.2	28.8	0.0	2.1
Iran	1.3	3.1	0.9	0.4	10.3	56.2	0.6	0.0
Austria	0.0	0.0	3.8	2.6	27.1	11.5	4.8	6.9
Japan	0.5	0.0	8.3	1.6	30.8	0.9	0.1	15.8

The remaining part of this section presents an example of a tour through the research cycle where a model based on theory is implemented in the multi-agent simulation, multi-agent simulation data are validated against gaming simulation observations, validation fails, theory and the model are adapted, the multi-agent simulation is adapted, and new simulation outputs are validated against the observations and are found to support the adapted theory. The example supports the validity of the multi-agent simulation as a research instrument in combination with gaming simulation. The example has been reported by Hofstede et al. (2010b).

The following hypotheses, to be tested against simulation results, can be formulated from observations in the TRUST & TRACING game (Meijer 2009).

1. Average quality of products traded in games played in the USA is higher than in the Netherlands.
2. Certification ratio (i.e., the fraction of high quality transactions where a certificate was negotiated) is higher in the USA than in the Netherlands.
3. Defection ratio (i.e., the frequency of deceit in uncertified high quality deliveries) is higher in the USA than in the Netherlands.
4. Tracing ratio (i.e., the fraction of uncertified high quality deliveries for which a trace is requested after delivery) is higher in the USA than in the Netherlands.

To test these hypotheses, 310 simulations were run, with cultural indices for the USA and the Netherlands taken from Hofstede (2001):

- Netherlands: PDI^*=0.38, IDV^*=0.80, MAS^*=0.14, UAI^*=0.53, LTO^*=0.44;
- USA: PDI^*=0.40, IDV^*=0.91, MAS^*=0.62, UAI^*=0.46, LTO^*=0.29.

The other agent parameters are randomly generated for each run pair.

Analysis of the results confirmed hypotheses 1, 3, and 4, but did not confirm hypothesis 2. The certification ratio as defined in hypothesis 2 was approximately equal for the USA and The Netherlands. In these simulations the negotiation model reported in Hofstede et al. (2010a) is applied. According to that model, customers do not take a differentiation of certification cost between themselves and suppliers into account. This difference was found to be an important factor in the gaming simulations in the USA. The negotiation model was modified to take tracing fee differences and probability to trace into account. The original equation for customers' risk in an uncertified deal is:

$$r_{customer} = (1 - c)(1 - t_b)q \ . \tag{15}$$

The modified equation is

$$r_{customer} = (1 - c)(1 - t_b)q + T'\phi_{customer} \ , \tag{16}$$

with $\phi_{customer}$ representing customers' tracing fee.

The simulation was repeated after replacing equation (15) with equation (16) and setting the tracing fee equal to 0.2 for suppliers and 0.3 for customers. Table 9 summarizes the results. The simulation results confirm hypotheses 1 through 4. Differences are found to be significant for all variables, with $p < 0.001$ according to the Sign test. This example illustrates how the combination of multi-agent simulation and gaming simulation can improve models of culturally differentiated agent behavior.

Table 9. Test data for 310 run pairs for USA and NL (source: Hofstede et al. 2010b)

Average of 310 runs	USA	NL	Test stat. [a]	Sample [a]	Probability [a]
Number of transactions	72	61	219	302	< 0.001
Quality ratio	0.37	0.15	277	285	< 0.001
Certification ratio	0.48	0.41	191	281	< 0.001
Defection ratio	0.25	0.13	128	154	< 0.001
Tracing ratio	0.40	0.07	169	177	< 0.001

[a] Test statistic, effective sample size, and two-sided probability level for Sign test

Conclusion

De Rosis et al. (2004) suggested to apply Hofstede's theory to build culturally consistent agent characters. The research presented in this chapter shows how this can be done. It shows that rules for cultural differentiation of universal models of aspects of human behavior can be formulated, following an expert systems knowledge acquisition approach. Working on a dimension-by-dimension basis reduces the complexity to a level where a domain expert can specify the rules and verify the results. Doing this for more dimensions simultaneously is too complex for an expert. Furthermore, this chapter proposes an approach to integrate the rules for individual dimensions into a joint effect, resulting in believable cultural differentiation of agent behavior. This approach has been applied to three domains in trade: partner selection, negotiation, and the interaction between trust and deceit. The resulting agent models have been applied in a multi-agent simulation.

A meta-modeling approach for sensitivity analysis of the simulation model has been developed (Burgers et al. 2010). Sensitivity analysis indicates that the outcomes and sensitivity for parameters in the universal models strongly depend on the cultural settings. It is found to be necessary to perform sensitivity analysis to statistics at the aggregated level as well to statistics of individual agent performance. However, the method for sensitivity analysis at the individual level needs further development (Burgers et al. 2010).

Face validity of the results for the extreme cultural situations – called "Synthetic Cultures" by Hofstede and Pedersen (1999) – indicates that the approach proposed in the present chapter is feasible for the development of agents which can be used for training purposes and educational simulations. Application of this model in, for instance, affective agents as it has been suggested by the Rosis et al. (2004) would require further validation.

A model as described in this chapter is what Gilbert (2008) has called a middle range model. Gilbert asserts that the generic nature of such a model means that it is not possible to compare its behavior with any observable instance in the real world. Having found some instance where the model reproduces stylized facts that resemble real world or gaming observations, cannot serve as a general validation and does not guarantee the correctness of predictions made for other cultural situations. Validation of this type of model is an ongoing process. Confidence that the model can predict the effects of culture in new situation grows according to the number of cases where its outputs correspond with those of gaming simulations or other data.

The pragmatic validation of the model – for its use in combination with gaming simulation as a research tool for the social sciences – is also an ongoing process. The example given in the preceding section of this chapter supports the usability of the model for hypothesis testing and positively answers the research question “Can such a model be applied to fulfill its function as a social sciences research instrument in combination with simulation gaming?”. In cases where the model does not correspond with data from games or other sources, these results can be used to improve the model and support the advancement of science.

Culture research is an ongoing process as well. The first version of Hofstede‘s model was defined in four dimensions. The dimension of long-term versus short-term orientation was discovered in a separate research program carried out in China, with questions devised by people with Asian mindsets. Hofstede’s model has recently been extended with the dimension of “*Indulgence versus Restraint*” found by Minkov (2007) using World Value Survey data, and included in Hofstede et al. (2010). To include this new dimension into the agent model would require the acquisition and formalization of expert knowledge, as it has been performed for the other dimensions, eventually resulting in the representation of extra cultural factors and their effects in Table 10 (appendix).

Extensions of the width of modeled behavior are also to be considered, and might increase the simulation’s validity. For instance, an important component not included in the present work but possibly very influential in real trade networks is contagion of behavior through imitation and social learning by means of a reputation mechanism.

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Table 10. Increasing (+) and decreasing (–) effects of relevant cultural factors per decision function variable (Hofstede et al. 2009a, 2010, 2010b)

Dimension	Culture and relational	Cultural factor	Partner selection				Negotiation						Deceit and trust			
Index	Characteristics		β	γ	J_j	a_j	w_q	w_r	η	χ	ω	ι	d_j	T	u^-	u^+
PDI	Large power distance	PDI^*														
	- self status high	$PDI^* s_i$					+									
	- self status low	$PDI^*(1-s_i)$					–									
	- with higher ranked partner	$\max\{0, PDI^*(s_j - s_i)\}$			–	+		+	+		+	–	+	–		
	- with lower ranked partner	$\max\{0, PDI^*(s_i - s_j)\}$			–			–						–		
UAI	Uncertainty avoiding	UAI^*		–			+			+		+			+	–
	- with stranger	$UAI^* \cdot D_j$			–			+					–	+		
	Uncertainty tolerant	$1 - UAI^*$	–													
IDV	Individualistic	IDV^*														
	- with trusted partner	$IDV^* t_j$			+											
	Collectivistic	$(1-IDV^*)$													+	
	- with in-group partner	$(1-IDV^*)(1-D_j)$			+				+			–		–		
	- with out-group partner	$(1-IDV^*)D_j$						+		–			–			
MAS	Masculine (competitive)	MAS^*	–				+	+		+		+	–	+	–	
	Feminine (cooperative)	$1 - MAS^*$		+			–			–		–		–		
	- with trusted partner	$(1 - MAS^*)t_j$			+											
LTO	Long-term oriented	LTO^*	+				–					–	+	–	+	
	- with trusted partner	$LTO^* t_j$			+											
	Short-term oriented	$(1-LTO^*)$					+									
	- with well-respected partners	$(1-LTO^*)s_j$			+			–	+			–	+	–		
	- with other partners	$(1-LTO^*)(1-s_j)$											–			

PDI^*, UAI^*, IDV^*, MAS^*, and LTO^* represent Hofstede's indices, s_i the agent's status, s_j partner's status, D_j group distance, and t_j trust; all in [0,1]

Part II: Context

This part introduces the multi-agent simulation of the TRUST & TRACING (T&T) game. Chapter 2 reports a first exploration of the feasibility of multi-agent simulation as a tool for supply chain research in combination with gaming simulation. It is joint work with Sebastiaan Meijer, the main stakeholder for the development of the multi-agent simulation. Dr. Meijer was by that time a PhD student at Wageningen University, exploring the application of gaming simulation as a tool for research into social processes in supply networks, focusing on the role of trust (Meijer 2009). In that research he faced two main problems to the resolution of which multi-agent simulation could contribute.

First, based on experiments in the gaming simulations, refinements of theoretical models of the participants' cognitive processes and models of the social processes of the interactions can be hypothesized. Those models are induced from observations during the game and from questionnaires completed by participants before and after the game. The models can be formalized in multi-agent simulations. By comparing the results of both types of simulation the models can be rejected or supported.

Second, playing the gaming simulations demands scarce resources: for each gaming run a "fresh" sample of participants is required and a game configuration must be repeated a number of times before conclusions may be drawn. A multi-agent simulation can be used to design game configurations that maximize the significance for testing hypotheses. In addition, multi-agent simulations can be used to explore the space of possible game configurations and results, and thus discover new hypotheses to test in gaming simulations.

The work reported in Chapter 2 was originally presented in the 2005 IEA/AIE conference (Meijer and Verwaart 2005).

After the feasibility of multi-agent simulation had been assessed, a detailed model of the T&T game was developed in joint work with Dmytro Tykhonov and Catholijn Jonker. The model and experimental results of the multi-agent simulation are reported in Chapter 3. That work has originally been published in JASSS - the Journal of Artificial Societies and Social Simulation (Tykhonov et al. 2008). Parts of that work have previously been presented in the 2005 Trust in Agent Societies workshop at AAMAS (Jonker et al. 2005) and in the Artificial Economics symposium (Jonker et al. 2006).

A description of the research method combining gaming and multi-agent simulation is contained in Chapter 3. Fig. II (see next page) summarizes that method. The present thesis can be viewed as the result of a first full cycle of the method. From the first rounds of gaming simulations, considerable difference between results of participants with different cultural background emerged (Meijer et al. 2006). The model described in Chapter 3 gives no explanation for these differences. That lack of explanation was the motivation to extend and re-implement the agent-based model, to include cultural differentiation of agent behaviour. The approach taken to adapt agents' behaviors to cultural background, and its results, are the main substance of this thesis and will be discussed in Parts III and further.

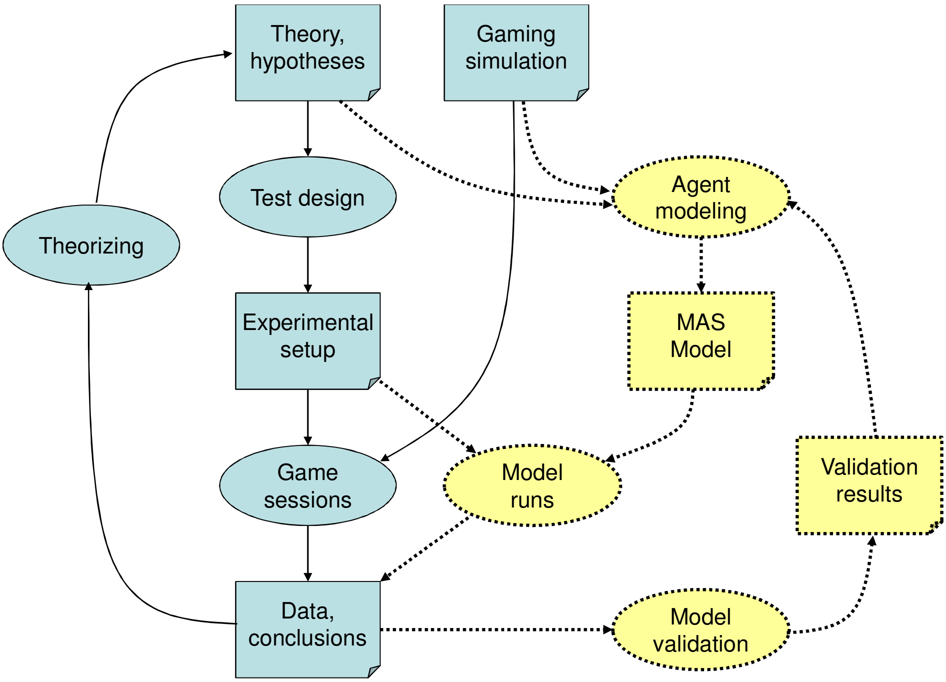

Fig. II. The research cycle combining gaming simulation with multi-agent simulation

2 Feasibility of Multi-agent Simulation for the Trust And Tracing Game

Abstract. Trust is an important issue in trade. For instance in food trade, market actors have to rely on their trade partner's quality statements. The roles of trust and deception in supply networks in various cultural and organisational settings are subject of research in the social sciences. The Trust And Tracing game is an instrument for that type of study. It is a game for human players. Conducting experiments is time-consuming and expensive. Furthermore, it is hard to formulate hypotheses and to test effects of parameter changes, as this requires many participants. For these reasons the project reported in this paper investigated the feasibility of multi-agent simulation of the game and delivered a prototype. This paper briefly describes the game and introduces the process composition of the agents. The prototype uses simple, but effective models. The paper concludes with directions for refinement of models for agent behaviour.

Introduction

The Trust and Tracing game is a research tool designed to study human behaviour in commodity supply chains and networks. The issue of trust is highly relevant to the field of supply chain and network studies. In their paper founding the field, Diederen and Jonkers [3] list six core sources of value improvement for supply chains and networks. For four out of six sources trust is a major aspect in the way people deal with each other about these issues (transaction, property rights and value capture, social structure, and network externalities). For each of these four sources case studies have been done describing the importance of human relationships ([1], [13]).

Meijer [11] describes the appropriateness of using simulation games to facilitate the six sources of value improvement. The Trust and Tracing game is an example of such a game. This tool places the choice between relying on trust versus relying on complete information in trade environments at the core of a social simulation game. In research conducted, the game has been used both as a data gathering tool about the role of reputation and trust in various types of business networks, and as tool to make participants feed back on their own daily experiences in their respective jobs.

There are several disadvantages to playing games with human players for research purposes. Firstly it is impossible to control all parameters, as any person has social relationships and cultural bias [2]. Furthermore it is expensive and time-consuming to acquire enough participants [4], so the number of games that can be played in varying configurations is limited. A simulation model could prove useful for:

1. Validation of models of behaviour induced from game observations
2. Testing of hypotheses about system dynamics of aggregated results in relation to parameter changes in individual behaviour

3. Selection of useful configurations for games with humans (test design)

A multi-agent approach of the simulation is obvious because the weak notion of agency as formulated by Jennings and Wooldridge [8] applies to the players. The players pursue individual goals and take decisions individually (autonomy), they can react on offers of others (responsiveness), they plan their actions according to their private needs and preferences (pro-activeness), and they are aware of the identity of other players, negotiate with them, and maintain beliefs about them (social ability).

A brief description of the Trust And Tracing game will be given here. An extensive description is available in [10]. The focus of study is on trust in stated quality of commodities. The game needs a group of 12 up to 25 persons that play roles of producers, middlemen, retailers, or consumers (Fig. 1). The goal of producers and traders is to maximise profit. The consumers' goal is to maximise satisfaction.

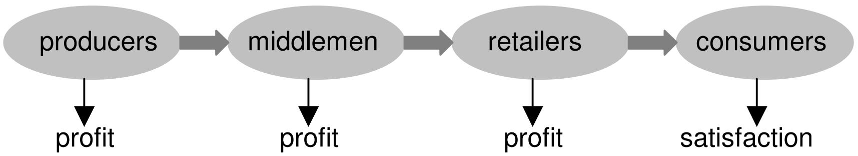

Fig. 1. Commodity flow and player's goals

Each player receives (artificial) money. Producers receive envelopes representing lots of commodities. Each lot is of a certain type of product and of either low or high quality. High quality products give more satisfaction points than low quality products. A ticket covered in the envelope (so it is not visible) represents quality. The producers know the quality. Other players have to trust the quality statement of their suppliers, or request a product trace at the cost of some money and some damage to the relations with their suppliers. The game leader acts as a tracing agency and can on request determine product quality. In case of deception the game leader will trace transactions and punish deceivers with a fine and public disgrace.

This paper describes the design of a prototype for the multi-agent simulation. Section 2 describes the design of the agents and their process composition and information exchange. Section 3 describes the simple models of behaviour implemented in this prototype and an example of simulation results. Section 4 discusses the feasibility of multi-agent simulation and directions for refinements of the behavioural models.

Agent design

This section first introduces the agents and the information flow between agents. After the introduction it focuses on the internal structure (process composition and information flow) of the trading agents.

The types of agents acting in the game are the trading agents (producers, middlemen, retailers and consumers) and the tracing agency. Fig. 2. depicts the information exchange between the agents.

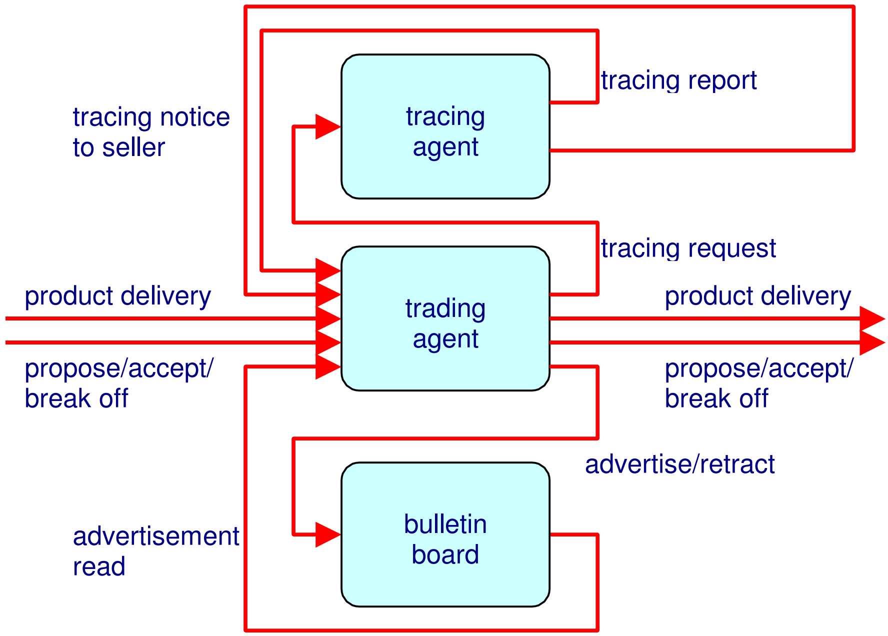

Fig. 2. Information exchange between agents

We choose to use a simple model for partner selection for the prototype. Trading agents may offer their products by advertising on a bulletin board. The agent offering may retract its advertisements. All agents can read all advertisements. An agent interested in buying a product proposes negotiations by sending a proposal to the offering agent. Agents negotiate by exchanging proposals until one of them accepts the last offer made or breaks the negotiation cycle. After a successful negotiation the product can be delivered. Together with the product the history of the lot arrives. The history contains the real quality and quality as stated by previous sellers as hidden attributes, which can be revealed by the tracing agent solely. A buying agent may request a trace. The tracing agent reveals hidden information for the requestor and informs the seller that a trace has been requested. In case of deception the tracing agent punishes all deceivers with a fine. Table 1 shows the attributes of the information exchanged.

The remaining part of this section is devoted to the trading agents. Producers, middlemen, retailers, and consumers have different roles in the market. However, they may be thought of as having similar process composition. Fig. 3 presents a model for process composition and internal information links in trade agents. The processes will be briefly described.

Table 1. Attributes of information exchanged between agents

Message	Attributes
Advertise	reference to offering agent; product quality; asking price
Retract	reference to offering agent; product quality; asking price
advertismt. read	reference to offering agent; product quality; asking price
Propose	ref. to proposing agent; product quality; proposed price
Accept	ref. to accepting agent; product quality; accepted price
break off	reference to agent breaking off negotiations
product delivery	ref. to selling agent; stated product quality*; real quality (hidden)*; list of [reference to selling agent; *stated quality (hidden)*] containing data about previous deliveries *(hidden attributes to be revealed only by tracing agent)*
tracing request	ref. to requesting agent; reference to product delivery
tracing report	reference to product delivery; real quality
tracing notice	reference to requesting agent; *if applicable*: fine

The central process is *need determination*. It sets the priorities for buying or selling products. It uses information about the current levels of stock and financial resources. It sends orders to the processes *supplier search* and *customer search* to initiate buying or selling of products.

The *customer search* process advertises products, using market price beliefs to make product offers. It advertises and stops search or advertising if no response occurs within a reasonable time, or if a proposal has been received through the *negotiation* process. It will report expiration of advertisements to the *seller's beliefs maintenance* process.

The *supplier search* process reads advertisements and uses asking prices and partner belief information from the *buyer's beliefs maintenance* process to select the most promising candidate for negotiations. If it succeeds in selecting a potential supplier it forwards the advertisement to the *negotiation* process to make a proposal. If not, the failure is reported to *buyer's belief maintenance*.

The *negotiation* process exchanges proposals with negotiation partners. It informs the *customer* search process as soon as it has received a reply on an advertisement. It uses beliefs about market price from a buyer's point of view or seller's point of view, depending on its role. It has limited patience and will break off negotiations if no agreement has been reached in a preset time. The outcomes of negotiations will be sent to *buyer's beliefs maintenance* or *seller's beliefs maintenance*.

The *buyer' beliefs maintenance* process maintains beliefs about the market (maximal prices from a buyer's point of view), each of the trade partners (ease of bargaining, reliability with respect to quality statements), and the agent itself (patience, confidence, and risk-attitude). Based on experience from *supplier search*, *negotiation*, and tracing reports the beliefs may be updated, e.g. negotiation outcomes lead to updates of patience or price beliefs and tracing reports lead to updates of trust in the supplier. In response to product delivery, the buyer's trust in the supplier is used in the *trust or trace decision*. In case of a negative tracing report stock update messages will be sent to the *stock and cash beliefs maintenance* process to adjust the beliefs about the products in stock.

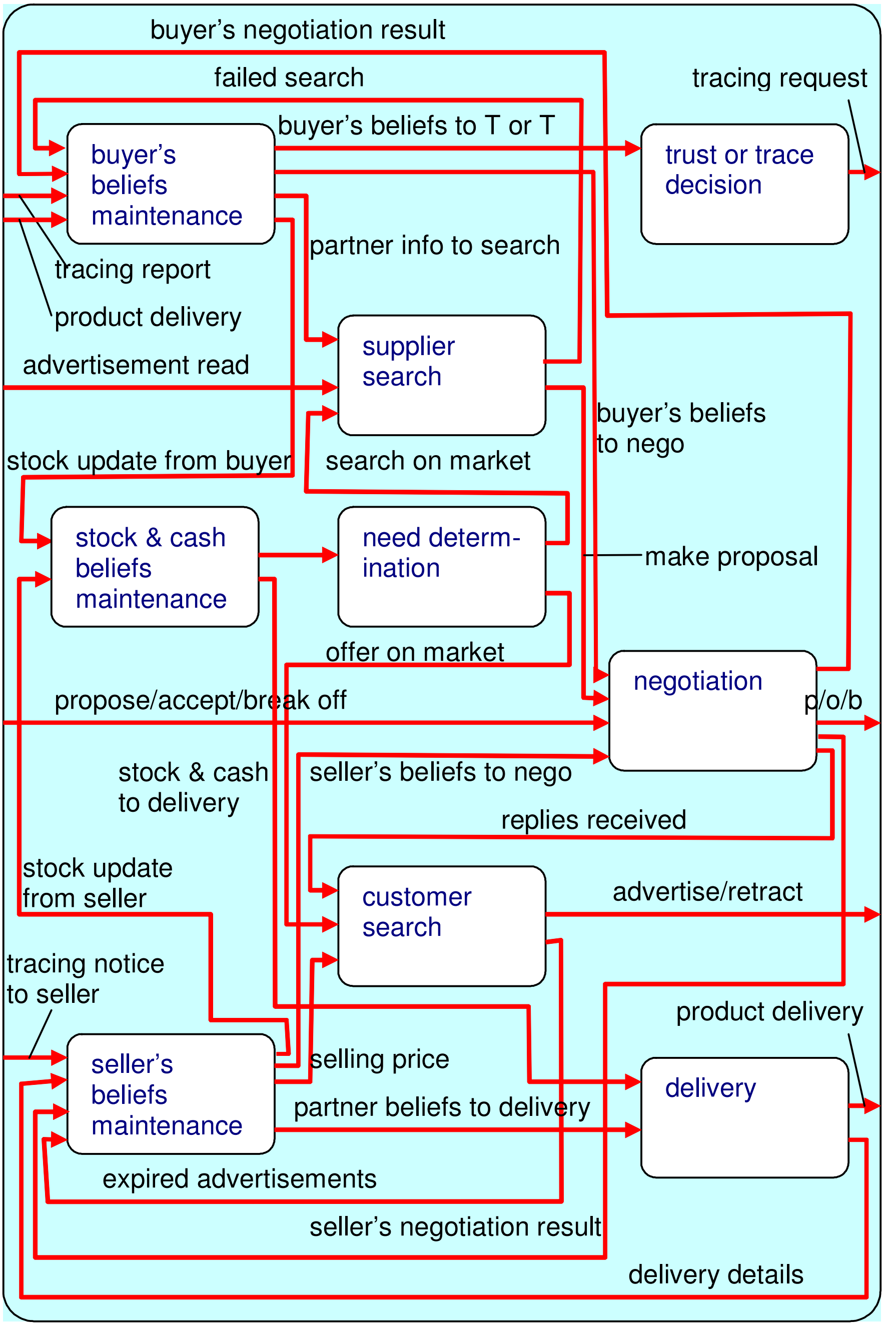

Fig. 3. Process composition and information links in trade agents

The *trust or trace decision* process evaluates the pros and cons of tracing. There is a tracing fee and tracing does damage to the interpersonal relation with the supplier if he is not deceiving. On the other hand the seller should not get the idea that the buyer is an easy prey. Also the seller might be deceived and deliver bad products in good faith. The decision depends mainly on the subjective estimate of seller's reliability and the buyer's confidence and reserve with respect to showing suspicion and buyer's willingness to take risk.

The *seller's beliefs maintenance* process maintains beliefs about the market (minimal prices from a sellers point of view), each of the trade partners (ease of bargaining, tracing frequency), and the agent itself (patience, honesty, and risk-attitude). Based on experience from *customer search*, *negotiation*, and tracing reports the beliefs may be updated, e.g. honesty may decay over time and be increased in response to a punishment; failing negotiations may lead to updates of patience or price beliefs. The *seller's beliefs maintenance* process forwards successful negotiation results to the *delivery* process, along with information about the relation with the buyer and honesty parameters.

The decision to deceive or to be truthful will be taken in the *delivery* process which sends product delivery information to the buyer. It can use the information provided by the *seller's beliefs maintenance* process to determine the intention to deceive, and information about stock and cash position to determine the opportunity to deceive.

The *stock and cash beliefs maintenance process* accumulates changes in cash and stock positions reported by the *buyer's* and *seller's beliefs maintenance* processes. The beliefs about quality of products in stock may be incorrect.

The next section presents a prototype that partially implements these processes, along with an example of simulation results.

Table 2. Traits and beliefs of TradeAgent in the prototype

Trait/Belief	Type	Range	Comments
patience	Integer	[1,∞)	Maximum number of time cycles an agent will take to achieve a result
m	Double	[0,1]	Lower bound for honesty (1: completely honest; 0: liar)
honesty	Double	[m,1]	Actual honesty, with experience based update
target	Integer	[0,∞)	Target number of products to get in stock, set for both product qualities
stock	Integer	[0,∞)	Target number of products to get in stock, maintained for both product qualities
cash	Integer	(-∞,∞)	Amount of money in cash
minSel	Integer	(0, ∞)	Belief about the minimal price for selling, maintained for both product qualities
maxBuy	Integer	(0, ∞)	Belief about the minimal price for selling, maintained for both product qualities
trust	Integer	[0,100]	Maintained for every other agent individually; < 50: unreliable, >50: reliable, 50: don't know

Prototype implementation and results

In this project we tested the feasibility of multi-agent simulation models for study of social aspects of supply chains and networks. We developed a prototype using the Swarm simulation environment [15]. The prototype partially implements the processes described earlier. This section presents the implementation and simple models for agent behaviour. The section concludes with an example of simulation results.

The agents are implemented as Java objects. The class TradeAgent has subclasses Producer, Middleman, Retailer, and Consumer, which differ in the type of partners they select for trading. Table 2 presents traits and beliefs of TradeAgents.

Swarm is a simulation environment based on time-cycles. In each time-cycle all agents are activated once by sending them the "step" message. Agents must implement a step-method that directs their activities. The prototype is based on three cycles, depicted in Fig. 4. Depending on the state of the agent the step-method executes one of the cycles, until it gets in a wait-state for next time-step.

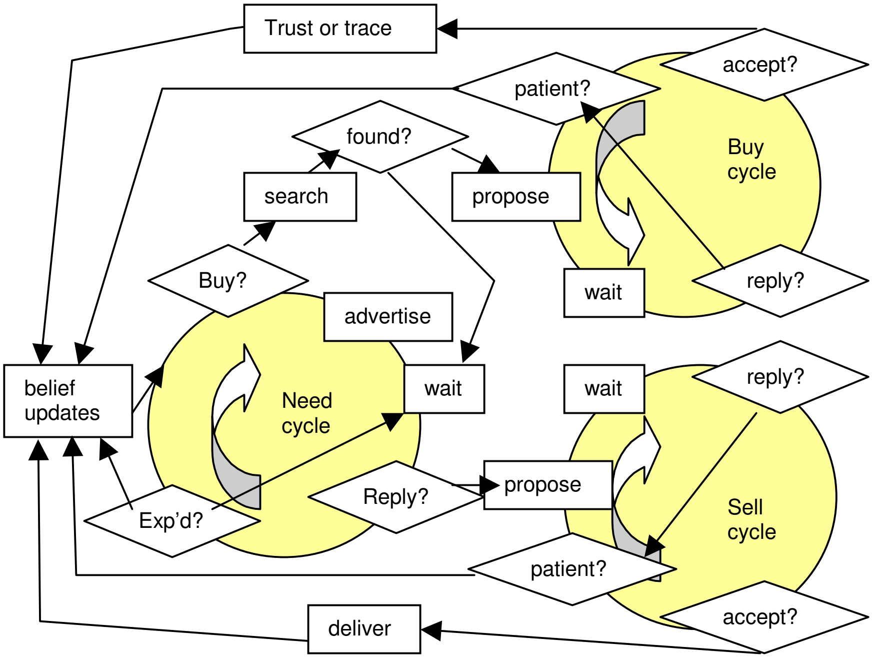

Fig. 4. TradeAgent: need-cycle, buy-cycle, and sell-cycle

In the need-cycle the agent checks for a reply to a current advertisement. If so, it will enter the sell-cycle. If an advertisement has been open for more cycles than the agent's patience, it will retract the advertisement and update beliefs (decrease minimum selling price and increase patience). If there is no advertisement, the agent has to decide to buy or sell. Only if stock is at target level for all qualities, an agent advertises a product of randomly selected quality (price=1.5*minSel) and waits for reply. Otherwise the agent will try to buy.

After the decision to buy, the agent searches a partner with best reliability advertising the desired quality. In case of success he makes a proposal (price=maxBuy/1.5). In the buy- and sell-cycles agents use a simple price negotiation model. If an agent runs out of patience he will break off and update price belief and patience. If an agreement is made in a number of time-steps half or less of patience, price belief and patience is updated in the opposite direction.

After an agreement has been reached, the selling agent has to deliver. If agreed product quality is high, and trust in partner < 55, and a random number in [0, 1] exceeds the current honesty, and it has cash to pay for the fine, it will cheat. The buying agent has to trust or trace. It will trace if product quality is high, and trust in partner < 55, and it has cash for the tracing fee. Table 3 summarises updates of honesty and trust that result from the decisions taken.

Table 3. Honesty and trust updates (trust limited in [0, 100]; honesty limited in [0, 1])

Event	Seller's trust	Seller's honesty	Buyer's trust
Successful negotiation	+1	0	+1
No trace requested	0	-0.02	0
Trace: truthful	-1	0	+3
Trace: deception	-5	+0.1	-5

The effect of reliable delivery on product flow is demonstrated in two simulations depicted in Fig. 5.

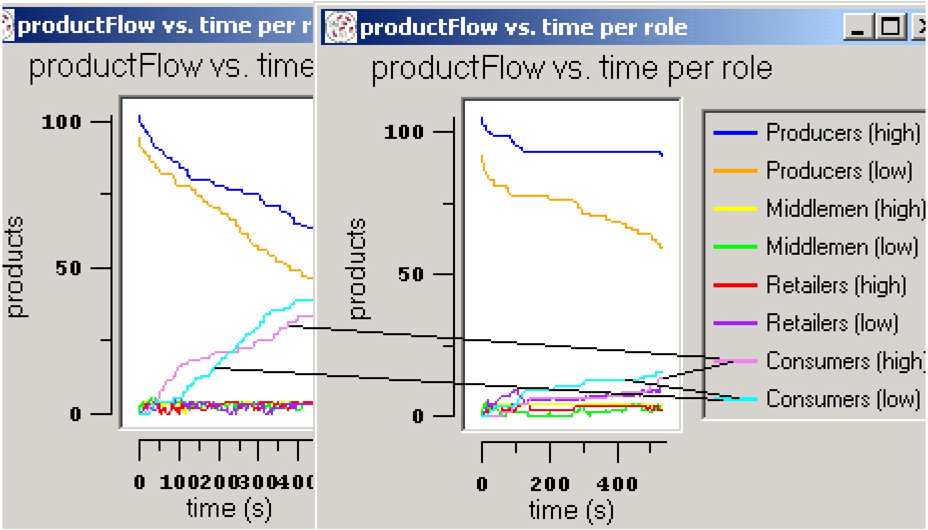

Fig. 5. Effect of honesty in the supply network. In the left hand run the honesty is set to 0.9 for all agents. Commodities flow rapidly from producers to consumers. In the right hand run honesty is set to 0.1. Hardly any products get to the consumers.

Conclusion and directions for future development

This research delivered a design and a working prototype based on simple models of agent behaviour in a Trust and Tracing game environment. The prototype captures the most characterising aspects of the human game [10], with bargaining, cheating, and deciding whether to trust or not. 'Trust' has been modelled as an opinion of the buyer about the chance a supplier will cheat. Multi-agent simulations of supply chains usually focus on techno-economic cooperation between agents. This prototype adds opinions about other agents to the economic reasoning implemented in other models (for instance [5], [6], [12]).

Initial experiments show that manipulation of the basic configuration parameters leads to attenuations in agent behaviour. The example given in this paper shows a faster trade when agents are honest. This is similar to observations in the real game and in real world business cases. We tested several other manipulations like increase of cheating behaviour, increase of supply and increase of honesty and found the simulation to react in a direction we expected from real game experiences.

Because of the limited detail in the models this prototype does not allow valid conclusions for the research purpose as the magnitude of changes has not been tested, nor modelled realistically. However, the prototype demonstrates the feasibility of multi-agent simulation for the Trust and Tracing game. The prototype proved sensitivity to manipulation of the major variables and showed similar changes in behaviour as observed in the human game.

The three contributions a multi agent simulation can make presented in the introduction (validation of models, testing of hypotheses and selection of useful game configurations) are yet unfulfilled. Future research should focus on more sophisticated models of behaviour in the game. The dimension of trust deserves special attention, as the human notion of trust and the agent definition will differ. The agent is not a social being, living in a complex society and culture. Furthermore, the current prototype implements a simple price negotiation model. Multi-attribute negotiation models like the one proposed by Jonker and Treur [9] support negotiation about price, quality, guarantee conditions, etc. simultaneously. Utility functions should involve risk assessment and trust. The cheating and trust or trace decisions should involve transaction cost economics [14]. For realistic modelling of beliefs maintenance Hofstede's synthetic cultures [7] can be used.

In a more sophisticated model of the Trust and Tracing game, the validation phase will require special attention. The complexity of human relationships cannot be caught fully in the simulation. Therefore the model should focus on theoretically correct outcomes. The validation phase will show where real humans differ from the theoretically correct agents.

The contribution of this research in the field of supply chain and networks research is a better insight in the working of trust on economic performance of chains and networks. Camps *et al* [1] show that long-term human relationships are of major importance in successful chains and networks. An empirically tested model of trust in long-term chain relationships will help understanding what happens in real world chains and networks and will facilitate design of the economic institutions.

Acknowledgement

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3 Simulation of the Trust and Tracing Game for Supply Chains and Networks

Abstract. This paper describes a multi-agent simulation model of the Trust And Tracing game. The Trust And Tracing game is a gaming simulation for human players, developed as a research tool for data collection on human behaviour in food supply chains with asymmetric information about food quality and food safety. Important issues in the game are opportunistic behaviour (deceit), trust and institutional arrangements for enforcing compliance. The goal is to improve the understanding of human decision making with respect to these issues. To this end multi-agent simulation can be applied to simulate the effect of models of individual decision making in partner selection, negotiation, deceit and trust on system behaviour. The combination of human gaming simulation and multi-agent simulation offers a basis for model refinement in a cycle of validation, experimentation, and formulation of new hypotheses. This paper describes a first round of model formulation and validation. The models presented are validated by a series of experiments performed by the implemented simulation system, of which the outcomes are compared on aggregated level to the outcomes of games played by humans. The experiments cover in a systematic way the important variations in parameter settings possible in the game and in the characteristics of the agents. The simulation results show the same tendencies of behaviour as the observed human games.

Introduction

Trust and deceit are key concepts in international trade. In the globalizing production of goods the connections between companies from raw material suppliers to retail outlets are important to optimise the overall efficiency of production. The concept of linked companies producing a good is called supply chain, or supply network in case alternative suppliers and buyers are considered too (Lazzarini et al. 2001). Supply chains and networks are important economic institutional forms (Camps et al. 2004). Connections between companies in a supply chain or network are governed by a mixture of three governance mechanisms, being market, hierarchy and network mechanism (Powell 1993). The market mechanism uses perfect information to bring together supply and demand at an equilibrium price. The hierarchy mechanism uses contracts to determine the production of the supply company for a pre-determined price. Ultimately, the buyer takes over the supplier. The network mechanism uses relations to ensure that agreements are met and situations that are not covered by a previous agreement will be solved equally beneficial to both companies. The relations between companies are operational via relations of employees of a firm. Trust between people from different firms is important.

New institutional economics (Williamson 1985) is a branch of economics that aims to understand the emergence of economic institutions governing transactions. It analyses the way transactions are made. The concept of Transaction Costs (Williamson 1998) incorporates social interactions around searching, bargaining, monitoring and enforcing of contracts in economic models. Trust between companies can lower transaction costs when trusted trade partners become preferred business partner. Searching and bargaining contracts will go faster and the need for monitoring and enforcing contracts will be low when you trust deliveries.

If a deception is detected, e.g., at the end of chain, who is the culprit? In case of food supply chains a number of food crises putting consumers at risk received major attention in media and politics over the last decade (Hofstede et al. 2004). The retailer could be the deceiver, but he could also trade in good faith, since he might have obtained the goods from an untruthful middleman or producer. What motivates the agent to cheat, and how does it affect trust? Understanding deceit is vital for detecting deceit, and to design mixes of governance mechanism in trading to discourage deceit, thus safeguarding food for consumers.

The reality of economic institutional forms is too complex to allow for individual participant based analysis directly: there are too many people involved, the institutions influence each other, and nature plays an unpredictable role as well. An intermediate step between the real world and a model is needed that retains the essential elements of the economic institutional form under consideration. Special gaming simulations are developed that can fulfil the intermediate role (Duke and Geurts 2004; Meijer and Hofstede 2004). By playing these gaming simulations with selected groups of human participants, the exactly same gaming simulation can be played in different settings, with people from different backgrounds, resulting in unique sessions. In this manner useful insight is gained in the way people behave in a certain dilemma (e.g., Zuniga et al. 2006; Druckman 1994; Van Liere et al. 2004; Meijer et al. 2006). However, the number of sessions that can be played with humans is limited as it is expensive and time-consuming to acquire participants (Duke and Geurts 2004). Furthermore, one needs many sessions to control for variances between groups. In short, human gaming simulation is an essential step to overcome the complexity of real economic institutional forms. The number of sessions that needs to be played is a real disadvantage of the gaming simulation method.

The Trust and Tracing game (Meijer and Hofstede 2003) is a research tool designed to study human behaviour with respect to trust and deceit in commodity supply chains and networks in different institutional and cultural settings. The game played by human participants is used both as a tool for data gathering and as a tool to make participants feed back on their daily experiences. Although the Trust and Tracing game has been played numerous times (Meijer et al 2006), obviously, the problem of the number of sessions that can be and has to be played with humans and the expenses involved and the time-consuming nature of acquiring participants also holds true for this game. Therefore, of necessity, a research method had to be developed to overcome this problem.

The approach of modelling the Trust and Tracing game differs from other approaches incorporating trust and supply chains in multi-agent systems. It models aspects of a structured socially rich trade environment in a fully automated agent model. TAC-SCM (http://www.sics.se/tac/) and the ART-testbed (http://www.art-testbed.net) are competitions of agents in a notional market that aim to find the best performing agent models, while the Trust and Tracing model is a research instrument to improve understanding of human behaviour in the game. The Global Supply Chain Game (http://www.gscg.org) uses models of a supply chain in which multiple human agents can play. The emphasis is on chain performance, where the Trust and Tracing game focuses on human relations.

An empirically validated model of seller behaviour with regard to trust and deceit will be of value to the field of New Institutional Economics. A time-honoured method of checking whether a model is a correct representation of reality is by simulating the model and analyzing the results with respect to reality. However, as mentioned above, the problem of the real world is its complexity. Therefore, it is better to first study the phenomenon in the limited setting of a human gaming simulation, just focussing on the aspects that are well represented in the gaming simulation. The research method to understanding economic reality we introduce in this paper extends the idea of human game playing with agent-based simulation of those games and a rigorous validation method that incorporates both data from the human game playing and insights from conventional economic rationality. In our view agent-based simulation can to some extent overcome the disadvantages of gaming simulation in two ways. It can validate models of behaviour induced from game observations and it can be a tool in the selection of useful configurations for games with humans (test design). Validation of the models is done on the aggregated level using computer simulations. Simulation results are to be compared to a set of hypotheses based on human session observations and conventional economic rationality.

The theoretical contribution of this paper is in the introduction of an interdisciplinary research approach, bridging the gap between new institutional economics and agent-based economics by using human gaming simulation as intermediary in which individual human transactions can be explicitly monitored and simulated. From the agent-technology perspective, the clear focus of a human gaming simulation presents detailed requirements for the design of the agent-based simulation, whereas the general aims of agent-based economics and new institutional economics set the general requirements of the agent-based simulation. The agent models introduced can be used as a point of departure for the modelling of other trade agents.

The practical importance of this work is that it provides a tool for research and education. Researchers can use the tool for research into trust and governance mechanisms in supply chains. Business schools and companies acting in supply chains can use the simulation and the game as training tools.

This paper presents the research method we developed, and illustrates its application for the study of supply chains and networks, using the Trust and Tracing game as gaming simulation. Section 2 describes the fundamental steps of the research method, The Trust & Tracing game, and the results from human sessions. Sections 3 and 4 describe the foundations and elaboration of the agent model. The model has been tested for sensitivity to parameter changes with respect to trust level and honesty of the agents. Section 5 illustrates the validity of the approach by experimental results from multi-agent simulations. It presents the results of the sensitivity tests, together with a first validation against some hypotheses derived from the theory of new institutional economics and game session conclusions. The validation is on the macro level: tendencies expected from theory and game session conclusions correspond with tendencies in model run outcomes. Currently available data do not allow for model validation on the micro level. Section 6 presents the main conclusions of the paper and discusses future directions.

Research approach

The research subject is the role of trust and deceit in commercial transactions in different cultural and institutional settings. A main problem in the study of the mechanisms involved is that the macro-level system behaviour is not simply a linear combination of micro-level decision functions. There is great interdependence between the behaviour of actors. The main reason to apply gaming simulation as an instrument for experimental data collection is the opportunity it offers to collect data in controlled experiments on the effect of micro-level conditions on macro-level system performance.

This section provides a brief description of the Trust and Tracing game; an extensive description is available in Meijer and Hofstede (2003) and Meijer et al. (2006). Observations from sessions played are discussed at the end of this section.

The focus of study is on trust in a business partner when acquiring or selling commodities with invisible quality. There are five roles: traders (producers, middlemen and retailers), consumers and a tracing agency. Typically there are 4 producers, 4 middlemen, 4 retailers and 8 consumers, to reflect the multiple steps and oligopoly character of most supply networks. The real quality of a commodity is known by producers only. Sellers may deceive buyers with respect to quality, to gain profits. Buyers have either to rely on information provided by sellers (Trust) or to request a formal quality assessment at the Tracing Agency (Trace). This costs a tracing fee for the buyer if the product is what the seller stated (honest). The agency will punish untruthful sellers by a fine. Results of tracing are reported to the requestor only or by public disgrace depending on the game configuration. A strategy to be a truthful seller is to ask for a trace before selling the product. Sellers use the tracing report as a quality certificate. Middleman and Retailers have an added value for the network by their ability to trace a product cheaper than a consumer can. Producers cannot trace, to force the environment to use at least one transaction with an unchecked product.

The game is played in a group of 12 up to 25 persons. Commodities usually but not necessarily flow from producers to middlemen, from middlemen to retailers and from retailers to consumers. Players receive 'monopoly' money upfront. Producers receive sealed envelopes representing commodities lots. Each lot is of a certain commodity type (represented by the colour of the envelope) and of either low or high quality (represented by a ticket covered in the envelope). The envelopes may only be opened by the tracing agency, or at the end of the game to count points collected by the consumers (table 1). The player who has collected most points is the winner in the consumer category. In the other categories the player with maximal profit wins.

Table 1: Consumer satisfaction points by commodity type and quality

Quality	Commodity type		
	Blue	Red	Yellow
Low	1	2	3
High	2	6	12

Participants in sessions with the Trust and Tracing game can be students for whom participation is a means to learn about transactions and embeddedness in supply chains and networks (Meijer et al. 2006), but also real decision makers from real-world supply chains. In the development of the Trust and Tracing game real decision makers have been used to criticize the design and to indicate parallels with real-world phenomena.

Sessions played until 2005 provided many insights (Meijer and Hofstede 2003; Meijer et al. 2006). We mention three examples applicable here:

- Dutch groups (with a highly uncertainty tolerant culture;Hofstede and Hofstede 2005) tend to forget about tracing and bypass the middlemen and retailers as they don't add value. This gives the producers a good chance to be opportunistic. The low tracing frequency encourages deceit.
- American groups tend to prefer guaranteed products. They quickly find out that the most economic way to do this is by purchasing a traced product and to let the middlemen do the trace, as this is the cheapest step. After initially tracing every lot, when relationships establish the middlemen agree with their customers to take samples.
- Participants who know and trust each other beforehand tend to start trading faster and trace less. The afterwards indignation about deceits that had not been found out during the game is higher in these groups than it is when participants do not know each other.

Below we explain how gaming simulation and multi-agent simulation are combined to analyze the dynamics of the Trust and Tracing game under different institutional and cultural settings. First, the gaming cycle is introduced. Then the combination of gaming and multi-agent simulation as applied in this research is explained.

In our approach we started with a ready to use gaming simulation that has been designed and tested in previous projects. It is ready for application in experiments with human subjects, to collect data for testing hypotheses. The data and conclusions from the experiments can be used to refine theory and formulate new hypotheses. The process of test design includes the variable settings for the experiments. Figure 1 presents this gaming cycle.

The introduction of this paper referred to some shortcomings of the gaming simulation approach. The first reason for applying multi-agent simulation is that game sessions are time-consuming and require many new participants for each experiment. This research aims to provide a tool that in the long run can be used to select the most interesting game configurations to play. A second reason is the possible use of validated models to predict agent behaviour and test institutional settings and combinations of agents for their impact on supply chain performance.

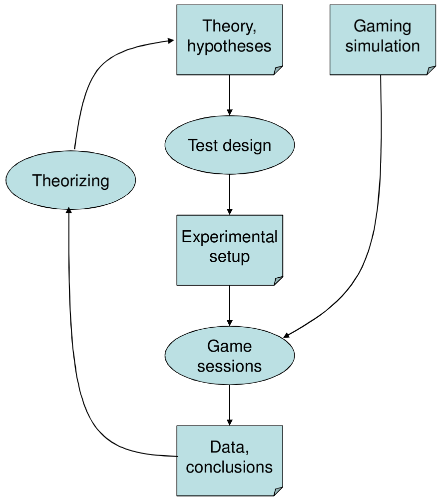

Fig. 6. The gaming cycle

Figure 2 shows how multi-agent simulation fits in the research cycle from Figure 1. By analysis of the design of the gaming simulation, a task model for the agents is constructed. The decision functions implemented in these tasks are formulated on the basis of existing theory. Outcomes of model runs can be compared with gaming results in order to validate the MAS model. This can lead to adaptation of the task model or the decision functions, or to the configuration of the model, or to the tuning of model parameter settings in order to better fit the gaming results.

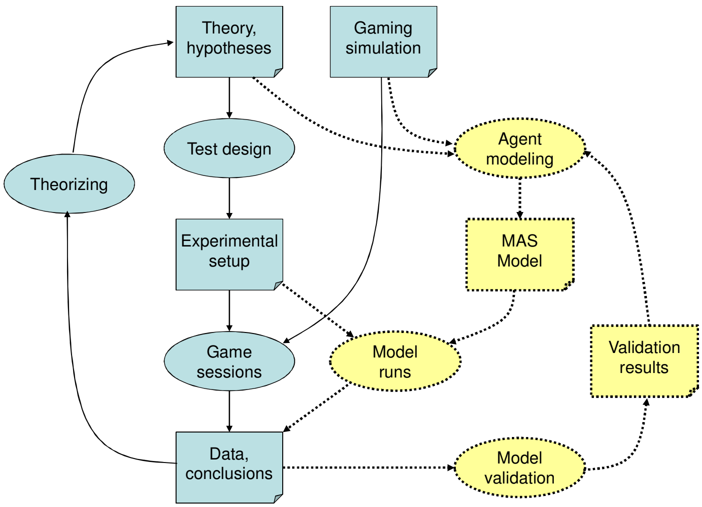

Fig. 2. The research cycle combining gaming simulation with multi-agent simulation

In the combined research cycle, the process of test design results in an experimental setup that includes the variable settings for both game sessions and model runs. Conclusions from model runs can in combination with game session conclusions lead to refinements or falsification of theory, for instance improved or rejected models of decision functions.

From the general theory of new institutional economics underlying the gaming simulation as explained in Meijer and Hofstede (2003) and Meijer et al. (2006), and from the results of the first set of human gaming simulations, we constructed five hypotheses for a preliminary validation of the multi-agent model, following the right-hand cycle in figure 2. The validation results are described in section 6.

Some hypotheses refer to the *opportunistic*, *quality-minded*, and *thrifty* strategies defined in 4.13. *Opportunistic* traders aim to trade high quality for attractive prices, and are not particularly serious about the truthfulness of quality statements. *Quality-minded* traders do take these statements serious: like the opportunists they prefer high quality, but their priority is certainty, not attractive price. *Thrifty* traders prefer a good price and avoid risk, and have no particular preference for high quality.

Hypothesis 1: When the initial willingness to trust is high the percentage of high quality products sold is higher than when the initial willingness to trust is low.

Hypothesis 2: In a homogeneous environment with all opportunistic agents there are more cheats than with other profiles.

Hypothesis 3: In a homogeneous environment in which all agents are thrifty, i.e., who want to be certain about value for money, there are more traces than with other profiles.

Hypothesis 4: Thrifty agents buy less high quality products than opportunistic and quality-minded agents.

Hypothesis 5: In a mixed setting with opportunistic and thrifty agents, the opportunistic agents cheat less than in a mixed setting with opportunistic and quality-minded agents.

Literature Overview

The classical approach explains economic systems at the micro-economic (individual) level and at the macro-economic (system) level independently, using equilibrium-based models (McConnel and Brue 2001). This approach is criticized for being unable to model various real-life economic and social systems such as financial markets and markets for fast-moving consumer goods (Moss and Edmonds 2005). The new field of Artificial Economics (Batten 2000) aims on building a bridge between micro- and macro levels through agent simulations that demonstrate how complex system properties emerge from the interaction of individuals.

Individual level models in the Trust and Tracing simulation model reproduce agents' decisions and behaviour in the following aspects:

- Trust
- Deception
- Trade

In the literature a variety of definitions of trust phenomena can be found. The common factor in these definitions is that trust is a complex issue relating belief in honesty, trustfulness, competence, reliability of the trusted system actors (e.g., Grandison 2000; Ramchurn et al. 2004; Castelfranchi and Falcone 2001; Jøsang and Presti 2004). Furthermore, the definitions indicate that trust depends on the context in which interaction occurs or on the observer's point of view.

According to Ramchurn et al. (2004) trust can be conceptualized into two directions when designing agents and multi-agent systems:

- Individual-level trust — agent's beliefs about honesty of his interaction partner(s);
- System-level trust — system regulation protocols and mechanisms that enforce agents to be trustworthy in interactions.

In this paper we address problems and models for individual-level trust as our simulation environment already has system-level trust mechanisms such as the tracing agency that encourage trading agents to be trustworthy.

Defining trust as a probability allows relating it to risk. Jøsang and Presti (2004) analyse the relation between trust and risk and define reliability trust as "trusting party's probability estimate of success of the transaction". This allows for considering economic aspects; agents may decide to trade with low-trust partners if loss in case of deceit is low.

With respect to deceit, our approach differs from that of Castelfranchi, Falcone and de Rosis (2001) and de Rosis et al. (2003) that treat deception strictly rational as an instrument to win the game. In the social simulation aimed in our research we had to tune the agents to model actual human behaviour including their moral thresholds for deceit. Furthermore, our model does not simulate the purely rational decision as for instance the model of de Rosis et al. (2003) does.

Ward and Hexmoor (2003) describe an approach similar to ours, but their model does not explicitly recognize honesty as a moral threshold for deceit; it simply enables reinforcement learning from successful versus revealed deceit.

Our work acknowledges the work of Williamson (1998) stating that transaction cost economics possesses properties of bounded rationality, more precisely, that additional contractual complications can be attributed to an agent's opportunism rather than frailty of its motive. The importance of opportunistic behaviour is further supported by Diederen and Jonkers (2001) that mentions production quality and quality assurance as issues of chain and networks research to keep fast-switching consumers as a client.

In the real world, chains avoiding opportunistic (free rider) behaviour is an issue (Powell 1993). Following the economic literature (Williamson 1998; Diederen and Jonkers 2001), the simulation has three economic incentives not to cheat:

- Need to refund money (Contract specific rules)
- Fee from tracing agency (Governance rules)
- Damaged reputation / lowering of trust (Social system rules)

The Trust and Tracing game has possibilities to experiment with relative importance and size of the three cost types. The contract-specific costs are easy to determine and therefore a calculated risk. The governance rules come with more uncertainty, because the fee depends on possible cheating of the agent you bought from. The damaged reputation depends on the socio-cultural system the agents come from, which formed their opinions on importance of trust and honesty and the reaction on being deceived.

Agent Models

We apply a compositional design approach to the Trust and Tracing simulation. The components represent decision making models for aspects of the agent's behaviour. The models of decision functions were partially published in Jonker et al. (2005a, 2005b). In this section we present the general architecture of the agent and explain details of the individual models. Additional information about the algorithms can be found at http://mmi.tudelft.nl/~dmytro/trustandtracing/.

Agent Architecture

Types of agents acting in the simulated game are trading agents (producers, middlemen, retailers, and consumers) and the tracing agent. The architecture of the tracing agent is straightforward: it reports the real quality of a product lot to the requestor, informs the sellers that a trace has been requested and penalizes untruthful sellers. In this paper we focus on the trading agents. The agent architecture for simulation of trading agents in the Trust and Tracing game was originally described in Meijer and Verwaart (2005). For the research reported in this paper we apply the modified architecture represented in Figure 3. All trading agents are built according to this architecture except the fact that producers do not have the *buying* process because they stand in the beginning of the supply chain and receive products from the game leader and consumers do not have the *selling* process because they stand in the end of the supply chain.

Trading agents start up with the initialization process that handles communication with the game leader that informs them about initial stock and money. When the game leader broadcasts the "start game" message to the agents the initialization process transfers the control to the goal and partner selection process. The goal and partner selection process decides to buy or to sell, depending on the agent role and stock position, and selects a partner at random, weighted by success or failure of previous negotiations with particular partners. Then the control is transferred to the trading process.

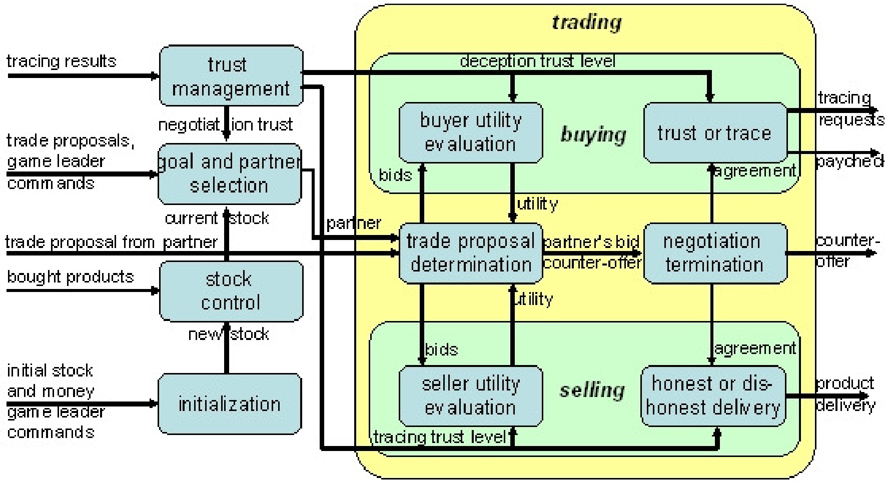

Fig. 3. Trading agent architecture

Because of it's similarity to human bargaining behaviour, as evidenced in Bosse and Jonker (2005), we based the trading process on the algorithm presented in Jonker and Treur (2001). This approach to multi-issue simultaneous negotiations is based on utility theory. Negotiation partners send complete bids (a set of negotiation issues with assigned values) to each other. Once an agent has received a bid from the partner it can accept, or respond with a counter-offer, or cancel the negotiation that is decided in the negotiation termination process. Agents evaluate their own and partner's bids using the buyer (seller) utility evaluation process that uses a generalized utility function that is a weighted linear combination of particular issue evaluation functions.

If agreement is reached the seller selects the product to be delivered to the buyer in the honest or dishonest delivery process. On the other side the buyer decides whether he wants to trace the product in the trust or trace process.

The utility functions involve individual experience-based trust as an argument to estimate risk. Modelling of trust for this purpose and experience-based updating of trust - as part of the trust management process - is the subject of next subsection. In subsequent subsections we explain the utility functions and the way it can be used to represent agent's preferences or market strategies, and the decision making models for tracing, delivery and goal determination.

Trust Model

An important sub-process of the agent's trust management process is the update of trust values based on tracing results. Following Castelfranchi and Falcone (2001) we model trust as a joint subjective probability representing the opponent's willingness, capability, and opportunity to behave in a particular way. In the Trust and Tracing simulation we consider three different behaviours that we maintain a subjective probability about:

– successful negotiation (an agreement will be achieved);
– truthful product delivery (buyer: the opponent will deliver the agreed quality);

– not tracing the delivered products (seller: the opponent will trust after delivery).

Because all interaction that happens in the Trust and Tracing simulation involves two agents we model the trust as an individual-level agent's characteristic. This means that agent A can have low trust in agent B due to a series of bad experiences with him but have high trust in agent C, whose behaviour was honest and reliable.

In the Trust and Tracing simulation we assume that the experience gained by agents during the game is the only source of information about other agents. Thus, trust evaluation is built as a function of experience evaluation. Formula (1) formalizes trust updating as a function of the agent's experience of trading with its opponent. Instead of Bayesian updating, in order to represent short memory and an endowment effect, we chose an asymmetric trust update function, with either completely positive or completely negative experience according to the classification of Jonker and Treur (1999).

$$trust_{t+1} = \begin{cases} \left(1-d^{+}\right) trust_t + d^{+} & \text{, if experience is positive} \\ \left(1-d^{-}\right) trust_t & \text{, if experience is negative} \end{cases} \qquad (1)$$

where $trust_t$ represents trust after the t transactions. The value of $trust$=1 represents complete trust, $trust$=0 represents complete distrust, and $trust$=0.5 represents complete uncertainty. The model represents that the most recent experience has the strongest impact (short memory) and that negative experience may have stronger impact than a positive experience. The latter is similar to the endowment effect (Hanemann 1991). Losing trust that one thought to be endowed with has more impact than finding a partner's trustworthiness confirmed. The factors d^{+} and d^{-} are impact factors of positive and negative experiences respectively. They are related by an endowment coefficient e.

$$d^{+} = e \cdot d^{-}, \quad 0 < e \leq 1 \qquad (2)$$

Buyer Model

Trade is an essential type of interaction between agents in the Trust and Tracing game. In the Trust and Tracing game trade is an agreement between buyer and seller achieved through negotiation. The negotiation issues are:

– kind of the product;
– quality of the product;
– price;
– additional conditions: guarantee or certificate or none of these.

A buyer's motivation to accept or refuse a bid, depends on the price and other attributes of the bid, and on the player's trust in the seller. The buyer will compare the price with value of the product and decide. However, the value will depend on personal preferences of the buyer. Some buyers have a special preference for valuable high quality products, motivated by some form of self-esteem; others prefer low quality to avoid the risk of being deceived. So the trade-off between value and price is not a rational decision in economic sense. A similar reasoning applies to uncertainty. Some players are prepared to evaluate the risk of being deceived based on their trust in sellers; others are afraid to be deceived and avoid risky tranactions even if a rational economic evaluation would suggest to accept the risk. Depending on the trust in the seller (belief about the opponent) and risk-attitude (personal trait of buyer), the buyer can try to reduce risk. Risk can be eliminated by trading low quality or demanding a quality certificate, or it can be reduced by a money-back guarantee. The attributes of a transaction are product type, stated quality, price, and certificate or money-back guarantee.

The negotiation model applied in this simulation, requires that bids can be valuated and compared in terms of utility. Real people will not actually calculate a utility. However, a utility function may approximate the player's preference in a simulation. For that purpose the utility is modelled as the sum of three terms, each having a weight factor. The three terms represent the price, the quality, and the risk associated with the bid. The weight factors may be used to model "irrational" preferences for quality and certainty. The buyer's utility function is a weighted sum of normalized functions of price, satisfaction difference between high and low quality (for consumers) or expected turnover (for others), and risk (estimate based on trust in seller, guarantee and prices):

$$\begin{aligned} u_{buyer}(bid) = w_1 \cdot f_{price}\left(price_{effective}(bid)\right) + \\ + w_2 \cdot f_{expected\_turnover}\left(expected\_turnover(bid)\right) + w_3 \cdot f_{risk}\left(risk_{buyer}(bid)\right) \end{aligned} \tag{3}$$

The weight factors implement buyer's preference for a particular market strategy. For *quality-minded* buyers that are willing to pay to ensure high quality, both w_2 and w_3 are high relative to w_1, for instance <0.2, 0.4, 0.4>. The *opportunistic* buyer prefers a high quality for a low price but is prepared to accept uncertainty, for instance <0.4, 0.4, 0.2>. The *thrifty* buyer also prefers low price, but avoids risk, represented for instance by <0.4,0.2,0.4>.

The unction of price f_{price} normalizes the price of the bid according to the agent's beliefs about maximum and minimum market prices of the product of the given type and quality. The expected turnover normalization function $f_{expected\_turnover}$ normalizes the expected turnover with respect to the maximal and minimal possible number of satisfaction points (see table 1). The risk of the buyer is normalized using the f_{risk} normalization function that is based on the estimation of maximal risk over all possible bids. Such risk value corresponds to the bid with a "yellow" product of high quality and the price equal to the agent's belief of the maximum price. This bid would lead to the maximal money loss in case of deception because the probability of deception attached to the seller does not change during the negotiation.

Effective price is the total cost of the purchase:

$$price_{effective}(bid) = price_{purchase} + cost_{transaction} \tag{4}$$

where $cost_{transaction}$ represents some extra cost for the buyer that depends on the type of partner. In the current simulations the value is set to zero for purchases of consumers from retailers, of retailers from middlemen, and of middlemen from producers. It is set to infinity for all other combinations, to enforce the agents to follow their role in the supply chain. In future simulations it may be varied to allow for bypassing some links.

The expected turnover is the average of the agent's beliefs about the minimal and maximal future selling price of the commodity to be bought. For consumers the expected turnover is set to the satisfaction level.

The buyer's risk represents is calculated as the product of the probability of deceit and the cost in case of deceit.

$$risk_{buyer}(bid) = p_{deceit} + cost_{deceit} \tag{5}$$

The probability of deceit is greater than zero only if the quality of the commodity quality is high and it is not certified. If these conditions are satisfied than the probability of deceit is estimated as the complement of buyer's trust in the seller.

$$p_{deceit}(bid) = q(bid) \cdot c(bid) \cdot (1 - trust(seller)) \tag{6}$$

where q=1 if the bid suggests high quality, 0 for low quality and c=0 if the bid suggests a certified transaction, 1 without certificate.

The costs in case of deceit are estimated for middlemen and retailers as the sum of the fine for untruthfully reselling a product and, only if no guarantee is provided, the loss of value that is assumed to be proportional to the loss of consumer satisfaction value taken from table 1. The formula for middlemen and retailers is:

$$cost_{deceit}(bid) = fine_{reselling} + loss_{reslling}(bid) \tag{7}$$

where

$$loss_{reselling}(bid) = g(bid) \cdot price_{effective} \cdot (1 - ratio_{low/high}(bid)) \tag{8}$$

and g represents the guarantee function (5): $g(bid) = 1$ if the bid involves a guarantee; $g(bid) = 0$ otherwise.

For consumers the cost in case of deceit is also assumed to be proportional with the loss of satisfaction value, but they do not risk a fine, so for consumers:

$$cost_{deceit}(bid) = g(bid) \cdot price_{effective} \cdot (1 - ratio_{low/high}(bid)) \tag{9}$$

This subsection presented the buyer's model. Before introducing the seller's model in subsection 4.5, we present the model for the tracing decision entailed by a purchase.

Tracing Decision

Tracing reveals the real quality of a commodity. The tracing agent executes the tracing and punishes cheaters as well as traders reselling bad commodities in good faith. The tracing agent only operates on request and requires some tracing fee. Agents may request a trace for two different reasons. First, they may want to assess the real quality of a commodity they bought. Second, they may provide the tracing result as a quality certificate when reselling the commodity. The decision to request a trace for the second reason originates from the negotiation process. This subsection focuses on the tracing decision for the first reason.

In human interaction the decision to trust or to trace depends on factors that cannot be modelled in a multi-agent system. Hearing a person speaking and visual contact significantly influences the estimate of the partner's truthfulness (Burgoon et al. 2003). To not completely disregard the variance introduced by these intractable factors the trust-or-trace decision is modelled as a probability instead of as a deterministic process. The distribution involves experience-based trust in the seller and the buyer's confidence factor.

Several factors influence the tracing decision to be made after buying a commodity. First of all the tracing decision is based on the buyer's *trust* in the seller. Secondly, buyers may differ with respect to their *confidence*, an internal characteristic that determines the preference to trust rather than trace. It can be represented as a value on the interval [0,1]. We expect players with low trust to trace more frequently than players with high trust and we expect players with low confidence to trace more frequently than players with high confidence. Many other factors may influence the decision, like the amount of the tracing fee relative to the effective price, and the value ratio of low and high quality (satisfaction ratio). However, we have insufficient information to realistically model these unexplained influences. Therefore we modelled the decision to trust as a Bernoulli random variable with

$$p(\text{trust rather than trace}) = trust(seller(bid)) \cdot confidence \tag{10}$$

If an agent has decided to trace the product, it sends a tracing request message to the tracing agent. Once the tracing result has been received the agent updates its trust belief about the seller and adds the product to the stock.

Seller model

The utility-based multi-attribute negotiation algorithm presented in Jonker and Treur (2001) is used to model the bargaining process. The seller's model mirrors the buyer's model. It accepts and produces bids with the same attributes:

– kind of the product;
– quality of the product;
– price;
– additional conditions: guarantee or certificate or none of these.

To reduce the buyer's risk, a seller can give a 'money back'-guarantee if the product delivered turns out not to have the promised quality. A buyer can trace a product only when he has paid for it and received it. However, to completely eliminate a buyer's risk, a seller can request a 'trace' for the product which results in a certificate ensuring the real quality. The guarantee itself costs no money, but a certificate involves the tracing agency at the cost of a fee that depends on the position of the seller in the chain. Tracing early on in the chain is cheaper, as fewer steps have to be checked. Consumers pay the highest fee for tracing. Following section 3, producers cannot trace, to force the environment to use at least one transaction with an unchecked product.

As explained in 3.9, we follow Williamson (1998) and Diederen (2001), in giving a seller three economic incentives not to cheat, which are included in the risk component of the sellers' utility function:

- Need to refund money. (Contract specific rules)
- Punishment by the tracing agency. (Governance rules)
- Damaged reputation / lowering of trust. (Social system rules)

The opportunity of deceit is not included in the utility function during negotiations. Firstly, for believable deceit sellers would have to act as if they were honest. Secondly, negotiation and delivery are separate processes and actual deceit takes place in the delivery phase. This resembles the real-world situation of firms having departments responsible for different functions in a firm. The model of the decision to deceive is discussed in the next subsection.

The seller's utility function is the weighted sum (linear combination) of normalized functions of effective price and seller's risk:

$$u_{seller}(bid) = w_1 \cdot f_{price}\left(price_{effective}(bid)\right) + w_2 \cdot f_{risk}\left(risk_{seller}(bid)\right) \tag{11}$$

The functions f_{price} and f_{risk} present the normalized effective price and seller's risk in the interval [0; 1]. The normalization function of the price f_{price} is similar to the one of the seller. The risk is normalized over the maximum possible risk for the seller. This risk value corresponds to the bid of high quality "yellow" product with a money back guarantee and the price equal to the agent's belief of the maximum price for the product on the market. The weight factors add up to one and represent the seller's strategy with respect to the risk he is willing to take in reselling commodities of uncertain quality. In order to model a risk-neutral seller that acts rationally in economic sense, $w_1=w_2=0.5$. For a risk-avoiding agent $w_1 < w_2$. We use w_1=0.2 and w_2=0.8 for the producers, middlemen and retailers following the quality-minded or thrifty strategies and $w_1=w_2=0.5$ for opportunistic agents.

The effective price represents the seller's benefit:

$$price_{effective}(bid) = price_{purchase}(bid) - price_{sell,min} - cost_{transaction} - cost_{certification} \tag{12}$$

where $price_{purchase}(bid)$ represents the proposed price of the anticipated transaction , $price_{sell,min}$ represents seller's belief about the minimal price he may receive receive from alternative buyers (opportunity cost); $cost_{transaction}$ represents cost of making a transaction with the given partner, in the current simulations the value is set to zero for sales of retailers to consumer, middlemen to retailers, and of producers to middlemen (for more details, see the definition of the transaction costs in the "Buyer Model" section); $cost_{certification}$ represents the fee a player has to pay the tracing agency for tracing the commodity and providing a certificate, if needed.

A seller's risk represents the risk to lose money in case of reselling a high quality commodity untruthfully delivered to the seller:

$$risk_{seller} = p_{negtrace} \cdot cost_{negtrace} \tag{13}$$

The probability of a negative trace is zero when the product is stated to be of low quality, or when the seller has bought the product with a certificate, or when seller would provide a certificate in the current transaction. Otherwise the seller has to estimate the probability that a trace would be requested (taking into account the trust he has in the buyer not to trace), and the probability that the product was untruthfully delivered by the supplier of the seller (based on the trust in the honesty of that supplier):

$$p_{negtrace} = \left(1 - \prod_{seller_i \in S} trust_{honest}(seller_i)\right) \cdot \left(1 - trust_{tracing}(buyer)\right) \cdot q(bid) \cdot \left(1 - c(bid)\right) \quad (14)$$

where S is the set of agents upstream in the supply chain of this particular lot; $trust_{honest}(seller_i)$ represents the experience-based trust the seller has in an upstream seller to deliver according to promise; $trust_{tracing}(buyer)$ represents the experience-based trust the seller has in its negotiation partner to accept a delivery without tracing it; $q(bid)=1$ if the quality is high, 0 if the quality is low; $c(bid)=1$ if a certificate is present or will be provided, 0 otherwise. Both $trust_{honest}(seller_i)$ and $trust_{tracing}(buyer)$ will be updated according to equation (1).

'Money-back', governance fees and reputation damage are the components of cost in case of a negative trace. Whenever the player bought a high quality product without a certificate and he again sells that product as a high quality product without a guarantee, he runs the risk of a fee for untruthful selling, and a risk of reputation damage. If the seller provides a guarantee, there is the risk of having to pay money back and his reputation would be more severely damaged.

$$\begin{aligned} cost_{negtrace}(bid) &= fine_{goodfaith} \cdot rep\_damage + \\ &+ g(bid) \cdot \left(rep\_damage\_guarantee + money\_back(bid)\right) \end{aligned} \quad (15)$$

where $g(bid)=1$ if the bids entail a guarantee, 0 otherwise.

From the seller's point of view the 'money back' guarantee can be interpreted in terms of costs as an obligation to buy a low-quality product for a high-quality price: if seller is caught on deception he has to pay buyer full price of the transaction but he receives low-quality product back. In a formal way 'money back' can be considered as the following expression:

$$money\_back(bid) = price_{purchase}(bid) \cdot \left(1 - satisfaction\_ratio(bid)\right) \quad (16)$$

where the satisfaction ratio is taken from table 1.

Reputation damage is difficult to estimate, because of the complexity of the phenomenon. It is currently represented in the simulation by a fixed amount of money, set by the game leader at a global level (reflecting societal values). However, further development of models is required. The Trust and Tracing game simulation offers a good environment for developing and testing the models.

Honest or Dishonest Product Delivery

The seller has to deliver a product after agreement on transaction conditions has been achieved. If low quality has been agreed, the seller will simply deliver a low quality product. If high quality has been agreed, the seller may consider delivering low quality to gain profit. The decision to deceive is not merely a rational one with respect to financial advantages and risks. In real world business social-cultural influences change the decision (Hofstede et al. 2004). As said before, we incorporate reputation and trust in our agents.

The opportunity of deceit occurs when the agent has sold a high quality product without a certificate and has a low quality product of the same type in stock. The motivation to deceive is in the extra profit that can be gained. In our model we assume that the motivation depends on the difference in consumer satisfaction between high and low quality. Three types of costs (money-back, fine and reputation / trust damage) provide a counterforce to the opportunistic behaviour, of which the third one comes from socio-cultural backgrounds.

In the agent model for delivery the trust level is only used to estimate the risk of being unmasked, so credulous buyers have an increased risk of being deceived. Thus, trust is not modelled as an incentive not to deceive friends, but only as an asset that enhances market position (Duke and Geurts 2004).

In reality other factors may influence the decision and not all of them can be taken into account. A random term represents the aggregated effect of unknown influences in the simulation. Furthermore the random effect may cause some unexpected events that may prevent the simulation from getting into a deadlock. The game leader can adjust the weight of the random term. Model calibration on human gaming data is necessary to find realistic values of this parameter.

All factors are normalized on [0, 1]. The following expresses the deceit decision.

$$\begin{aligned} \text{IF} \quad & q(bid)\cdot(1-c(bid))\cdot s(type(bid),low)\cdot \\ & ((1\text{-}rtw)\cdot(1-satisfaction\_ratio(bid))\cdot trust_{tracing}(buyer)+rtw\cdot rnd) \\ & > honesty \\ \text{THEN} \quad & deceive \end{aligned} \tag{17}$$

where rtw is the weight of the random term, set in the interval [0, 1]; rnd represents a uniformly distributed random real number from interval [0, 1]; function s[type(bid),low] returns 1 if the selling agent has low quality products in stock (opportunity to deceive), 0 otherwise. The temptation to deceive depends on the value ratio of low and high quality. Each agent has an honesty parameter that represents the agent's threshold for deceit.

Four parameters are used to model the dynamics of honesty. The first parameter is the initial level of honesty. The second parameter d^+ defines the honesty decay. Honesty is modelled to decay autonomously over time until some minimum level, which is the third parameter with respect to honesty. The fourth parameter is the tracing effect d^-. The awareness of being traced is assumed to improve honesty to an extent depending on d^-. The following equations model the honesty dynamics analogue to the trust dynamics in equation (1).

$$honesty_{t+1} = \begin{cases} \left(1-d^{+}\right) honesty_t + d^{+}\ minimal\_honesty\,, & \text{if not traced} \\ \left(1-d^{-}\right) honesty_t + d^{-}\,, & \text{if traced} \end{cases} \tag{18}$$

Goal determination

In the game consumers will buy as much as they can. Producers will try to sell all products they have in stock. However, for middlemen and retailers some stock management is needed in order to negotiate efficiently. For example, imagine a situation in which a retailer tries to sell a product having in stock only a low quality product with low satisfaction level. This would lead to a negotiation in which the consumer makes concessions in favour of the retailer, whereas the retailer proposes the same product in each bid. Such retailer's behaviour can break consumer's patience, leading him to cancel the negotiation and to update the negotiation trust accordingly. In such a situation it would not be reasonable for a retailer to start or enter negotiations as a seller.

Middlemen and retailers must decide to operate on the market as a seller or as a buyer. The decision to search a partner for selling or buying is taken at random with

$$p(\text{sell}) = \frac{\sum_{i=\{\text{Blue,Red,Yellow}\}} \sum_{j=\{Low,High\}} S_{ij}}{\sum_{i=\{\text{Blue,Red,Yellow}\}} \sum_{j=\{Low,High\}} T_{ij}} \tag{19a}$$

$$p(\text{buy}) = 1 - p(\text{sell}) \tag{19b}$$

where S_{ij} stands for actual stock level of product i and quality j, and T_{ij} stands for the corresponding target level.

In reaction to a proposal from a seller, a middleman or retailer will refuse if the stock of the proposed product is at target level, and enter negotiations otherwise. Expected turnover is set to zero in the buyer's utility of middlemen and retailers if the stock of the product/quality offered is at target level. Sellers will refuse negotiations if the requested product is completely out of stock.

Simulation results

This section presents the results of the first set of simulation runs, following the right-hand cycle in figure 2. The following subsections present the results of verification runs, aiming to test the model construction and the sensitivity for parameter settings (does it work as intended when designing the model?; do parameter changes adequately influence the results?). This section's final subsections presents the results of the simulation runs aiming the preliminary validation of multi-agent model against the human gaming simulation based hypotheses that were postulated at the end of section 3.

All of the verifications and validations reported in this section concern aggregated game statistics; they do not concern the behaviour of individual agents. The results confirm that emergent behaviour observed in human simulation games can also be observed in the multi-agent simulations.

The agent parameters to represent individual characteristics of the agents are the trust parameters (initial trust and positive and negative trust update) and honesty parameters (initial and minimal honesty, honesty decay and punishment effect). Only these parameters and the trading strategies were varied in the results discussed in this section. Other parameters, such as game configuration, target stock levels, and fine and damage amounts, were equal for all simulations.

Verifying the multi-agent model

To test the multi-agent model we performed sensitivity analyses for the parameters that represent individual characteristics (trust and honesty). As a last verification we checked for the occurrence of the so-called endowment effect. During the design of the multi-agent model the asymmetric speed of gaining trust and loosing trust has been a recurring issue. To test for correct implementation we assume that the endowment effect shall occur if trust is implemented correctly. Furthermore the results of this subsection give insight in the magnitude of effects when changing parameters.

Sensitivity of trust update parameters

The first series of simulation results demonstrate the effect of trust learning in an environment of perfectly honest traders. With an increasing value of the trust update parameters we expect the agents to learn more rapidly that they deal with perfectly honest traders. As a consequence we expect the proportion of high quality transactions to increase, the proportion of certificates and guarantees to decrease, and the tracing frequency to decrease.

To test the actual sensitivity of the simulation model for trust learning, games were simulated with both positive and negative trust update parameters set to an equal value for all agents (three games with trust update set to 0.1, three with 0.5, and three with 0.9). The games were terminated after 500 transactions or as soon as one of the producers ran out of stock.

All agents were configured with a neutral negotiation strategy, assigning equal weights to transaction value and transaction risk, the latter being the product of estimated damage and estimated probability that the damage will occur. The weight tuples associated with this strategy are <0.33, 0.33, 0.33> for buyers and <0.5, 0.5> for sellers (see explanation of equation (3) and (11)). Each agent's initial trust in all other agents was set to 0.5, representing total uncertainty about the opponents trustworthiness. All agents were configured to be perfectly honest (initial honesty and minimal honesty = 1.0). The confidence parameter was set to 0.95, so on average the agents will even request a trace in 5% of cases if they completely trust their opponents.

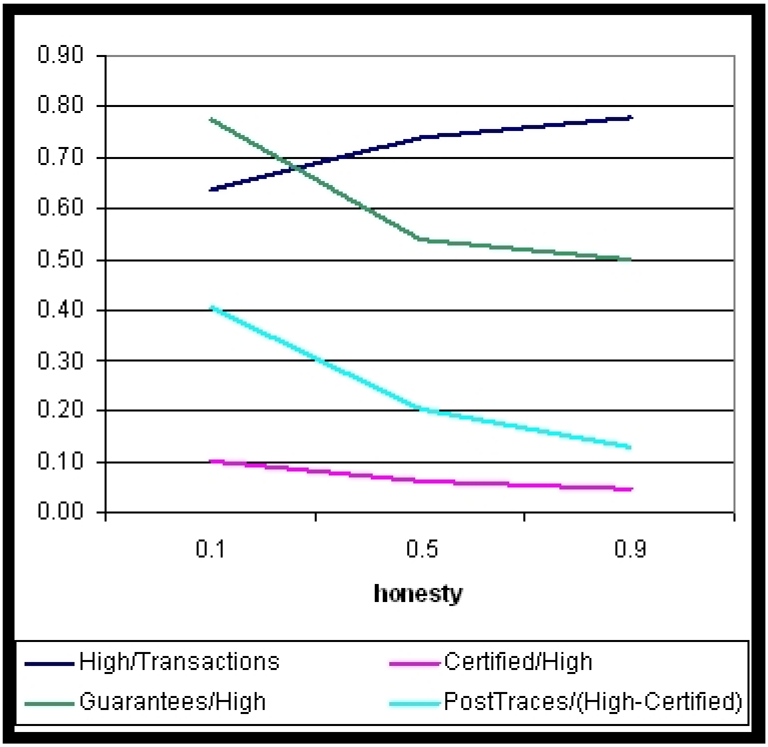

Figure 4. Sensitivity of trust update parameters

Figure 4 presents the statistics of the simulated games (see Table A1 for details). The effects of increasing trust update factors on statistics in games with perfectly honest agents are:

- increasing proportion of high quality transactions (H/N=0.64, 0.74, 0.78),
- decreasing proportions of certified or guaranteed transactions (C/H=0.10, 0.06, 0.05; G/H=0.77, 0.54, 0.50),
- decreasing tracing ratio (P/(H-C)=0.40, 0.20, 0.13), so game statistics are sensitive to the trust update factor as expected.

Sensitivity of initial trust

Table A2 shows statistics of simulated games with different strategies that are defined in the explanation of equations (3) and (11), different values of initial trust, and different values of honesty. All games were simulated with a homogeneous agent population: in a particular game all agents had exactly equal parameter settings. Trust update was set to 0.3 for positive and 1.0 for negative experience, honesty decay to 0.3, and punishment effect to 1.0. The confidence parameter was set to 0.95. The games were terminated after 200 transactions, or as soon as one of the producers ran out of stock.

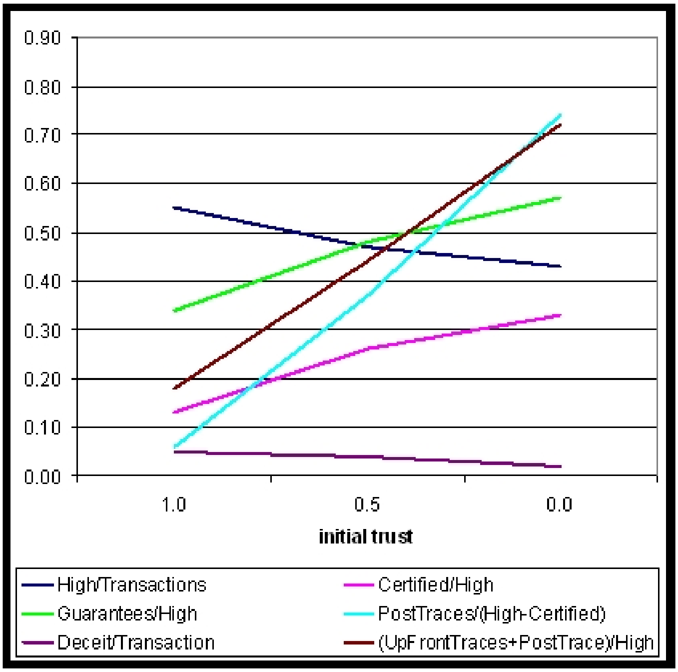

Figure 5. Sensitivity of initial trust

In short games, decreasing initial trust is expected to decrease the proportion of high quality transactions, to increase the number of certificates and guarantees, and to increase the tracing frequency. Indirectly, decreasing average trust is expected to decrease the deceit frequency in games with agents that are not perfectly honest, because a decreased proportion of high quality and increased certification decrease the opportunity to deceive and more intensive tracing will increase honesty through punishment.

Figure 5 shows that the sensitivity for initial trust is as expected (see Table A3). The aggregated statistics of games with initial trust set to 1.0, 0.5, and 0 show a decreasing trend for the proportion of high quality transactions (H/N=0.55, 0.47, and 0.43, respectively). The proportions of certificates (C/H) and guarantees (G/H) both show an increasing tendency. Tracing is increased (P/(H-C)=0.06, 0.37, 0.74) and deceit is decreased (D/N=0.05, 0.04, 0.02).

Sensitivity of honesty

The deceit frequency is expected to be strongly correlated with honesty of the agents. The average level of honesty is also expected to have some indirect effects on game statistics. The average value of trust will decrease when tracing reveals the deceit. As a consequence, the proportion of high quality products is expected to decrease as well, and the frequencies of certificates, guarantees, and tracing are expected to increase.

Figure 6a presents aggregated game statistics (see Table A4) for games with different values of honesty, taken from Table A2. Initial honesty and minimal honesty are set to equal values in these games. As expected, Figure 6b shows that honesty has a strong effect on the deceit frequency. No deceit occurs in simulated games with initial and minimal honesty both set to 1.0. Setting of the honesty parameters has no effect in games with thrifty agents, because they offer little opportunity for deceit. The strongest effect of the settings of the honesty parameters is found in games with opportunistic agents. These games are the most sensitive for honesty, because opportunistic agents accept the risk of deceit for transactions with a good quality/price ratio. The tracing frequency depends on honesty as expected (P/(H-C)=0.31, 0.33, 0.37 respectively).

Figure 6 presents the effect of different values of honesty. Of course, simulated games with completely honest agents have the highest proportion of high quality transactions, and only a small proportion of certified transactions. However, the frequency of high quality transactions is higher than one would expect for the completely dishonest agents. This is to be explained as follows. In the beginning of the game, any tracing request will reveal deceit. Average trust is decreased and the average tracing frequency is increased, thus strongly reinforcing honesty. Some agents trace in the beginning of the game, some don't, for instance because the commodity was low quality or certified. The cause of the relatively high frequency of untraced high quality transactions is the rapid decrease of trust in the first links of the chain. A tracing request will always reveal deceit, reduce the remaining trust, and increase the tracing frequency in subsequent transactions. On the other hand, the punishment effect of tracing increases average honesty more rapidly than trust decays: deceit reduces trust of a single buyer, but all buyers benefit from the honesty that is reinforced by tracing. "Knowing" that they will not dare to deceive, sellers offer guarantees for a very attractive price. Thus the delicate equilibrium between trust, tracing frequency and honesty is reached sooner in games that start from complete dishonesty than in "half-honest" games.

The frequency of certificates (C/H) is much greater in games with dishonest agents. There is a shift from guarantees (G/H) towards certificates (C/H) if honesty decreases. The reason for this is that even after having given a guarantee, sellers may deliver untruthfully. The rapid decrease of trust in games where much is revealed, also decreases trust in guarantees. The total frequency of certificates and guarantees increases with decreasing honesty, as expected (C/H+G/H= 0.61, 0.71, 0.74, respectively).

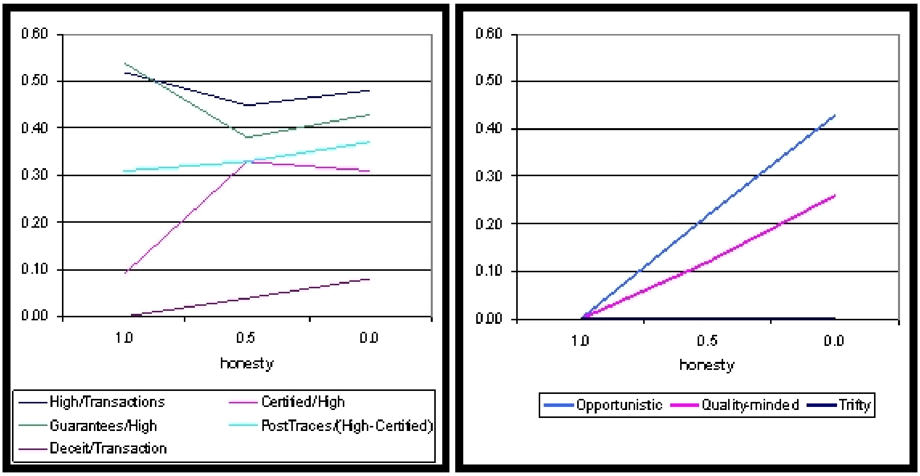

Figure 6. Sensitivity of honesty: a — game statistics for different honesty levels, b — deceit frequency for opportunistic, quality-minded and thrifty agent for different honesty levels

Endowment effect

The fourth series of simulation results demonstrate the sensitivity of the simulated game statistics for the so-called endowment effect: people experience loosing something they possessed as more painful than not gaining the same thing if they did not possess it. The endowment effect entails a high value of trust update after a negative experience and a low value of trust update after a positive experience.

We expect the endowment effect to lower the average trust level, so in games with endowment effect the proportion of high quality transactions will be lower, the frequency of certificates and guarantees will be higher, and the tracing frequency will be higher than in games without endowment effect.

Simulation of the endowment effect requires the introduction of dishonest agents. Figure 7 (see also Table A5) presents statistics of simulated games in which all agents have initial honesty = 0.5 and minimal honesty = 0.5. Other settings are unchanged with respect to the previous subsection, except for the update parameters represented in the Table A5.

As expected, the endowment effect is shown to decrease the proportion of high quality transactions (H/N= 0.17, 0.18 with endowment effect versus 0.26, 0.23 without endowment effect). The cheating frequency (D/N) is lower in games with endowment effect, because it takes a long time to heal the negative experience of punishment. Yet the endowment effect decreases the proportion of high quality transactions, because average trust is lower. Once deceived it takes long to regain trust. Variance is high in games with strong endowment effect or high sensitivity ($\delta^{+}=1$ and $\delta^{-}=1$), due to the fickle behaviour of the agents. Statistics of these games of a limited number of transactions are more sensitive to the coincidental revelation of deceit early in the game.

The impact of the endowment effect on certificates and guarantees is not that obvious as we expected (C/H+G/H=0.86, 0.76 with endowment effect, versus 0.74, 0.74 without endowment effect), probably because the number of certificates and guarantees is high anyway given the settings of the other parameters used in these games. Tracing frequency, as expected, is higher in games with endowment effect (P/(H-C)=0.36, 0.34 with endowment effect versus 0.24, 0.25 without endowment effect).

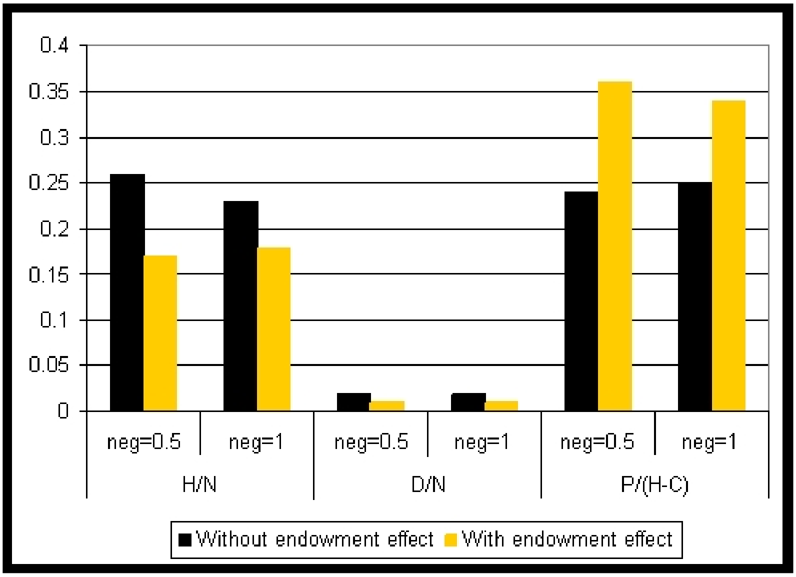

Figure 7. Sensitivity of endowment effect

Testing of the hypotheses

This subsection offers a preliminary validation of tendencies reflected by the multi-agent simulation. We compare tendencies in multi-agent simulations with tendencies observed in human games, as formulated in the hypotheses in section 3.

Hypothesis 1: *When the initial willingness to trust is high the percentage of high quality products sold will be higher than when the initial willingness to trust is low.*

Hypothesis 1 is directly confirmed by the data in Figure 5: The aggregated statistics of games with initial trust set to zero, 0.5, and 1.0 show an increasing trend for the proportion of high quality transactions (H/N=0.43, 0.47, and 0.55, respectively).

For the purpose of testing the remaining hypotheses, the results from Table A2 are aggregated per strategy in Table A6 (in the Appendix).

Hypothesis 2: *In a homogeneous environment with all opportunistic agents there are more cheats than with other profiles.*

Hypothesis 2 is confirmed by the results: D/N=0.07 for the opportunists, 0.04 for the quality-minded, and 0.00 for the thrifty agents, the latter simply giving little opportunity for deceit (Figure 8). Thrifty agents prefer low quality unless they can get certified or guaranteed high quality products for a very good price. Quality-minded agents prefer to avoid the risk of deceit by trading certified products, thus reducing the possibility of deceit at the cost of up-front tracing, but unlike the thrifty agents they will buy high quality even if a risk remains. Opportunistic agents prefer high quality and in addition they prefer a good price over certainty. In the buyer role they take an increased risk of being deceived; in the seller role they are easily tempted to deceive. As a consequence deceit occurs most frequently in games with opportunists.

Hypothesis 3: *In a homogeneous environment in which all agents are thrifty, i.e., who want to be certain about value for money, there will be more traces than with other profiles.*

Hypothesis 3 is confirmed by the results for (Q+P)/H in Figure 8 (i.e., the sum of up-front and post-transaction tracing requests relative to the number of high quality transactions). The absolute number of traces is low in games with thrifty agents, because they trade little high-quality products (column H/N in Table A6). However, relative to the number of high quality transactions, they have the highest tracing level. The tracing frequencies found in simulated games with quality-minded agents are not as high as for thrifty agents, but relatively high compared to the opportunists, due to up-front tracing in order to certify products before selling them. This increases price, but the quality-minded are willing to pay for the certainty that comes with it.

Hypothesis 4: *Thrifty agents buy less high quality products than opportunistic and quality-minded agents.*

Hypothesis 4 is confirmed by the detailed data in column (Q+P)/H of Figure 5 (the aggregation level of Figure 8 does not give sufficient information to compare with hypothesis 4). The proportion of high-quality transactions is less sensitive for trust in the quality-minded games than it is for the other strategies. The quality-minded prefer high quality and if they distrust they likely compensate the risk by either up-front or post-transaction tracing (high values of (Q+P)/H and P/(H-C) in the lower rows for quality-minded in Table A3). They are prepared to pay a higher price to reduce uncertainty.

Opportunists also trade many high-quality products, but they pay for it in a different way. They accept the risk of deceit more easily. This is an effect of the low weight of risk evaluation in their utility functions that makes opportunist negotiate about price or potential profits. The latter makes them trade more high-quality products. Opportunists agree to trade with a money-back guarantee (column G/H) more often than agents with other strategies, that prefer a certificate (column G/H). This is due to lower cost of guarantees with respect to certification and the low weight of risk evaluation in the negotiation models of opportunists.

Agents following a thrifty negotiation strategy prefer to pay a low price, so they will not easily agree on buying with certificates or guarantees. In addition, they avoid the risk of being deceived. This results in a low ratio of high quality products (H/N) being traded.

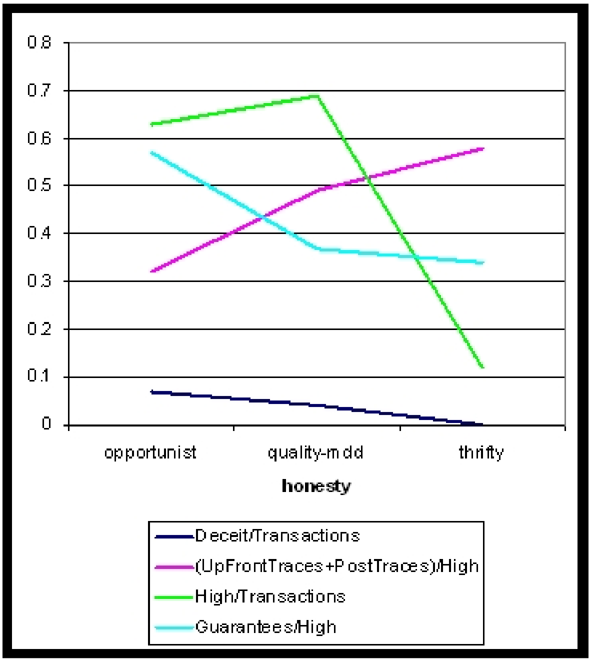

Figure 8. Sensitivity of strategies

The simulation results presented so far concerned games with homogeneous agent populations. Hypothesis 5 is about games with differently configured agents in the same game.

Hypothesis 5: *In a mixed setting with opportunistic and thrifty agents, the opportunistic agents cheat less than in a mixed setting with opportunistic and quality-minded agents.*

This hypothesis reflects observations of human simulation games that reveal extreme values of deceit frequency between games with mixed populations of opportunists and quality-minded on the one extreme and games with mixed populations of opportunists and thrifty agents on the other extreme. Figure 9 (see also Table A7) presents statistics of simulated games populated with agents with different strategies. Some agents were configured to follow an opportunistic strategy. The others were following a quality-minded strategy in the first series of games, and a thrifty strategy in the second series of games. The simulation statistics confirm hypothesis 5: much deceit in the first series (D=114), little deceit in the second series (D=23), although all agents are configured as dishonest.

The experiments confirm the validity of the models against the five hypotheses based on experience in human gaming simulations, formulated in section 3. Thus one cycle of the research approach presented in figure 2 was completed. So far we only validated the tendencies, like "thrifty agents buy less high quality commodities than other agents". A quantitative calibration of the model would require additional cycles.

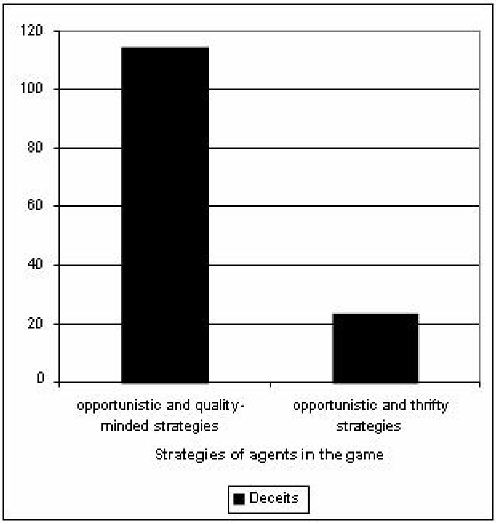

Figure 9. Deceits in games with mixed strategies

Conclusions and discussion

The research method for the development and validation of agent-based simulation of economic institutional forms consists of a cycle of steps, that can be started anywhere in the cycle depending on the state of data, theories, and hypotheses available. Human gaming simulation is used to obtain reliable data about the economic institutional form being studied. The advantage of this approach is that different variable settings can be tested in experimental setups, something that is generally impossible to do in real situations. The data obtained is analyzed, leading to the conclusions about tendencies on the aggregated level. Theories are formed on the basis of those tendencies and learned from literature. The theories and design of the gaming simulation are translated into multi-agent models that are then incorporated into a computer simulation of the same game. Within the computer simulation the same variable settings can be loaded as were used to play the human games. As a result the tendencies in the data obtained from the computer simulations can be compared to those obtained from the human games. Observed differences lead to adjustments of theories, with which the cycle can be repeated.

Furthermore, exploring various variable settings is much easier and faster for the computer simulation than for the human game. Therefore, one of the steps in the method is a systematic exploration of variable settings in the computer simulation, to a level of exhaustiveness as deemed necessary. The exploration is used to determine variable settings that are worth while to play out using humans. The exploration of various variable settings is also of importance for verifying that the models correctly represent the theories about individual behaviour. For instance, it is possible to rapidly generate results for different institutional settings (size of the products supply, cheating fine, publication of tracing results, number of agents per role) and produce results similar to Figure 3-9 (Table A1-A7). Strategies of human game players can be analyzed by running agent simulation with various player strategies.

The approach is illustrated by applying it to commodity supply chains, and more specifically to the Trust and Tracing game. This is a trade game on commodity supply chains and networks, designed as a research tool for human behaviour with respect to trust and deceit in different institutional and cultural settings. Using the approach, individual-level agent models have been developed that simulate the trust, deception and negotiation behaviour of humans playing the Trust and Tracing game. The models presented have been verified and validated by a series of experiments performed by the implemented simulation system, of which the outcomes are compared on the system level to the outcomes of games played by humans. The experiments cover in a systematic way the important variations in parameter settings possible in the Trust and Tracing game and in the characteristics of the agents. The simulation results show the same tendencies of behaviour as the observed human games.

Aside from showing the validity of the research method introduced here, the paper also presents the agent models that simulate trust, deception, and negotiation behaviour of humans when playing the Trust and Tracing game, with respect to a number of hypotheses and theories.

In an environment of perfectly honest traders, the speed with which agents learn that they are dealing with perfectly honest traders is directly related to the trust update parameters. As observed in human gaming simulations and in computer simulations, the higher the trust update parameters, the higher the proportion of high quality transactions, the lower the proportion of certificates and guarantees, and the lower the tracing frequency.

The endowment effect is the hypothesized effect that people experience loosing something they possessed as more painful than not gaining the same thing if they did not possess it. As expected, including the endowment effect in the computer simulations is shown to decrease the proportion of high quality transactions, to lower the cheating frequency and to increase the tracing frequency. Explanations are that in such games average trust is lower, and that once deceived it takes a long period to regain trust.

Finally, the research confirms the following hypotheses: there is more deceit in games with opportunistic agents than with other strategies, there is more tracing in games with thrifty agents, and games with quality minded agents have lower tracing frequencies if trust is higher. During the validation phase also two series of games were compared. In the first series some agents are opportunistic and others are quality-minded. The other series of games had opportunistic agents and thrifty agents. In all series agents were configured as dishonest. The level of deceit was higher in the first series than in the second series.

In current and future work more variations of the setting (including the current one) will be tested in both the human and simulated environment. This will lead either to further adjustments of the multi-agent model or to more variations to test. By testing large numbers of settings quickly in the simulated environment we can select more interesting settings for the human sessions, and thus save research time. The long-term result will, hopefully, be a fully validated model of trust with respect to situations comparable to the Trust and Tracing game, where validation is reached for the individual and the aggregated level.

Finally, the research method introduced in this paper, shows promise to bridge the gap between agent-based economics and new institutional economics by the use of human simulation games as intermediate steps. In human games, transactions can be monitored in much more detail than in real life trade. That way it is much easier to collect the necessary data to set up dependable agent-based simulations of the situations enacted in the human games. The agent-based simulation will be informative for the more generic case in as far as the human game is a proper reflection of real life trade processes. The results presented in this paper show that an agent-based simulation of the Trust and Tracing Game is indeed possible. The approach furthermore opens up the possibility of modelling specific groups of humans in trade situations (e.g., traders from different cultures). This will lead to agent-models that reflect the background of the group under consideration, and improve the accuracy of the models.

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Appendix A: Simulation Results

Table A1. Statistics of simulated games with varying values of trust update. Positive trust update=negative trust update; strategy neutral; initial trust 0,5; initial and minimal honesty 1.0; confidence 0.95.

trust update	N	H	L	Q	C	G	P	D	H/N	C/H	G/H	(Q+P) /H	P/ (H-C)	D/N
0.1	375	250	125	0	29	196	89	0	0.67	0.12	0.78	0.36	0.40	0.00
0.1	366	232	134	0	18	180	84	0	0.63	0.08	0.78	0.36	0.39	0.00
0.1	364	220	144	0	25	167	81	0	0.60	0.11	0.76	0.37	0.42	0.00
total	**1105**	**702**	**403**	**0**	**72**	**543**	**254**	**0**	**0.64**	**0.10**	**0.77**	**0.36**	**0.40**	**0.00**
0.5	376	266	110	0	23	141	62	0	0.71	0.09	0.53	0.23	0.26	0.00
0.5	465	356	109	0	18	186	69	0	0.77	0.05	0.52	0.19	0.20	0.00
0.5	500	369	131	0	21	208	58	0	0.74	0.06	0.56	0.16	0.17	0.00
total	**1341**	**991**	**350**	**0**	**62**	**535**	**189**	**0**	**0.74**	**0.06**	**0.54**	**0.19**	**0.20**	**0.00**
0.9	500	385	115	0	17	201	47	0	0.77	0.04	0.52	0.12	0.13	0.00
0.9	500	386	114	0	26	177	47	0	0.77	0.07	0.46	0.12	0.13	0.00
0.9	500	396	104	0	11	206	50	0	0.79	0.03	0.52	0.13	0.13	0.00
total	**1500**	**1167**	**333**	**0**	**54**	**584**	**144**	**0**	**0.78**	**0.05**	**0.50**	**0.12**	**0.13**	**0.00**

Legend:		
	N	Number of Transactions
	H	Number of High Quality Transactions
	L	Number of Low Quality Transactions
	Q	Number of Certification Traces
	C	Number of Certified Transactions
	G	Number of Guarantees
	P	Number of Post-Transaction Traces
	D	Number of Deceptions
	H/N	Proportion of High Quality Transactions
	C/H	Proportion of Certified Transactions wrt High Quality Transact's
	G/H	Proportion of Guarantees wrt High Quality Transactions
	(Q+P)/H	Total Tracing Frequency wrt High Quality Transactions
	P/(H-C)	Post-Transaction Tracing Frequency
	D/N	Deceit Frequency

Table A2. Statistics of simulated games with varying values of initial trust and honesty for different negotiation strategies. Minimal honesty=initial honesty; positive trust update=0.3, negative trust update=1.0; confidence=0.95. Tables 5, 6, and 7 present aggregated views of the data.

init. t	honesty	N	H	L	Q	C	G	P	D	H/N	C/H	G/H	(Q+P) /H	P/ (H-C)	D/N
opportunistic															
1.0	1.0	200	164	36	0	0	69	7	0	0.82	0.00	0.42	0.04	0.04	0.00
1.0	0.5	200	147	53	0	0	64	8	20	0.74	0.00	0.44	0.05	0.05	0.10
1.0	0.0	200	124	76	0	0	61	6	39	0.62	0.00	0.49	0.05	0.05	0.20
0.5	1.0	200	133	67	0	10	81	49	0	0.67	0.08	0.61	0.37	0.40	0.00
0.5	0.5	200	121	79	0	1	68	34	13	0.61	0.01	0.56	0.28	0.28	0.07
0.5	0.0	200	131	69	0	3	80	55	31	0.66	0.02	0.61	0.42	0.43	0.16
0.0	1.0	200	116	84	0	19	78	69	0	0.58	0.16	0.67	0.59	0.71	0.00
0.0	0.5	200	107	93	0	8	80	72	10	0.54	0.07	0.75	0.67	0.73	0.05
0.0	0.0	200	99	101	0	4	72	69	14	0.50	0.04	0.73	0.70	0.73	0.07
quality-minded															
1.0	1.0	200	154	46	5	5	32	6	0	0.77	0.03	0.21	0.07	0.04	0.00
1.0	0.5	200	148	52	60	63	22	9	9	0.74	0.43	0.15	0.47	0.11	0.05
1.0	0.0	200	155	45	34	35	54	7	24	0.78	0.23	0.35	0.26	0.06	0.12
0.5	1.0	200	133	67	6	23	82	38	0	0.67	0.17	0.62	0.33	0.35	0.00
0.5	0.5	200	135	65	67	91	25	17	12	0.68	0.67	0.19	0.62	0.39	0.06
0.5	0.0	200	144	56	49	73	54	34	18	0.72	0.51	0.38	0.58	0.48	0.09
0.0	1.0	200	122	78	2	18	99	71	0	0.61	0.15	0.81	0.60	0.68	0.00
0.0	0.5	200	116	84	65	79	34	31	2	0.58	0.68	0.29	0.83	0.84	0.01
0.0	0.0	200	132	68	53	73	52	50	9	0.66	0.55	0.39	0.78	0.85	0.05
thrifty															
1.0	1.0	200	65	135	0	1	32	4	0	0.33	0.02	0.49	0.06	0.06	0.00
1.0	0.5	200	7	193	4	4	3	1	0	0.04	0.57	0.43	0.71	0.33	0.00
1.0	0.0	200	24	176	24	24	0	0	0	0.12	1.00	0.00	1.00		0.00
0.5	1.0	200	24	176	0	0	17	4	0	0.12	0.00	0.71	0.17	0.17	0.00
0.5	0.5	200	7	193	4	4	2	2	0	0.04	0.57	0.29	0.86	0.67	0.00
0.5	0.0	200	16	184	16	16	0	0	0	0.08	1.00	0.00	1.00		0.00
0.0	1.0	200	17	183	1	3	14	12	0	0.09	0.18	0.82	0.76	0.86	0.00
0.0	0.5	200	19	181	13	13	6	5	0	0.10	0.68	0.32	0.95	0.83	0.00
0.0	0.0	200	37	163	36	37	0	0	0	0.19	1.00	0.00	0.97		0.00

Table A3. Aggregated statistics of 3×9 simulated games with varying values of initial trust the ratios H/N, … ,D/N are calculated on the rows of the table, so they are a weighted average of the ratios in table A2, applying the ratio's denominator as weight factor

initial trust	N	H	L	Q	C	G	P	D	H/N	C/H	G/H	(Q+P) /H	P/ (H-C)	D/N
1.0	1800	988	812	127	132	337	48	92	0.55	0.13	0.34	0.18	0.06	0.05
0.5	1800	844	956	142	221	409	233	74	0.47	0.26	0.48	0.44	0.37	0.04
0.0	1800	765	1035	170	254	435	379	35	0.43	0.33	0.57	0.72	0.74	0.02

Table A4. Aggregated statistics of 3×9 simulated games with varying values of honesty (minimal honesty and initial honesty both set equal to the value in the first column).

hon-esty	N	H	L	Q	C	G	P	D	H/N	C/H	G/H	(Q+P) /H	P/ (H-C)	D/N
1.0	1800	928	872	14	79	504	260	0	0.52	0.09	0.54	0.30	0.31	0.00
0.5	1800	807	993	213	263	304	179	66	0.45	0.33	0.38	0.49	0.33	0.04
0.0	1800	862	938	212	265	373	221	135	0.48	0.31	0.43	0.50	0.37	0.08

Table A5. Statistics of simulated games with varying values of trust update. Strategy=neutral; initial trust=0,5; initial and minimal honesty=1.0; confidence=0.95.

delta t pos	neg	N	H	L	Q	C	G	P	D	H/N	C/H	G/H	(Q+P) /H	P/ (H-C)	D/N
0.05	0.5	500	67	433	21	30	22	9	1	0.13	0.45	0.33	0.45	0.24	0.00
0.05	0.5	500	125	375	70	91	23	13	6	0.25	0.73	0.18	0.66	0.38	0.01
0.05	0.5	500	67	433	28	37	19	14	4	0.13	0.55	0.28	0.63	0.47	0.01
	total	**1500**	**259**	**1241**	**119**	**158**	**64**	**36**	**11**	**0.17**	**0.61**	**0.25**	**0.60**	**0.36**	**0.01**
0.5	0.5	500	136	364	59	82	33	15	8	0.27	0.60	0.24	0.54	0.28	0.02
0.5	0.5	500	125	375	24	35	54	24	10	0.25	0.28	0.43	0.38	0.27	0.02
0.5	0.5	500	128	372	28	47	36	14	8	0.26	0.37	0.28	0.33	0.17	0.02
	total	**1500**	**389**	**1111**	**111**	**164**	**123**	**53**	**26**	**0.26**	**0.42**	**0.32**	**0.42**	**0.24**	**0.02**
0.1	1.0	500	100	400	17	37	37	22	3	0.20	0.37	0.37	0.39	0.35	0.01
0.1	1.0	500	76	424	24	33	25	14	0	0.15	0.43	0.33	0.50	0.33	0.00
0.1	1.0	500	88	412	30	40	27	17	8	0.18	0.45	0.31	0.53	0.35	0.02
	total	**1500**	**264**	**1236**	**71**	**110**	**89**	**53**	**11**	**0.18**	**0.42**	**0.34**	**0.47**	**0.34**	**0.01**
1.0	1.0	500	143	357	37	57	57	24	15	0.29	0.40	0.40	0.43	0.28	0.03
1.0	1.0	500	90	410	27	40	28	10	2	0.18	0.44	0.31	0.41	0.20	0.00
1.0	1.0	500	119	381	25	39	39	20	11	0.24	0.33	0.33	0.38	0.25	0.02
	total	**1500**	**352**	**1148**	**89**	**136**	**124**	**54**	**28**	**0.23**	**0.39**	**0.35**	**0.41**	**0.25**	**0.02**

Table A6. Aggregated statistics of 3×9 simulated games with different strategies defined in section 5.

strat-egy	N	H	L	Q	C	G	P	D	H/N	C/H	G/H	(Q+P)/H	P/(H-C)	D/N
opportunistic														
	1800	1142	658	0	45	653	369	127	0.63	0.04	0.57	0.32	0.34	0.07
quality-minded														
	1800	1239	561	341	460	454	263	74	0.69	0.37	0.37	0.49	0.34	0.04
thrifty														
	1800	216	1584	98	102	74	28	0	0.12	0.47	0.34	0.58	0.25	0.00

Table A7. Statistics of simulated games with different mixed strategies. Minimal honesty=intitial honesty=0.5; initial trust=0.5; positive trust update=0.3, negative trust update=1.0; confidence=0.95.

strat-egies	N	H	L	Q	C	G	P	D	H/N	C/H	G/H	(Q+P)/H	P/(H-C)	D/N
opportunistic and quality-minded strategies														
	500	195	305	13	26	101	49	40	0.39	0.13	0.52	0.32	0.29	0.08
	500	169	331	8	22	72	33	24	0.34	0.13	0.43	0.24	0.22	0.05
	500	213	287	6	20	113	58	50	0.43	0.09	0.53	0.30	0.30	0.10
total	1500	577	923	27	68	286	140	114	0.38	0.12	0.50	0.29	0.28	0.08
opportunistic and suspicious strategies														
	500	64	436	4	8	35	7	6	0.13	0.13	0.55	0.17	0.13	0.01
	500	59	441	0	5	32	11	6	0.12	0.08	0.54	0.19	0.20	0.01
	500	60	440	2	7	33	12	11	0.12	0.12	0.55	0.23	0.23	0.02
total	1500	183	1317	6	20	100	30	23	0.12	0.11	0.55	0.20	0.18	0.02

Part III: Modelling Hofstede's Dimensions One by One

The approach taken to model culture in this work is an expert systems approach. It entails the study of literature about the effects of culture on norms and social processes and formalization of expert knowledge.

Literature and expert knowledge on culture are available in two basic types. The first type is the "thick description" (Geertz 1993) of particular cultures that ethnographic studies offer. The second type is the universal description of cultural phenomena that aims to position cultures in a multidimensional framework, based on quantitative analysis of world-wide, large-scale, surveys. The first type of descriptions can be used to model in facsimile the culture of some group, nation, etc. It is less feasible for a general model of culture's effects on particular social processes across many cultures. Since the second type of describing cultures is intended as a framework to compare cultures in general, it offers a natural basis for cultural differentiation of agent behaviour in multi-agent simulations aiming to model social processes across many cultures. Several frameworks of the second type have been reported in social sciences literature (e.g., Hofstede 2001, House et al. 2004, Schwarz 1994, Trompenaars 1993).

Hofstede's framework was chosen over other candidates for various reasons. First, Hofstede's work is parsimonious and accessible, with only five dimensions compared to GLOBE's 18, and with its 1-to-100 scales. Second, it has a wide scope, compared to Trompenaars' model, whose dimensions are statistically correlated and can be described as aspects of only individualism and power distance (Smith et al. 1996) or Hall (1976) who focused on the dimension of individualism (low-context communication) versus collectivism (high-context communication). Those models miss out on issues related to gender roles, anxiety and Confucian values. Third, it has the greatest empirical base of these studies, with a well-matched sample of 117.000 respondents to the original study plus hundreds of replications during a quarter century that validate the model (Kirkman et al. 2006, Schimmack et al. 2005). Fourth, it is the most widely used. It has survived fashions and hasty storms of criticism (Smith 2006, Sóndergaard 1994). Fifth and most important, it shows continued predictive value for many societal phenomena (Hofstede 2001, Smith 2002).

In addition to the reasons given in the previous paragraph, a practical reason for selecting this framework is that expertise on particularly this framework was at hand, in the person of Gert Jan Hofstede. Availability of an expert is a sine qua non for an expert systems approach.

From the beginning of the research it became clear that understanding, predicting and formalizing the joint influence of all dimensions simultaneously was too complex, even for an expert. After all, this is the reason why multidimensional frameworks have been developed. Literature describes the effects of individual dimensions and experts like to build up explanations of culture using individual dimensions (see, e.g., the synthetic cultures described by G.J. Hofstede et al. 2002). Therefore, the approach taken to model culture's consequences started with expertise-based modelling of the effects of the dimensions one-by-one.

Part III of this thesis is composed of papers based on joint work with Gert Jan Hofstede and Catholijn M. Jonker, and, for the first paper relating the work to the TRUST & TRACING game, with Sebastiaan Meijer.

Chapter 4, originally presented in the 2006 iTrust workshop (Hofstede et al. 2006), introduces the observations made from the human gaming simulation, that motivated this work. This chapter focuses on Hofstede's masculinity versus femininity dimension. The paper develops the way the effects of culture are modelled for all individual dimensions.

Chapter 5, originally presented in the MABS workshop at AAMAS 2008 (Hofstede et al. 2009), studies the dimension of power distance and relates this work to other approaches and applications to model culture. A special aspect of the power distance dimension is that not only the agent's cultural background influences its behaviour. In societies scoring high on the power distance dimension the agent's position in society relative to the other agent is salient as well.

Chapter 6, modelling the dimension of individualism versus collectivism, was originally presented at the 2008 IEA/AIE conference (Hofstede et al. 2008a). In this dimension, another relevant relational attribute is introduced: common group membership. It is most relevant in collectivistic societies. The paper shows how different patterns of trade relations can be generated along this dimension, combined with different configurations of group membership.

For the dimensions described in Chapter 7 and 8, relational attributes are relevant as well. An important conclusion is that for modelling culturally differentiated interactions not only the agent's cultural background, but also characteristics of the relation with its actual trading partner should be taken into account. It should be noted that the treatment of personal and relational variables in this thesis is abstracts and actually quite limited, both in scope and in depth, and should be seen as a first step only.

Chapter 7 on the uncertainty avoidance dimension was originally presented in the 2008 Agent-Directed Simulation Symposium (Hofstede et al. 2008). Like chapter 6, it shows that the model can simulate the development of different patterns of trade relations based on relational characteristics of which the salience depends on culture.

Chapter 8 was originally presented in the 2008 Artificial Economics symposium (Hofstede et al. 2008b). It models the effects of the dimensions of long-term versus short-term orientation, with maintaining relations as an important issue on the long-term oriented end, and respect for status on the short-term oriented end. This chapter contains a first attempt at sensitivity analysis; the sensitivity analysis approach is extended in Part V of this thesis.

4 Modelling Trade and Trust across Cultures

Abstract. Misunderstandings arise in international trade due to difference in cultural background of trade partners. Trust and the role it plays in trade are influenced by culture. Considering that trade always involves working on the relationship with the trade partner, understanding the behaviour of the other is of the essence. This paper proposes to involve cultural dimensions in the modelling of trust in trade situations. A case study is presented to show a conceptualisation of trust with respect to the cultural dimension of performance orientation versus cooperation orientation.

Introduction

"High quality! Traced and guaranteed!" Thus yells an American middleman in a session of the Trust and Tracing Game [1]. The man is buying and selling envelopes that have an invisible quality attribute. They can be either high quality or low quality, and of course the first variant fetches a better price. But why is he having his products traced up front? The producer he buys from knows the hidden quality of each envelope, and if the middle man trusted him he could save himself the tracing cost.

The answer has to do with trust. The middle man may or may not trust his provider, but he expects that no buyer will trust *him* to be sincere about the quality of his pretended high-quality envelopes unless he has them traced. So he makes the best of a cost factor and he uses the act of tracing as a marketing device.

The same game, played with Dutch participants, yields a different network. The game's pace tends to be slower and some negotiations are prolonged. Nobody traces anybody else, until the game leader reveals that consumers have been cheated and are stuck with low quality after having paid for high quality. This induces some tracing in the next round, but not much. By having his purchase traced, a Dutch buyer would indicate distrust of the seller, and that is not done. The seller himself would never think of tracing up front, because that would be throwing away money in vain, and he expects to be trusted anyhow.

We have been witness to the above events. In miniature, they mirror the unwritten rules of the game of real trade in the US and the Netherlands. The same game with the same explicit rules yields very different behaviour of the trade network because the hidden rules and assumptions differ.

Agent models of trade networks have been around for some years. The behaviour in an agent model is an emergent property resulting from the behaviour of all the agents. The role of the agents' preferences in such a model is not too hard to represent. But can we also incorporate the unwritten rules and expectations of culture? That is the subject of this paper.

The context of this study is research into social aspects of food supply chains and networks, as introduced in [2]. That research aims to increase insight in human behaviour in trade relations, with the goal to design efficient institutional environments for production and distribution of food, meeting high standards of to consumer satisfaction, health, food safety, and social responsibility. Especially for food with its potential hidden contaminations that can lead to severe health effects, trust is a key research item [3]. But this preliminary study abstracts from the food context and applies to any trade situation in which the products have hidden quality attributes. Human simulation games are used in combination with multi-agent simulations, to develop models for the role of trust in supply networks, by iteratively implementing models in multi-agent simulations, comparing simulation results with human simulations, and refining the models [4]. As illustrated by the example in the beginning of this section, observations of human games indicate that culture cannot be ignored.

Models of player's behaviour in simulation games entail models for deciding about agent's intentions, based on agent's beliefs and desires. According to March [5], decision making processes may be rational or rule following. Rational decision making aims to maximize a utility function. In rule following decision making, a decision maker classifies the situation and its own role in it; subsequently, she applies rules to answer the question: what is appropriate for a person like me to do in a situation like this? Human decision making processes often have both rational and rule-following aspects. Rule-following decision making can be seen as imposing moral boundaries on acceptable outcomes of rational decision making. It can also be seen as consolidated experience or an evolutionary outcome of rational decision making [5].

It is an interesting question to ask if artificial agents like human decision makers should apply both types of decision making. Agents that are designed to outperform people in rational decision making processes by use of superior computation power can probably do without rule-following. Agents that are designed to simulate human behaviour in some way will probably need to apply both processes of decision making simultaneously, although it may not strictly be necessary to follow equal procedures to get sufficiently resembling results. Especially in simulations that aim to increase understanding of human decision making, simulation of human rules is a sine qua non. This implies that the latter kind of agents must have cultural scripts.

Both a decision maker's desires (goals of the decision making) and its procedures for decision making are culture-dependent in several ways. First, the priority of goals depends on culture; for instance "maximize personal wealth" may have priority over "maintain pleasant interpersonal relations". Second, preferences for rational versus rule following procedures differ across cultures; e.g. in collectivistic cultures with large power distance, following the rules is more appropriate then in individualistic cultures with little power distance where rational decision making will prevail. Third, if a rule following procedure is chosen, the rules depend on culture. Fourth, a decision may be interpreted offensive by an opponent having a different cultural background. Also, the appropriate reaction to inappropriate behaviour differs across cultures.

The focus of this paper is on the relation between culture and trust in human trade networks. We abstract from personality and select a single dimension of culture as a modelling case. The next sections describe the background of culture theory, the background of trust literature used for the case study, the Trust and Tracing Game, a case study of modelling a dimension of culture, its application to the Trust and Tracing Game, and conclusions.

Culture and trust

Culture is what distinguishes one group of people from another [6]. This implies that culture is not an attribute of individual people, unlike personality characteristics. It is an attribute of a group that manifests itself through the behaviours of its members.

For a trading situation, culture of the trader will manifest itself in four ways. First, culture filters observation. It determines the salience of clues about the acceptability of trade partners and their proposals. Second, culture sets norms for what constitutes an appropriate partner or offer. Third, it sets expectations for the context of the transactions, e.g. the enforceability of regulations and the possible sanctions in case of breach of the rules. Fourth, it sets norms for the kind of action that is appropriate given the other three, and in particular, the difference between the actual situation and the desired situation.

Our US middle man, for instance, sees as acceptable a trade partner who has his products traced so that quality is out in the open. He will be keen to observe any offer of untraced high-quality goods and to distrust the one offering it. He expects his clients to think in the same way, and in order to be deemed respectable, he has traces performed himself. It also helps that he expects heavy-handed punishment in case of infringement of explicit laws.

Our Dutch trader, on the other hand, likes trade partners who are forgiving and friendly and who place implicit trust in one another's good intentions. He will perceive it when somebody asks for a trace and label that person as distrustful. In order not to be thought distrustful himself, he will not trace until proven wrong, and if proven wrong he will try to avoid the bad guy, or most likely (if it is the first offence) ask the cheater to be honest the next transaction and sell for a low price to make up the losses from the cheated transaction.

What is it that makes these two traders behave in such different ways? It could be their personalities, or their experiences, or it could be the way they were brought up, in other words: their culture. It turns out that in terms of culture, the USA and the Netherlands are unusually easily comparable, because they are rather alike but for one aspect. Culture at the national level is concerned with five big issues of social life: hierarchy, identity, cooperation-performance orientation, the unknown, and the gratification of needs. Hofstede and Hofstede [6] conceptualize each of these issues as a bipolar continuum ranging from about 0 to about 100: from small to large power distance, from collectivist to individualist, from cooperation oriented to performance oriented, from weak to strong uncertainty avoidance, and from short-term to long-term orientation. As figure 1 shows, the Netherlands and the USA differ considerably on the Cooperation-Performance orientation dimension and little on the other four. Incidentally, this is not to say that culture only occurs at a national level – but the national averages in these two countries happen to differ. Of course, every individual is unique, and many subgroups with their own culture exist within any country.

In this article, we shall abstract from the real world in an important way. We shall describe agents as if the dimension of performance orientation were the only one. This is a deliberate choice, but it should be borne in mind that in reality, behaviour is always the outcome of a mix of factors: all elements of one's culture, all elements of one's personality and all contextual and historical coincidences.

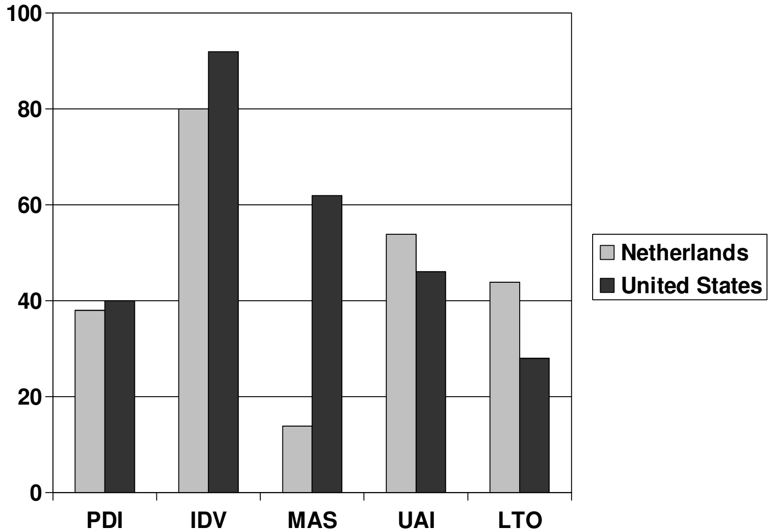

Fig. 1. The cultures of the Netherlands and the USA compared (PDI = Power Distance index, IDV = Individualism index, MAS = Masculinity index, also called the cooperation-performance orientation index, UAI = Uncertainty avoidance index, LTO = Long-term orientation index).

What does the dimension of performance orientation indicate? Let us describe the two extremes – more extreme in fact than any real-world culture – to give the big idea. Performance oriented cultures are cultures in which people are expected to place value on measurable performance criteria such as size, speed and quantity. Money is good and rich people are admired. Life is conceptualized as a series of contests and winning is paramount while losing is a disaster. Implicit trust is low; if you get cheated upon it is your own fault and you are a loser. If you do good, you also do it in a large way. If you commit crimes, they are large ones, not petty ones. Big is beautiful in everything.

Cooperation oriented cultures are the opposite. Winners are at risk of awakening feelings of jealousy. Small is beautiful, implicit trust is high, and cheaters are looked down upon. Yet small-scale cheating occurs a lot because society is permissive, and punishments are low or, in the case of small misdemeanours, you may be forgiven. Good intentions are more important than good performance.

These two descriptions are stereotyped extremes. Yet citizens from either of these two countries who have been exposed to the other one's culture probably recognize quite a bit of them. And because the Netherlands and the USA also have quite many contacts in actual business life, the comparison is meaningful in the real world.

The meaning of trust across cultures is related to this dimension of culture. In fact, the statement ‘Most people can be trusted’ was one of the constituents of the dimension in Hofstede’s original research. In cooperation-oriented cultures, people agree with it more. Since then, many others have investigated the variations of the meaning of the concept across cultures. See e.g. chapter 8 in [3] for a discussion of the dynamics of trust and transparency across cultures, and [7] for a conceptualization of trust and a literature review. This latter article distinguishes *intrinsic trust* from *enforceable trust*. Intrinsic trust is trust that accepts vulnerability, while enforceable trust is trust in good performance that is backed up by the option of rewarding and punishing the trustee. To sum it up in a simplified way: the former is what people mean by trust in cooperation oriented cultures, and the latter is what they mean by trust in performance oriented cultures.

Some published results confirm the relevance of cultural difference for electronic trade, for instance Huang et al. [8] report relations between nationality, trust and internet adoption. Jarvenpaa and Tractinsky [9] report only slight differences in consumer trust in on-line bookstores across cultures. The latter results were based on observations in three countries with an individualistic culture: Australia, Finland and Israel. The authors assume that larger differences may exist between individualistic and collectivistic nations. They emphasize the importance of gathering more data. However, only few publications have appeared, presenting fragmented data of only a few countries. An example is the study by Vishwanath [10] that relates on-line auction participation and the effect of seller ratings in Germany, France and Canada. His findings confirm that in a country with higher masculinity index, trust is less relevant: bidders do rely on the information in seller ratings; they do not trust.

All available data suggest a relation between culture and trust in internet participation. However, available data are insufficient for foundation of cross-cultural models of consumer trust that can be used for agent design. Development of well-founded trust models incorporating culture requires empirical, preferably experimental, data.

Agent based Simulations of Trust and Trade

Castelfranchi and Falcone proposed a model of trust that can serve as a basis for agent based simulations [11, 12]. The main issues in their model are:

- Trust is at the same time: a mental attitude towards another agent, a decision to rely on another agent, and a behaviour that entails a relation with another agent.
- Trust consists of beliefs about another agent’s competence and willingness to fulfil some task. Willingness arises from a complex of motivations.
- A condition for trust is the belief that it is better to rely on the trustee than not.
- The decision to trust may be influenced by environmental factors: opportunities, obstacles, adversities, and interferences.
- In the decision whether to trust or not, an agent weights and prioritises the above influences and compares the result with a threshold of acceptable risk. Weight factors, priorities and risk threshold depend on context and agent’s personality.

Although the authors do not relate trust with culture, their model offers opportunities to do so. When viewing trust as a mental attitude towards another agent, an agent's cultural background and the cultural context will influence its valuation of the motivations to trust. When viewing trust as an intention to rely on an agent, the criteria, priorities, and weight factors for the decision process reflect cultural background.

Trust models can be put into operation in a testbed. A recently proposed approach is the ART testbed architecture [13]. The authors propose a software architecture for testing and comparing reputation and trust models, either in experimentation or in competition mode. The testbed provides relative performance indicators for reputation and trust models. The testbed offers a java environment where researchers can implement java methods to implement the models. Thus, it can test any model with any cultural script in any cultural or cross-cultural setting. However, the testbed approach is not related to data from real human cultures.

Jonker et al. [4] present an approach to interrelate multi-agent simulations and human simulation games in order to validate and refine trust models, especially with respect to different cultural and institutional settings. The game focuses on the role of trust in supply chains with asymmetrical information about product quality between sellers and buyers. Playing this game with people from different countries showed different development of patterns of trust and co-operation between cultures. The approach is effective in producing empirical data. As it requires multiple game sessions of several hours with some twenty players, it is very time-consuming. This is the necessary cost of a controlled way to acquire empirical data for model formulation, parameter estimation and model validation in multi-agent systems.

Simpler experiments, e.g. those presented by Jonker et al. [14], could be used to compare isolated aspects of trust across cultures. The paper presents a method for measuring the effect of sequences of positive experiences and disappointments on the level of trust. Results are acquired from a single cultural setting. It would be interesting to compare dynamics of trust across cultures using this experimental approach.

Partner selection is a special point of attention in trade models, especially in multi-agent simulations. Partner selection starts with models for partner preference. Models based on experience with regard to negotiation success are describeded by, for instance, Tesfatsion [15] and Munroe and Luck [16]. Sen et al. [17] present a model for players that anticipate their opponents selecting partners based on experience. However, none of these models explicitly represents cultural dimensions.

Trust and Tracing Game

The Trust and Tracing [1] game for human players is a research tool for supply chain and network studies. This tool places the choice between relying on trust versus spending money on complete information in trade environments at the core of a social simulation game. The game is used both as a data gathering tool about the role of reputation and trust in various types of business networks, and as a tool to make participants reflect on their own daily experiences in their respective jobs.

In the game sellers of a commodity have more information about the quality of the goods than buyers, as quality is invisible and only known by the producers. This leads to information asymmetry and the opportunity for deceit. Meijer and Hofstede [1] describe the dilemma similar to the well-known Prisoners Dilemma in the so-called Trader's Predicament.

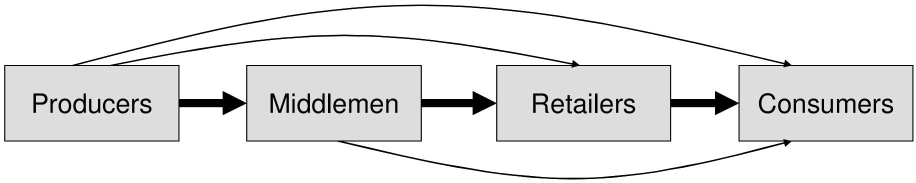

Fig. 2. Supply network configuration

In the human Trust and Tracing game 12 to 25 participants play roles in a supply network. There are producers, middlemen, retailers and consumers (see Figure 2). The producers receive an initial amount of goods. The good traded is a sealed envelope that comes in 3 different types (colours) and each of the types in two qualities (high and low). The quality is invisible, as it is hidden in the sealed envelope. Producers know which envelopes are high quality and which are low. The only person in the game allowed to open an envelope is the tracing agency. Table 1 specifies satisfaction values of each good for a consumer (utility).

Table 1. Consumer satisfaction value by the type and quality

Quality	Type		
	Blue	Red	Yellow
Low	1	2	3
High	2	6	12

An agent buying a high quality envelope takes a risk, as he cannot know the real quality. The buyer can check afterwards by doing a trace at the tracing agency, but this costs money. Tracing is cheaper early on in the network than for consumers. When consumers prefer traced goods (certified high quality) it would be economical to let a middleman do the trace and sell the traced product throughout the network along with the certificate. Successful deception is beneficial for a seller as he receives an additional income. (The difference between the price of a high and that of a low-quality product) However, if the deception is discovered the cheater has to pay a fine. Resellers of cheated products who did not check the quality themselves have to pay a smaller "ignorance" fine.

In the case study a situation is considered in which two traders meet for the first time and know nothing about each other. Trader P is very much performance oriented, trader C is the opposite, i.e., cooperation oriented. The traders negotiate about one envelop, said to contain a high quality commodity. The profile of trader P is such that he is willing to trade for a final price of about Q. The profile of trader C is such that he is willing to trade for a final price of about Q. Given that Q is an acceptable price, everything is set in such a way that a deal is possible if the negotiations are performed in an acceptable manner, acceptable that is to the other party.

Modelling Cooperation- versus Performance Orientation

The dimension of performance orientation versus cooperation orientation has its effect on the way people will behave in the Trust and Tracing Game. In this section this effect is described informally and then (partially) specified formally as prodcution rules).

A performance oriented trader is interested in fast trades, with as many goods as possible in one trade. This trader is rather impatient, and if bids are too far off from his profile, he will walk away quickly. The performance oriented trader always traces the goods after buying, since he expects the possibility of deception. He sticks to the contract of the deal, and will deceive the trade partner to the limits of the contract without any compunction. As a consequence, the performance oriented trader sees no problems in dealing again with a trader that conned him in the past: "It's all in the game". Each subsequent negotiation will be dealt with without taking past trustworthiness into account. Each new contract will be set up from scratch. The trader learns from mistakes to make sure that the contract will not lead to new and uncomfortable surprises on his side.

A cooperation oriented trader is interested in the relationship with the trade partner, building trust is important, the amount of goods is not of the most interest. The trader is also interested in negotiating about one envelope only, because the relationship built during that negotiation might pay off in future negotiations. Given the interest in the relationship with the trade partner, a first negotiation with a trade partner will take time that is willingly spent by the trader. During such negotiations, the trader appreciates a negotiation process in which both partners show a willingness to accommodate the other over time. Past negotiations do play an important role in subsequent negotiations. The trader is perfectly willing to see the current negotiation as a kind of continuation of the previous one. If the trade is about the same commodity, the trader will start the negotiation from the deal of the last one. If the other accepts, then the deal can be made in one round and in seconds, whereas the first deal might have taken a lot of rounds and lots of time. In principle, the cooperation oriented trader does not trace, since in his mind this would constitute ostentation of distrust. If conned, then the cooperation oriented trader will avoid the conman if possible, or give him one more chance. In the human games we observed that he then asks for a very good new deal to reaffirm the relationship. In the application of the rules to the setting described in Section 4, the following simplifications are made. The cooperation oriented trader C is content in a first ever trade with another trader T, if negotiation takes 5 rounds before a deal is found, and over the rounds T tries to accommodate C. A bad negotiation is one that is not satisfying. A performance oriented trader P is content in a first ever trade with another trader T, if negotiation is successful and fast (at most 2 rounds), and both P and T showed steadfastness in their bidding. Trader P respects and appreciates steadfastness in T and will show the same behaviour towards T. For trader P a satisfying negotiation is one that is short (at most 2 rounds) and in which both traders show steadfastness.

Both trader P and trader C prefer reaching a deal after a satisfying negotiation over a deal that was reached on the basis of a bad negotiation. Not reaching a deal after a satisfying negotiation is better than having no deal after a bad negotiation. Bear in mind that the traders differ strongly in what is considered a satisfying negotiation. Furthermore, note that their cultural scripting will also lead them to behave differently during the negotiations. Trader P might very well walk away (no deal) as soon as he receives a first bid of trader C that is very far off price Q. Whereas trader C might be put off by the steadfastness of trader P, and certainly by his walking away after few rounds. However, C will be forgiving and willing to negotiate with P one more time, although C will trust P less and avoid risk in the next deal.

Some essential parts of the specification are presented in the remainder of this section; more can be found in Appendix A, and a full specification can be obtained from the authors. The specifications are formulated as production rules.

The cultural dimension has performance orientation at one extreme of the spectrum, and cooperation orientation at the other. This dimension is modelled by one value, indicated by the function named pc_orientation. A value of 0 corresponds to extreme cooperation orientation, whereas value 1 corresponds to extreme performance orientation. A personality factor is used to account for individual differences in decision making.

```
(1)  If cultural_script_contains(pc_orientation(F: Real))
       And minimum_utility(M: Real)
       And personality_factor(impatience, I: Real)
     Then impatience_factor(F: Real * (I: Real + 0.5))
       And preferred_relative_deal_size(F: Real)
       And allowed_relative_gap_size(F: Real)
       And cut_off_value(M: Real * F: Real);
```

At each moment during the negotiation the trader can decide to cut off the negotiations without a deal, or to accept the opponent's last offer (deal), or to continue with the negotiations. The other party can of course also take the initiative to accept the deal of the trader or to cut off the negotiations without a deal. A deal corresponds to a contract that stipulates the conditions of the sale. His decisions after a negotiation has ended in a deal depend on the role that the trader is playing. As a seller, he has to decide whether or not to cheat upon his trade partner. This aspect is not considered in this paper, see [18] for a model on cheating in the Trust and Tracing Game. If the agent is a buyer, he has to decide whether or not to trace the commodities sold to him. Aspects of the negotiation process determine whether or not he changes his opinion of his trade partner. A change in opinion is regulated by change factors (values between 0 and 1). The change factors (big and small) and their dynamics are part of the personality profile of the trader, and not further elaborated here. The negotiations in the Trust and Tracing Game have a closed character, therefore, both negotiation partners only have their own utility function to evaluate both own bids and those of the negotiation partner. In reality many factors influence decisions to continue negiation, to trust or deceive a trade partner, etc. Where not all of the factors can be included in the model, random factors between 0 and 1 are used to obtain a more natural variability in behaviour.

Rule 2 describes that the trader will stop the negotiation if he considers the starting points of the bidding as too far apart. The impatience factor influences the decision; the higher F, the sooner the trader will stop for this reason.

```
(2)  If impatience_factor(F: Real)
       And current_negotiation(T: Trader, X: Integer, L: Commodity_List)
       And current_round(X: Integer)
       And others_bid_utility_in_round(U: Real, X: Integer)
       And cut_off_value(C: Real)
       And U: Real < C: Real
       And random(0, 1, S: Real)
       And 0.5 < S: Real * (F: Real + 0.5)
     Then stop_negotiation(T: Trader, X: Integer, L: Commodity_List, gap);
```

The lower the impatience factor, the higher the probability that the trader will stop the negotiation if progress is slow:

```
(3)  If impatience_factor(F: Real)
       And current_negotiation(T: Trader, X: Integer, L: Commodity_List)
       And current_round(X: Integer)
       And progress_in_bids(X: Integer – 3, X: Integer, P: Real)
       And minimal_progress_value(M: Real)
       And P: real < M: Real
       And random(0, 1, S: Real)
       And 0.5 < S: Real * (1.5 - F: Real)
     Then stop_negotiation(T: Trader, X: Integer, L: Commodity_List, no_accom);
```

Rule 4 is an example of using a random factor to obtain more natural behavior. The rule updates the acceptability of the negotiation partner. The impatience factor influences the decision whether or not a change is made. If a decision is made for change, the size of the change depends on the change factor, which is part of the agent's personality profile.

```
(4)  If stop_negotiation(T: Trader, X: Integer, L: Commodity_List, gap)
       And impatience_factor(F: Real)
       And acceptability(T: Trader, R: Real)
       And change_factor(B: Real, big_change)
       And random(0, 1, S: Real)
       And 0.5 < S: Real * (F: Real + 0.5)
     Then new_acceptability(T: Trader, R: Real * B: Real) ;
```

Rule 5 describes the effect of a negotiation in which the other partner did not accommodate our trader. The smaller the impatience factor, the more the acceptability will decrease; the bigger the impatience factor, the more the acceptability will increase (see rule 1 for the relation of impatience with culture and personality). The turning point is at 0.5 at which no change occurs. Normalisation functions can be added to maintain the acceptability value between 0 and 1, however, they are left out for reasons of transparency.

```
(5)  If stop_negotiation(T: Trader, X: Integer, L: Commodity_List, no_accom)
       And impatience_factor(F: Real)
       And acceptability(T: Trader, R: Real)
     Then new_acceptability(T: Trader, R: Real * (F: Real + 0.5) );
```

A buyer that is rather performance oriented will almost always trace the deal. Other aspects that play a role are his personality profile (for this example, only risk-attidude is taken into account) and the trustworthiness of the other party. Notice, that for a performance oriented trader the issue of trust is not that important as it is for cooperation oriented traders. The changes he makes to partner's trustworthiness are small, thus impact of trust on the next item is related to his initial trust in people. For the cooperation oriented trader, trust is important. Thus, for the cooperation oriented trader, the trust he has in others has a higher impact on his decision to trace or not.

```
(6)  If cultural_script_contains(pc_orientation(F: Real))
       And deal_in_round(T: Trader, B: Bid, X: Integer)
       And my_role(buyer)
       And personality_factor(risk_attitude, I: Real)
       And trustworthiness(T: Trader, H: Real)
       And random(0, 1, S: Real)
       And 0.5 < S: Real * (F: Real – H: Real – I: Real + 1.5)
     Then to_be_traced(B: Bid);
```

Rules 7-10 model the opposite effects of the negotiation length on performance oriented and cooperation oriented traders. The p-round boundary used in rule 7 is the number of rounds that a performance oriented trader typically allows before cutting off. The c-round boundary is the number of rounds a cooperation oriented trader would minimally prefer in negotiation with a trader he has no experience with. The p-round boundary could, for example, be set to 2 and the c-round boundary to 5.

```
(7)  /* performance oriented trader appreciates a fast deal */
     If deal_in_round(T: Trader, B: Bid, X: Integer)
       And impatience_factor(F: Real)
       And p_round_boundary(A: Integer)
       And F: Real > 0.5
       And X: Integer ≤ A: Integer
       And change_factor(I: Real, big_change)
       And acceptability(T: Trader, R: Real)
     Then new_acceptability(T: Trader, R: Real * I: Real * (F: Real + 0.5) );

(8)  /* performance oriented trader dislikes long negotiation */
     If deal_in_round(T: Trader, B: Bid, X: Integer)
       And impatience_factor(F: Real)
       And F: Real > 0.5
       And change_factor(D: Real, big_change)
       And p_round_boundary(A: Integer)
       And X: Integer > A: Integer
       And acceptability(T: Trader, R: Real)
     Then new_acceptability(T: Trader, R: Real * D: Real);
```

A cooperation oriented trader appreciates a first long negotiation, even if it ends without a deal. To get a big increment, given change factors between 0 and 1, the change factor is mirrored in the line x=1, thus the factor 2 – I: Real.

```
(9)  If stop_negotiation(T: Trader, B: Bid, X: Integer, W: Reason)
       And number_of_earlier_negotiations_with(0, T: Trader)
       And not W: Reason = no_accom
       And impatience_factor(F: Real)
       And F: Real < 0.5
       And acceptability(T: Trader, H: Real)
       And change_factor(I: Real, big_change)
       And c_round_boundary(A: Integer)
       And X: Integer > A: Integer
     Then new_acceptability(T: Trader, H: Real * (2 - I: Real) );
```

A cooperation oriented trader dislikes a first short negotiation, even if it ended in a deal. Note that earlier rules can intensify this effect if during the negotiation the other party made no accommodations in his direction.

```
(10) If stop_negotiation(T: Trader, B: Bid, X: Integer, W: Reason)
       And number_of_earlier_negotiations_with(0, T: Trader)
       And impatience_factor(F: Real)
       And F: Real < 0.5
       And change_factor(D: Real, big_change)
       And c_round_boundary(A: Integer)
       And X: Integer < A: Integer
       And acceptability(T: Trader, H: Real)
     Then new_acceptability(T: Trader, H: Real * I: Real);
```

The trader compares different negotiation options as offered by other traders. These offers can be made to him on the initiative of the other trader, or on his request.

```
(11) If offered(T: Trader, X: Integer, L: Commodity_List)
       And my_wish_list(L': Commodity_List)
       And subset_of(L: Commodity_List, L': Commodity_List)
     Then possible_negotiation_with(T: Trader, X: Integer, L: Commodity_List);
```

Traders choose their trade partners on the basis of their acceptability value. As can be seen from the rules above, the performance oriented trader directly updates the acceptability value in many of these rules. The cooperation oriented trader decides mostly on trust, and only slightly updates the acceptability value directly. However, the cooperation oriented trader also chooses a trade partner on the basis of the acceptability values. In general, the acceptability value of a trade partner is an accumulation of several factors: effects as described by the rules above, personality traits, and other cultural dimensions. In this paper the only aspect modelled is the following. For the cooperation oriented trader the trustworthiness of the partner has a higher impact on the computated value of acceptability than for the performance oriented trader. Furthermore, the acceptability value used to determine new trade partners is recalculated after all negotiations have finished.

```
(12) If cultural_script_contains(pc_orientation(F: Real))
       And no_ongoing_negotiations
       And acceptability(T: Trader, R: Real)
       And trustworthiness(T: Trader, H: Real)
     Then new_acceptability(T: Trader, F: Real * R: Real + (1 – F: Real) * H:Real);
```

Application of the Model in the Trust and Tracing Game

Consider a performance oriented buyer P (pc_orientation 0.9) and cooperation oriented seller C (pc_orientation 0.1). The traders meet each other for the first time and start a negotiation about 1 envelope. Both traders have in mind to trade for a price of about 10 euro. The (relevant parts of the) profiles for the players are:

	Player C	Player P
Minimum utility	0.7	0.7
Personality factor impatience	0.4	0.6
Impatience factor	0.09	0.99
Cut off value	0.07	0.63
Minimal progress	0.1	0.01

In the first round P offers 9 euro for a high quality red commodity, and C replies with a bid including 16 euro and high quality. The utility of C's bid in the eyes of P is 0.6, which is below the cut-off value of 0.7. Now P has to decide whether he will continue or stop. Let us assume that P decides to continue (only rule 2 would apply, but assume the random factor determines otherwise), and bids 9 euro in the second round for high quality. C responds with 14 euro for high quality (none of the stopping rules apply). The utility is 0.62 which is again below P's cut-off value. We assume that P decides to continue the negotiation again (assume rule 2 randomly discarded), and he offers 10 for high quality in the third round. C continues and responds with 12 euro and low quality. P's utility for that bid is 0.5, again below his cut-off value. We assume that this time P decides to stop the negotiation (rule 2). P evaluates the process using the "gap" rule (4), and considerably lowers the acceptability of C. C uses the "no_accom" rule (5) and considerably lowers the acceptability of P. A shame because the prices they had in mind allowed for reaching a deal, but this behaviour is in conformity with the culture scripts.

Conclusion

Trade situations in the real world can be better understood by taking into account the cultural background of the traders. Concepts like trust and honesty do not mean the same in different cultures, nor do practical aspects such as cheating, negotiation time and good relationships. To be able to model and test agents with culture scripts a comparable data set from real world trade is needed. The Trust and Tracing game provides a conceptualisation of trust in a well-defined laboratory trade environment to compare artificial agent behaviour with.

This case study models one of the culture dimensions of Hofstede, that of cooperation-orientation versus performance orientation. This dimension is obviously related to the meaning of trust. Although singling out one dimension is a deliberate distortion of reality, there is a look-alike real-world case. American and Dutch cultures are alike on all dimensions but this one and thus provide a good analogy.

The culture scripts of performance and cooperation oriented agents presented use the four ways in which a culture manifests itself: culture filters observation, culture sets norms for what constitutes an appropriate partner or offer, it sets expectations for the context of the transactions, and it sets norms for the kind of action that is appropriate given the other three.

This paper advocates the incorporation of culture scripts in the modelling of trade and associated aspects such as trust. As an example, the paper presents a model of the effects of the Cooperation-Performance orientation index of the culture scripts in the models of trustworthiness and acceptability of trade partners in negotiation settings. An application of the model to an extreme setting of performance orientated versus cooperation oriented traders shows the expected behaviour as sketched in Section 2.

Future research should test our scripts against data from human games to validate the approach and find plausible values for the parameters in the models. Then the model can be extended to take into account other dimensions of culture as well, increasing validity.

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Appendix A. Additional Parts of the Formal Specification

If a trader feels he has no more room to accommodate the other party, then he will stop the negotiations.

```
(13) /* stop: no more room */
     If current_negotiation(T: Trader, X: Integer, L: Commodity_List)
       And current_round(X: Integer)
       And my_bid_utility_in_round(U: Real, X: Integer -1)
       And minimum_utility(M: Real)
       And U: Real - M: Real < 0.01
     Then stop_negotiation(T: Trader, X: Integer, L: Commodity_List, no_more_room);
```

If the trader has decided to stop the negotiation because his minimal utility was reached, then he also checks the progress made during the whole negotiation process. Apparently, the negotiation originally did not stop for this reason, so this rule only affects the acceptability and trustworthiness once.

```
(14) If stop_negotiation(T: Trader, X: Integer, L: Commodity_List, no_more_room)
       And progress_in_bids(1, X: Integer, P: Real)
       And minimal_progress_value(M: Real)
       And P: real < M: Real
     Then stop_negotiation(T: Trader, X: Integer, L: Commodity_List, no_accom);
```

In negotiations the trader can accept the current bid of the other party if the utilities (according to his own function) of that bid and his own last bid are close enough. This notion of close enough is formalised by the acceptable_utility_gap.

```
(15) If current_negotiation(T: Trader, X: Integer, L: Commodity_List)
        And current_round(X: Integer)
        And others_bid_utility_in_round(U: Real, X: Integer)
        And my_bid_utility_in_round(U': Real, X: Integer)
        And acceptable_utility_gap(R: Real)
        And | U: Real – U': Real | ≤ R: Real
     Then stop_negotiation(T: Trader, X: Integer, accept_offer);

(16) If current_negotiation(T: Trader, X: Integer, L: Commodity_List)
        And current_round(X: Integer)
        And other_accepted_my_bid_in_round(T: Trader, B: Bid, X: Integer)
     Then stop_negotiation(T: Trader, X: Integer, my_offer_accepted)
        And deal_in_round(T: Trader, B: Bid, X: Integer);

(17) If stop_negotiation(T: Trader, X: Integer, accept_offer)
        And other_bid_in_round(B: Bid, X: Integer)
     Then deal_in_round(T: Trader, B: Bid, X: Integer);
```

Once the acceptability of the traders is determined, and the current negotiations have all stopped, new trade partners can be identified.

```
(18) If no_ongoing_negotiations
        And acceptability(T: Trader, R: Real)
        And acceptability(T': Trader, R': Real)
        And R: Real > R': Real
     Then more_acceptable_with_diff(T: Trader, T': Trader, |R: Real – R': Real| );

(19) If no_ongoing_negotiations
        And acceptability(T: Trader, R: Real)
        And acceptability(T': Trader, R': Real)
        And R: Real < R': Real
     Then more_acceptable_with_diff(T': Trader, T: Trader, |R: Real – R': Real| );

(20) If no_ongoing_negotiations
        And possible_negotiation_with(T: Trader, X: Integer, L: Commodity_List)
        And possible_negotiation_with(T': Trader, X': Integer, L': Commodity_List)
        And more_acceptable_with_diff(T: Trader, T': Trader, R: Real)
        And allowed_acceptability_difference(Epsilon: Real)
        And R: Real > Epsilon: Real
     Then to_be_ignored(T': Trader, X': Integer, L': Commodity_List);

(21) If no_ongoing_negotiations
        And preferred_relative_deal_size(F: Real)
        And max_deal_size(M: Integer)
        And P: Real = M: Integer * F: Real
        And possible_negotiation_with(T: Trader, X: Integer, L: Commodity_List)
        And possible_negotiation_with(T': Trader, X': Integer, L': Commodity_List)
        And | X: Integer – P: Real | < | X': Integer – P: Real|
        And acceptability_difference(T: Trader, T': Trader, R: Real)
        And allowed_acceptability_difference(Epsilon: Real)
        And R: Real < Epsilon: Real
     Then to_be_ignored(T': Trader, X': Integer, L': Commodity_List);
```

5 Individualism and Collectivism in Trade Agents

Abstract. Agent-Based Modeling can contribute to the understanding of international trade processes. Models for the effects of culture and cultural differences on agent behavior are required for realistic agent-based simulation of international trade. This paper makes a step toward modeling of culture in agents. The focus is one of the five dimensions of culture according to Hofstede: individualism versus collectivism. The paper presents an analysis based on social science literature about national cultures. For cultural differentiation of agent behavior, rules are formulated for individualist versus collectivist agent behavior with respect to negotiations, cooperation or defection in the delivery phase of transactions, trade partner selection, and trust. Example computations demonstrate the feasibility in multi-agent simulations.

Introduction

Agent-Based Economics (ABE) studies economic processes as interactions of individual actors [1]. Cultural differences are known to have their effects on international business interactions and on trust between business partners [2]. Gorobets and Nooteboom [3] argue on the basis of a multi-agent simulation that different economic systems could be viable in societies with different levels of trust. Models of culture-bound agents will advance the understanding through ABE of intercultural trade processes as well as differences in trade processes across cultures.

Culture has different aspects or dimensions [4]. The current paper focuses on the widely recognized distinction between individualistic and collectivistic cultures. Section 2 presents this distinction as it is described in the social sciences. Section 3 analyzes its effect on trade processes as the basis for the formal modeling in section 4. Section 5 presents example computations. The results and future directions of this research are discussed in section 6.

The cultural dimension of individualism and collectivism

People are gregarious by nature. But the life conditions of societies vary, and they have adapted accordingly. Hunter-gatherers live in small bands, usually consisting of a few nuclear families. In agricultural societies, larger units have developed, and the people may live in extended families or clans. This is still the default model of social organization in most of the world, although it is being put under strain by urbanization. In modern, affluent industrial societies people tend to revert to nuclear families. The variation in basic group size and cohesion between societies has been shown by sociologists, e.g., in the distinction between *Gemeinschaft* (community) and *Gesellschaft* (society) that Tönnies introduced as early as 1887 [5]. In a *Gemeinschaft*, people share everything, both material and immaterial, whereas in a *Gesellschaft,* private property and other individual-centered institutions are possible. This variation has been confirmed by social psychological cross-national studies of practices or values, for instance the work of Triandis [6] and Hofstede [4]. These authors speak of the distinction between *individualism* and *collectivism* that serves as this section's caption. Another independent confirmation comes from the World Values Survey by political scientist Inglehart and colleagues. Minkov [7] showed that the individualist – collectivist continuum is visible in Inglehart's survey data. He names it universalism versus exclusionism.

Recently the dimension has also become the main ingredient of theories about cross-cultural business, e.g., in the work of Trompenaars [8] who posits a number of dimensions of culture that were shown by Smith *et al.* [9] to be correlated with the dimension of individualism versus collectivism. Trompenaars' dimensions relate to individual versus community, universalist versus particularist reasoning, affective versus neutral emotional style, specific versus diffuse communication, performance versus ascription, sequential versus synchronous time use, and control versus acceptance of nature, each mentioned in the same direction of the individualism – collectivism continuum. The relevance of this particular dimension of culture to the management literature lies in the fact that Anglo countries are at the extreme individualist end of the scale, and so business partners from almost any country they try to do business with are bound to have more collectivist cultures.

Variation along the dimension of collectivism versus individualism also affects value systems and the functioning of institutions aside from the family, such as education, religion, politics and trade. Hofstede [4] incorporates a host of other studies that confirm the occurrence of the dimension and its relevance to many societal phenomena. These include the kind of processes that occur in trade relations: whether to show one's cards or not, whether to confront the other party or not, how to distribute favors, and the like. Table 1 shows typical distinctions, relevant for trade.

Table 1. Some distinctions between norms in collectivistic and individualistic societies [4]

Collectivistic	**Individualistic**
Maintain harmony, avoid confrontation	Speak your mind
High-context, implicit communication	Low-context, explicit communication
Use the word "we"	Use the word "I"
Show favor to in-group customers	Treat all customers equally
No business without a personal relation	Task is more important than a good relation
A relation brings rights and obligations	Mutual advantage is the basis of relations
Relations are given	Build and maintain relations actively
Save face for in-group	Keep self-respect
Responsible for group interests	Responsible for personal interests

One typical distinction between individualist and collectivist practices is that to collectivist mindsets, relations are more important than business – and so, business tends to be done among friends and family, in contexts that to individualistic mindsets do not seem fit for business. In an individualistic society there tends to be a strict separation between various spheres of life, e.g., family, business, and leisure. In a collectivistic society, one tends to do all of these things with the same extended group of people. The term “in-group” is often used to denote this kind of self-evident unit of social life at large as it exists in collectivist societies. Finding new trading partners and establishing a working relationship with them, is not easy in these societies. The usual way is to use existing business relationships. In the very collectivist Chinese culture, the term *guanxi* denotes the social network that allows extending business contacts [10]. The term consists of two Chinese characters: *guan* (gate) and *xi* (connection). In individualistic societies a roughly equivalent notion is *social capital*.

Individualism is associated with direct, low-context communication while collectivism is associated with indirect, roundabout, high-context communication. In psychological terms, people from individualistic societies are on average more extraverted. This was indeed found by Hofstede and McCrae [11].

According to Hofstede and Hofstede [12] the world’s countries have a wide continuum of scores on the dimension. The rough pattern, exceptions omitted, is as follows: at the collectivist end of the scale we find Central America, Pakistan, Indonesia, and the South East Asian tigers with China. Moderately collectivistic are Latin America, Africa, Latin and Balkan Europe. Moderately individualistic are India, Arab countries, and Central Europe. Individualistic are West- and North Europe. The most individualistic countries of all are those of the Anglo world. Importantly, Hofstede’s own data as well as replications show that countries’ orientation on this dimensions shift towards more extreme individualism with increases in wealth, and towards more collectivist values with increasing poverty. Individualism can thus be interpreted as an adaptation to wealth. Yet the dependency is not complete. There exist cultures that remain rather collectivist despite wealth, such as Japan, or rather individualist despite poverty, such as India.

Individualism and Collectivism in Trade Processes

Figure 1 presents a model of trade processes. This model is based on the Trust and Tracing game [13], a human gaming simulation of supply chain processes. The participants negotiate contracts about commodities with invisible quality attributes. Before entering negotiations, agents have to select each other as partners, based on their trade goals (sell or buy?; which commodity?; which quality?) and knowledge about potential partners. Once a contract has been agreed upon, traders can either cooperate (deliver truthfully) or try and use an opportunity to defect. Upon delivery the receiver can either trust or put the delivery to the test, the latter usually at some cost where trust is for free. The delivery and trust decisions are based on personal preferences and cultural background, as well as beliefs about the trade partner and the trade environment. In future research the Trust and Tracing game trading game can serve as an instrument to validate the models presented in this paper.

Experience from negotiation and delivery processes may change a trader’s beliefs. In this paper we limit ourselves to beliefs about trade partners. We distinguish three beliefs. The belief about another agent’s *fairness* represents an agent’s expectation that a fair contract can be negotiated. The belief about another agent’s *trustworthiness* represents an agent’s expectation that the other will cooperate. The belief about *benevolence* represents an agent’s expectation that the other will trust.

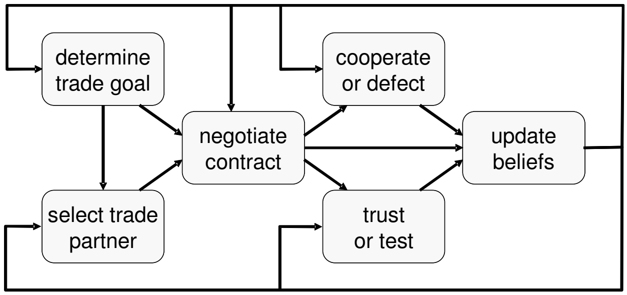

Fig. 1. Processes and internal information flows of trading agents.

Table 1 in the previous section displays relevant distinctions for trade between individualistic and collectivistic societies. The remainder of this section analyses the effects of this dimension of culture on the trade processes depicted in Figure 1.

Negotiation behavior. To a collectivist mindset, negotiation has to be preceded by the formation of a relationship. If that goes wrong there will be no negotiation. During the negotiation, collectivist traders discriminate between in-group and out-group partners. They feel obliged to be more modest (or realistic, following their in-group's rules) in their first proposal to an in-group partner, are more hesitant to break off negotiations with in-group partners, and will try to maintain harmony as long as the opponent follows the in-group rules. When doing business with individualist traders the collectivists may be shocked by their opponent's explicit communication. Breaking the rules asks for a reaction. The style of that reaction may be furious, or they might never explicitly say anything, but just avoid the other from now on.

The first reply to a new proposal from an in-group partner will be modest, but there is no need to be modest to an out-group partner. If an out-group partner replies with no or small concession, negotiation is likely to be broken off, where an in-group partner or an acquainted relation would get a second chance.

In a collectivist mind the responsibility for in-group welfare and the compliance with in-group rules always play a prominent role. A collectivist will accept benefits for his in-group rather than his personal advantage as a convincing argument. Individualists have one thing in mind during negotiations: their own personal interest. This might be the material advantage of the deal in question, or the development of new trust relations with perspectives of future deals, or just the pleasant conversation during the negotiations, or the satisfaction of winning the game, but one thing stands for sure: individualists only pursue private interests. So individualist traders are not very modest in their negotiations, nor will they give in for the purpose of maintaining harmony. If they are not aware of the cultural differences when trading with collectivists, they may be upset by the lack of explicit communication, or they may upset their opponents by being too explicit, or by talking business before the relationship has been established and acknowledged. They are not particularly patient or impatient negotiators, but behave patiently as long as it serves their interest.

Truthful or untruthful delivery. After an agreement has been reached, it comes to delivery. Traders can defect or cooperate in this phase. For instance, if the quality of the commodity is invisible at first sight, a supplier can be opportunistic and try to deliver a lower quality product than agreed upon. By doing so, in both collectivist and individualist societies deceivers takes the risk of serious damage to the relation with their partner if the deceit be revealed. However, in collectivist societies there is the extra sanction of shame, so there is damage to the relations with other possible customers as well. Furthermore, the shame will not be restricted to the deceiver, but will hit his relatives, friends, and business associates too. Therefore, a collectivistic supplier takes extra care not to deceive in-group business partners.

In collectivist societies the thresholds for opportunistic behavior, trust and forgiveness are based on group memberships and norms. In individualist societies these properties are based on personal relations and the personal interests in these relations. Traders in individualist societies do not have to fear the social sanctioning system in case their opportunistic behavior is revealed. For individualist traders, decisions to deceive, to trust, and to forgive are motivated by personal interest in the relation, be it in the framework of the current transaction or in the long run. Their personal relations represent their social capital.

Trust or Distrust. Being aware of the sanctioning mechanisms in case of deceit, and for the sake of maintaining harmony, traders in collectivist societies show trust toward in-group suppliers. Following the rules of their societies, and trying to maintain harmony, they also tend to show trust toward out-group partners when they have had long lasting relations. Not being trusted by a business partner puts pressure on the perceived relation. Especially in collectivist societies, showing distrust does serious damage to relations.

Individual trust is more relevant in individualist societies than it is in collectivist societies. Group membership is the main item for collectivist traders, individual relations are the main item for individualist traders. In individualist societies, customers cannot rely on social sanctioning systems, so they depend on their personal judgment and will be more careful to trust. Although suppliers in individualist societies do not like to be distrusted, they will more easily accept a trade partner tracing their trustworthiness than collectivist suppliers.

Maintenance of Beliefs about Partners. The acceptability of trade partners and the estimate of their trustworthiness are primarily based on group membership in collectivist societies. In addition, and for individualist societies in particular, the experience of previous deals counts, be it personal experience or the experience of others (reputation). For both individualists and collectivists, negotiations resulting in an agreement increase the partner's acceptability, and failing negotiations decrease it. The weight of reputation compared to personal experience is stronger in collectivist societies than it is in individualist societies.

The individualism dimension of culture does not influence the extent to which negotiation success influences the belief about a partner's trustworthiness. However, the negative effect of revealed deceit is stronger in collectivist societies than it is individualist societies. Whenever deceit by out-group suppliers is revealed, collectivists will be unforgiving toward the deceivers and the groups they belong to. The deceived and their relations will exclude the deceivers and their relations from business for some time.

For an individualist trader, partner's acceptability after revealed deceit will be determined by future interests, but of course the estimate of partner's trustworthiness is decreased.

Partner selection. The question "whom do I deal with?" is important for collectivist traders. They prefer to do business with in-group members, or will have to familiarize with out-group trade partners before doing business. Business is only possible if some personal relation exists. With respect to out-group relations the traders benefit from information exchange in the in-group. On the other hand they are accountable to their in-group for their out-group relations. Questionable relations weaken their position. Collectivist traders do not take the initiative to propose to others than in-group members and existing business relations. Upon a proposal made by a previously unknown counterparty, a collectivist trader will only respond if the proposal is framed in a socially acceptable way, for instance introduced through a common relation.

Individualist traders feel free to enter into negotiations on the basis of new proposals and take the initiative to propose to new partners. Taking initiatives and starting new business in one's own interest is respected in individualist societies, but on the other hand individualists will value personal trust relations, as these relations represent the social capital that they acquired by investments, and that is not given to them like in collectivist societies. When entering into negotiations with new partners, individualists do not like proposals that appeal to common group membership. An individualist trader proposing business to a collectivist trader may be surprised by the refusal of the other, not realizing that business is only possible after an introduction by a common relation, or some other way to get familiarized before explicitly considering business proposals.

Representation in Agents

Building on the analysis in section 3, the present section formalizes rules for culture dependent agent behavior in trade, with respect to the individualism dimension.

Simulation of the negotiation process follows the negotiation architecture of Jonker and Treur [14]. The architecture defines negotiation processes in terms of utility functions, and parameters of the negotiation process: negotiation speed, impatience factor, allowable gap between own bid and partner's bid, concession factor, configuration tolerance, and some parameters for financial aspects.

Impatience is modeled as the likelihood that an agent will break off negotiations if the utility of a partner's bid is below the critical cut-off value or if the partner makes not enough progress. The first two rules express that impatience is moderated by common group membership and trust relations, relative to the extent that an agent is collectivist. All real valued parameters are normalized in the interval [0, 1]. Finally, the rules apply to sellers – for buyers replace benevolence with trustworthiness.

```
/* 1 have patience if in-group partners make unrealistic bids */
if cultural_script_contains(individualism_index(I: Real))
   and current_negotiation(C: Trader, X: Integer, L: Commodity_list)
   and current_round(X)
   and partner_model_contains_belief(C, group_distance, D: Real)
   and partner_model_contains_belief(C, benevolence, B: Real)
   and agent_trait_value(impatience, P: Real)
   and agent_trait_value(cut_off_value, M: Real)
   and others_bid_utility_in_round(U: Real, X)
   and U < M
   and random(0, 1, Z: Real)
   and P * (1 - (1-I)*max(1-D,B)) * 0.5 > Z
then stop_negotiation(C, X, L, gap);

/* 2 have patience if in-group partners make little concessions */
if cultural_script_contains(individualism_index(I: Real))
   and current_negotiation(C: Trader, X: Integer, L: Commodity_list)
   and current_round(X)
   and X > 3
   and partner_model_contains_belief(C: Trader, group_distance, D: Real)
   and partner_model_contains_belief(C: Trader, benevolence, B: Real)
   and agent_trait_value(impatience, P: Real)
   and agent_trait_value(minimal_progress, M: Real)
   and progress_in_bids(X-3, X, N: Real)
   and N < M
   and random(0, 1, Z: Real)
   and P * (1 - (1-I)*max(1-D,B)) * 0.5 > Z
then stop_negotiation(C, X, L, no_accommodation);
```

The minimum utility that an agent will accept depends on the concession factor. The following rule expresses that collectivists give less negotiation room to strangers.

```
/* 3 collectivist agents are indulgent only to in-group partners */
if cultural_script_contains(individualism_index(I: Real))
   and current_negotiation(C: Trader, X: Integer, L: Commodity_list)
   and partner_model_contains_belief(C, group_distance, D: Real)
   and partner_model_contains_belief(C, benevolence, B: Real)
   and agent_trait_value(concession_factor, F: Real)
then minimum_utility (1-F*(I + (1-I)*max(1-D,B)));
```

Deceit occurs in both collectivist and individualist societies, but for collectivistic agents, the threshold to deceive depends on group distance. The following rule only models the influence of group distance. In the eventual decision to deceive or not, other factors - such as personal relations - play a role as well, but we do not model these factors to depend on individualism versus collectivism.

```
/* 4 collectivist agents: opportunism increases with group distance */
if cultural_script_contains(individualism_index(I: Real))
   and current_negotiation(C: Trader, X: Integer, L: Commodity_list)
   and partner_model_contains_belief(C, group_distance, D: Real)
   and agent_trait_value(honesty, H: Real)
then deceit_treshold( H*(1-(1-I)*D) );
```

When a deal has been closed, the agents have to decide whether to trust the delivery or to put it to the test (*trace* it). In both types of societies, the decision is based on the personal trust relation between agents. Agents are less likely to trace as trust increases. However, in collectivist societies tracing in-group members is even less likely done. The decision is modeled as follows in the simulation agents.

```
/* 5 collectivist agents hesitate to trace in-group partners */
if deal_in_round(C: Trader, B: Bid, X: Integer)
   and current_round(X)
   and cultural_script_contains(individualism_index(I: Real))
   and partner_model_contains_belief(C, group_distance, D: Real)
   and partner_model_contains_belief(C: Trader, trustworthiness, T: Real)
   and random (0, 1, Z: Real)
   and (1-T)*(I+(1-I)*D) > Z
then to_be_traced(B: Bid);
```

The beliefs about partner's trustworthiness and benevolence are updated in the simulation, using the experience based trust update function

$$t_{C,x} = (1-\delta^+)t_{C,x-1} + \delta^+ e_{C,x}\ ,\ \text{ if } e_{C,x} > t_{C,x-1}\ ,$$
$$t_{C,x} = (1-\delta^-)t_{C,x-1} + \delta^- e_{C,x}\ ,\ \text{ if } e_{C,x} \le t_{C,x-1}\ . \quad \textbf{(1)}$$

$t_{C,x}$ represents the new value of an agent's trust in partner C, $t_{C,x-1}$ represents the value before the last experience, and $e_{C,x}$ represents the value of the last experience. δ^+ and δ^- are in the interval (0,1) , and $\delta^+ = \varepsilon\delta^-$, with $0 < \varepsilon < 1$: a negative experience has more impact than a positive one. The value of the endowment coefficient ε is a personal trait. It will usually be closer to 1 in individualist societies than in collectivist societies, as individualists expect more opportunism and distrust.

```
/* 6 the endowment effect is stronger in collectivist societies */
if cultural_script_contains (individualism_index(I: Real))
   and agent_trait_value(base_endowment_coefficient, E: Real)
   and agent_trait_value(collectivist_endowment_coefficient, F: Real)
then agent_trait_value (endowment_coefficient, E*I + F*(1-I) );
```

After a negotiation the fairness belief is updated in a similar way as trust is. In case of a successful negotiation, the utility of the deal is taken as experience value. If the negotiation is broken off without a deal, the experience value equals 0.

Update information originates from own experience or shared information (reputation). The experience value equals 0 in case of revealed deceit, 1 otherwise. For shared information, which is especially important for collectivist agents, δ^+ and δ^- are multiplied by the maximum of the information source's believed trustworthiness and (1-individualism_index)(1-group_distance) of the source.

The following is an example of an update rule for partner beliefs.

```
/* 7 process shared information for positive experience */
if info_from_about(S: Trader, C: trader, R: Trait, V: Real)
   and cultural_script_contains(individualism_index(I: Real))
   and partner_model_contains_belief(S, group_distance, D: Real)
   and partner_model_contains_belief(S, trustworthiness, T: Real)
   and partner_model_contains_belief(C, R, Z: Real)
   and agent_trait_value(base_negative_update_factor, U: Real)
   and agent_trait_value(endowment_coefficient, E: Real)
```

```
      and V > Z
      and P = E * U * max(T,(1-I)*(1-D))
   then modify_partner_belief_in_round_source(C, R, (1-P)*Z + P*V , X, S);
```

The following rule expresses the acceptability of another agent as partner for future deals. An agent tries and selects the most acceptable partner that is available for the next negotiation, i.e., not currently negotiating with another agent.

```
/* 8 collectivists: relations are important for partner selection */
if cultural_script_contains(individualism_index(I: Real))
   and partner_model_contains_belief(C: Trader, group_distance, D: Real)
   and partner_model_contains_belief(C: Trader, benevolence, B: Real)
   and partner_model_contains_belief(C: Trader, fairness, F: Real)
then acceptability (C, I*F + (1-I)*max(1-D,B) );
```

Simulation examples

Table 2 presents results of multi-agent simulations of trade in populations of 8 suppliers and 8 customers. The agents apply the rules presented in section 4.

Simulations in populations with collectivist agents belonging to different groups typically show the distribution of run **1** in Table 2: in-group trade. Individualist agents rapidly develop networks of preferred relations, on which they trade very efficiently. In mixed settings like run **2**, the individualists develop the same pattern, but collectivist agents stick to their in-group trade. However, in run **3** where no in-group partners are available, the collectivist agents develop the individual relations pattern. Group *C* agents can find in-group partners in run **4** and show the collectivist pattern, while the other collectivist agents develop the individual relations pattern.

Table 2. Number of successful transactions in simultations with 8 suppliers and 8 customers.

1. Customers		collectivist gr *A*				collectivist gr *B*			
Suppliers		C1	C2	C3	C4	C5	C6	C7	C8
collectivist group *A*	S1	9	7	5	3	0	0	0	0
	S2	3	8	9	3	1	0	0	0
	S3	5	6	5	4	0	0	0	0
	S4	2	3	5	11	0	0	0	0
collectivist group *B*	S5	0	0	0	0	4	5	5	4
	S6	0	0	0	0	6	6	5	5
	S7	0	0	0	0	8	4	6	6
	S8	0	0	0	0	8	7	8	9

2. Customers		individualist				collectivist gr *A*			
Suppliers		C1	C2	C3	C4	C5	C6	C7	C8
individualist	S1	3	2	24	0	0	0	0	0
	S2	1	0	0	12	0	1	0	1
	S3	0	16	1	2	0	0	0	0
	S4	14	2	0	7	0	0	0	0
collectivist group *A*	S5	0	0	0	0	5	6	6	6
	S6	0	0	0	0	8	3	5	6
	S7	0	0	0	0	5	7	5	8
	S8	0	1	0	0	8	7	5	4

3. Customers		individualist				collectivist gr *A*			
Suppliers		C1	C2	C3	C4	C5	C6	C7	C8
individualist	S1	1	25	1	0	0	0	0	0
	S2	9	1	0	5	1	0	3	6
	S3	0	0	2	0	0	0	9	4
	S4	2	0	0	1	15	3	5	0
collectivist group *B*	S5	1	0	0	0	0	20	0	0
	S6	0	1	1	17	0	0	4	0
	S7	5	0	4	0	1	0	1	9
	S8	1	0	18	0	1	0	1	1

4. Customers		collectivist gr *C*				collectivist gr *B*			
Suppliers		C1	C2	C3	C4	C5	C6	C7	C8
collectivist group *C*	S1	6	7	7	5	0	0	0	0
	S2	9	3	4	8	0	0	0	0
	S3	4	7	6	6	0	0	1	0
	S4	4	5	5	6	0	0	0	0
collectivist group *A*	S5	0	0	0	0	17	0	1	1
	S6	0	0	0	0	1	0	1	16
	S7	0	0	0	0	0	23	1	1
	S8	0	0	1	2	1	15	1	2

Conclusion

The experiments correspond to the hypotheses in that trade goes smoothly when all traders are collectivistic, and have group relations, or when all agents are individualists. In mixed settings where buyers and sellers can be either collectivistic or individualistic, collectivist traders end up trading with in-group partners.

The work presented in this paper shows that the approach to vary cultural dependent behavior in trade processes in simulations, leads to behavior that corresponds to human behavior in trade simulation games [13]. Therefore, the paper shows that agent-based simulation contributes to the understanding of international trade processes.

Future work is (1) to develop models and study the effects of Hofstede's other dimensions of culture, using the same approach, (2) to integrate the models for the separate dimensions, and (3) to validate the models in human experiments.

Applications of this work are (1) as a tool for research in supply chains and institutional economics, (2) for education and training in business schools and multinational corporations, and (3) negotiation support systems.

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6 Modeling Power Distance in Trade

Abstract. Agent-based computational economics studies the nature of economic processes by means of artificial agents that simulate human behavior. Human behavior is known to be scripted by cultural background. The processes of trade partner selection and negotiation work out differently in different communities. Different communities have different norms regarding trust and opportunism. These differences are relevant for processes studied in economics, especially for international trade. This paper takes Hofstede's model of national culture as a point of departure. It models the effects on trade processes of one of the five dimensions: power distance. It formulates rules for the behavior of artificial trading agents and presents a preliminary verification of the rules in a multi-agent simulation.

1 Introduction

Any experienced international traveler knows that economic transactions do not come to pass in the same way across cultures. Haggling, checking on quality, and style of negotiation vary considerably across the world.

In the quest to understand the mechanisms that underlie these differences this article adopts the approach of designing agent-based simulation models. It builds on [1], that describes the modeling of behavioral differences of participants in a human gaming simulation. The game gives players the choice to either trust their trade partners to live up to their promises, or to spend money, time, and relational assets to check (trace) them. In the game, differences are observed between players from different cultural backgrounds [2]. Generally negotiation - which is an essential process in trade - is recognized to develop differently in different cultural settings, see e.g. [3]. For electronically mediated negotiations, [4] reports considerable differences across countries with respect to expectations and process.

Negotiation relates to the pre-contract phase of economic transactions. Trust and opportunism predominantly relate to the post-contract phase: the delivery. [5] gives evidence that both trust and opportunism can be profitable in this phase. It suggests that in different societies self-sustaining systems of either trust or opportunism might prevail. [6] supports these findings: the extent to which people expect deceit and are likely to lie in business negotiations differs considerably across cultures.

The discipline of agent-based economics [7] recognizes that using artificial agents to simulate human behavior contributes to the understanding of economic processes. Models of cultural influences on behavior in searching, bargaining, monitoring, and enforcing contracts are essential for developing realistic agents that can help us understand the differentiation of economic systems and institutions across the world. The design of culturally scripted agents serves several purposes. First it is useful for research into the effects of culture in trade, as described in the previous paragraph.

Secondly, it can be used in education and training to make traders aware of cultural differences. Furthermore, the models can be used for developing negotiation support systems.

The approach taken by the authors is to make use of the widely used 5-dimension framework of Hofstede [8]. The present paper's research goal is to investigate the role of the cultural dimension of power distance as a determinant of trade processes and outcomes. We adopt the perspective of the trader that uses the endemic logic of a particular orientation on the power distance scale.

2 Power Distance and Trade

Can traders predict the behavior of potential partners depending on which part of the world these partners come from? Granting that each individual is unique, they can. For this, traders need knowledge about the socialization that the potential partners underwent in childhood, in other words about their culture. In many cases, nationality is a good predictor of the participants' basic values. For instance, business in China tends to be done over a meal, and observing social hierarchy during meals is important. In the Netherlands, business is done during working hours and little concern is given to the formal status of traders. This statement is inadequate for some Chinese and some Dutch traders but it is certainly more true than its opposite would be. The work of Hofstede [8, 9] characterizes these values in the form of five basic dimensions of social life that pertain to identity, power distance, gender roles, fear of the unknown, and long- vs short-term orientation.

The dimension of power distance is central in the present paper. Hofstede [8] defines power distance as the extent to which the less powerful accept and expect that power is distributed unequally. The dimension runs from egalitarian (*small power distance, e.g., in* Anglo, Germanic and Nordic cultures) to hierarchical (*large power distance,* in most other cultures; see table 1).

Table 1. Some distinctions between norms in hierarchical and egalitarian societies

Large power distance (hierarchical)	Small power distance (egalitarian)
Might is right	No privileges and status symbols
Formal speech; acknowledgement	Talk freely in any context
Dictate, obey	Negotiate
Show favor to mighty business partners	Treat all business partners equally

There are some pairs of countries in the Hofstede database that differ on power distance more than they do on other dimensions. They are Russia - Israel, Costa Rica - Guatemala, and France - Austria. Still it would not do to take subjects from these pairs of countries, have them negotiate, and attribute the results to difference in power distance. Besides cultural differences on other dimensions, differences in perceived identity, historical antecedents, personality factors and a host of other context factors have to be taken into account. By using software agents, these other contextual factors can be excluded and power distance can be isolated. However, simulation results will have to be interpreted as an abstraction that cannot be extrapolated to the real world without much caution. Isolating one dimension for the sake of experiment is a decidedly artificial method. In real life, the dimensions always operate as one whole, a cultural Gestalt, together with contextual factors. One of the contextual factors is personality: in any trade situation it matters what personalities the partners bring to the table. As it turns out personality and culture are not independent. In a meta-analysis of their mutual cross-country data Hofstede and McCrae [10] found that power distance correlates negatively with extraversion and openness to ideas and positively with conscientiousness.

In spite of the limitations of isolating a single dimension, we argue that the experiment is worthwhile carrying out. Empiric evidence for the relevance of the power distance dimension for negotiation processes is given in [3]. Furthermore, modeling the isolated dimensions can serve as a preparation for the more complicated integral modeling of culture's consequences for trade.

The core of trade is the execution of transactions: exchanging commodities or rights for money. Transactions are based on a contract that may specify additional conditions that enforce the delivery according to the contract. The contract is to be negotiated among the trade partners. Contracting is not the only relevant activity of trading agents, however. Fig. 1 presents an overview of relevant processes.

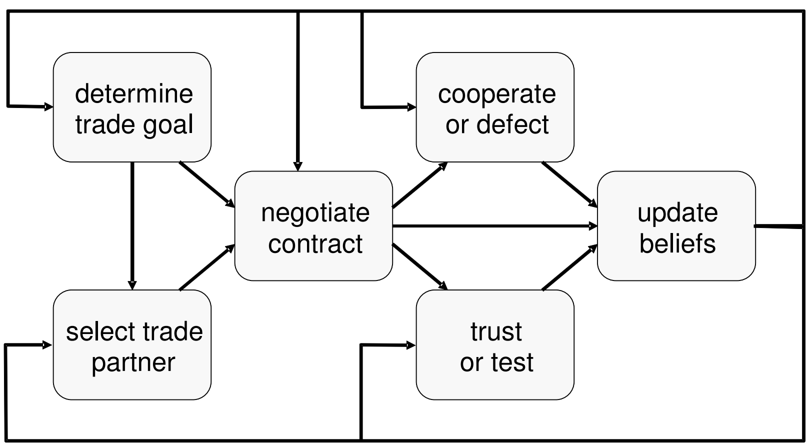

Fig. 1. Processes and internal information flow of a trading agent

Before entering negotiations, agents have to select each other as partners to negotiate with, based on their trade goals (sell or buy?; which commodity?; which quality?) and knowledge about potential partners. This information also plays an important role during the process of negotiation. Once a contract has been agreed upon, the traders can either cooperate (deliver truthfully) or try and use an opportunity to defect. Upon delivery the receiver can either trust or put the delivery to the test, the latter usually at some cost where trust is for free. The delivery and trust decisions are based on personal preferences and cultural background, as well as on beliefs about the trade partner and the trade environment. Experience from the negotiation and delivery processes may change a trader's beliefs about the trade environment or about individual trade partners.

The beliefs will, in addition to a trader's preferences, guide decision making in future trading. In this paper we limit ourselves to beliefs about trade partners. For this purpose three traits can be defined that trading agents maintain a belief about: fairness, trustworthiness, and benevolence. These beliefs are maintained for each trade partner. The belief about another agent's *fairness* represents an agent's expectation that a fair contract can be negotiated with the other agent. The belief about another agent's *trustworthiness* represents an agent's expectation that the other agent will deliver according to contract. The belief about another agent's *benevolence* represents the expectation that the other agent will accept deliveries without putting them to the test, in other words that the other agent will trust.

The power distance dimension has its effect on behavior in trade. The relevant issues are a trader's cultural background in a hierarchical or egalitarian society and the status or rank difference with its partner that an agent experiences against this cultural background. The following subsections specify the expected behavior with respect to these issues for each trade process.

Negotiation Behavior. Traders from small power distance cultures may have different ways to negotiate, but they will always negotiate. Traders from large power distance cultures on the other hand are not used to negotiating seriously. The powerful dictate the conditions. The less powerful have to accept. In cultures of large power distance that are also feminine or collectivistic the powerful may exercise restraint, or the lower ranked may successfully plead for compassion, but this is not a common decision making process, like a negotiation. The most powerful decides. When people from hierarchical cultures are forced to negotiate, because they are in a position of equal status or trade with foreigners, the negotiations often end in a game of power.

A trader from a culture with large power distance expects a lower ranked business partner to accept his conditions rapidly. If the lower ranked partner has the same cultural background, there is no problem and the rights of the higher ranked partner will be recognized and respected: the lower ranked opponent will be modest and give in easily. However, a trader from an egalitarian culture will not give in to the pressure if his status is lower, but will either react furiously (e.g., break off negotiations) or simply ignore the pressure (make a counterproposal), in which case the opponent will be furious (and e.g., break off negotiations).

If a trader from a culture with large power distance negotiates with a foreigner and assumes the foreigner to have a higher status, he may give in more easily than the foreigner expected. In that case the foreigner will be happy, but his opponent will have "left money on the table". If both are from hierarchical cultures but do not perceive one another's hierarchical position they may make misattributions resulting in one of them being dominated or stopping the negotiations.

Trade Goal Selection. Traders having a cultural background of small power distance opportunistically trade both low and high quality commodities and have a risk attitude that is not particularly influenced by power distance.

In hierarchical societies there are differences in selected trade strategy. The higher ranked prefer to trade high quality valuable commodities to underline their status that fits their position in life. They will not avoid deals where less powerful opponents technically have the opportunity to defect, because the higher ranked rely on their power to enforce cooperation.

The lower ranked have three incentives to prefer trade in low quality commodities in hierarchical societies. First, they know their place. Second, they are poor. Third, they may be cheated by high status opponents that make improper use of their power when trading valuable commodities; the lower ranked can avoid the risk of being deceived by trading commodities that have little appeal for higher ranked.

Maintenance of Beliefs about Partners. If counterparts have equal status, like in egalitarian societies, the experience of previous deals counts, be it personal experience or the experience of others (reputation). Failed negotiations decrease partner's future acceptability, and negotiations resulting in an agreement increase it for egalitarian traders.

In case of status difference in hierarchical societies, the acceptability of trade partners does not depend on experience in previous deals: the lower ranked have no choice but to accept business conditions and to show truthful and trusting behavior, whatever experience they have and whatever the reputations of their opponents are. So a lower ranked trader may have a belief about the fairness and trustworthiness of a higher ranked trader, but cannot show distrust. However, he may avoid a powerful trader that he believes to be unfair or untrustworthy... In a hierarchical society a trader of lower status forced into an adverse agreement by one of higher status will of course not find the opponent more acceptable afterwards, and try harder to avoid the opponent.

This cultural scripting may have its repercussions in intercultural trade. A lower ranked trader from a hierarchical culture might avoid a foreign trader if he assumed that his lower status did not allow him to negotiate successfully. A higher ranked trader from a hierarchical culture might overplay if he assumed that a foreigner would recognize his status and comply with his demands. An egalitarian trader who did not sufficiently respect the status of a hierarchical partner might fail to do business.

Truthful or Untruthful Delivery. After an agreement has been reached, it comes to delivery. If the quality of the commodity is invisible at first sight, the supplier can be opportunistic and deliver a lower quality product than agreed upon, thus making an extra profit. By doing so, regardless of the society's power distance, the supplier takes the risk of serious damage to the relation with the customer if the deceit be revealed.

For egalitarian traders, decisions to deceive, trust, and forgive are not influenced by their partner's status. Instead they depend on the quality of the relations they want to maintain and the sanctions they may expect.., In hierarchical societies, the higher ranked do not have to fear for repercussions when trading with lower ranked opponents, so the decision whether to defect or not merely depends on their morality, relationship, personality and/or circumstances. The lower ranked on the other hand will not easily consider to defect and will usually comply when trading with higher ranked and will only defect if in need. In collectivist societies, they would expect the higher ranked to recognize their need and to mercifully condone their behavior.

Trust or Trace. After delivery, the buyer may either request the delivered commodity to be traced, or accept it trustingly without tracing,.. In societies with large power distance, the lower ranked have no choice but to show trust in the higher ranked, whatever belief about their trustworthiness they may have. The higher ranked have no reason to distrust the lower ranked, because they assume that deceit of a higher ranked would not even be considered. So for the decision to trust, the belief about partner's trustworthiness is only relevant among equally-ranked or in relations where egalitarian traders are involved.

In intercultural contacts, the behavior of traders from hierarchical societies may be credulous in the eyes of their egalitarian opponents, because the high ranked rely on their status and the low ranked think it is improper to trace, thus encouraging deceit by the foreigners and eventually damaging the relation if deceit be revealed.

In egalitarian societies trust is equally important in every relation, regardless of partner's status. In these societies, decisions to trust a delivery or to request a trace (thus showing distrust) are not influenced by status difference. However, showing distrust may be harmful for relations, so there may be other incentives for benevolent behavior, but those incentives are not related to the dimension of power distance.

We assume that trust between parties will develop if negotiations succeed, even in the absence of positive evidence for the truthfulness of deliveries. On the other hand, a tracing report that reveals deceit will reduce trust.

Partner Selection. A trader has to select partners to deal with, either through response to a proposal made by another trader, or by proposing to another trader. Traders may use different criteria to select partners for new deals, according to their personal preferences and societal rules. The important criterion that differentiates partner selection across the power distance dimension is *status*.

In hierarchical societies traders will try to avoid partners who have higher status than they have themselves, because the higher ranked have the power to dictate business conditions. Traders will never propose business to higher ranked others because they are afraid of getting a bad deal. However, if they receive a proposal from a higher ranked trader they have to accept and the only thing they can do is plead and hope for magnanimity. Although one can exploit status in trading with less powerful counterparts, powerful traders in hierarchic societies prefer to do business with partners of their own level of power, because it would lower their status to get involved with people below their own standing.

In egalitarian societies status plays no role in partner selection. There are people who are labeled to have a high or low status in some respect like (show) business, politics, or sports. In strictly egalitarian societies, this will not influence the behavior of business partners. However in intercultural contacts, the traders from hierarchical societies may be influenced by the status labels of their egalitarian partners.

3 Representation in Agents

This section formalizes the knowledge about the influence of power distance on trade processes that was introduced in section 2. The relevant attributes of transactions from this viewpoint are the economic value of the transaction, the quality of the traded goods as a status attribute in its own ("we deal in superior quality products only") and a perceived risk that the trade partner will not fulfill his or her contractual obligations.

The latter is based on trust in the supplier and attributes of the transaction, including product quality: highly valued products such as organic food, designer clothes, and jewelry are a more likely target for swindle and counterfeiting than are commodities. The formalization is based on DESIRE [11], an agent specification language based on information type definitions, process composition, and production rules.

The negotiation process is simulated using the negotiation architecture of Jonker and Treur [12]. The architecture is based on utility functions for comparing bids and a set of decision parameters. In this case we use the following utility function. In other cases, other types of functions may be appropriate, possibly involving additional attributes. In such case, some of the rules given later in this section may have to be adapted.

$$U_{\mathrm{bid}} = w_1 f_1(\mathrm{value}_{\mathrm{bid}}) + w_2 f_2(\mathrm{quality}_{\mathrm{bid}}) + w_3 f_3(\mathrm{risk}_{\mathrm{bid}}) \tag{1}$$

with $w_1 + w_2 + w_3 = 1$, and w_i in [0, 1] , for all i. f_1 presents the economic value of the bid in the interval [0, 1]; f_2 presents the additional value in [0, 1] that is attached in society to trading in high quality products; f_3 evaluates the risk of swindle of the transaction in [0, 1], with 1 representing a transaction without any risk.

Weight factors $<w_1, w_2, w_3>$ characterize an agent's trade strategy, e.g., <*high*, *high*, *low*> represent an *opportunistic* strategy, <*low*, *high*, *high*> a *quality-minded* strategy, and <*high*, *low*, *high*> represent a *thrifty* strategy.

Traders in extremely egalitarian societies do not adapt their trade strategy to partner's status. Traders in hierarchic societies do. Lower ranked traders in hierarchical societies prefer a more thrifty strategy than the higher ranked ones. The higher ranked follow an opportunistic or quality-minded strategy, depending on status difference with their trade partner. Let the relation agent_trait_value: ISSUE × Real, stand for the natural inclination of the agent to weigh an issue. Then the effect of the power-distance and the status of both parties can be implemented as follows.

```
/* 1 calculate weight factors using PDI and status */
if cultural_script_contains(power_distance_index(H: Real))
   and agent_label(status, S: Real)
   and current_partner(C: Trader)
   and partner_model_contains_belief(C, status, Y: Real)
   and agent_trait_value(value_preference, P: Real)
   and agent_trait_value(quality_preference, Q: Real)
   and agent_trait_value(risk_aversion, R: Real)
   and N: Real = P + (1-H)*Q+H*S*Q + (1-H)*R+H*(1-S+Y)*R
then utility_weight_for_value( P / N )
   and utility_weight_for_quality( ( (1-H)*Q + H*S*Q ) / N )
   and utility_weight_for_risk( ( (1-H)*R + H*(1-S+Y)*R ) / N );
```

Traits, status, and power distance index are real numbers in [0, 1]. This rule represents that - in proportion with the power distance index - the weight that traders attribute to trading valuable high quality products relatively increases with their social status, while the weight they attribute to risk relatively decreases with increasing feeling of superiority to the partner or increases with decreasing feeling of inferiority. The divisions by N normalize the sum of the weight factors to 1, so the weight of the economic value is indirectly affected by changes of quality and risk weights.

After evaluating a partner's bid with respect to value, quality, and risk, an agent has to decide whether to accept or to refuse the bid, and, in the latter case, whether to break off the negotiation or to make a counteroffer. Decision parameters are *utility gap* (difference of utilities that an agent will accept between partners' and own bid), *impatience* (probability that an agent will quit if utility or progress is low), *concession factor* (maximal relative concession with respect to the opening bid), and *negotiation speed* (maximal relative step toward maximal concession in a negation round). Furthermore, the rules use a *cut-off value* (minimal utility of partner's bid for which an agent continues) and a *minimal progress value* (minimal relative improvement of utility of partner's bids required in three rounds) as criteria to break off negotiations.

In the architecture of Jonker and Treur, agents accept an offer if the difference between partner's bid and their own bid is smaller than the *utility gap* parameter. As explained in section 2, negotiation in a hierarchical society is a game of power. The more powerful dictate the conditions of the deal. An agent from a hierarchical society feels forced to accept a bid of a more powerful partner even if the utility gap is not covered: the agent is aware that the utility of the bid would be unacceptable if it were made by a less powerful agent, but accepts.

```
/* 2 hierarchic agents accept sooner if partner is powerful */
if cultural_script_contains(power_distance_index(H: Real))
   and agent_label(status, S: Real)
   and current_round(X: Integer)
   and current_negotiation(C: Trader, X, L: Commodity_list)
   and partner_model_contains_belief(C, status, Y: Real)
   and agent_trait_value(acceptable_utility_gap, G: Real)
   and others_bid_utility_in_round(U: Real, X)
   and my_bid_utility_in_round(V: Real, X)
   and V-U < G * (1 + H * max(0, (Y-S)) * X )
then stop_negotiation(C, X, L, accept_offer);
```

Rules 3 and 4 express that in a hierarchic society an impatient agent will less likely break off negotiations with a more powerful opponent (suppressed impatience).

```
/* 3 have patience if powerful partners make unrealistic bids */
if cultural_script_contains(power_distance_index(H: Real))
   and agent_label(status, S: Real)
   and current_round(X: Integer)
   and current_negotiation(C: Trader, X, L: Commodity_list)
   and partner_model_contains_belief(C, status, Y: Real)
   and agent_trait_value(cut_off_value, M: Real)
   and others_bid_utility_in_round(U: Real, X: Integer)
   and U < M
   and agent_trait_value(impatience, I: Real)
   and random(0, 1, Z: Real)
   and I * (1-H*max(0, Y-S) ) * 0.5 > Z
then stop_negotiation(C , X , L, gap);
```

```
/* 4 have patience if powerful partners make no concession */
if cultural_script_contains(power_distance_index(H: Real))
   and agent_label(status, S: Real)
   and current_round(X: Integer)
   and X > 3
   and current_negotiation(C: Trader, X,  L: Commodity_list)
   and partner_model_contains_belief(C, status, Y: Real)
   and agent_trait_value(minimal_progress, M: Real)
   and progress_in_bids(X-3, X, P: Real)
   and P < M
   and agent_trait_value(impatience, I: Real)
   and random(0, 1, Z: Real)
   and I * ( 1-H*max(0, Y-S) ) * 0.5 > Z
then stop_negotiation(C, X, L, no-accom);
```

Rule 2 is about accepting partners' bids. A hierarchic agent also accommodates a more powerful partner by making greater concessions in his own bids. In the architecture of Jonker and Treur: decrease the *minimum utility* parameter (rule 5).

```
/* 5 hierarchic agents give in easily if partner is powerful */
if cultural_script_contains(power_distance_index(H: Real))
   and agent_label(status, S: Real)
   and current_partner(C: Trader)
   and partner_model_contains_belief(C, status, Y: Real)
   and agent_trait_value(concession_factor, F: Real)
then   minimum_utility ((1-F)*(1-H*(0.5*(Y-S)+0.5*abs(Y-S))));
```

The *negotiation speed* parameter, i.e. the relative size of concessions toward the minimum utility, is not influenced by power distance. However, the absolute size of concessions increases with power distance, because concession size is the product of negotiation speed and the difference between the previous bid's utility and minimum utility.

The following rule (rule 6) is about the delivery, once a deal has been closed. Contracts may leave room for opportunistic behavior such as delivering goods of inferior quality. The decision whether to defect or to cooperate is modeled as comparing the temptation to deceive with a threshold (*honesty*, an agent's personal trait). The temptation depends on factors like the product quality agreed in the contract. In hierarchic societies the threshold for defection is influenced by status.

```
/* 6 hierarchic agents are conscientious with a powerful partner */
if cultural_script_contains(power_distance_index(H: Real))
   and agent_label(status, S: Real)
   and current_partner(C: Trader)
   and partner_model_contains_belief(C, status, Y: Real)
   and agent_trait_value(honesty, T: Real)
then   deceit_treshold(T+H*(Y-S)*(1-T));
```

The agents maintain a belief about the trustworthiness of other agents, i.e. the probability that they will not deceive. However, the decision to trust does not depend on this belief only. The relevance of this belief depends on two factors. First, the product quality agreed in the contract influences the relevance: expensive, high quality products are more sensitive to deceit than cheap, low quality products. Second, in hierarchic societies the relevance of interpersonal trust for the decision to put deliveries to the test (trace) decreases as status difference increases (rule 7, which is only relevant for contracts about high quality product transactions). Low status agents do not trace high status agents, because they do not dare to show distrust. High status agents do not trace low status agents, because they trust that the opponents of lower status will not dare to defect.

```
/*  7 hierarchical agents do not trace if status difference is big */
if deal_in_round(C: Trader, B: Bid, X: Integer)
   and current_round(X: Integer)
   and cultural_script_contains(power_distance_index(H: Real))
   and agent_label(status, S: Real)
   and partner_model_contains_belief(C , status, Y: Real)
   and partner_model_contains_belief(C , trust, T: Real)
   and random (0, 1, Z: Real)
   and (1-H*abs(Y-S))*(1-T) > Z
then  to_be_traced(B);
```

Beliefs about partners are updated, based on experience. For trustworthiness belief:

$$t_{C,x} = (1-\delta^{+})\, t_{C,x-1} + \delta^{+}\, e_{C,x}\,, \ \text{if } e_{C,x} \geq t_{C,x-1}\,,$$
$$t_{C,x} = (1-\delta^{-})\, t_{C,x-1} + \delta^{-}\, e_{C,x}\,, \ \text{if } e_{C,x} < t_{C,x-1}\,. \tag{2}$$

with $\delta^{+} = \varepsilon\delta^{-}$ and δ^{+}, δ^{-} , and ε all in the interval [0,1] ; $t_{C,x}$ represents trust in agent C after round x; $e_{C,x}$ represents the experienced result with C in round x. $e_{C,x}$ is either 1 (partner cooperated) or 0 (partner defected). Note that the model does not reason about the cause of the experience, e.g. by maintaining beliefs about partner's competence and honesty; the only thing that counts is the effect.

A similar update function is defined for benevolence. Being traced reduces the belief in partner's benevolence and not being traced is perceived as a confirmation of trust.

The belief about fairness is maintained similarly. For fairness the utility of the deal is used as experience value, a broken negotiation having an experience value of zero. When selecting partners, egalitarian agents compare others with respect to fairness. Hierarchic agents also use fairness, but their priority is to avoid status difference (rule 8). However, they cannot refuse if a higher-ranked proposes to do business (rule 9).

```
/* 8 hierarchic agents avoid partners with status difference */
if no_ongoing_negotiations
   and not_recently_proposed_to_me (C: Trader)
   and cultural_script_contains(power_distance_index(H: Real))
   and agent_label(status, S: Real)
   and partner_model_contains_belief(C , status, Y: Real)
   and partner_model_contains_belief(C , fair, F: Real)
then acceptability (C,  (1-H*abs(Y-S))*F);
```

```
/* 9 high-ranked partner is hard to refuse for a hierarchic agent */
if no_ongoing_negotiations
   and recently_proposed_to_me (C: Trader)
   and cultural_script_contains(power_distance_index(H: Real))
   and agent_label(status, S: Real)
   and partner_model_contains_belief(C, status, Y: Real)
   and partner_model_contains_belief(C, fair, F: Real)
then acceptability (C, (1-H*abs(Y-S))*F + H*max(0, Y-S));
```

Details of partner selection that are not related to specific cultural dimensions are given in [1].

With respect to the decision making presented in this section the following must be noted. According to March [13], decision making can be modeled as either rational or rule-following. Equation (1) may suggest that the agents are modeled as rational utility maximizers. To some extent they are, as the first term of the function represents economic value of the transaction, e.g. the profit that a trader expects to gain based on market price beliefs and calculated risk. However, the other terms of equation (1) represent deviations from economic rationality that may be influenced by a trader's personality and culture. The second term represents an economically irrational preference for quality, for instance for dealing in luxury products in a situation where more profit can be made by dealing in standard products. The third term represents a risk aversion that goes beyond the calculated risk accounted for in the economic value of the transaction. Furthermore, the utility function is only used to valuate and compare bids during the negotiation process. All decisions about partner selection, accepting a bid, continuation of negotiation, deceit, and trust are modeled to be rule-following in the terminology of March.

4 Experimental verification

The production rules formulated in the preceding section were verified in two steps. First, the formulation of the rules was verified in one-to-one agent scenarios. The rules were verified by step-by-step observation of the actions (duration of negotiations, quality levels and utilities of closed deals, break-off, trust and deceit decisions, and belief update) for different values of power distance index and status difference. Secondly, as DESIRE is not a suitable environment for simulating larger populations of agents, for verification of emerging properties at the macro level the agents were implemented in a multi-agent environment. For this purpose, CORMAS was chosen. CORMAS is a Smalltalk-based tool for multi-agent simulations that facilitates simulation with larger populations [14]. The verification results at macro level are discussed in this section.

Table 2 presents results of multi-agent simulations in single-culture and multicultural settings. Agents have the role of either supplier, customer, or tracing agent. In time step 1 the customers send a proposal to a supplier of their choice. In each next time step the trading agents may wait for a reply when they did send a proposal in the previous time step, or they may either reply with an acceptance message or a counter proposal, or ignore received proposals and take the initiative to send a new proposal to a preferred potential partner. If a deal has been closed, the supplier delivers and the customer may accept the delivery or forward it (at the cost of a fee) to the tracing agent. The tracing agent tests the quality, returns the delivery and reports its findings to the customer and the supplier. In case of deceit the tracing agent fines the supplier.

The results illustrate that the ease of trade depends on trader's status in hierarchic societies (runs 1 and 2). Trade stratifies according to status in hierarchic societies, but not in egalitarian ones (3, 4). In mixed settings stratification occurs especially when the hierarchic make the first proposal (5). Stratification is reduced when egalitarians make the first proposal, especially for the lower classes (6). When hierarchic traders have no choice but to trade with egalitarians they do so (7, 8). However, when given the choice they prefer peers (9-12). These results demonstrate that realistic tendencies emerge from interactions of agents following the rules specified in this paper.

Table 2. Number of successful transactions in runs of 100 time steps. The agents are divided into two groups of four suppliers (S1 and S2) and two groups of four customers (C1 and C2). All agents have equal parameter settings, except power distance and status that may differ across groups. H stands for hierarchic cultural background (power distance index = 0.99); E for egalitarian (p.d.i. = 0.01); S for superior status (status = 0.8); I for inferior (status = 0.2).

	run#	S1	S2	run#	S1	S2	run#	S1	S2	run#	S1	S2
run#	**1**	HS	HS	**2**	HI	HI	**3**	HS	HI	**4**	ES	EI
C1	HS	11	12	HI	8	10	HS	36	1	ES	17	13
C2	HS	19	13	HI	12	10	HI	0	23	EI	10	13
run#	**5**	ES	EI	**6**	HS	HI	**7**	EI	EI	**8**	ES	ES
C1	HS	33	0	ES	20	11	HS	10	14	HS	14	16
C2	HI	0	30	EI	5	13	HI	9	14	HI	16	17
run#	**9**	ES	EI	**10**	HS	HS	**11**	ES	EI	**12**	HI	HI
C1	HS	23	0	ES	20	13	HI	1	21	ES	10	11
C2	HS	26	0	EI	10	10	HI	1	24	EI	14	11

5 Conclusion

There is a wealth of literature on trade and culture that so far has not been considered in formalized models of trade. In agent-based economics, individual traders are modeled as intelligent agents cooperating in an artificial trade environment. The agents are modeled to mimic authentic human behavior as closely as possible. In recent papers the differences between such agents is no longer solely attributed to differences in their individual economic situations. Aspects such as personality and attitude are considered as well, see for example, [15]. Without considering such aspects, the simulations will not correspond to reality. With respect to formalizing the important influence of cultural background on trade, we only found a few papers. These papers study trade at the macro-level. An example is [16]. This paper presents an equilibrium analysis on the amount countries invest in learning another language and culture and the size and welfare of those countries. Another example is [17]. That paper presents a formal model of the influence of trade on culture, i.e., the reverse direction of influence as studied in the current paper. Other literature also uses macro-level models, such as the gravity model to study the correlation between culture and trade, e.g., [18].

Most agent models of culture that can be found in the literature aim to adapt system behavior and user interfaces to the user's culture. Kersten [19] urges the necessity of cultural adaptation of e-Business systems and proposes an architecture that adapt both business logic and user interface. The rationale for adapting systems to user's cultures is given by Kersten et al. [4], who report significant differences in expectations, perception of the opponent, negotiation process, and outcomes of electronic negotiations across cultures. However, no actual implementations of models of culture in e-Business have been found to be reported. Blanchard and Frasson [20] and Razaki et al. [21] report an application of Hofstede's dimensions in a model to adapt e-Learning systems to the user's culture. Recent research on cultural modeling in agents mostly focus on Embodied Conversational Agents (ECA), including non-verbal behavior like facial expressions, gestures, posture, gazing, and silence in conversations; see, e.g., [22, 23]. For instance, the CUBE-G approach of Rehm et al. [24, 25] is based on the Hofstede dimensions and focuses on modeling into virtual characters the processes of first meeting, negotiation, and interaction in case of status difference.

All models discussed so far have in common that they model culture with the purpose to support human decision making or to improve human-computer interaction. The purpose of the model proposed in the present paper is to realistically simulate emergent behavior in multi-agent based simulations for research in the social sciences. The aspects of ECA are of less relevance in this context. Agent behavior may be modeled in a more stylized way. An approach that does so for the purpose of multi-agent simulations is that of Silverman et al. [26, 27]. They model agents as a composition of biological, personal (personality, culture, emotions), social (relations, trust), and cognitive (decision) modules, completed with modules for perception, memory, and expression. Their approach is a generic structure for modeling the influence of culture on agent behavior – along with factors like stress, emotion, trust, and personality – through Performance Moderator Functions (PMF). It differs from our approach in that it is an environment to implement validated models of culturally differentiated behavior, while our approach aims to develop and validate such models.

The contribution of this paper is the formalization of culture with respect to the influence of the power distance dimension on trade. This formalization has been carried out at the micro-level, i.e. at the level of individuals participating in trade. The traders' behavior is formalized in the form of rules that take power distance and status difference into account. The agents reason with a perceived model of the parties they consider for trading. These perceived models do not contain estimates of the culture of the other parties. Furthermore, the rules do not model the motivations and emotions that underlie the behavior. However, for study of macro-level effects as a consequence of cultural differences in micro-level interaction it is sufficient that the rules realistically model the effects of culture on individual behavior.

The theory of Hofstede [8] offers detailed information to model the effect of culture on human behavior. Hofstede's model is based on a thorough statistical analysis of a massive amount of data. The five dimensions of culture discovered by factor analysis of the data are an efficient instrument to type national cultures. For each of the dimensions Hofstede's work offers extensively validated descriptions of difference in behavior along the dimensions. These descriptions are very well applicable to modeling differences in behavior of artificial agents.

The approach taken in this paper is to model a single one of Hofstede's dimensions. The other dimensions are treated in other work [1, 28, 29, 30]. Modeling a single dimension of culture is artificial. In reality, all aspects of cultural background have their effect simultaneously. However, modeling behavioral differences for a single dimension offers the possibility develop narrative descriptions of hypothetical behavior as presented in section 2 of this paper, to implement this behavior into agents, and to verify if the aggregated effects correspond with the expected behavior on the basis of Hofstede's theory. The results of the simulations presented in section 3 demonstrate that realistic tendencies emerge from interactions of agents that follow the rules specified in this paper.

Future work aims to integrate models for the separate dimensions into agents with believable culturally differentiated behavior, and to validate and calibrate the integrated models in two ways. First, business, economics, and negotiation science literature offer hundreds of papers that describe and analyze differences between cultures and intercultural interactions. Second, gaming simulations like [2] can be used to validate agent model behavior in specific configurations.

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7 Modeling Culture in Trade: Uncertainty Avoidance

Abstract. A model is presented of the way that our cultural attitude towards the unknown influences the decisions we make in trade. Uncertainty avoidance is one of Hofstede's five cultural dimensions. The paper presents a model of how this dimension affects trade. This influence has been explicated for the decisions regarding trade: partner selection, negotiation behavior, trust, and the interpretation of the trade partner's behavior. It has been verified in simulations showing that the generic tendencies as attributed to uncertainty avoidance are reflected in the simulation results. Our approach is an example of instantiating generic knowledge on the influences of culture on decision-making in general.

Introduction

The international food economy is rapidly changing. Important issues are concentration and globalization, growing information intensity, consumer demands, and social responsibility [Kinsey 2001]. An important issue in current food trade research is the emergence and performance of international supply chain networks [Lazzarini et al. 2001]. Agent-based modeling extends the understanding of processes in society and economy. It enables simulation of the emergence of macro-level phenomena from micro-level interactions between individual agents [Tesfatsion and Judd 2006]. It is therefore well-suited for modeling the emergence and performance of supply chains under different institutional and social arrangements.

Differences between national cultures are well-known to have their effect on trade at the micro-level: cultural differences hinder international business contacts - e.g., [Trompenaars 1993]. Relevant processes at the micro-level with respect to chain networks are strategy determination, trade partner selection, negotiation, delivery, and monitoring. The influence of culture on these processes and on trust as an enabler has been the subject of research. In particular negotiation had much research attention - e.g., [Gelfand and Brett 2004] - and the attention for trust, in particular in relation to the food economy, is growing - e.g., [Fritz et al. 2006]. [Gorobets and Nooteboom 2006] give evidence by means of a multi-agent simulation that different economic systems (trust versus opportunism) may be efficient in different societies. Other economic literature stresses the relevance of culture for international trade, but models it at the macro-level - e.g., [Bala and Long 2005] and [Kónya 2006]. Given that cultural differences exist and that they are recognized as relevant, realistic agent-based modeling of international trade requires culturally differentiated agent behavior.

This paper introduces an exercise in modeling of culture based on the work of [Hofstede 2001]. The context is a gaming simulation of trade in commodities with invisible quality properties [Meijer et al. 2006]. That game is designed as a research tool for study of human behavior with respect to trust in commodity supply chains and networks in different institutional and cultural settings. The work reported in this paper is a step toward modeling of cultural aspects of behavior in trade, that may eventually be validated in this or other games. It reports a multi-agent modeling step in the research cycle described in [Jonker et al. 2006]. Figure 1 schematically depicts this cycle.

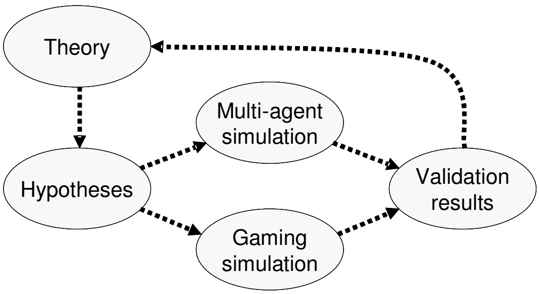

Fig. 1. Research cycle, schematically after [Jonker et al. 2006]

Hofstede recognized five dimensions of culture. The present paper focuses on the dimension of uncertainty avoidance. The other dimensions are dealt with in other publications - e.g., [Hofstede et al. 2006]. Isolating a single dimension and analyzing it separately from the other dimensions is artificial, but it brings the opportunity to verify the partial model and validate it against specifically designed gaming simulations. In future work, integrating all the dimensions should lead to more realistic agents; this paper represents an intermediate step.

The paper is structured as follows. Section 2 introduces culture and the uncertainty avoidance dimension. Section 3 elaborates on the dimension of uncertainty avoidance in trade processes. Section 4 models the dimension of uncertainty avoidance for application in agents. Section 5 presents some experimental results. Section 6 concludes the paper and discusses future research.

Culture and Uncertainty Avoidance

People live in groups. Any one person is a member of several groups, e.g. nuclear family, extended family, village, region, club, political organization, religion, country, company. The existence of a group implies that there is an outer boundary. Some cultures like to draw strict, solid boundaries between the various group identities that exist, while in others, group boundaries are not a big issue. Why this is so, is a matter of speculation. From an evolutionary point of view, human beings are in a state between a purely solitary life and one as a perfect group – between a bear's lair and a bee hive. This implies that in almost all human social interactions, the question "are we part of the same group?" is relevant. The practical implications are that more trust is placed in members of the same group. It is evolutionarily natural for people to collaborate with group members against other groups. At the same time we are more or less flexible in our group memberships. The details are dependent on group culture. [Hofstede 2001] identified five major issues that a society has to resolve in order to function as a group:

issues of (1) individual freedom versus group loyalty, (2) division of power, (3) aggression and permissiveness against offenders, (4) gratification of needs, and (5) the unpredictable. This last issue will be examined in the present paper, artificially tearing it apart from social life as a whole.

The world is an unpredictable place, and people are aware of this. This knowledge is stressful, but not equally much to all people, nor to all societies. Individual people who cannot cope with unpredictability are likely to score high on neuroticism tests. Cultures that practice strong rituals and beliefs to cope with unpredictability are called uncertainty avoiding. [Hofstede 2001, p. 161] defines this dimension of culture as “the extent to which the members of a culture feel threatened by uncertain or unknown situations”. It is important to realize that this has nothing to do with computable risk. It is about fear of situations in which “anything can happen and one has no idea what” [ibid., p. 148]. Hofstede goes on to explain

> *“Uncertainty-avoiding cultures shun ambiguous situations. People in such cultures look for structure in their organizations, institutions, and relationships, which makes events clearly interpretable and predictable. Paradoxically, they are often prepared to engage in risky behavior in order to reduce ambiguities – such as starting a fight with a potential opponent rather than sitting back and waiting.”*

People from societies or groups that are highly uncertainty avoiding do not tolerate ambiguity as to who is a member of their group. In case of doubt they have a tendency to close the ranks and shut strangers out. They tend to have strict moral criteria as to who fits in: adherents of the same religious subgroup, perhaps, or people from the same region, people who speak their language, people of their gender, or similar clear-cut criteria. People from such societies will not easily engage in interactions with others who do not share their most salient group characteristics. It follows that trade will often be a within-group activity, and contacts with alien groups are not easily made. Within-group contacts, on the contrary, are charged with tokens of loyalty, often through intricately prescribed shared ritual that is needed to counteract the stress that people experience. The average person in such a society is more neurotic, and less agreeable, than in an uncertainty tolerant culture [Hofstede and McCrae 2004]. According to [Hofstede and Hofstede 2005] countries high on uncertainty avoiding are: Central and Latin Europe, Latin America, Japan, South Korea, Russia, Middle East, and Pakistan. On the other hand, societies or groups that are uncertainty tolerant are easy travelers, and will engage in novel activities without needing much time to adjust. They will strike up trade relations with foreigners if the opportunity presents itself. Their social interactions tend to be laid-back. Countries with this orientation are China and Southeast Asia, Scandinavia, Anglo countries and India.

The origin of differences on this dimension is not clear. Presumably, uncertainty avoiding societies have occurred where evolution favored conservatism and closed social networks, and uncertainty tolerant societies have occurred where evolution rewarded exploration and mixing. Societies with an old tradition of agriculture are frequently uncertainty avoiding and those that involve fishing or trading are uncertainty tolerant; but there are exceptions. Current pressures of globalization may change the situation; yet evidence for the moment does not indicate that worldwide differences in uncertainty avoidance have been changing over the last decades. Thus, in discussing trade behaviors, uncertainty avoidance can be considered a causal factor. Pairs of countries that differ much on this dimension of culture and less on others, where the first is the more uncertainty avoiding, are Japan-China, Germany-Great Britain, South Korea-Singapore, Italy-Ireland, Finland - Denmark. Table 1 displays some distinctions that characterize the difference between uncertainty avoiding and uncertainty tolerant societies.

Table 1. Some distinctions - relevant for trade - between norms in uncertainty avoiding and uncertainty tolerant societies; source: [Hofstede 2001, p. 161]

Uncertainty tolerant	Uncertainty avoiding	
Being busy is not a value per se	Inner urge to be busy	(1)
Suppression of emotions	Expression of emotions	(2)
Openness to change and innovation	Conservatism, law and order	(3)
Willingness to take unknown risks	Only known risks are taken	(4)
What is different is curious	What is different is dangerous	(5)
Tolerance of diversity	Xenophobia	(6)
Comfortable with ambiguity and chaos	Need for clarity and structure	(7)
Appeal of novelty and convenience	Appeal of purity	(8)

Uncertainty avoidance in trade

The core of trade is the execution of transactions: exchange of commodities or rights for money. Transactions are based on a contract that may specify additional conditions, to enforce delivery according to the contract. From the perspective taken in this paper, contracting is not the only relevant activity of trading agents. Figure 2 presents a process model of trading agents.

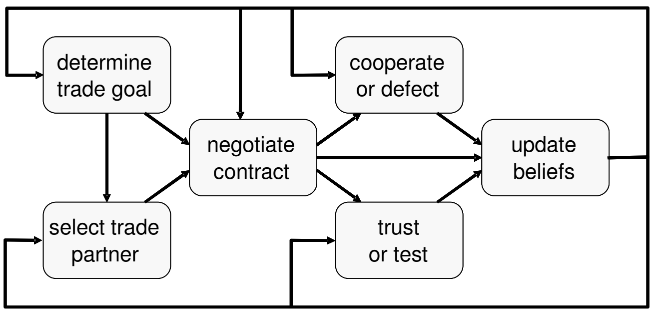

Fig. 2. Processes and internal information flow of trading agents

Before entering negotiations, agents have to select each other as partners to negotiate with, based on their trade goals (sell or buy?; which commodity?; which quality?; what risk is acceptable?) and knowledge about potential partners. This information also plays an important role during the negotiation process. Once a contract has been agreed upon, the traders have to deliver. In this phase of the transaction they can either cooperate (deliver according to the contract) or defect, deliberately or as a flaw of their control system. Traders may either trust their partner to deliver truthfully or monitor the delivery (put it to the test). The latter usually incurs some cost, while trust is for free. The decisions about cooperation and trust are based on personal preferences and cultural background, as well as beliefs about the trade partner and the trade environment. Delivery and monitoring and the decisions about cooperation and trust are relevant for both sellers and buyers. However, the research reported in the present paper models trade in the Trust And Tracing game [Meijer et al. 2006]. In this context the cooperation decision is relevant for agents in the selling role and the trust decision is relevant for agents in the buying role.

Experience from the negotiation and delivery processes may change a trader's beliefs about the trade environment or about individual trade partners. The beliefs will, in addition to a trader's preferences, guide decision making in future trading. In the present paper we limit ourselves to beliefs about trade partners. For the purpose of modeling trade processes three traits about partners can be defined that trading agents maintain a belief about:

– the belief about another agent's *fairness* (represents an agent's expectation that a fair contract can be negotiated in a fair way with the other agent);
– the belief about another agent's *trustworthiness* (represents an agent's expectation that the other agent will deliver according to contract);
– the belief about another agent's *benevolence* (represents an agent's expectation that the other will accept deliveries without putting them to the test, in other words that the other agent will trust; note that what the authors call benevolence may in other cultures be seen as credulity).

The effect that uncertainty avoidance has on these beliefs, and on the decision making in trade processes, is also influenced by the agent's cultural background with respect to the other dimensions. This mutual influence is not taken into account for the moment.

Based on the works of [Hofstede 2001, 2005] and preliminary observations in the Trust And Tracing game [Meijer et al. 2006] hypothetical differences in behavior can be formulated for traders from different cultures. The following paragraphs describe expected differences across the uncertainty avoidance dimension. The descriptions are used in the next section to specify rules for agent behavior.

Negotiation behavior. The first bid of an uncertainty avoiding trader tends to be modest in the sense that it is a price he thinks is right. The uncertainty avoiding have an emotional style of negotiation, making sure that the opponents understand their feelings (see row 2 in table 1). They will not adapt their behavior to their opponent's. In the bargaining that follows they will not easily give in nor will much time be spent. After a few unsuccessful iterations, the uncertainty avoiding trader will break off the negotiation.

The uncertainty tolerant traders on the other hand have a relaxed style of negotiation. They try to adapt their behavior to their counterparty's, although they are not prepared to come to an agreement at all cost. They do not show their emotions and may be disconcerted if their opponents do. They are careful not be more yielding than their counterparts are, not especially modest, and are ready to break off negotiations in case of insufficient progress.

Trade goal selection. In uncertainty avoiding societies the main concern of traders is not to be deceived. They are willing to pay a price for certainty. Although they prefer valuable high quality commodities, they will opt for cheaper low quality rather than valuable high quality if they do not feel certain about the high quality. Traders with a cultural background of uncertainty tolerance opportunistically trade both low and high quality products and have a neutral risk attitude. They prefer high quality, but only if the price is right; they are not adverse of trading low quality if it brings them a profit.

Maintenance of beliefs about partners. In uncertainty avoiding societies the traders need some external justification (group membership or reputation) for doing business with new partners. The new partners will not be trusted. However, a low estimate of trustworthiness does not hinder a transaction. If the uncertainty avoiding know what to expect, they arm themselves and enter only into contracts with sufficient securities. Once, in the course of repeated transactions, sufficient evidence for trustworthiness has been found through tracing of deliveries, and partners have become familiar, the uncertainty avoiding will come to trust their partners and expect them to follow the rules like they do themselves. After they have come to trust, any unexpected revelation of deceit provokes furious reactions from uncertainty avoiding traders. They will not easily deal again with a partner that abused their trust. Like for uncertainty avoiding, uncertainty tolerant traders increase the partner's future acceptability if negotiations result in an agreement, and decrease it if negotiations fail. Uncertainty tolerant traders are not particularly distrusting, and trust will develop through repeated transactions. They will trace now and then, with decreasing frequency as trust develops. Revealed deceit will of course reduce trust and increase the frequency of tracing.

Truthful or untruthful delivery. After an agreement has been reached, it comes to delivery. If the quality of the commodity is invisible at first sight, the supplier can be opportunistic and try to deliver a lower quality product than agreed upon, thus making an extra profit. An uncertainty tolerant trader may be tempted to do so, calculating the risk of being exposed as a deceiver and the damage that would do to his reputation and future trading opportunities. An uncertainty avoiding trader may have a lot of rules and contracts that forbid defecting, but that does not mean that he will follow the rules. Depending on the other dimensions of culture, traders from uncertainty avoiding cultures may just as easily or even more defect than uncertainty tolerant, especially when dealing with out-group partners.

Trust or distrust. An uncertainty avoiding trader does not expect the rules to be broken and will trust, unless he is dealing with a stranger. A new partner will be distrusted until sufficient evidence for the contrary has been found. In uncertainty tolerant societies, the other dimensions of culture determine the level of trust. The rules and contracts do not have a value per se for the uncertainty tolerant.

Partner selection. In both uncertainty avoiding and uncertainty tolerant societies, traders prefer to deal with familiar relations, because that brings the experience gathered in previous transactions to value. However, in uncertainty tolerant societies traders will not hesitate to propose or enter negotiations with strangers, if for some reason dealing with familiar relations is inconvenient. Uncertainty avoiding traders on the other hand have a high threshold for entering into new relations. They feel uncomfortable proposing to parties they did not deal with before. For acceptance of new partners, they need an external justification, for instance based on group membership or a good reputation. In addition, they prefer to deal with counterparts having equal status (and profession if applicable).

Representation in agents

This section defines production rules that formalize the knowledge about the influence of uncertainty avoidance on trade processes. The rules are formulated for one-to-one verification of the agents in DESIRE [Brazier et al. 2002]. The simulation applies many more rules, but because of space limitations we only present the rules that involve the uncertainty avoidance index of culture.

The relevant attributes of transactions are the economic value of the transaction, the quality of the traded goods as a status attribute in its own ("we deal in superior quality products") and a perceived risk that the trade partner will not fulfill its contractual obligations. The latter is based on trust, contractual conditions, and other attributes of the transaction, including product quality: higher valued products like organic food, designer clothes, and jewelry are a more likely target for swindle and counterfeiting than lower valued products.

The negotiation model for both traders, i.e. buyer and seller, uses a utility function to compare bids.[2]

$$U_{\text{bid}} = w_1 f_1(\text{value}) + w_2 f_2(\text{quality}) + w_3 f_3(\text{risk}) \qquad \textbf{(1)}$$

with $w_1+w_2+w_3=1$, and w_i in [0, 1], for all i. f_1 presents normalized economic value of the bid in the interval [0, 1]; it is more or less objective in terms of cost and market value, but is calculated differently for buyers and sellers: e.g., a high price for low quality has a high value for sellers, but a low value for buyers. f_2 presents normalized additional value in [0, 1] that is attached in society to trading high quality; it is subjective and its value may differ according to personal preferences and cultural background. f_3 evaluates the risk of swindle normalized in [0, 1], with 1 representing a transaction without any risk; for a buyer it is based on the opportunity for the seller to deceive and the buyer's belief about seller's trustworthiness; for a seller it is based on opportunity and belief about the buyer's benevolence.

Weight factors <w_1, w_2, w_3> characterize an agent's strategy, e.g., <*high*, *high*, *low*> represent an *opportunistic* trade strategy, <*low*, *high*, *high*> a *quality-minded* strategy, and <*high*, *low*, *high*> represent a *thrifty* strategy.

[2] In the context of the current research, we apply equation (1). If for some reason another utility evaluation function were used, the knowledge presented in this section would remain valid, but some rules might need to be reformulated.

Traders in uncertainty avoiding cultures strongly prefer a quality-minded strategy, while traders in uncertainty tolerant societies tend to follow an opportunistic strategy (see rows 4, 7, and 8 in table 1). Uncertainty avoiding agents have an increased risk aversion for "strangers". In our simulation we use labels to distinguish groups of agents and societal status. The following rule uses these variables as indicators of similarity of agents. Let the relation `agent_trait_value: ISSUE × Real`, stand for the natural inclination of the agent to weigh an issue. Then the effect of uncertainty avoidance and agent labels of both negotiation partners can be implemented as follows.

```
/* 1 calculate w-factors using UAI and group and status labels*/
if cultural_script_contains(uncertainty_avoidance_index(U: Real))
   and agent_label(status, S: Real)
   and agent_label(group, G: Group_label)
   and partner_model_contains_belief(T: Trader, status, Y: Real)
   and partner_model_contains_belief(T, group, L: Group_label)
   and group_distance (G, L, D: Real)
   and agent_trait_value(value_preference, P: Real)
   and agent_trait_value(quality_preference, Q: Real)
   and agent_trait_value(risk_aversion, R: Real)
   and N: Real = (P + Q + R+(1-R)*U*(1+max(D,abs(S-Y)))/2 )
then weight_for_value_toward( T, P / N )
   and weight_for_quality_toward( T, Q / N )
   and weight_for_risk_toward(T,  (R+(1-R)*U*(1+max(D,abs(S-Y)))/2) / N );
```

Traits, status, and uncertainty avoidance index are real numbers in [0, 1]; N is the sum of the the weight factors w_i before normalization. The divisions by N normalize the sum of the weight factors to 1.

Agents use the utility function to decide whether to accept or to refuse a bid, and, in the latter case, whether to break off the negotiation or to make a counteroffer. The simulated negotiation process applies the negotiation architecture of {Jonker and Treur 2001]. Parameters in this approach are *utility gap*, *impatience*, *concession factor*, and *negotiation speed.* Furthermore the algorithm uses a *cut-off value* and a *minimal progress value* as criteria to break off negotiations. All parameters are implemented as agent traits, i.e. they are represented in real values in the interval [0, 1]. Some are influenced by the value of the uncertainty avoidance index. Realistic base values of the parameters were established in human experiments [Bosse 2004].

Agents accept offers if the difference of their own bid's utility and partner's bid utility is less than the *utility gap*, realistically valued 0.02 according to human experiments.

If an agent does not accept an offer, it has to decide whether to stop the negotiation or to make a counteroffer. The simulated agents use a random generator for this decision. The following rules - involving *impatience*, *cut-off value*, and *minimal progress value* – express that impatient agents (impatience is an agent trait) and agents from uncertainty avoiding cultures are more likely to stop (rows 1 and 2 in table 1). In these rules a uniform random variable Z in [0, 1] is used. The probability of stopping if the other conditions in rules 2 and 3 hold is equal to the maximum of the cultural uncertainty avoidance index and the impatience as a personality trait.

```
/* 2 rather stop if impatient or UA and cut-off value is not met */
if cultural_script_contains(uncertainty_avoidance_index(U: Real))
   and current_negotiation(T: Trader, X: Integer, L: Commodity_list)
   and agent_trait_value(cut_off_value, C: Real)
   and agent_trait_value(impatience, I: Real)
   and current_round(X)
   and others_bid_utility_in_round(B: Real, X)
   and B < C
   and random(0, 1, Z: Real)
   and max(I, U) > Z
then stop_negotiation(T, X, L, gap);

/* 3 rather stop if impatient or UA and partner makes little progress */
if cultural_script_contains(uncertainty_avoidance_index(U: Real))
   and current_negotiation(T: Trader, X: Integer, L: Commodity_list)
   and agent_trait_value(minimal_progress, M: Real)
   and agent_trait_value(impatience, I: Real)
   and current_round(X)
   and X > 3
   and progress_in_bids(X-3, X, P: Real)
   and P < M
   and random(0, 1, Z: Real)
   and max(I, U) > Z
then stop_negotiation(T, X, L, no-accom);
```

If an agent does not stop following rules 2 and 3, it tries and makes a counteroffer. In the process of preparing a counteroffer the agent may still stop if no room for further concessions can be found, taking the minimum utility into account. The minimum utility is related with the opening bid through the *concession factor* γ: $U_{\text{minimum}}=(1-\gamma)U_{\text{opening\_bid}}$. We assume that U_{minimum} is not significantly different across the cultural dimension of uncertainty avoidance, but that agents in uncertainty avoiding cultures are more modest in their opening bid and have a lower concession factor (rows 3 and 7). They also have a lower *negotiation speed*, i.e. their relative concessions from their previous bid towards the minimum utility are smaller. As an example we present the rule for the maximal concession.

```
/* 4 uncertainty avoiding agents make smaller concessions */
if cultural_script_contains(uncertainty_avoidance_index(U: Real))
   and current_round(X: Integer)
   and my_bid_utility_in_round(B: Real, X-1)
   and agent_trait_value(minimum_utility, M: Real)
   and base_negotiation_speed (S: Real)
   and ua_negotiation_speed (V: real)
then maximal_concession_in_round (X, (B-M)*((1-U)*S+U*V) );
```

The agents stop the negotiation if the maximal concession is less than 0.01. In this rule and some other decision rules linearly weighted sums are used, with the uncertainty avoidance index as weight factor. Future validation of the models must decide if this simplification is justified.

After successful negotiations the supplier has to deliver the commodities. If the agreement was to deliver a high quality commodity, the supplier may deliver low quality, if the difference is invisible at first sight. Whether an agent actually defects or cooperates depends on many factors, including the quality of the relation with the customer and the estimate of the customer's benevolence. An uncertainty avoiding agent's has a lower threshold for defection of strangers than for similar partners (table 2, rows 5, 6, and 7).

```
/* 5 uncertainty avoiding have a low deceit threshold for strangers */
if cultural_script_contains(uncertainty_avoidance_index(U: Real))
   and agent_label(status, S: Real)
   and agent_label(group, G: Group_label)
   and current_partner(T: Trader)
   and partner_model_contains_belief(T, status, Y: Real)
   and partner_model_contains_belief(T, group, L: Group_label)
   and group_distance (G, L, D: Real)
   and agent_trait_value(honesty, H: Real)
then deceit_treshold_toward(T, H * (1-U*max(D,abs(S-Y)));
```

The deceit threshold is used in the rules for the decision whether to cooperate or to defect. The latter rules are not presented in this paper for space limitations. They do not differ across the dimension of uncertainty avoidance.

The customer has to decide whether to trust the delivery or put it to the test (trace it). The likelihood that a customer will rather test, depends on his trust in the partner, but an uncertainty avoiding customer will rather trace if he has little in common with the supplier (rows 4, 5, 6 in table 2).

```
/* 6 uncertainty avoiding agents do not trust strangers */
If cultural_script_contains(uncertainty_avoidance_index(U: Real))
   and deal_in_round (T: Trader, B: Bid, X: Integer)
   and current_round (X)
   and agent_label(status, S: Real)
   and agent_label(group, G: Group_label)
   and partner_model_contains_belief(T , trustworthiness, W: Real)
   and partner_model_contains_belief(T , status, Y: Real)
   and partner_model_contains_belief(T , group, L: Group_label)
   and group_distance (G, L, D: Real)
   and random(0, 1, Z: Real)
   and (1-U)*(1-W) + U*max(D,abs(S-Y),(1-W)) > Z
then to-be-traced(B);
```

Tracing results are a source for trust update. Trust update can be modeled as follows.

$$t_{C,x} = (1-\delta^{+})\, t_{C,x-1} + \delta^{+}\, e_{C,x} \text{ if } e_{C,x} \geq t_{C,x-1}$$
$$t_{C,x} = (1-\delta^{-})\, t_{C,x-1} + \delta^{-}\, e_{C,x} \text{ if } e_{C,x} < t_{C,x-1} \quad (2)$$

with δ^{+} and δ^{-} in the interval [0,1]; $t_{C,x}$ represents trust in agent C after round x; $e_{C,x}$ represents the experienced result with C in round x. In this case the result of tracing $e_{C,x}$ is either 1 (partner cooperated) or 0 (partner defected). An uncertainty avoiding agent has a low value of δ^{+} and an high value of δ^{-} (table 2, rows 3 and 7), in particular if it has little in common with its trade partner (rows 5 and 6).

```
/* 7 trust comes slowly and vanishes rapidly in UA societies */
if cultural_script_contains(uncertainty_avoidance_index(U: Real))
   and agent_label(status, S: Real)
   and agent_label(group, G: Group_label)
   and partner_model_contains_belief(T: Trader, status, Y: Real)
   and partner_model_contains_belief(T , group, L: Group_label)
   and group_distance (G, L, D: Real)
   and agent_trait_value(base_neg_update_factor, N: Real)
   and agent_trait_value(base_pos_update_factor, P: Real)
   and max_ua_neg_update_factor(E: Real)
   and min_ua_pos_update_factor(F: Real)
then neg_update_factor_toward(T, N*(1-U)+E*U*(1+max(D, abs(S-Y))/2)
   and pos_update_factor_toward(T, P*(1-U)+F*U*(1+max(D, abs(S-Y))/2);
```

In this rule the UA-factors differ a factor of at least 3 with the base-factors.

Fairness, as defined in section 3, is used to select a future trade partner. Agents will rather select a partner they believe to be fairer than another partner. The belief about a partner's fairness is maintained similar to equation (2) after a negotiation has stopped. For a successful negotiation, the utility is taken as experience value; the experience value of an unsuccessful negotiation is 0. Uncertainty *tolerant* agents select their partners primarily on the basis of fairness. The following rule expresses that uncertainty *avoiding* agents have additional preferences for common group membership and common status (table 2, rows 5 and 6).

```
/* 8 uncertainty avoiding agents prefer similar partners */
if cultural_script_contains(uncertainty_avoidance_index(U: Real))
   and agent_label(status, S: Real)
   and agent_label(group, G: Group_label)
   and partner_model_contains_belief(T: Trader, fairness, F: Real)
   and partner_model_contains_belief(T , status, Y: Real)
   and partner_model_contains_belief(T , group, L: Group_label)
   and group_distance (G, L, D: Real)
then acceptability (T, F*(1-U*max(D,abs(S-Y))) );
```

Experimental results

In order to verify the correct formulation of the rules presented in section 4, one-to-one scenarios were simulated step by step. For reasons of space, the results are not included in this paper. Results are available from the authors. Subsequently, the behavior was implemented in a multi-agent model of a trade process, based on the gaming simulation in Meijer *et al.* (2006). In this simulation sellers and buyers can

- select each other for negotiation,
- exchange bids,
- deliver commodities, and
- send received commodities to a tracing agent for testing.

By tracing they incur a tracing fee. The tracing agent is authorized to punish deceivers by a fine.

The multi-agent simulation is implemented in Cormas (http://cormas.cirad.fr). Source code is not included in this paper, but is available from the authors. The Cormas simulation is synchronized in time steps. In the first step each buyer may send a bid to a seller of its choice. In each following time step each agent may:

– either wait for a reply to a bid it made,
– or stop the ongoing negotiation and propose a new one to any agent in the opposite role by sending it a bid,
– or reply to a received bid with a counter bid,
– or accept a bid and, in case it is selling, send a delivery,
– or receive a delivery and decide whether to forward it to the tracing agent or not.

In the last two cases it may subsequently propose a new negotiation by sending a bid to any agent in the opposite role. The agents cannot negotiate synchronously with more then one partner. They send no (if they wait for a reply) or one bid per time step.

Table 2 presents typical results of example runs for simulation runs of 100 time steps. The agents have a group label that is visible for other agents. The agents interpret other agents carrying a label different from their own as having maximal group distance. One label was attached to uncertainty tolerant agents (UAI=0.2), two different labels were attached to uncertainty avoiding agents (UAI=0.8). Both sellers and buyers either belonged to a single group of eight or were divided into two groups of four in which all group members have an equal group label and UAI. All agents have equal negotiation parameters and other initial settings.

Table 2. Number of successful transactions between two groups of 4 sellers and two groups of 4 buyers, with different values of uncertainty avoidance index, in simulation runs where sellers and buyers can individually select each other for negotiation (*UT*: UAI = 0.2; *UA1*: UAI=0.8; *UA2*: UAI=0.8; group distances *UT-UA1*, *UA1-UA2*, and *UA2-UT* are all 1.0, so maximal)

run 1		buyer groups	
		UT	*UT*
seller	*UT*	13	25
groups	*UT*	18	25

run 2		buyer groups	
		UA1	*UA1*
seller	*UA1*	5	12
groups	*UA1*	14	14

run 3		buyer groups	
		UA1	*UT*
seller	*UA1*	36	0
groups	*UT*	1	46

run 4		buyer groups	
		UA1	*UA2*
seller	*UA1*	26	1
groups	*UA2*	3	33

run 5		buyer groups	
		UA2	*UA2*
seller	*UA1*	7	4
groups	*UA1*	9	9

run 6		buyer groups	
		UT	*UT*
seller	*UA1*	19	14
groups	*UA1*	11	13

run 7		buyer groups	
		UA2	*UT*
seller	*UA1*	7	10
groups	*UA1*	12	4

run 8		buyer groups	
		UA 1	*UT*
seller	*UA1*	25	2
groups	*UA2*	4	17

Table 2 presents the total number of successful transactions. This number results from the combination of all processes. There may be variance because of the occasional selection of partners, the occurrence of defection that may lower trust in individual relations, and the failure of negotiations if agents lose their patience or do not sufficiently accommodate their partners.

If all agents are uncertainty tolerant and belong to a common group, trade goes smoother than if all agents are uncertainty avoiding and belong to a common group (compare run 1 and run 2). If uncertainty avoiding agents can find in-group partners, stratification occurs: the uncertainty avoiding agents exclude out-group traders (see runs 3 and 4). Trade stagnates if the uncertainty avoiding agents cannot deal with in-group partners, but it goes a bit smoother with uncertainty tolerant partners (run 6) than it does with uncertainty avoiding (run 5). The latter effect vanishes in the mixed settings like run 7, where uncertainty avoiding agents are holding up trade. They spend much time on negotiations that fail because of insufficient progress and impatience of the uncertainty tolerant agents. In run 8 one group of uncertainty avoiding agents (group 1) can find each other; as a result, group 2 and the uncertainty tolerant can speed up.

Conclusions and future work

This paper contributes to the research into trade processes by offering a model of the influence of the uncertainty avoidance dimension of culture on trade processes. The work in this paper is a sequel to Hofstede et al. (2006), in which the influence on trade of the masculinity / femininity dimension of culture is modeled. Our choice to model the dimensions first in isolation is deliberate. Despite its partial nature the model is applicable for traders from cultures that differ mostly on this dimension, e.g., Japan-China, Germany-Great Britain, South Korea-Singapore, Italy-Ireland, Finland - Denmark. By modeling only the influence of one dimension, the model can be validated with respect to the general theory, and with respect to dedicated human simulation games. The model is based on the theory of [Hofstede 2001], as well as on the experience of the authors with the Trust and Tracing Game [Meijer et al., 2006], in which people from different cultures participate in a gaming simulation. Trade aspects considered were: trade goal selection, partner selection, negotiation behavior, maintenance of beliefs about trade partners, and related to these trust and the truthful or untruthful delivery of goods.

The model has not been validated against human negotiators and this remains to be done. The results do however show good face validity. Uncertainty tolerant agents find it easy to trade with partners they do not know and their negotiations are often successful. Whether they trust their trade partner or not does not so much depend on group membership. Neither does their selection of trade goods, or their decision to deliver truthfully or not. Furthermore, their interpretation of the behavior of their trade partners, which determines the way they maintain beliefs about these partners, does not depend on the groups they belong to. This is different for people from uncertainty avoiding cultures. They base their selection of trade goals on a minimization of risk, they would rather trade with people they know, are reluctant to trust strangers, progress more slowly during negotiations, and have a low threshold regarding deception of people they have little in common with. *Vice versa* they are looking for a pretext to see their suspicions confirmed, thus when deceived, they tend to respond furiously, and tend to avoid that partner if possible. The model has been tested in simulations showing that the generic tendencies as attributed to uncertainty avoidance are reflected in the simulation results.

Our work shows how the influence of culture on decision-making processes can be modeled. So far, the literature on the influence of culture is largely generic in nature and not formalized into working simulations and/or agent-based systems. The pattern in our approach is that for each possible decision-making rule two aspects are considered. Would the cultural background:

- make the rule inappropriate, and
- change the parameters of the rule?

With this in mind, the normal decision making process for the task at hand is considered in all its stages.

Future work. The authors aim to validate and calibrate the model against experiments with human participants, as depicted in Figure 1. Future work comprises experiments with questionnaires and one-to-one negotiation gaming simulations. As a preparation for this work, more extensive sensitivity analyses are required.

When all five dimensions have been modeled and validated in isolation, the next step is to combine models of several dimensions. The main problem here is to maintain validation; by entering too many variables at once, attributing behavior to some of them is hard. For that reason, combinations of two dimensions are aimed for. Combinations will be selected with respect to available pairs of cultures comparable with respect to the remaining dimensions, and differ with respect to the selected two dimensions. The various models that combine the influence of two dimensions are of direct use to model traders coming from the cultures for which only those two dimensions differ, and for traders from cultures for which only one of those dimensions differ. The final model combining five dimensions can be used to model traders from any cultural background.

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8 Long-Term Orientation in Trade

Abstract. Trust does not work in the same way across cultures. This paper presents an agent model of behavior in trade across Hofstedes cultural dimension of long-term vs. short-term orientation. The situation is based on a gaming simulation, the Trust and Tracing game. The paper investigates the micro-dynamics of trust in a trade relationship, focusing on one dimension of culture only. This is a deliberate simplification that is made in order to highlight the role of this particular dimension of culture. The dimension is relevant for trade between East Asia and the Western world. The paper discusses the cultural dimension of long-tern vs. short-term orientation and specifies decision rules for trading agents, differentiated across the dimension. The paper contributes to bridging the gap between macro level analysis of intercultural trade and micro level knowledge about culturally determined behaviour. To this end the agent model is implemented in a multi-agent simulation. Potential applications of the model are to be found primarily in research into the formation and performance of supply chains and networks, and secondarily in training, education, and advice systems. The implementation of the model has been verified to qualitatively represent the effects expected on the basis of Hofstedes theory.

Introduction

Trade requires trust. A buyer has to trust the seller, or the virtues of the product, or if he trusts neither he could still trust the enforcement mechanisms that can be put into operation in case of cheating. For a seller it is the same, except that he usually knows about the product, so that he is on the knowing side of an information asymmetry.

Trust does not work in the same way across cultures (Hofstede 2007). For instance, in some societies the emphasis is on interpersonal trust based on kinship; in others it is on interpersonal trust based on other markers; yet in others it is in impersonal institutions such as certification or law. Gorobets and Nooteboom (2006) provided some evidence, on the basis of a multi-agent simulation, that economic systems based on trust as well as systems based on opportunism might be viable in different societies.

This paper investigates the micro-dynamics of trust in a trade relationship. It does so by specifying an agent model for trade in a product with a hidden quality attribute. The situation is based on a simulation game, the Trust and Tracing game (Meijer et al. 2006; Jonker et al. 2006). The focus of study of this game is on trust in a business partner when acquiring or selling commodities with invisible quality.

When playing the game with people from different parts of the world, different patterns of trade and trust emerge (Meijer et al. 2006). A multi-agent model of the interactions in the game may help to improve the understanding of effects of culture on trade, and may help to understand if different economic systems and institutions may have been differently efficient in different parts of the world.

This paper focuses on one aspect of culture only. This is a deliberate simplification that is made in order to highlight the role of this particular dimension of culture. The 5-dimension model by Hofstede (2001) allows for this approach. The paper first discusses the cultural dimension of long-tern versus short-term orientation and its effects on trade. It then specifies the decision rules for the trading agents. After this, results of test runs are presented. Some conclusions and caveats round off the paper.

Long- versus Short-Term Orientation

Behaving as a good, upstanding member of the group is at the core of the lives of all beings that live in social groups (Wilson 2007). Human beings are intensely social and they exemplify the point very well. Ensuring the successful functioning of our social groups is a basic requirement for survival. We spend up to twenty years being taught how to act as virtuous members of society. But how to be virtuous? It turns out that different societies have found different answers to that question. In some, rationality is a prominent virtue; in others, common sense. In some, virtue consists primarily in honouring tradition; in others, it consists more of becoming prosperous. The issue of whether the sources of virtue are to be found in the past and present on the one hand, or in the future on the other hand, is one of the basic dimensions of culture found by Hofstede (2001). It is a dimension not easily recognized by Western minds. The other four dimensions (individualism / collectivism, power distance, masculinity / femininity, uncertainty avoidance) in Hofstede's model are more often mentioned in research. Yet this fifth dimension, called 'long-term versus short-term orientation' (LTO) by Hofstede, is very important for trade. If nothing else, its strong correlation with economic growth across 39 countries in the period 1970-2000 testifies to this (Hofstede and Hofstede 2005, p. 223).

Hofstede (2001, p. 359) gives the following definition of the LTO-dimension:

> "*Long Term Orientation stands for the fostering of virtues oriented towards future rewards, in particular, perseverance and thrift. Its opposite pole, Short Term Orientation, stands for the fostering of virtues related to the past and the present, in particular, respect for tradition, preservation of "face" and fulfilling social obligations*".

Both positively and negatively rated values of this dimension are found in the teachings of Confucius, but the dimension also applies to countries without a Confucian heritage, for instance Brazil. Long-term orientation needs not be correlated with collectivism, as it is in the very collectivist Southeast Asian countries. Within Europe, Finland and the Netherlands are fairly long-term oriented, whereas Sweden and Germany are more short-term oriented.

The LTO-dimension can be predicted to have some effect on behaviour of participants in the Trust And Tracing game. The game has a limited time frame, so a long term oriented strategy may not be a successful one to win the game. The game's reward system is about gains made during the game run, not about building a strong market position; the game is finite. One typical characteristic of long-term oriented thinking is that it is not limited to the time frame or to the logical puzzle set by any single event. Chinese, Japanese, Korean and Vietnamese culture are long-term oriented. Hampden-Turner and Trompenaars (1997) were thinking about this when they entitled their book about Asian business values “Mastering the infinite game”. Asian logic is not atomistic. Table 1 displays distinctions that are relevant to the work in this paper.

Table 1. A summary of relevant distinctions between norms in long-term oriented and short-term oriented societies (source: Hofstede 2001, p. 367)

Short-term oriented	**Long-term oriented**	
Immediate gratification of needs expected	Deferred gratification of needs accepted	(1)
Traditions are sacrosanct	Traditions adaptable to changed circumstances	(2)
Short-term virtues taught: social consumption	Long-term virtues taught: frugality, perseverance	(3)
Spending	Saving, investing	(4)
The bottom line	Building a strong market position	(5)
Analytical thinking	Synthetic thinking	(6)

The LTO-dimension can be predicted to have some effect on behaviour of participants in the Trust And Tracing game. The game has a limited time frame, so a long term oriented strategy may not be a successful one to win the game. The game’s reward system is about gains made during the game run, not about building a strong market position; the game is finite. One typical characteristic of long-term oriented thinking is that it is not limited to the time frame or to the logical puzzle set by any single event. Chinese, Japanese, Korean and Vietnamese culture are long-term oriented. Hampden-Turner and Trompenaars (1997) were thinking about this when they entitled their book about Asian business values “Mastering the infinite game”. Asian logic is not atomistic.

Hofstede (2001) performs an extensive literature review that confirms the importance of long-term orientation to trade. Long-term orientation opposes the disruption of harmonious relationships. This does not mean that conflict or competition are nonexistent. It means that they will not be framed as such. There are strong encouragements to self-discipline, and any emotion that might cause repercussions is repressed. Subordinates are very ready to comply, because it is in the interest of the social entity as a whole. Usefulness to the whole of society is an important criterion for behaviour, and it takes precedence over truth. Making statements that are not factual in order to achieve benefits for the group is not a sin, but a virtue.

Long-term orientation is correlated with self-effacement. This was found by Minkov (2007) in a meta-analysis of data from the World Values Survey. The individual thinks of itself as a small element within the continuity of life. Hence, learning and developing one’s capacities is more important than winning a particular game, or obtaining a particular result. Winning that game might even be harmful if it damaged relationships that could be useful in the future. In contrast, short-term orientation correlates with self-enhancing values in which being successful in a game is a desirable thing that will improve one’s reputation.

It can thus be expected that the performance of long-term oriented traders is much dependent upon factors that are not within the scope of the experimental setting. They will be more aware of possible adverse real-world consequences of what they do during the game than will participants from short-term oriented cultures. Of course this problem needs not affect the performance of agents – but it will affect validation against the behaviour of human traders.

The effect of LTO on trade processes

Figure 1 presents a process model of a trading agent, inspired by the setting of the Trust and Tracing game. The focus of this game is on trust in a business partner when acquiring or selling commodities with invisible quality. There are five roles: traders (producers, middlemen and retailers), consumers and a tracing agency. Typically there are 4 producers, 4 middlemen, 4 retailers and 8 consumers, to reflect the multiple steps and oligopoly character of most supply networks. The real quality of a commodity is known by producers only. Sellers may deceive buyers with respect to quality, to gain profits. Buyers have either to rely on information provided by sellers (Trust) or to request a formal quality assessment at the Tracing Agency (Trace). This costs a tracing fee for the buyer if the product is what the seller stated (honest). The agency will punish untruthful sellers by a fine. Results of tracing are reported to the requestor only or by public disgrace depending on the game configuration. A strategy to be a truthful seller is to ask for a trace before selling the product. In that case sellers use the tracing report as a quality certificate. Middleman and retailers have an added value for the network by their ability to trace a product cheaper than a consumer can.

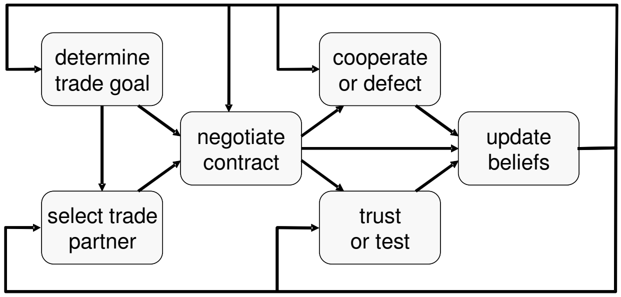

Fig. 1. Processes and internal information flow of a trading agent.

Agents determine their trade goals, select partners, negotiate, and, after contracting, they may deliver truthfully or defect, and have to decide if they will trust their partner's deliveries to be truthful. Based on their experience and cultural preferences, the agents maintain beliefs about individual partners with respect to trustworthiness and acceptability for future deals. For each of the processes represented in figure 1, this section elaborates on the expected differences in behaviour between from long- and sort-term oriented cultures, based on Hofstede's work.

Partner selection. Long term oriented traders aim to develop lifetime relations. Not only a transaction's calculated pay-off counts; the resulting relation is of value by itself. Given the choice, a long term oriented trader would not neglect a proposal from a known relation in order to make a one more attractive one time deal with a stranger.

Short term oriented traders are not interested to develop long lasting relations. They want to make attractive deals as soon as possible. Their preferences in partner selection depend on other dimensions of culture, but they may be interested in doing business with high status partners to show off.

Trade strategy selection. Long term oriented traders will follow a thrifty strategy. They trade valuable high quality products if it serves their purpose, but they do not need them to show off. They avoid the risk of damaging their relations and do not trade commodities that they are not certain about. Rather will they trade low quality, avoiding the risk of unintentionally selling low quality for high quality, or being forced to show distrust in suppliers by tracing their deliveries. Even if they like to gamble, they will not do it in business. They invest in relations and will not defect.

Short term oriented traders are more opportunistic. They analyze a deal in terms of pay-off (which may include future prospects), rather than a relational network. More than the long term oriented, and depending on other dimensions of culture, they like to show off and are prepared to take risks if this is necessary to save face and meet social demands.

Negotiation behaviour. Long term oriented traders show patience. They do not break off negotiations. They do not overcharge. A first proposal may be modest, but they do not rapidly give in.

Extremely short term traders are impatient. They want rapid deals. If they give in they do it quickly and with substantial concessions. If partners do not make concessions too, they break off easily and try their luck elsewhere.

Truthful or untruthful delivery. After an agreement has been reached, it comes to delivery. If the quality of the commodity is invisible at first sight, the supplier can be opportunistic and try to deliver a lower quality product than agreed upon, thus making an extra profit.

Given the opportunity (and depending on other preferences), a short term oriented supplier may be tempted do so, after calculating the possible gain. A long term oriented supplier will not put a relation with a customer at stake by deceiving.

Trust or distrust. Long term oriented traders cannot take the risk of unintentionally reselling low quality products for high quality products. They do not easily trust new relations. Trust has to be earned. They deliver truthfully and demand equal seriousness from their suppliers. Once relations have developed, they may signal their valuation of the relation by showing trust. When they find out that their trust has been abused, they lose all respect and banish the supplier from business.

The short term oriented traders trust or distrust on the basis of calculated risk and preferences, but the scope of their calculations is no more than the bottom line of the current transaction.

Maintenance of beliefs about partners. People from long term oriented cultures value their relations. They value a deal not only by the financial pay off, but also by the relational gains. They invest in relations by behaving truthfully and by trusting their partners. They have no respect for others that put their relations at stake for some short term profit. If they turn out to be deceived by a business partner they will not easily forgive the deceiver.

People from short term oriented cultures find it hard to understand the sacrifice of the long term oriented. The short term oriented tend to grab a chance for an easy profit and are willing to put their relations at stake for it (the other dimensions of culture, personality and circumstances determine the extent to which they will actually defect). They can understand that a business partner may be tempted to defect if a profitable opportunity occurs, and they have trouble understanding that people from long term oriented cultures cannot.

Representation in Agents

This section formalizes the knowledge about the influence of power distance on trade processes, formulated in section 2. The relevant attributes of transactions from this viewpoint are the economic value of the transaction, the quality of the traded goods as a status attribute in its own, and a perceived risk that the trade partner will not fulfill its contractual obligations or will not trust the delivery.

The negotiation process is modeled according to the negotiation architecture of Jonker and Treur (2001). That approach uses an additive utility function to compare bids. In the results presented in this paper, the following function is used.

$$U_{\text{bid}} = w_1 f_1(\text{value}) + w_2 f_2(\text{quality}) + w_3 f_3(\text{risk}) \quad (1)$$

with $w_1+w_2+w_3=1$, and w_i in [0, 1], for all i. $f_1 \ldots f_3$ normalize value, quality, and perceived risk of the transaction in the interval [0, 1].

Agents are modeled to have personal traits that determine their decisions and behavior. The traits are implemented as real values in [0, 1]. Some traits are related to negotiation behavior; the most important are the weight factors in the utility function, impatience, concession factor, negotiation speed, and other parameters in the negotiation architecture of Jonker and Treur (2001). Some traits are related to the delivery decision and trust (honesty, confidence), some to the update functions that maintain beliefs about partners' trustworthiness, benevolence, and acceptability as a trade partner. In addition to the traits, each agent has a long term orientation indicator - a real number in [0, 1]. Traits and LTO-indicator are not visible to other agents. Furthermore, each agent has a label, that represents it societal status. The status label is visible to other agents.

In the partner selection process, the agents rank potential partners according to acceptability and select at random, where more acceptable partners have a higher probability of being selected. They try and open new negotiations either by replying, if a the selected partner has recently sent a proposal, or by taking the initiative to propose to a partner. Agents may ignore a proposal if the partner is not sufficiently acceptable. If proposals are ignored, the acceptability of the partner is reduced. The agents repeat the partner search until it is successful.

This section formulates rules for the decisions of the agents, based on the values of personal traits, LTO, and beliefs about the partner. The simulation implements many more rules. Only the rules that include an effect of LTO are presented here. The agents implement the following rules to simulate the LTO dimension:

1. An STO agent tends to follows a *quality-minded* strategy, represented by relatively high values of w_2 and w_3 in equation (1); an LTO agent tends follow a *thrifty* strategy: relatively low value of w_2. The denominator N guarantees that the sum of the weight factors equals 1.

```
if cultural_script_contains(long-term-orientation (L: Real))
   and agent_trait_value(value_preference, P: Real)
   and agent_trait_value(quality_preference, Q: Real)
   and agent_trait_value(risk_aversion, R: Real)
   and N: Real = P + Q*(1 - L)*2 + R*min(1, (1 - L)*2)
then weight_for_value (P / N)
   and weight_for_quality (Q*(1-L)*2 / N)
   and weight_for_risk (R*min(1, (1-L)*2) / N);
```

2. In negotiations, an STO agent shows impatience if partner makes unrealistic bids or makes little progress, unless the partner's societal status is high. The follwing rules express how the probability that a negotiation will be terminated if U<M or N<M, depends on impatience, LTO, and status difference. Furthermore the rules record the reason for termination: there is either a gap between the partners proposal and what the agent finds reasonable, or the partner show too little intention to accommodate the agent.

```
if cultural_script_contains (long-term-orientation(L: Real))
       and current_round(X: Integer)
       and current_negotiation (T: Trader, X, C: Commodity_list)
       and others_bid_utility_in_round(U: Real, X)
       and agent_trait_value(cut_off_value, M: Real)
       and U < M
       and agent_trait_value(impatience, I: Real)
       and agent_label(status, S: Real)
       and partner_model_contains_belief (T, status, Y: Real)
       and random(0, 1, Z: Real)
       and I * (1 - max(L, (1 - L)*(Y - S)))*0.5 > Z
then stop_negotiation(T, X, C, gap);

if cultural_script_contains (long-term-orientation(L: Real))
       and current_round(X: Integer)
       and current_negotiation (T: Trader, X, C: Commodity_list)
       and progress_in_bids(X-3, X, N: Real)
       and agent_trait_value(minimal_progress, M: Real)
       and N < M
       and agent_trait_value(impatience, I: Real)
       and agent_label(status, S: Real)
       and partner_model_contains_belief (T, status, Y: Real)
       and random(0, 1, Z: Real)
       and I * (1 - max(L, (1 - L)*(Y - S)))*0.5 > Z
then stop_negotiation(T, X, C, no_accom);
```

3. An STO agent delivers opportunistically; an LTO agent has a high threshold to defect deliberately. The threshold is used in the decision to cooperate or defect. The probability that an agent will cooperate is a monotonous function of the threshold, but also depends on other factors, like beliefs about the other agent and the relation.

```
if cultural_script_contains(long-term-orientation (L: Real))
        and agent_trait_value(honesty, H: Real)
then deceit_treshold(H + (1 - H)*L);
```

4. An LTO agent exercises restraint to trace, cautious to preserve the relation; an STO agent only exercises restraint if partner's status is high .

```
if cultural_script_contains(long-term-orientation (L: Real))
        and current_round (X: Integer)
        and deal_in_round (T: Trader, B: Bid, X)
        and partner_model_contains_belief(T , trustworthiness, W: Real)
        and agent_label(status, S: Real)
        and partner_model_contains_belief(T , status, Y: Real)
        and random(0, 1, Z: Real)
        and W + (1-W)*max(L, (1 - L)*(Y - S)) < Z
then to-be-traced(B);
```

5. An LTO agent's trust is more deeply affected than an STO agent's if a partner defected. Beliefs about another agent's traits and attitudes are update on the basis of an experienced value E, for a positive experience as $B_{t+1} = (1\text{-}d^{+})B_t + d^{+}E$, and for a negative experience as $B_{t+1} = (1\text{-}d^{-})B_t + d^{-}E$, with $d^{-} \geq d^{+}$ and the endowment factor e $= d^{+}/ d^{-}$.

```
if cultural_script_contains(long-term-orientation (L: Real))
        and agent_trait_value(base_neg_update_factor, N: Real)
        and agent_trait_value(base_endowment_factor, E: Real)
        and lto_endowment_factor (F: Real)
then neg_update_factor (N*(1 - L) + L)
and endowment_factor (E*(1 - L) + F*L);
```

6. An STO agent has stronger preference to select high-status partners than an LTO agent. The acceptability of a partner depends primarily on its believed fairness, but an STO agent also takes the partners societal status into account. It likes to show off, while an LTO agent is interested to have long-standing business relationships, independent of partner's status.

```
if cultural_script_contains(long-term-orientation (L: Real))
        and partner_model_contains_belief(T: Trader, fairness, F: Real)
        and agent_label(status, S: Real)
        and partner_model_contains_belief(T , status, Y: Real)
then acceptability (T, F + (1 - F)*(1 - L)*max(0, Y - S));
```

7. An STO agent has aversion against partners that did not respect it (rule 2) or simply did not reply to a bid in an ongoing negotiation. It drastically reduces its fairness belief about the partner if a partner did not show respect by making acceptable proposals.

```
if cultural_script_contains(long-term-orientation (L: Real))
        and current_round(X: integer)
        and stop_negotiation(T: Trader, X, C: Commodity_list, gap)
        and partner_model_contains_belief(T: Trader, fairness, F: Real)
        and neg_update_factor(N: Real)
then new_fairness(T, (1 - max(N, 1 – L))*F);

if cultural_script_contains(long-term-orientation (L: Real))
        and current_round(X: integer)
        and stop_negotiation(T: Trader, X, C: Commodity_list, no_accom)
        and partner_model_contains_belief(T: Trader, fairness, F: Real)
        and neg_update_factor(N: Real)
then new_fairness(T, (1 - max(N, 1 - L))*F);

if cultural_script_contains(long-term-orientation (L: Real))
        and current_round(X: integer)
        and stop_negotiation(T: Trader, X, C: Commodity_list, no_reply)
        and partner_model_contains_belief(T: Trader, fairness, F: Real)
        and neg_update_factor(N: Real)
then new_fairness(T, (1 - max(N, 1 - L))*F);
```

5 Experimental verification

The implementation of the rules developed in the previous section was verified at two levels. First the rules were verified at the level of individual decisions in scenario's of one-to-one agent interactions. Secondly the rules were verified in multi-agent simulations. In the multi-agent simulations, eight supplier agents and eight customer agents were trading commodities with a varying quality, visible to the supplier but invisible to the customer.

To assess the sentisitivity of the model for parameter settings, a thousand runs of 100 time steps were performed to test the sensitivity for a set of 10 parameters. For each parameter a random value was independently drawn from the uniform distribution for each run. 8 supplier agents and 8 customer agents were all configured homogeneously with the parameters drawn for the run. The number of successful transactions was observed per run. The observed output appeared to be particularly sensitive for three parameters: the LTO-index, the weight factor w_2 for quality in the utility function, and the initial fairness belief about other agents. A linear model of the number of successful transaction was fitted for the ten parameters. The adjusted R^2 value was 69 %.

Table 2 presents estimated values of the bottom marginal variance and the top marginal variance associated with the parameters for this model. The bottom marginal variance is the percentage of total variance of the output that is no longer explained if the parameter is removed from the model; the top marginal value is the percentage of variance explained by a simple regression model of the parameter (Jansen, 1994).

The percentage of variance explained is rather low. Adding an interaction term for the three dominant parameters resulted in an R^2 value of 74.3 %. A better fit could not be found. The remaining variance may be attributed to random effects in the simulation. In order to assess the variance introduced by random effects, 30 random parameters sets were generated. With each of these sets, 33 runs of 100 time steps were performed. For each set of 33 run with equal parameters, the standard deviation of the number of successful transactions was computed. The results for the standard deviation as percentage of the mean value are: minimum value 6.5, 25-percentile 8.2, median 9.6, mean 10.6, 75-percentile 12.9, maximum 17.9.

Table 2. Interval used for generation of ramdom values, and bottom marginal variance (BMV) and top marginal variance (TMV) of 10 parameters used for sensitivity anlysis

Parameter	interval	BMV (%)	TMV (%)
`LTO`	0.01 … 0.99	27.1	25.6
`status_difference`	0.01 … 0.99	0.4	0.3
`Honesty`	0.01 … 0.99	4.3	4.2
`initial_fairness`	0.01 … 0.99	6.5	7.8
`Impatience`	0.01 … 0.99	2.6	4.0
`endowment_coefficient`	0.50 … 0.99	0.4	0.3
`lto_endowment_coefficient`	0.20 … 0.50	0.0	0.0
`weight_Q`	0.01 … 0.99	26.3	27.1
`weight_R`	0.01 … 0.99	0.2	0.2
`negative_update_factor`	0.01 … 0.99	0.8	0.0

Scenario's were run to test the effect of the LTO index in different homogeneous and heterogeneous configurations, in 6 sets of 100 runs. 100 independent parameter sets were generated at random, except for LTO and for status. The random parameter sets were reused for each set of 100 runs, in order to enable pairwise comparison of individual runs. Values of LTO were fixed to LTO=0.2 for all agents in the first 100 runs, LTO=0.8 for all agents in the second 100 runs, LTO=0.2 for suppliers and LTO=0.8 for customers in the third 100 runs, vice versa in the fourth 100 runs. In the fith 100 runs, 4 suppliers and 4 customers were given a value of LTO=0.2, the other agents were given LTO=0.8. Status was equal for all agents in the first 500 runs. In the last set of 100 runs, status was assigned at random at each individual agent. Table 3 presents average results of multi-agent simulations.

Table 3. Average statistics of sample runs with long-term oriented (LTO=0.8) and short-term oriented (LTO=0.2) agents; the presented figures are mean values of 100 runs, each having a duration of 100 time steps; eight suppliers and eight customers can select each other for negotiation, exchange bids, deliver truthfully or defect, and request a trace

Supplier culture	STO	LTO	STO	LTO	mixed	rs *)
Customer culture	STO	LTO	LTO	STO	mixed	rs *)
Number of successful transactions	91	43	92	42	69	57
Number of traces requested	11.8	2.2	3.3	9.1	6.9	6.0
Number of defections revealed by tracing	0.7	0.0	0.2	0.1	0.3	0.4
Number of unrevealed defections	2.4	0.5	3.3	0.3	1.8	1.8
Average quality agreed in transactions	0.9	0.7	0.9	0.8	0.9	0.9

*) rs: random status: in these runs culture of suppliers and customers was mixed and status was assigned at random, uniform in [0,1]; in all other runs, status=0.5 for all agents.

The high frequency of tracing and defection and the high level of average quality where STO-agents are involved is as expected and corresponds to the rules. The differences in number of transactions are more puzzling. All differences are significant at the two-sided 99 % level, except the difference between run sets 1 and 3 and run sets 2 and 4. The high volumes of transactions occur in particular in individual runs with STO-agents where the weight factor w_2 for quality is very high. This makes the agents careless about money. For realistic simulations this parameter should not be set greater than 0.5. Another option might be to replace the additive utility function by a Cobb-Douglas type function. However, the latter requires a recalibration of the applied negotiation architecture, for which realistic parameter values were assessed for use with the additive utility function in human experiments.

A second factor that strongly influences the results is the initial setting of the fairness belief that agents maintain about other agents. It plays an important role in the partner selection process. If its value is low, the experience of a single successful transaction may improve the mutual beliefs to such extent that the agents stick together forever. So the initial setting of this parameter should be a realistic value, e.g., equal to the minimum-utility that agents apply in negotiations.

The results verify the implementation of the rules in the agents, in the sense that they behave and interact as expected. However, these tests do not validate the model to represent real trade processes. They only verify the correct implementation of the rules.

6 Conclusion

Hofstede and numerous other authors (e.g. Hampden-Turner and Trompenaars 1997) describe cultural differences and their effect on trade at the individual level. The present paper contributes to bridging the gap between those approaches with agent-based modelling. In agent-based economics, individual traders are modeled as intelligent agents cooperating in an artificial trade environment. The agents are modeled as closely as possible to authentic human behavior. In recent papers the differences between such agents is no longer solely attributed to differences in their individual economic situations. Aspects such as personality and attitude are considered as well, see for example Jager and Mosler, 2007. Without considering such aspects, the simulations will not correspond to reality. With respect to formalizing the important influence of cultural background on trade, we only found a few papers. The papers study trade at the macro-level. For instance, Kónya, 2006, presents an equilibrium analysis on the amount countries invest in learning another language and culture and the size and well fare of those countries. Bala and Long, 2005, present a formal model of the influence of trade on culture, i.e., the reverse direction of influence as studied in the current paper. Other literature also uses macro-level models, such as the gravity model to study the correlation between culture and trade, e.g., Guo 2004.

The contribution of the present paper is the formalization and simulation of culture with respect to the influence of Hofstede's cultural dimension of long-term versus short-term orientation. This dimension is relevant for trade between East Asia and the Western world. The formalization and simulation have been carried out on the micro-level, i.e., on the level of the individuals participating in trade. The trader behavior is formalized in the form of rules that take long-term versus short-term orientation of the parties involved into account. The agents reason with a perceived model of the parties they consider for trading. These perceived models do not contain estimates of the culture of the other parties.

The implementation of the model has been verified to qualitatively represent the effects expected on the basis of Hofstede's theory, if agents were configured either extremely long-term oriented or extremely short-term oriented. However, validations against empiric data from either literature or experiments are required to calibrate parameters to actual behavior and to scale Hofstede's LTO index realistically to the simulation parameter setting. Validation and refining and tuning the model to real-life situations remains for future work.

The model has been developed as a research tool to experiment with intercultural trade processes in different institutional settings. Other potential application area's are training programs for business schools and international companies.

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Part IV: Integrating the Dimensions into a Unified Model

In Part III the effect of Hofstede's dimensions has been modelled one by one, as if the effect of a single dimension could be isolated. Actual cultural effects in real trade interactions must be modelled as joint effects of all dimensions simultaneously.

The first chapter of the present part (Chapter 9) describes an approach to integrate the expert knowledge gained in modelling the dimensions one by one. That chapter was originally presented in the 2010 MABS workshop at AAMAS and revised for the post-proceedings (Hofstede et al. 2011). It proposes an approach to integrate the expert knowledge on the individual dimensions into a joint effect. The approach is based on weak disjunction of effects of the synthetic cultures according to the expert knowledge. The effects are based on the concept of cultural factors, which are either the relative position on a dimension toward a synthetic culture, or the product of such a score with a relational attribute, such as status or group distance.

Applying this approach, the subsequent chapters develop integrated models for the main issues of trade according to transaction cost economics (Williamson 1998): searching for trade partners offering the desired products, negotiating and drafting a contract, and delivery, where on the one hand partners are tempted to grab opportunities to defect and on the other hand agents must decide whether to trust partners to cooperate or to spend financial and social resources on monitoring and enforcing partner's compliance. These activities are depicted in Fig. III.

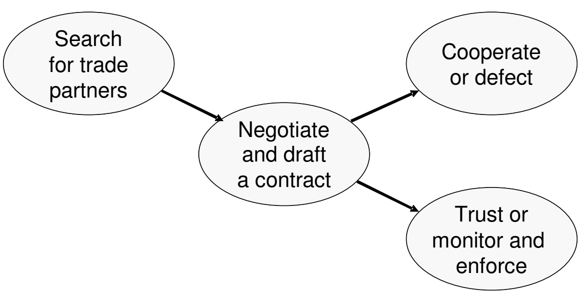


Fig. III. Pre-contract and post-contract activities according to transaction cost economics

In the following chapters, the approach proposed in Chapter 9 is applied to the simulated agents' decision functions. These functions are implemented in the components of the agents' process model. The decision functions are based on models of human behaviour for which evidence is reported in scientific literature that validates the models to realistically simulate real human behaviour.

Chapter 10 describes culture's effects on partner selection, building on a model originally proposed by Weisbuch et al. (2000) for the Marseille fish market. Chapter 10 was originally presented in the 2009 Artificial Economics symposium (Hofstede et al. 2009a). The introductory section includes a substantive motivation why Hofstede's framework has been selected to model culture's consequences.

Chapter 11 models culture's effects on the negotiation process. Negotiation is a subject that receives ample and continued attention in intelligent agent research and many different models are available (see, e.g., Ito et al. 2011, Lai et al. 2008, Li et al. 2006). For modelling of negotiations on trade transactions in the TRUST & TRACING game, the ABMP negotiation architecture (Jonker and Treur 2001) is selected. This agent negotiation architecture has been validated to represent human behaviour in negotiations by Bosse et al. (2004) and Bosse and Jonker (2005). The work presented in Chapter 11 has been published in Group Decision and Negotiation (Hofstede et al. 2010). This work is partly based on a paper originally presented in the First International Working Conference on Human Factors and Computational Models in Negotiation, 2008 (Hofstede et al. 2008c).

Chapter 12 models the delivery phase of transactions, both from the supplier's perspective (cooperate or defect?) and from the customer's perspective (trust or trace?). The chapter has been published in Transactions on Collective Computational Intelligence II (Hofstede et al. 2010a). It is partly based on a paper that received a best paper award in the ICCCI 2009 conference (Hofstede et al. 2009c). For the customer behaviour, Chapter 12 builds on trust dynamics as described by Jonker and Treur (1998) and validated by Jonker et al. (2004). The model for opportunistic supplier behaviour is informed by experimental data found in social sciences literature. This chapter closes the loop in that it reproduces the differences between American and Dutch participants in the TRUST & TRACING game reported in Chapter 4, thus offering a partial validation of the model.

9 Computational Modeling of Culture's Consequences

Abstract. This paper presents an approach to formalize the influence of culture on the decision functions of agents in social simulations. The key components are (a) a definition of the domain of study in the form of a decision model, (b) knowledge acquisition based on a dimensional theory of culture, resulting in expert validated computational models of the influence of single dimensions, and (c) a technique for integrating the knowledge about individual dimensions. The approach is developed in a line of research that studies the influence of culture on trade processes. Trade is an excellent subject for this study of culture's consequences because it is ubiquitous, relevant both socially and economically, and often increasingly cross-cultural in a globalized world.

Keywords: dimensions of culture, computational model, social simulation

1 Introduction

Being competent in trading depends on more than economic rationality. To model trade as it actually happens, creating agents that compute the most profitable deal is therefore not enough. The agents' incentives could be modeled using Williamson's framework [1] in which four time scales are used: resource allocation (for instance: trade) happens continuously, and is subject to governance rules that may change on a time scale of 1 to 10 years. These rules are themselves subject to institutional changes, e.g. new legislation, at a time scale of 10 to 100 years. Institutions in their turn are based on and attuned to the hidden rules of the game (culture) that are embedded in society and change on a time scale of 100 to 1000 years. So this model states that people involved in trade use governance rules, institutions and cultural values to guide their behavior, albeit unconsciously. The present article takes this position as a basis for modeling the effect of culture in agent-based social simulations.

Societies around the world differ greatly with respect to the value systems and ideas that govern patterns of human interaction. Hofstede [2], p.9, defines culture as "*the collective programming of the mind that distinguishes the members of one group of people from another*". The behavior of people and their interpretation of the behavior of others are based on their norms for appropriate behavior. These norms vary from culture to culture.

In different cultures, different norms may prevail for behavior in trade; e.g., trade partner selection, bargaining style, trust that has to be shown, favor that is given to in-group relations or high-ranked society members, and opportunistic advantage that may be taken from partners. Different systems may be viable in different societies. For example, [3] used multi-agent simulations to show that economic systems based on trust and systems based on opportunism may both be viable.

When traders operate in foreign cultures, the programming of their minds may not be efficient. This explains the existence of practical guides for business behavior in different countries, e.g. [4] and [5], and the extensive body of scientific literature that has been developed. The scientific literature ranges from business oriented studies, e.g. Kumar [6], and cross-cultural surveys, e.g., Kersten et al. [7], to economic models, e.g., Guo [8] and Kónya [9].

The approach proposed in this paper aims to model culture at the mid-range level according to the classification by Gilbert [10], p.42. Mid-range models depend on a rich description of processes, but do not in facsimile model a particular situation. For mid-range models, observed trends should be similar to those observed in reality. This is important for our long-term research goal of improving the understanding of human decision-making in international supply chains with asymmetric information, see, for instance, [11]. The research method proposed in [11] combines multi-agent models with gaming simulation, but a general multi-agent-based model as proposed in [11] does not explain the cultural difference observed in the gaming simulations.

For the modeling of culture, one must lean on social sciences literature. Two main streams of research can be distinguished. First, there is the anthropological approach of rich description, in which specific cultures are studied by detailed and close observation of behaviors during an extensive time-span. Examples are the works of Lévi-Strauss [12] and Geertz [13]. Second, there is the comparative approach that tries to identify dimensions on which different cultures can be ordered, aiming to develop a classification system in which cultures can be typed by a small number of qualifications. Examples are the models of culture by G. Hofstede [2], Schwarz [14], and Trompenaars and Hampden-Turner [15]. The approach of that type of research is to characterize cultures by their indices on a limited number of dimensions. The dimensions and the indices of cultures are identified by factor analyzing massive surveys with standardized questionnaires in many countries. The value of such dimensions largely depends on the questionnaires used in combination with the sets of respondents that are required. Questionnaire studies will be more reliable predictors of behavior if respondent samples are well matched (e.g. do not compare industry x in one country with industry y in another), and the number of cases (cases are group averages, often country averages) should be considerable. Results tend to be more reliable if they are asked to a broad range of types of respondents as opposed to just one type (e.g., students or managers). The resulting models provide a linear ordering of cultures along each dimension, where particular values and practices are hypothesized (based on empirical evidence) to be stronger or weaker or occur more frequently or less frequently according to the index on the dimension. For instance, in cultures on one extreme of a particular dimension concerned with asymmetry of power relations, the implicit norm is for parents to treat children as equals, while in cultures on the other end parents are supposed to teach children obedience. As authors of dimensional models stress, these same implicit norms carry over to all relationships in society that involve potential power differences, whether in school, in politics or in trade. In all social situations, they act as filters on perception and on action range. This means that there are no specific values for activity x, e.g. ‘trade values’, in a dimensional model. It also means that a dimensional model is suited for modeling any process that involves social intercourse, including trade and its sub-activities.

Cultural descriptions of the first type provide rich details about values, norms, symbols, beliefs, rituals, social structure, behavioral patterns etc. in a particular culture. These are useful for facsimile modeling of specific social systems. The model proposed in the present paper aims to compare the influence of a great diversity of cultures in the standardized environment of a gaming simulation which is by itself an abstraction of social life. For that purpose we need to posit the model at an impartial distance from any single culture. A dimensional model is more suited than a collection of incommensurable rich descriptions. Dimensional models are culture-level abstractions. They do not depict individuals, but average group characteristics, and therefore the agents in our simulation will be iconic for a culture (mid-range, in our term), not specific for any individual (facsimile, in our term).

Of the well-known dimensional models, the most widely used is Hofstede [2]. His work is accessible, sparse, and based on a very large, very well stratified sample of questions, asked of people in all professions, that continues to give it great explanatory value. No other model matches society-level variables so well to date [18].

The hypothesis of this research is that computational models of culturally differentiated agents can be deduced from social scientific theories that differentiate cultures along a limited number of dimensions. An agent-based model can be developed to incorporate behavior and agent interactions which are realistically differentiated along each of the cultural dimensions. Note that the model based on the cultural indices may reliably reproduce general trends, but will not differentiate up to the detail of actual individuals. For the long term, a computational model based on a dimensional theory of culture in multi-agent-based simulations can provide insights into the functioning of social systems and institutions in different cultural contexts.

To develop computational models of culturally differentiated agents in a specific domain of application a general agent-based model for that domain of application can be taken as a point of departure. That general model should be based on a task, process, or activity analysis of the domain of application. A dimensional theory of culture can be used to determine the required adaptations to the model to reflect the way culture influences behavior trends. Such adaptations also pertain to the way the agents perceive their environment and the behavior of other agents. For instance, if the theory describes that in some cultures favor is to be shown to in-group customers, while in other cultures the norm is to treat all customers equally, the agents need a cognitive model in which they can be aware of what group they belong to and maintain models of other agents in which they maintain beliefs about other agents' group memberships (e.g., "I belong to group x and she does not belong to that group"). For each of the processes of the general model, an adaptation must be developed that models the adaptation of decisions by culture. This paper describes an approach to develop computational adaptations of the processes within the agent that are based on a dimensional model of culture, and expert knowledge about cultural effects on decisions and interpretation of behaviors.

The case for which the approach described in this paper has been developed is a simulation game of trade under asymmetric information [17]. A multi-agent-based simulation of this game has been developed [11], with two purposes: to test hypotheses about players' decision making and to design optimal configurations for human games. When playing the game with human participants, differences in outcomes were observed that were attributed to differences in cultural background [17]. The latter was the rationale for modeling culture into the artificial agents.

The process model for trading agents acting in the game is given in Fig. 1. First, agents determine a short-term trade goal (e.g., to buy or to sell? what type of product? top quality or basic quality?). Next, agents search for acceptable trade partners with complementary needs that are willing to negotiate. After negotiating a contract, it comes to delivery, where an agent may deliver according to contract or defect in some way. Partners have the choice to trust the other to comply with the contract, or to spend resources on monitoring and enforcing deliveries. Finally, after these trade interactions, the trading agents reflect upon the effectiveness of their trade, on the trustworthiness of their trade partners, and on their own decisions. On the basis of that reflection they update their beliefs.

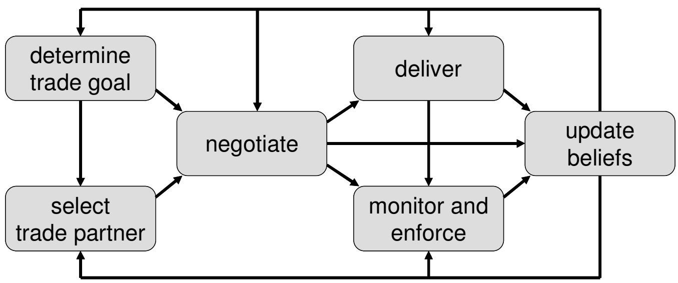


Fig. 1. Processes and internal information flows of trading agents (adapted from [18])

The plans that the agents execute for process fulfillment are based on validated models taken from literature on social sciences and artificial intelligence. The agent's decision models implemented in the plans were adapted to include effects of culture, based on Hofstede's [2] dimensional model. The present paper describes the approach taken to incorporate the dimensional model of culture into the decision functions. The paper is organized as follows. Section 2 presents an overview of the method that was followed in knowledge acquisition and model formulation. Section 3 formulates the computational model. A discussion of results concludes the paper.

2 Modeling Method

The exercise of modeling culture in trading agents could be carried out in a multitude of ways, using a variety of theories. The present article describes one such attempt. It also presents the choices and the line of reasoning behind this method. This could enable other researchers to choose which of the principles, choices and practices of this approach to adopt and from which ones to deviate.

In order to model cultural differentiation in agents the following steps were taken, once the domain to be modeled had been defined. Agent roles, possible actions and communications, agent network, the environment and entities in it, as well as their observable properties, were defined. For the agents, a process model had been established (see Fig. 1).

In each process the agents take decisions based on decision rules. For these rules, models were preferred that had in empirical research been validated to simulate actual human behavior. For instance, in the model of culture implemented by the authors, the ABMP negotiation architecture is applied. It has been validated in experiments with Dutch adolescents and adults [19]. If no validated model can be found in literature, a dedicated model has to be formulated based on empirical data or research; see, for instance, [20].

The decision models taken from literature can be implemented as a set of rules (the agent's knowledge base. Typically, the decision rules are parameterized. For instance, parameters in the rules of the ABMP negotiation strategy have names like *concession factor*, *negotiation speed*, *impatience*. So, the decision model can be formulated as a set of parameterized rules, and the labels of the parameters can be listed. We refer to this modeling activity as "decision function analysis". The results are the decision rule base and a list of parameter labels (see Fig.2).

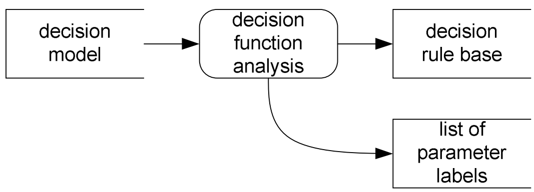
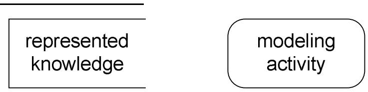


Fig. 2. Decision function analysis[3]

The decision rule parameters are the point of application for cultural differentiation. It is important to start from process models that allow for such adaptation. Validations of behavior with subjects from one culture are no guarantee for the occurrence of similar behavior in other cultures. This is amply shown by a multitude of experimental studies published in journals such as the Journal of Cross-Cultural Psychology, and in review volumes such as [21]. This fact implies that ideally, only models shown to be valid across cultures should be used. This condition could not be met for all the models used in this paper. The Hofstede dimensions of culture were derived using a sample of people in a broad range of professions from over 70 countries on all continents, and explicitly aiming to compare these countries. They qualify. For the ABMP negotiation architecture, however, we had to be content with validation in only one culture. Further validations in other countries of ABMP could yield results that necessitate revisions of our agent models.

For the cultural differentiation a dimensional model of culture was selected, in this case Hofstede's five-dimensional model [2]. Two criteria were important in the selection. First, the model had to be applicable for the social processes to be simulated, based on the contexts in which it has been developed and validated, and the availability of research results that provide rules for decision parameter adaptation. As argued in section 1, this condition holds for the Hofstede framework. Second, the modelers had to

[3] Legend of Fig. 2…5:



have access to expertise on the cultural model to be applied, for knowledge acquisition and expert validation of results.

Knowledge about the influence of individual dimensions of culture on the decision functions of the process model was acquired, using the concept of Synthetic Cultures [22] complemented by an expert systems approach. Synthetic Cultures are scripts, created by experts on cross-cultural communication, that catch a single extreme of a single dimension of culture in rules of behavior. They have been created for use in training counselors [22] and later adapted for use in simulation gaming for a multitude of applications [23]. Synthetic Cultures lead to believable behavior by simulation participants, and to realistic cross-cultural miscommunication, even though the synthetic cultures themselves are obviously unrealistic. Since their publication, a number of simulations based on synthetic cultures were created, the synthetic cultures were refined based on experience [24] and they have become adopted by cross-cultural trainers around the world.

Literature and expert knowledge are mostly based on differentiation along the dimensions. It is feasible to acquire knowledge on the differentiation along a single dimension, whereas it proved to be impossible in practice to interpret the joint influence of multiple dimensions on general rules. A classical knowledge acquisition approach was followed for each dimension: interview experts on the cultural theory, read literature, write narratives of expected system behavior, have experts validate the narratives, correct until the experts have confidence in the narratives. In addition to the narratives, the knowledge acquisition resulted in a list of relevant cultural factors[4] for each dimension. On the basis of the knowledge gained, the influence of the relevant factors for a single dimension on each parameterized decision rule can be formalized as a set of rules that modify the parameter values (see Fig. 3).

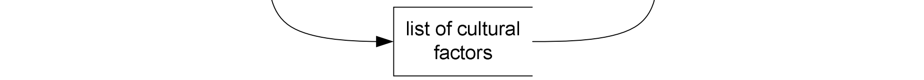


Fig. 3. Knowledge acquisition and formalization

The next activity in the modeling was to implement the adaptation rules in multi-agent-based models for each single dimension (Fig. 4). The step of the modeling per dimension is described for each of Hofstede's dimensions in [25], [26], [27], [28], and

[4] Some dimensions adapt the perceived relevance of certain relational attributes. For instance, the salience of common group membership (in-group versus out-group) is adapted by the dimension of individualism versus collectivism. Other such relational attributes are status difference and trust. 'Cultural factors' combine dimension scores and relational attributes.

[29]. The results of these models can practically only be validated through expert validation, because they concern synthetic cultures, which work as a concept for reasoning about cultures, but have no examples in the real world. In reality, cultures are composites of all dimensions and only effects of interactions with the other dimensions can be observed.

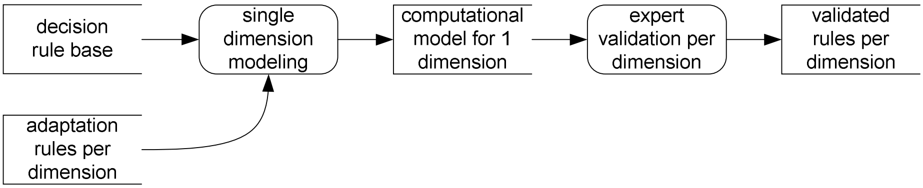


Fig. 4. Computational modeling and validation for a single dimension

Finally, the parameter adaptation rules of the individual dimensions were combined into an integrated set of rules, as the basis for a computational model of the simultaneous influence of all dimensions (Fig. 5). The integration technique used to integrate the adaptation rules is described in the next section. This technique has been applied in models for the agent's processes of partner selection [30], negotiation [31], and delivery, monitoring and enforcing, and belief update [20].

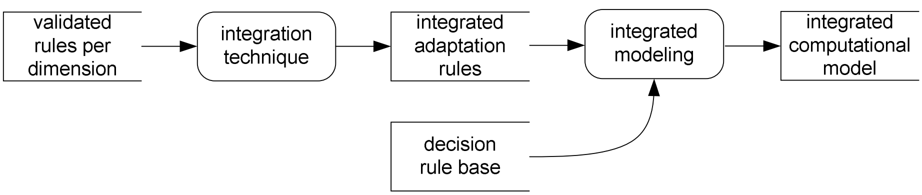


Fig. 5. Integration and computational modeling of joint dimensions

3 Integrated Computational Model

This section describes the approach taken to integrate the parameter adaptation rules for the single dimensions into an agent model that simulates a complete cultural "Gestalt". The approach has been applied to differentiate trading agents in a simulation game according to Hofstede's dimensions, but it is described in a more general way. The approach can also be applied when using other dimensional models or to other processes where the decisions can be described by parameterized rules and data or expertise is available to assess the effects of culture on the parameter values. From this general perspective, we formulate the approach as follows.

Assume for some domain of application that a set of adapted decision rules per dimension and accompanying sets of parameters and cultural factors are given (see Fig. 2 and Fig. 3). This section discusses an approach to integrating all this knowledge into one integrated computational model that reflects the influence of culture on decision making in the domain. The key concepts used in our approach are described as follows (see Table 1 for an overview).

Table 1. An overview of the key concepts

Dimensions	*Cultural factors*		*Parameters ranging over 1≤ i≤ m*			
ranging	Factor	Factor	Label set P:	p_1	…	p_m
over	label set	value set	default value:	x_1	…	x_m
$1\leq j\leq n$	L	F	adjusted value:	x_1'	…	x_m'
1	l_{11}	f_{11}		r_{111}	…	r_{m11}
	…	…		…	…	…
	l_{1q_1}	f_{1q_1}		r_{11q_1}	…	r_{m1q_1}
…	…	…		…	…	…
n	l_{n1}	f_{n1}		r_{1n1}	…	r_{mn1}
	…	…		…	…	…
	l_{nq_n}	f_{nq_n}		r_{1nq_n}	…	r_{mnq_n}

The m parameters used in the domain model are labeled p_1 through p_m, with associated default values x_1 through x_m, for some reference culture, and values adjusted for culture x_1' through x_m'. For instance, in the ABMP negotiation model applied in the trading agents simulation, the i-th parameter may have label p_i="negotiation_speed" with an associated global default value x_i, equal for all agents for a particular type of trade; for each individual agent, the value is modified to its cultural adjusted value x_i', so x_i' may be different for agents having different cultural profiles.

For each culture dimension j, there is a range of q_j cultural factor labels l_{j1} through l_{jq_j} with associated values f_{j1} through f_{jq_j}. Variable i is consistently used in this paper to range over parameters (values or labels), whereas j ranges over dimensions, and k over cultural factors per dimension j. For each factor label l_{jk} and each parameter p_i, there is a function r_{ijk} that maps factor value f_{jk} and default value x_i to adjusted parameter value x_i'. Table 1 presents an overview of these key concepts.

The integrated effect of culture on agent behavior can be modeled as a function h that maps a vector of cultural factors $\vec{f}$ and a vector of default values of model parameters $\vec{x}$ to a vector of culturally adjusted parameters $\vec{x}'$:

$$h\left(\vec{f},\vec{x}\right)=\vec{x}' \quad . \tag{1}$$

The hypothesis of this work entails that, given the set of decision functions, a dimensional theory of culture can be used (a) to identify the cultural factors to be taken into account and (b) to define the mapping h. If this is possible, the agent modeling can benefit from vast bodies of social sciences literature that describe the differentiation of many behaviors along the dimensions of the cultural model. This literature can be used to define h for the wide range of behaviors, assuming that we can formulate parameterized decision functions governing the behaviors. The literature is the basis for finding the attributes of agents and their relations which are relevant for adaptation of the model parameters. This approach to integration of effects of cultural dimensions has been applied in [20], [30], [31]. In expert-systems based knowledge acquisition the effect of culture can be formulated in statements like: "*In hierarchical societies there are differences in selected trade strategy. The higher ranked prefer to trade high quality valuable commodities to underline their status that fits their position in life. They will not avoid deals where less powerful opponents technically have the opportunity to defect, because the higher ranked rely on their power to enforce cooperation*" [25].

This example refers to the effect of Hofstede's power distance dimension. It refers to multiple decision processes: partner selection, delivery, and monitoring and enforcing. It illustrates that research and experts can explain the differentiation of behaviors along a single dimension on the basis of dimensional theory. It also illustrates that it is hard to acquire knowledge about the processes in isolation. Therefore, the approach is taken to first model individual dimensions and then integrate the models process-by-process. The example also illustrates that not just the values of the dimensional indices are relevant for modeling the effect of culture. Relational attributes are relevant as well. In this example Hofstede's power distance index (PDI) is relevant. It orders countries on a scale with the most hierarchical culture at the high end and the most egalitarian country at the low end. Conditional upon the value of PDI, the status of the agent and its partner are relevant: "*The higher ranked*" refers to agents that have a high status s_a in society; "*less powerful opponents*" refers to opponents with which the status difference $s_a – s_b$, where s_b refers to opponent's status, is high. So, in order to model cultural effects on decisions, not just the indices on the dimensions have to be taken into account as factors, but also relational attributes if their effect is differentiated across cultures. Based upon the example given, one can identify $\mathrm{PDI} \cdot s_a$ and $\mathrm{PDI}(s_a – s_b)$ as relevant factors in addition to PDI.

Based on the knowledge acquired for all individual dimensions, all relevant cultural, relational and situational factors can be identified. In the example of trade the following have been identified as relevant relational attributes: status, in-group versus out-group membership, and the trust relation between partners. For instance, the vector of cultural factors influencing the decisions to deceive and to trust identified by Jonker et al. [20] can be taken from the column labeled "Cultural factor" in Table 2.

Such a table is constructed for each process or group of processes, in this case the trade processes of delivery, monitoring and enforcing, and belief update. It contains the expert knowledge for cultural adaptation of the agents' decision making. It contains the relevant cultural factors (on the rows) and the parameters or variables to be adapted (in the columns). The cells describe the effect of culture. The effect may be either increasing or decreasing. For instance, according to Table 1, the inclination to trace is to be reduced for agents with a collectivistic cultural background, when they trade with in-group partners.

Table 2. Relevant factors with respect to trust and deceit, adapted from [20]; PDI*, UAI*, IDV*, MAS*, and LTO* represent Hofstede's indices of culture, s_a the agent's own status, s_b partner's perceived status, and d_b group distance between the agent and its partner; all variables were normalized to the interval [0,1]; + indicates an increasing effect on the parameter; – indicates a decreasing effect.

Dimension index	Culture and relational characteristics	Cultural factor	Effect on			
			deceit threshold	inclination to trace	negative update factor	positive update factor
PDI	Large power distance	PDI^*				
	- with higher ranked partn.	$\max\{0, PDI^*(s_b - s_a)\}$	+	–		
	- with lower ranked partn.	$\max\{0, PDI^*(s_a - s_b)\}$		–		
	Small power distance	$1 - PDI^*$				
UAI	Uncertainty avoiding	UAI^*			+	–
	- with stranger	$UAI^* \cdot d_b$	–	+		
	Uncertainty tolerant	$1 - UAI^*$				
IDV	Individualistic	IDV^*				
	Collectivistic	$1 - IDV^*$			+	
	- with in-group partner	$(1 - IDV^*)(1 - d_b)$		–		
	- with out-group partner	$(1 - IDV^*)d_b$	–			
MAS	Masculine (competitive)	MAS^*	–	+	–	
	Feminine (cooperative)	$1 - MAS^*$		–		
LTO	Long-term oriented	LTO^*	+	–	+	
	Short-term oriented	$1 - LTO^*$				
	- with well-respected part.	$(1 - LTO^*)s_b$	+	–		
	- with other partners	$(1 - LTO^*)(1 - s_b)$	–			

Having identified $\vec{f}$ for a particular set of processes, and assuming that the vector of parameter values $\vec{x}$ follows from the chosen decision functions, it comes to the definition of the function h. h can be decomposed into a vector of functions g_i, i.e., one per parameter, that map h's arguments to the individual culturally adjusted parameter values x_i':

$$h(\vec{f}, \vec{x}) = (g_1(\vec{f}, \vec{x}), \ldots, g_m(\vec{f}, \vec{x})) = (g_1, \ldots, g_m)(\vec{f}, \vec{x}) = \vec{g}(\vec{f}, \vec{x}) \,, \tag{2}$$

so that

$$\begin{aligned} x_1' &= g_1(\vec{f}, \vec{x}) \\ &\ldots \\ x_m' &= g_m(\vec{f}, \vec{x}) \end{aligned} \,. \tag{3}$$

The problem now is to find the functions g_i for $i = 1,\ldots,m$. For this purpose the following hypothesis can be formulated: given that dimensional models of culture aim to provide for each dimension a linear ordering of the strength or frequency of occurrence of phenomena associated with that dimension, the effect of each cultural factor may be modeled as a strictly monotonic function r_{ijk} that adapts the i-th parameter to the k-th factor associated with the j-th dimension. r_{ijk} can be seen as a member of a set of functions r that can be indexed by the labels of cultural factors and parameters as arguments. r_{ijk} maps the value f_{jk} of the cultural factor with label l_{jk} into an effect e_{ijk} on the parameter with label p_i:

$$r_{ijk} : f_{jk} \times x_i \rightarrow e_{ijk} \ , \qquad \textbf{(4)}$$

$$r_{ijk} \equiv r(p_i, l_{jk}) \ , \qquad \textbf{(5)}$$

and

$$e_{ijk} = r_{ijk}(f_{jk}, x_i) = r(p_i, l_{jk})(f_{jk}, x_i) \ , \qquad \textbf{(6)}$$

where $p_i \in P$, the set of parameter labels, and $l_{jk} \in L$, the set of factor labels.

As the r_{ijk} are strictly monotonic, they can be classified as either increasing or decreasing. For each parameter label p_i its set of factors L_i^+ that have an increasing effect and its set of factors L_i^- that have a decreasing effect can be defined:

$$\forall p_i \in P: \quad L_i^+ \equiv \{ l_{jk} \mid r_{ijk} \text{ is increasing} \} \ , \qquad \textbf{(7)}$$

$$\forall p_i \in P: \quad L_i^- \equiv \{ l_{jk} \mid r_{ijk} \text{ is decreasing} \} \ . \qquad \textbf{(8)}$$

By the knowledge acquisition process taken, the increasing and decreasing effects of the cultural factors can be identified, as illustrated in Table 2 [20]: L_i^+ is the set of factor labels that have a + sign in the column associated with the parameter labeled p_i; L_i^- is the set of factor labels that have a minus sign in the column associated with p_i.

The next problem to solve is the combination of these influences into a single effect on each parameter, i.e. to identify the functions g_i that map the effects of culture onto the parameters. On the basis of expert knowledge the following rules can be formulated as hypotheses:

1. In g_i there is no interaction between the factors $\vec{f}$ and other parameters than x_i. This assumes that any decision model can be formulated in such a way that any parameter can be modified for culture without taking the values of the other parameters into account. For the models we have implemented so far ([20], [30], [31]) this assumption is valid.

2. The joint decreasing and the joint increasing effect can compensate for each other. This expertise is confirmed by expert statements, e.g. (in cultures with high power distance) "*The powerful dictate the conditions. The less powerful have to accept. In feminine or collectivist cultures the powerful may exercise restraint, …*" [25].
3. For the increasing and for the decreasing effects, the effect with the maximal influence is dominant: influences in the same direction do not reinforce each other. According to expert knowledge, if several factors influence a parameter in the same direction, it is sufficient for one to be maximal in order to sort maximal effect (disjunctive factor influence, see e.g. "*feminine or collectivist*") under 2 above.
4. Cultural factors working in the same direction do not reinforce each other. This means that, for instance, in Table 2 three factors are identified to have increasing effect on deceit threshold. If two of the factors have effect 0.5 and one has effect 0.2, their joint effect is 0.5; not 0.4 (the average) or another linear combination (see 3 above); not 0.8 (probabilistic) or another product combination.

The first of these three hypotheses implies that the integration can be performed column-by-column using factor tables like Table 2, and we can write the functions as:

$$g_i\left(\vec{f}, \vec{x}\right) = g_i\left(\vec{f}, x_i\right) . \quad \mathbf{(9)}$$

The second hypothesis implies that the functions g_i can each be defined as the sum of x_i and a function $g_i^+ \geq 0$ that combines the increasing effects and a function $g_i^- \leq 0$ that combines the decreasing effects:

$$g_i\left(\vec{f}, x_i\right) \equiv x_i + g_i^+\left(\left\{r_{ijk}\left(f_{jk}, x_i\right) \mid l_{jk} \in L_i^+\right\}\right) + g_i^-\left(\left\{r_{ijk}\left(f_{jk}, x_i\right) \mid l_{jk} \in L_i^-\right\}\right) . \quad \mathbf{(10)}$$

For the functions g_i^+ and g_i^- a range of function types were experimented with (probabilistic and linear combinations, to name the most obvious). However, under the third and fourth hypotheses all except weak disjunction proved to be untenable[5]. We found that both g_i^+ and g_i^- can be written as a weak disjunction:

$$g_i^+\left(\left\{r_{ijk}\left(f_{jk}, x_i\right) \mid l_{jk} \in L_i^+\right\}\right) = \max\left\{r_{ijk}\left(f_{jk}, x_i\right) \mid l_{jk} \in L_i^+\right\} , \quad \mathbf{(11)}$$

$$g_i^-\left(\left\{r_{ijk}\left(f_{jk}, x_i\right) \mid l_{jk} \in L_i^-\right\}\right) = \min\left\{r_{ijk}\left(f_{jk}, x_i\right) \mid l_{jk} \in L_i^-\right\} . \quad \mathbf{(12)}$$

Equations (11) and (12) enable the integration of the computational models constructed for the single dimensions. For this the form of the functions $r_{ijk}\left(f_{jk}, x_i\right) = r\left(p_i, l_{jk}\right)\left(f_{jk}, x_i\right)$ has to be defined. All that is known so far about these functions is that they are strictly monotonic. As long as there is no further evidence, a

[5] Weak disjunction is consistent with the hypotheses 3 and 4 above. Any linear or product combination of cultural factor is not.

first order approach can be taken, i.e., let r_{ijk} adjust x_i proportionally to f_{jk} from its default value in the direction of the extreme values $\varepsilon_{ijk}^{+} > x_i$ and $\varepsilon_{ijk}^{-} < x_i$:

$$\forall i \mid p_i \in P: \quad \forall j \forall k \mid l_{jk} \in L_i^{+}: \quad r_{ijk}\left(f_{jk}, x_i\right) = \left(\varepsilon_{ijk}^{+} - x_i\right) f_{jk} \ , \tag{13}$$

$$\forall i \mid p_i \in P: \quad \forall j \forall k \mid l_{jk} \in L_i^{-}: \quad r_{ijk}\left(f_{jk}, x_i\right) = \left(\varepsilon_{ijk}^{-} - x_i\right) f_{jk} \ . \tag{14}$$

Under this first order approach, using (11) and (12), (10) becomes:

$$g_i\left(\vec{f}, x_i\right) = x_i + \max\left\{\left(\varepsilon_{ijk}^{+} - x_i\right) f_{jk} \mid l_{jk} \in L_i^{+}\right\} + \min\left\{\left(\varepsilon_{ijk}^{-} - x_i\right) f_{jk} \mid l_{jk} \in L_i^{-}\right\} . \tag{15}$$

In practice, the values of ε_{ijk}^{+} and ε_{ijk}^{-} are unknown. However, minimal and maximal values can be assumed not to depend on the cultural dimension *j*, and estimates $\hat{\varepsilon}_i^{-}$ and $\hat{\varepsilon}_i^{+}$ can be determined per model parameter. Under the assumptions

$$\forall i \mid p_i \in P: \quad \forall j \forall k \mid l_{jk} \in L_i^{+}: \quad \varepsilon_{ijk}^{+} = \hat{\varepsilon}_i^{+} \ , \tag{16}$$

$$\forall i \mid p_i \in P: \quad \forall j \forall k \mid l_{jk} \in L_i^{-}: \quad \varepsilon_{ijk}^{-} = \hat{\varepsilon}_i^{-} \ , \tag{17}$$

(15) can be written (N.B.: $\hat{\varepsilon}_i^{+} - x_i > 0$ and $\hat{\varepsilon}_i^{-} - x_i < 0$):

$$g_i\left(\vec{f}, x_i\right) = x_i + \left(\hat{\varepsilon}_i^{+} - x_i\right) \max\left\{f_{jk} \mid l_{jk} \in L_i^{+}\right\} + \left(\hat{\varepsilon}_i^{-} - x_i\right) \max\left\{f_{jk} \mid l_{jk} \in L_i^{-}\right\} . \tag{18}$$

Concluding, given default values for a specific context, e.g. trade in biologically grown vegetables or trade in second hand cars, and realistic minimal and maximal values for each parameter, using knowledge represented as in Table 2, the function in equation (18) can be used to estimate parameter values x_i' that are adjusted for culture.

4 Conclusion

This paper presents an approach to model cultural differentiation in multi-agent based simulations. It argues that a dimensional theory of culture is a good basis for middle-range agent-based models that simulate differentiation over a broad range of cultures. In the case where a specific culture were to be modeled, an ethnographic type "thick description" could offer a better basis for modeling of culture-specific processes, but where a model aims for differentiation of particular behaviors across many cultures, combining a dimensional theory with expert-knowledge about the differentiation is a practicable approach.

The decomposition of cultural phenomena into a set of linear orderings on a limited number of dimensions enables dimension-by-dimension modeling of cultural effects. The concept of Synthetic Cultures [22, 23, 24], which is well tested in practice, shows that dimension-by-dimension scripts give rise to believable, if unrealistic, behavior. As the dimensions provide a linear ordering, it is reasonable to assume that each dimension (and relational attributes relevant for differentiation of behavior associated with it) has a strictly monotonic effect on decision rule parameters, if all other factors are kept constant.

This paper has proposed a technique to integrate the effects of individual dimensions. The assumptions underlying the integration technique are the following:

1. It is possible to formulate universally valid, parameterized, process models with default values for typical, minimal, and maximal values of the parameters.
2. Effects of culture on parameters are independent: culture's effect on a parameter does not depend on the value of any other parameter.
3. Relevant cultural factors can be modeled as either the relative positions on a dimension, or as the product of such a score with the score on a relational aspect (e.g. status, group distance, trust).
4. For each parameter, an expert can identify a (possibly empty) set of factors having an increasing effect and a (possibly empty) set of factors having a decreasing effect.
5. The joint effect of each set is the effect of the dominant cultural factor, i.e. the factor having the maximal value.
6. The joint decreasing effect may compensate for the joint increasing effect, vice versa.

On the basis of these assumptions, expert knowledge can be used to identify a function h that adapts the global default values of model parameters to culture-specific values according to the indices of a dimensional model of culture. It follows from the assumed independence of parameters that the function h can be decomposed into a set of m functions g_i, $i = 1 \ldots m$, where each g_i adapts the default value x_i of a parameter p_i independently of the values of other parameters. The expert knowledge concerning relevant cultural factors and their effects on model parameters can be summarized in tables of the form of Table 2. In a first order approach, the functions g_i follow from these tables, applying equation (18).

The validity of the approach depends on whether the above-mentioned assumptions are reasonable for the domain of application. For the application of Hofstede's model to trade, the validity of the approach is supported by several simulations of trade processes. In these simulations, the approach has shown to produce realistic tendencies across cultures in expert validations [20, 30, 31, 32].

An approach as followed in this paper aims to reproduce general tendencies of behavioral differentiations across cultures at an aggregated level. It can be used as a research instrument to generate hypotheses about behavioral differentiation that can be validated in experiments, or to validate theories induced from experimental results. As a mid-range model, it cannot be used to predict effects of culture in actual situations or at the individual level.

The approach has been applied to simulations of trade processes, on the basis of Hofstede's five-dimensional theory of culture (e.g. [23]), but it is not specific for this domain and this theory of culture. It could also be applied to other domains, using other theories of culture, provided that parameterized decision models are available that may be expected to have general validity across cultures, and that sufficient knowledge for cultural adaptation can be acquired from social sciences literature and experts.

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10 Simulation of effects of culture on trade partner selection

Abstract The criteria that traders use to select their trade partners differ across cultures. The rational criterion of expected profit of the next contract to be negotiated dominates the decision in individualistic, egalitarian, uncertainty tolerant cultures. In other cultures, criteria like personal relations, group membership, status difference and trust may strongly influence trade partner selection. There also exist differences in the level of information about potential partners that traders require before entering into business contacts. This paper models the role of culture at the level of individual agents, based on Hofstede's five dimensions of culture. The model is applied in multi-agent simulations, that are designed as a research tool for supply chain research. The model is implemented as a random selection process, where potential partners have unequal probabilities of being selected. The factors influencing the probabilities are: expected profit and trust (learnt from previous contacts with potential partners or reputation), common group membership, societal status, and personal relations. Results are presented, that indicate that Hofstede's model can be used to simulate the effect of culture on the formation and maintenance of business relationships.

Introduction

Strategies for selecting trade partners are known to be heterogeneous among traders operating in the same environment. For instance, Kirman (2008) describes trade on the Marseille wholesale fish market: according to recorded transaction data of this market, some buyers are loyal to sellers, while others persistently display shopping behaviour, moving from seller to seller. Weisbuch et al. (2000) showed how this heterogeneous behaviour can be reproduced in a multi-agent simulation. The approach is based on reinforcement learning of expected profitability of trade relations, where the length of an agent's memory and its sensitivity to past experience are parameters that differentiate agent behaviour. An interesting observation in that research is, that both loyal buyers and shopping buyers survive in this market.

Literature on international business, e.g. Hofstede and Hofstede (2005), Trompenaars and Hampden-Turner suggests that the distribution of the parameters introduced by Weisbuch et al. (2000) - i.e. the length of memory and loyalty to business relations versus the drive to explore new opportunities – will be different across different cultures. Furthermore, besides expected profit, phenomena like trust and personal relations are relevant and are known to have different influence on trade partner selection and network formation across cultures (G.J. Hofstede, 2007). In some societies, economic systems may be based on trust, in other societies on opportunism. Gorobets and Nooteboom (2006) showed by means of a multi-agent simulations that both types of systems might be viable in different societies. However, in intercultural trade these differences may hamper trade relations, because trust and opportunism may be appreciated differently. Also, loyalty may be appreciated differently across cultures.

The relation between culture and international trade has been studied at the macro level, e.g. (Guo, 2004; Kónya, 2006). The research reported in the present paper models the relation between culture and trade partner selection at the micro level. The purpose is the development of multi-agent simulations that can be used as an instrument in supply network research, in combination with human gaming simulations (Jonker et al., 2006; Meijer et al., 2006). The simulations and the human games are based on the paradigm of transaction cost economics (Williamson, 1985, 1998), with focus on asymmetric information, opportunism and trust. The main processes to be modeled in the agents are trade partner selection and bargaining in the pre-contract phase, and the decisions to either cooperate or defect and either trust or monitor and enforce in the post-contract phase of transactions. The present paper focuses on the process of trade partner selection.

The computational models of the effects of culture are based on the work of G. Hofstede (2001). Hofstede identified five dimensions of national cultures, that can be measured by a numerical index. The dimensions are: individualism versus collectivism, inequality of power, uncertainty avoidance, masculinity versus femininity, and long-term versus short-term orientation. G.J. Hofstede et al. (2006, 2008a, 2008b, 2008c, 2009) describe production rule models of the influence of culture on trade processes for each of the individual dimensions. Section 2 of the present paper summarises the analyses reported in these models in as far as they are relevant for trade partner selection.

Although other dimensional models of culture could certainly be used for similar purposes, Hofstede's framework was chosen over possible other candidates (such as Hall, 1976; House et al., 2004; Schwartz, 1994; Trompenaars and Hampden-Turner, 1993) for various reasons. First, Hofstede's work is parsimonious and accessible, with only five dimensions compared to GLOBE's 18, and with its 1-to-100 scales. Second, it has a wide scope, compared to Trompenaars and Hampden-Turner, whose dimensions are statistically intercorrelated and can be described as aspects of only individualism and power distance (Smith et al., 1996) or Hall who focused on the dimension of individualism (low-context communication) versus collectivism (high-context communication). Those models miss out on issues related to gender roles, anxiety and Confucian values. Third, it has the greatest empirical base of these studies, with a well-matched sample of 117.000 respondents to the original study plus hundreds of replications during a quarter century that validate the model (Kirkman et al., 2006; Schimmack et al., 2005). Fourth, it is the most widely used. It has survived fashions and hasty storms of criticism (Smith, 2006; Sóndergaard , 1994). Fifth and most important, it shows continued predictive value for many societal phenomena (Hofstede, 2001; Smith, 2002). The most likely candidates for extension of the Hofstede model are the new dimensions found by Minkov using World Value Survey data (Minkov, 2007).

This paper aims to integrate the rules for the individual Hofstede dimensions into a model of the partner selection process, simultaneously taking all five dimensions into account. The basis of the model is the reinforcement learning model proposed by Weisbuch et al. (2000), enhanced with "non-rational" aspects that are relevant from the culture perspective. Section 3 describes the model.

The main goal of the authors' current research is to assess the feasibility of the Hofstede dimensions for agent-based simulation of the effects of culture on international trade, in particular in international supply chains of food products, where intensive trade among many small-scale firms occurs, and where usually product quality information is asymmetric. Section 4 presents results of simulations that indicate that believable simulation results can be obtained by applying the Hofstede model. Section 5 concludes the paper.

Hofstede's dimensions and trade partner selection

Behaving as a good, upstanding member of the group is at the core of the lives of all beings that live in social groups (Wilson, 2007). Human beings are intensely social and spend up to twenty years being taught how to act as virtuous members of society. But how to be virtuous? Different societies have found different answers to that question. In some, rationality is a prominent virtue; in others, common sense. In some, virtue consists primarily in honouring tradition; in others, it consists more of becoming prosperous. Although traders basically attempt to maximize profits, their cultural background sets limits to the means they use, to the partners they deal with, to the extent they get personally involved with partners, to loyalty, to the time spent on establishing relations, to bargaining tactics, to duration of bargaining etc. (Hofstede and Hofstede, 2005; Trompenaars and Hampden-Turner, 1993).

In a series of papers, G.J. Hofstede et al. (2006, 2008a, 2008b, 2008c, 2009) proposed a process model of trading agents, inspired by the context of the trust and tracing game and transaction cost economics, and described the effects of culture on the processes for each of the individual five dimensions of culture as identified by G. Hofstede (2001). The relevant processes are:

- Trade goal selection: sell or buy, what product, quality level;
- Partner selection: search for a partner to deal with, agree to start negotiation;
- Negotiation: bargain about conditions and guarantees, resulting in a contract;
- Delivery: deliver according to the contract or use opportunities to defect;
- Monitoring and enforcing: spend resources on tracing or trust the partner;
- Belief update: while dealing, record experience to apply it in the future.

The present paper focuses on partner selection. The next paragraphs summarize the effects of culture on trade partner selection for each dimension.

Individualism versus collectivism. In individualistic societies people primarily feel to be an individual, responsible for his or her personal actions and well-being. Traders in individualistic societies traders actively build and maintain relations, and cut-off in case of insufficient utility. In collectivistic societies people have given group memberships and relations, that cannot be cut-off, and feel responsible for and loyal to their ingroup. Traders prefer ingroup partners, but outgroup partners can get ingroup status by mutual investment in the relation.

Power distance. This dimension differentiates between hierarchical societies where the less powerful accept that power is distributed unequally, and egalitarian ones where power relations are functional, as in principal-agent relations. In hierarchical societies, traders prefer business partners with equal status. They avoid the more powerful, but cannot refuse business proposed by a more powerful.

Uncertainty avoidance. In extremely uncertainty avoiding societies, people fear what they are unfamiliar with (xenophobia) and feel uncomfortable in uncertain situations. Uncertainty avoiding traders are distrusting and do not deal with strangers and people belonging to different social classes. traders from uncertainty-tolerant societies may actively search for new partners without limits.

Masculinity versus femininity. In masculine societies people are oriented toward competition, performance, and material success. Traders actively search for new partners, or better: opponents, and experience trade as a game to be won. In feminine societies, people are oriented toward cooperation and take care for others. They prefer relations with a good atmosphere, prefer getting acquainted before doing business, forgive betrayal but avoid repetitive cheaters.

Long-term versus short-term orientation. In long-term oriented societies, thrift and perseverance are respected as virtues. Traders actively build and maintain network relations and see them as an asset for future prosperity. In short-term oriented societies consumption, social obligations, and face are important, for instance showing off by doing business with a high status partner.

Representation in Agents

Data for the trade partner selection process are modeled into the agents as follows:
- the agent's culture <IDV*, PDI*, UAI*, MAS*, LTO*>: five variables that represent the Hofstede indices, scaled to the interval [0, 1];
- parameters β and γ that represent an agent's loyalty (β) and learning characteristic (γ), according to the model of Weisbuch et al. (2000);
- a *partner model* (a set of variables) for each potential partner;
- *labels* that represent an agents group memberships and societal status.

An agent's labels are visible to other agents; the other information is private.

A *partner model* for partner *j* represents an agent's beliefs about *j*:
- the expected utility J'_j, learnt in previous business contacts, as a basis for preference in partner selection;
- experience-based trust t_j: a subjective probability that the partner will cooperate once a contract has been closed, also representing the experienced quality of the relation;
- group distance D_j, between partner and self, computed from *group labels*;
- belief about the partners societal status s_j, and the status difference $S_j = s_j - s_i$ with self, observed from *status labels*.

Note that the agents are not modeled to be aware of other agents' cultures.

The mechanism for partner selection is based on the reinforcement learning of expected utility proposed by Weisbuch et al. (2000). Agents select their partners at random, with probability:

$$P_j = \exp(\beta J_j) \,/\, \textstyle\sum_{j'} \exp(\beta J_{j'}) \,, \qquad (1)$$

where β is a parameter that represents an agent's loyalty to partners with high values of J_j ; J_j represents the preference for a particular partner, based on experience of profitability of previous deals with the partners, and effected by the agent's culture. The effects of culture on partner preference are summarized in Table 1.

Table 4. Partner model information taken into account for computing preference

Culture type	Trust / relation	Distrust	Ingroup	Outgrou p	Status difference	Partner status
Individualist	+					
Collectivist			+			
Hierarchical					–	
Egalitarian						
Unc.avoiding		–		–	–	
Unc.tolerant						
Masculine						
Feminine	+					
LT-oriented	+					
ST-oriented						+

+ indicates that the partner trait increases preference in the particular type of culture;
– indicates that the trait has a negative influence on preference.

Table 1 presents 5 factors that increase the preference for another agent, depending on culture. In individualistic, feminine, or long-term oriented cultures the quality of the trusted relation with the partner is more important than in other cultures. In collectivistic cultures ingroup partners are more probable to be selected than outgroup partners. In short-term oriented cultures, there is a special preference for partners with a high societal status. The increasing effect of culture on preference for J_j is computed as follows:

$$e^+_j = \max\{\mathrm{IDV}^* t_j, (1-\mathrm{MAS}^*)t_j, \mathrm{LTO}^* t_j, (1-\mathrm{IDV}^*)(1-D_j), (1-\mathrm{LTO}^*)s_j\}\ , \qquad (2)$$

so influence of a single factor is modeled as the product of the normalized Hofstede index and the value of the relevant belief in the partner model, all represented on the interval [0, 1], and from these the maximal value is selected.

The decreasing effect is computed similarly:

$$e^-_j = \max\{\mathrm{UAI}^*(1-t_j), \mathrm{UAI}^* D_j, \mathrm{PDI}^*|S_j|, \mathrm{UAI}^*|S_j|\}\ . \qquad (3)$$

The total effect of culture

$$e_j = e^+_j - e^-_j \qquad (4)$$

is used to compute the agent's preference for partner j, taking the history of previous dealing J'_j and culture into account:

$$J_j = (1 + e_j)^{\alpha} J'_j \qquad (5)$$

Where the parameter α determines the extent of the cultural impact on preference.

The resulting preference J_j is used in equation (1) to compute the probability that j will be selected. Parameter β in equation (1), representing loyalty, also depends on an agent's culture. We expect it to be increased to a maximal value in long-term oriented societies, and to be decreased to minimal value in uncertainty-tolerant or masculine societies.

$$b = \max\{\mathrm{LTO}^*\} - \max\{1-\mathrm{UAI}^*, \mathrm{MAS}^*\} . \quad (6)$$

$$\beta = \beta' + (\beta^{\max} - \beta')(|b|+b)/2 - (\beta' - \beta^{\min})(|b|-b)/2 , \quad (7)$$

where β' represents a parameter that is assigned to the agent at initialization, with $0 < \beta^{\min} < \beta' < \beta^{\max}$.

The experience of dealing with agent j is processed after each negotiation:

$$J'_j(n) = (1-\gamma)J'_j(n-1) + \gamma u_j(n) , \quad (8)$$

where $u_j(n)$ is the utility of the n-th negotiation result with j; $u_j(n) = 0$ if the negotiation was terminated without agreement. The value of γ is expected to depend on culture: an higher value in feminine, a lower value in uncertainty avoiding cultures:

$$c = 1 - \mathrm{MAS}^* - \mathrm{UAI}^* \quad (9)$$

$$\gamma = \gamma' + (\gamma^{\max} - \gamma')(|c|+c)/2 - (\gamma' - \gamma^{\min})(|c|-c)/2 \quad (10)$$

Parameter γ' is assigned to the agent at initialization, with $0 < \gamma^{\min} < \gamma' < \gamma^{\max} < 1$.

After a agent has targeted a partner, applying equation (1), it sends a proposal to negotiate about a deal. The receiver may either accept or ignore the proposal. The proposing agents waits for some time, and if it receives no reply, it updates J'_j with u_j=0 , see equation (1), and than tries and targets a partner again.

If an agent has no negotiation going on, it checks for received proposals. It may have recent proposals from several agents simultaneously. From the simultaneous proposers, it selects the one with the maximum preference, but with some influence of culture. Agents from hierarchical societies that face a higher-ranked proposer are inclined to accept even if they do not prefer the partner, because it is not done to refuse in that case. The acceptability is calculated for all proposers,

$$a_j = J'_j / \max_{j'}(J'_{j'}) + (1-J'_j)\mathrm{PDI}^*\max(S_j, 0) . \quad (11)$$

Subsequently the agent selects, from the agents that proposed to negotiate, an agent k with maximal acceptability and decides whether to accept its proposal or to start looking for a partner by itself, with probabilities:

$$p(\text{start negotiation with } k) = a_k ; \quad (12)$$

$$p(\text{start new partner selection}) = 1 - a_k . \quad (13)$$

4 Simulation results

This section presents two series of simulation results. In the first series, the effects of the individual Hofstede dimensions are investigated by varying the index of one dimension, while keeping the other indices constant. These simulations are run in culturally homogeneous societies, i.e. all agents having equal cultural settings and, in some simulations, different group memberships or different societal status. The purpose of this first series of experiments is to verify the implementation of the model. In the second series, Hofstede's indices for some imaginary countries are used to simulate trade patterns emerging in multicultural settings. The results show that believably differentiated patterns can be generated. However, the model needs further tuning and validation with real-word data in order to generate realistic results for real countries.

Tables 2 presents results of simulation runs in different cultural settings. The simulation model is based on Meijer et al. (2006). In the simulation, agents can select partners, negotiate, deliver, and process the experience gained in these activities, to update belief about expected utility J'_j and trust or quality of the relationship t_j . The agents are homogeneous: all agents have equal parameter settings. In all runs, eight supplier agents and eight customer agents were trading, all with parameters $\alpha = 1$, $\beta' = 1.5$, $\beta^{min} = 0.3$, $\beta^{max} = 3$, $\gamma' = 0.3$, $\gamma^{min} = 0.1$, $\gamma^{max} = 0.5$. The normalized indices of culture were all set to 0.5 , except one, which was set to either 0.1 or 0.9. The agents had no group distance or status difference.

Table 5. Loyalty, expressed as percentage of trade contacts with the most frequently contacted partner in different (artificial) cultural settings; $\alpha = 1$, $\beta' = 1.5$, $\beta^{min} = 0.3$, $\beta^{max} = 3$, $\gamma' = 0.3$, $\gamma^{min} = 0.1$, $\gamma^{max} = 0.5$; all agents have status 0.5 and common group labels

Value of index	PDI*	UAI*	IDV*	MAS*	LTO*
0.9	28	21	28	26	45
0.1	31	32	30	35	24

$PDI^* = 0.9$: hierarchical; $PDI^* = 0.1$: egalitarian;
$UAI^* = 0.9$: uncertainty avoiding; $UAI^* = 0.1$: uncertainty tolerant;
$IDV^* = 0.9$: individualistic; $IDV^* = 0.1$: collectivistic;
$MAS^* = 0.9$: masculine; $MAS^* = 0.1$: feminine;
$LTO^* = 0.9$: long-term oriented; $LTO^* = 0.1$: short-term oriented.

Table 6. Loyalty, with increased $\beta' = 3$, $\beta^{max} = 10$ (other setting as in Table 2)

Value of index	PDI*	UAI*	IDV*	MAS*	LTO*
0.9	38	21	33	34	71
0.1	40	36	51	44	29

As may be expected from equation (6), Table 2 shows that long-term orientation, uncertainty avoidance and masculinity effect the emerging loyalty. As Table 3 shows, increasing the basic values of β' and β^{max} increases average loyalty, but the cultural effect remains. In particular, the increasing effect of LTO^* is very strong with the high value of β^{max}, because of the non-linearity of equation (1). Further experiments are run with $\beta' = 1.5$, $\beta^{min} = 0.3$, $\beta^{max} = 3$.

In similar experiments, it was found that reducing γ' to 0.1 reduced the learning of loyalty so that no differentiation was found; increasing it to 0.5 did not produce results significantly different from Table 2. In all further experiments $\gamma' = 0.3$.

Table 4 and Table 5 present results with heterogeneous agents with respect to group distance and status difference, in homogeneous cultural settings. The results indicate that uncertainty avoiding, collectivistic, and, surprisingly, long-term oriented societies ingroup partners are preferred. In uncertainty avoiding societies, this is due to the aversion against anything unfamiliar. In collectivistic societies, it is due to the loyalty toward the own ingroup. In the LTO society in the simulation, the indices for uncertainty avoidance and collectivism are both set to 0.5 . In the beginning of the simulation preferences for individual agents are equal, and due to the increased value of β and the non-linearity of equation (1), the LTO agents stick to their original ingroup partners in this simulation.

Table 5 displays the effects of culture on trade situations with unequal societal status. Trade with partners from different classes is not done in hierarchical societies. In uncertainty avoiding societies, the aversion against what is different reduces cross-class shopping. In the simulations with masculine agents, the agents are less loyal, have no threshold toward contacting lower classed agents, and the powerful agents rapidly learn exploit their power, resulting in increased cross-class shopping.

Table 7. Outgroup shopping, expressed as percentage of trade contacts with outgroup partners; settings as in table 1, except group distance: both suppliers and customers are divided into equally sized groups 1 and 2 with group distance $D_j = 1$

Value of index	PDI*	UAI*	IDV*	MAS*	LTO*
0.9	31	20	35	28	16
0.1	27	41	18	30	42

Table 8. Cross-class shopping, expressed as percentage of trade contacts with partners having a different status; settings as in table 1, except status: half of suppliers and half of customers have status 0.01 , the others have status 0.99 ; group distance $D_j = 0$

Value of index	PDI*	UAI*	IDV*	MAS*	LTO*
0.9	24	27	34	40	35
0.1	36	35	36	31	34

The results presented so far concern artificial cultures. Table 6 presents some example results obtained with cultural settings that are similar to actual average Hofstede indices for national cultures. The results illustrate that differentiated behavior can emerge with differentiated loyalty and different inclination to outgroup shopping. In the table, the results for China show a very weak inclination to outgroup shopping. This may seam in contradiction with the position of China on the world market. However, in Chinese culture ingroup trading is indeed preferred, but after getting acquainted and mutual investment in the personal relation, an outgroup partner may become accepted as ingroup.

The results for outgroup shopping of Sweden and USA are similar, in spite of the different cultures. In experiments eight customer agents with USA-like configuration and eight customer agents with Swedish-like configuration traded with eight Chinese-like supplier agents. Different patterns of customer loyalty emerged, as displayed in Tables 7 and 8. The tables display the number of successful transactions between each supplier and each buyer. In the simulation with USA-like agents, the number of empty cells is 24 on 203 transactions, and average customer loyalty equals 46 percent. In the simulation with Swedish-like agents, the number of empty cells is 31 on 293, and average customer loyalty equals 56 percent.

Table 9. Average loyalty and inclination to outgroup shopping in societies of agents with two groups, with group distance $D_j = 1$, no status difference, other parameters as in Table 1; the cultures are modeled with some similarity to actual national cultures

Culture similar to	PDI*	UAI*	IDV*	MAS *	LTO*	loyalty	outgroup shopping
China	0.7	0.3	0.1	0.7	0.9	68	8
India	0.7	0.5	0.5	0.5	0.7	38	22
Russia	0.9	0.9	0.3	0.3	0.3	36	15
Sweden	0.3	0.3	0.7	0.1	0.3	32	44
USA	0.5	0.5	0.9	0.7	0.3	23	42

Table 10. Number of successful transaction between 8 USA-like customer agents and 8 Chinese-like supplier agents, in 500 time steps.

Agent	S1	S2	S3	S4	S5	S6	S7	S8
C1	2	1	1	9	5		8	
C2	1	1	5		5	1	1	25
C3			15					1
C4		6			10	6	6	4
C5		3		5		7	3	2
C6	1	6		3	5		3	
C7	6	4	5	11	1			
C8	10	1		3		1	10	

Table 11. Number of successful transaction between 8 Swedish-like customer agents and 8 Chinese-like supplier agents, in 500 time steps.

Agent	S1	S2	S3	S4	S5	S6	S7	S8
C1		1	3		6	30		
C2		1	17	9			2	6
C3	4	20				1	2	
C4	2	11		4			22	
C5	2		18			13		
C6	30			2	1		8	
C7	1		11	3	15			10
C8	7				8		11	12

5 Conclusion

The contribution of this work is that it shows how a model of culture can be formulated to simulate culturally differentiated behavior in agents. The model of Hofstede (2001) has been applied to partner selection in international trade in a context where personal relations between traders are important. The partner selection model is based on work of Weisbuch et al. (2000). Culture is modeled to effect both the preference for particular partners and the parameters of Weisbuch et al.'s model (the loyalty parameter and the discount or learning parameter).

The model described in this paper has been verified to qualitatively represent the effects expected on the basis of Hofstede's theory. It is implemented in agents. Multi-agent simulations have been run to verify the correct implementation of the model and to produce example results. Although further refinements are possible, the results show that believable behavior can emerge. However, validation against empirical data in the situations that the model aims to describe, is required to calibrate parameters to actual trader's behavior and to scale Hofstede's indices to the simulation parameter setting.

The situation that is modeled is a common market place. All agents can be aware of all other agents. The model does not include network extensions: the population of agents is fixed. The agents are free to select any partner, and the partner is free to enter into negotiations or to ignore proposals. The agents have labels that indicate their group memberships and societal status. These labels are visible to all agents and can be used for partner selection. The information about transactions is private. It is only available to the transaction partners. They can use it for future partner selection.

The purpose of this model of partner selection is to simulate the behavior of players in trade games (Jonker et al., 2006; Meijer et al., 2006). In order to validate the model for this purpose, it has to be integrated with models for bargaining and contract fulfillment. The combined models can be tuned to results obtained in human gaming simulations, and their usefulness for supply chain research can be assessed. Those tasks remain for future research.

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11 Cultural Differentiation of Negotiating Agents

Abstract Negotiations proceed differently across cultures. For realistic modeling of agents in multicultural negotiations, the agents must display culturally differentiated behavior. This paper presents an agent-based simulation model that tackles these challenges, based on Hofstede's model of national cultures. The context is a trade network for goods with a hidden quality attribute. The negotiation model is based on the ABMP negotiation architecture and applies a utility function that includes market value, quality preference and risk attitude. The five dimensions of Hofstede's model are the basis for the modification of ABMP parameters and weight factors in the utility function. The agents can observe each other's group membership and status. This information is used, along with the indices of Hofstede's dimensions, to differentiate behavior in different cultural settings. The paper presents results of test runs that verify the implementation of the model. The model helps to explain behaviors of actors in international trade networks. It proves that Hofstede's dimensions can be used to generate culturally differentiated agents. Further validations of the model with case studies from literature and experiments have yet to be conducted. Extensions can make this model a useful tool for training traders who engage in cross-cultural negotiation and for implementation in negotiation support systems.

Introduction

Anybody with experience in international trade knows that bargaining practices differ across the world. Multinational companies sometimes work with different price lists for different countries. To give just one example: whereas German buyers want to know exactly how much the products cost, Arabs need to have room for bargaining. In order to sell at the same price, the selling company needs to adapt its offer to the varying bargaining practices. This means that a single piece of advice about how to bargain, or a single model to describe bargaining, are obviously not valid across the world unless culture is taken into account.

'Culture' is a notion with many meanings, some of which are contested in some disciplines. However, the leading paradigm today is widely accepted and used in both practice and academia. According to it, culture refers to the *unwritten rules of society*. Culture is that which makes a group cohesive by smoothing communication. It is a phenomenon that is specific to a group, not to an individual. Its essence is unconscious shared systems of values, and it is transmitted in early youth through example and education. As a result it is stable across centuries in spite of huge changes in environment and technology. Cultural differences show no signs of diminishing in the Information Age (Hofstede and Hofstede 2005).

Within the literature various basic dimensions can be found according to which societies differ from one another. Of these, the most widely used is Hofstede's model

(Hofstede 2001), (Hofstede and Hofstede 2005). His work is accessible, sparse, and based on a very large, very well stratified sample that continues to give it great explanatory value. No other model matches society-level variables so well to date (Smith 2004).

This paper describes an agent-based model for bargaining in the context of trade. The agents follow common sense strategies such as maximizing gain, seeking good quality, and minimizing risk. But they also have models of how to behave in an appropriate manner. These models are based on Hofstede's five dimensions of culture. The challenge that we take up is the one posed by de Rosis et al. (2004), who suggested to investigate the feasibility of Hofstede's model for building culturally consistent agent characters. An agent-based model of bargaining in which the agents are cultured offers several promises. It can help understand the dynamics of international negotiations in trade. It could also serve as a training tool for aspiring international traders.

The paper first briefly introduces Hofstede's model of five dimensions of culture. Next, the ABMP (Agent-Based Market Place, Jonker and Treur 2001) negotiation model that we adopt is presented. We show how this model can be used in agent-based simulations. We also discuss the limited subset of negotiation situations that are considered in this article. In the third section we link culture and negotiation by describing the influence of each of Hofstede's dimensions of culture on negotiators' practices and preferences. This section sets the scene for the presentation of the rules for our cultured agents in the fourth section. Section five shows example runs with the model and discusses them. Finally we discuss the model and how to proceed, since this model forms the basis of future research and tools.

Hofstede's Five Dimensions of Culture

Each human society has found a different pattern of response to the problems of social life. In some societies, groups are permanent and close-knit while in others, group membership is volatile and voluntary. In some, leadership style is usually autocratic and in others, participative. Research has shown and repeatedly confirmed that basic tendencies to deal with a few central issues of social life are stable across the generations in societies (Hofstede and Hofstede 2005). They are, because they are instilled into a society's members from birth. As a baby and as a toddler, a child is primed as a social being. Once a child sets foot into the wider society as a teenager, its basic cultural orientation is firmly in place.

This research stream has led to dimension models of culture. The most widely used of these is the five-dimension model by Hofstede. The five dimensions are about five issues that relate to our basic drives. They will be introduced briefly in order to use them further on in the text. Note that these are not personality traits, but societal patterns! Also note that the picture drawn here is necessarily simplified. It presents the two caricatured extremes of each dimension. In reality, almost all cultures have intermediate positions on almost all dimensions. The dimensions are introduced in the following subsections.

Collectivism Versus Individualism

This dimension is about affiliation. To a collectivist (e.g., East Asian, most non-Western countries) mindset, fixed membership of a single group in which all members are interdependent is the natural state of being human. No member of the natural group can be cast aside. This means that maintaining harmony is crucial.

To an individualist (e.g., North-American, North-west European) mindset, self-sufficiency is the natural state of being. Everybody should be judged in the same way, whether or not the person is a group member. Honest people speak their minds, even if that means open disagreement.

Hierarchy: Large Versus Small Power Distance

This dimension is about dominance as an ascribed quality. It has to do with authority as seen from below. Are parents, teachers, priests and bosses held in awe, and is autocratic leadership expected? Then we have a society of large power distance (e.g., China, India, Russia.).

Or is leadership a role that could change from one person to another with ease, and are all people born equal? In that case, the society is one of small power distance (e.g., Anglo and Germanic countries).

Aggression and Gender: Masculinity Versus Femininity

This dimension is about assertive dominance, about muscle power, and about the emotional roles of the two sexes. In what is called a masculine society (e.g., Japan, Anglo countries), men in particular are supposed to be fighters. Women are supposed to be cheerleaders to the men's fight – but they have to be tough too. Men try to look and act like real men and women try to look and act like real women. These are tough societies, with strong-handed police and military and with heavy punishment for offenders.

In what is called feminine societies (e.g., Scandinavian countries), both men and women are supposed to be peace-loving and consensus seeking and their social behaviors are not strongly different.. Criminals should be helped, not punished.

Otherness and Truth: Uncertainty Avoidance

This dimension is about how to cope with the unknowable. Some societies are termed uncertainty avoiding (e.g., Arab, Latin and Slavic countries). They tend to have strict rules and rituals about things that are strange or different, such as religious rules and food taboos, or strange sexual practices. In these societies, the distinction between clean and dirty is important. In fact they feel that any distinction should be a sharp one. They are concerned about right and wrong, about theory, about arguing for its own sake. They like to show their emotions, particularly anxiety, verbally and non-verbally.

Other societies are termed uncertainty tolerant (e.g., Anglo countries, China, Scandinavia, Vietnam). They are relaxed and curious about strange things and people, and not worried about establishing strict classification schemes for everything. They value exploratory behaviors and novel experiences, and a relaxed communication style.

Short Versus Long-Term Gratification of Needs

This dimension is about all the basic human drives. Which drive should get precedence, one that presses now or one that might become pressing in ten years? Some societies live for today, and these are termed short-term oriented. Behaving in an appropriate manner and respecting conventions is important in these societies, as well as 'keeping up with the Joneses' as the Americans have it. There are strong opinions about good and bad, and these are believed to be immutable.

Other societies live for the future; these are termed long-term oriented (e.g. China, Japan). Reasoning is pragmatic, and principles are adapted to context. Good and bad are seen as complementary and changeable. Planning, foresight and perseverance are valued. On the downside, this could lead to stinginess and calculation.

Five Dimensions, One World

So far in this text, the dimensions of culture have been isolated from one another in an artificial way. In reality, cultures have a recognizable feel to them, a Gestalt that can be described, albeit only roughly, by its combination of dimension scores. The five dimensions are no more than abstractions that capture main behavioral trends. Cultures have 'gestalts' of behavior. Experienced negotiators know the range of behaviors that they can expect from negotiators from other parts of the world. They also know how gender, age, status and personality can affect the negotiation style of people from these parts of the world.

In (Hofstede et al. 2006; 2008a; b; c; 2009) the influence of each of the dimensions on trade processes was modeled separately; a slightly artificial, but also necessary intermediate step to model agents differentiated along the Hofstede dimensions. Reconciling these dimensional models into one believable model that shows the 'whole negotiator', although still abstracting from personality, is the aim of this article.

Negotiation

In bilateral negotiation, two parties aim at reaching a joint agreement. They do so by exchanging various offers or bids using e.g. an alternating offers protocol (Osborne and Rubinstein 1994) called the "negotiation dance" in (Raiffa et al. 2002). Negotiation is a complex emotional decision-making process aiming to reach an agreement to exchange goods or services (Thompson 2005).

Agent Models for Negotiation

The literature on automated negotiation contains a number of agent models for negotiation. The focus of that literature is on reaching deals that are Pareto-efficient (i.e., neither can improve without making the situation worse for the other). Furthermore, some aim at reaching fair outcomes, i.e., in which the deal is equally good for both parties. The strategies differ in whether or not they take knowledge about the domain, and/or opponent into account. Examples of strategies that do not use any domain or opponent knowledge can be found in (Faratin et al. 1998) and (Jonker and Treur 2001). Other strategies try to learn the opponent's preferences, see e.g., (Coehoorn and Jennings 2004) and (Hindriks and Tykhonov 2008). The work presented in this paper aims to develop models of actual human behavior. It does not aim to develop an optimal bargaining strategy that can outperform human negotiators or other agents.

Focus on Interpersonal Bargaining

This work focuses on a specific type of negotiations: two persons bargaining about business transactions. Gaming simulations form the context of the bargaining sessions. The gaming simulations are designed as tools in supply chains and networks research (Meijer et al. 2006). In this setting participants negotiate a transaction of a commodity with either base quality or a superior quality. The real quality is known to the supplier and invisible to the customer. The customer can either trust the supplier's quality statement, or request third-party testing at the cost of a fee. A customer may negotiate that the supplier provide certified quality by third-party testing and have the commodity delivered with the test report as a certificate. So, the relevant attributes for comparing bids are price, quality, and certification.

If the quality is above base level and the transaction is not certified, the customer is exposed to the risk of supplier's opportunism. The valuations of quality and risk have a rational component that can be calculated from market value and probability of deceit. Furthermore, they have a subjective component that is influenced by a trader's personality and culture. The rational component of the valuation of quality is the difference in market price with the price of base quality. The rational component of the valuation of risk is the product of probability of deceit and value of the quality attribute. The subjective valuation comes in addition to the rational value. For quality, it is the trader's quality preference, for instance because of the societal status that results from trading high quality products. For risk, it is an agent's risk aversion. To a risk-averse agent, the absence of risk has a value by itself.

In a culturally homogeneous society, not all agents have equal quality preference and risk aversion. However, significant differences between cultures exist in the average values of these parameters.

Agent-Based Market Place (ABMP) and its application in the agents

For the agents' negotiation strategy we chose ABMP (Jonker and Treur 2001), because its similarity to human negotiations has been validated (Bosse et al. 2004). The ABMP process is an exchange of bids, starting with a bid by one of the partners. The other partner evaluates the bid using a utility function that maps a weighted linear combination of bid attributes to the interval [0, 1]. The weight factors in the utility function represent an agent's preferences. The utility function used in this research is elaborated in a following subsection.

ABMP is a concession strategy. An agent prepares a bid that is a concession to its previous bid. Concession factor γ and negotiation speed β are the parameters that govern the concession making.

Concession factor γ is the fraction of the opening bid's utility that the agent is willing to give in during the negotiation. It determines the minimum utility that is acceptable to an agent, also called the reservation value.

Negotiation speed β is the fraction of difference between the agent's previous bid and the minimum utility that an agent uses to determine the target utility of its next bid.

After calculation of the utility of a partner's bid and the target utility of its own next bid, the agent decides whether to accept partners bid or not, governed by the utility gap parameter ω.

Acceptable utility gap ω is the maximal difference between own target utility and last partner's bid's utility for which an agent will accept partner's bid.

If the target utility minus the partner's last bid's utility is greater than the acceptable utility gap, the agent does not accept and has to decide about its next action. It can terminate the negotiation for several reasons. First, partner's bid may be interpreted as unrealistic if its utility is too far below the minimum utility. Second, an agent may be unsatisfied by the progress in partner's bids. Third, there may be no more room for a substantial change of attributes to make a bid with the target utility. In the latter case the agent terminates the negotiation. In the first two cases the probability that an agent terminates the negotiation depends on the impatience parameter ι.

Impatience ι is the probability that an agent will terminate the negotiation if (a) the utility of partner's bid is less than the cut-off value or (b) progress in the last three rounds is less than the minimal progress required. In the present model the cut-off value ϕ is computed from minimum utility μ:

$$\phi = (1 - \iota)\mu \ .$$

Minimal progress φ over three rounds of negotiation is computed as

$$\varphi = (1 - \mu)\iota \ .$$

So, the decisions whether to accept a bid or not and whether to continue or not depend on partner's bid, own last bid, partner's progress, and the values of parameters γ, β, ω, and ι. Evaluation of bids involves the utility function discussed in the next subsection. This utility function is also used in planning a new bid that has the target utility, taking the agent's quality preference and risk aversion into account.

The utility function

The agent model applies a utility function as proposed by Tykhonov et al. (2008):

$$U(b) = w_v V(b) + w_q Q(b) + w_r R(b) \ ,$$

with $0 \le w_i \le 1$, $i = v, q, r$, and $\sum w_i = 1$.

$V(b)$ represents the business value of a bid. A customer agent calculates it as

$$V_c = \frac{1 - v + q - r_c}{2} \ ,$$

with v representing the price of the bid, mapped to the interval [0, 1] (0 represents minimal market price for base quality of the commodity; 1 represents maximal market price for top quality); q in [0, 1] (0 represents base quality; 1 top quality); customers cost of risk is calculated as

$$r_c = (1 - c)(1 - t)q \ ,$$

with c=1 representing presence and c=0 absence of a quality certificate; t represents the customers trust in the supplier, defined as the customer's estimate of the probability that the supplier will cooperate and deliver according to contract, even if the supplier has the motive and the opportunity to defect.

For a supplier the business value of a bid is calculated as

$$V_s = \frac{1 + v - q - r_s}{2} \ ,$$

with suppliers cost of risk

$$r_s = cf \ ,$$

where f stands for the certification fee scaled to the same ratio as v.

Both customers and suppliers may have a preference in excess of the market value for dealing top quality rather than base quality products. A trader's preference for dealing top quality, even if profits from base quality trade are superior, is represented by w_q; in the present model $Q(b)$ is computed as:

$$Q = q - 0.5 \ .$$

Some traders may be risk-averse, in which case w_r is positive. In the present simulation suppliers are informed about the actual quality level, so

$$R_s = 0 \ .$$

For risk-avoiding consumers, the absence of risk may have a value in itself, which is represented as follows in the present model:

$$R_c = 0.5 - r_c \ .$$

Culture and Bargaining

Hofstede et al. (2006; 2008a; b; c; 2009) modeled the influence of culture on trade processes for each of the five dimensions separately. From these papers, the narrative descriptions of the influences of the dimensions on trade negotiations – i.e. the bargaining about transactions – are cited below.

Power Distance (Hofstede et al. 2009)

Traders from egalitarian cultures may have different ways to negotiate, but they will always negotiate. Traders from large power distance cultures on the other hand are not used to negotiate seriously. The powerful dictate the conditions. The less powerful have to accept. In feminine or collectivist cultures the powerful may exercise restraint, or the lower ranked may successfully plead for compassion, but this is not a joint decision making process like a negotiation is. The higher ranked partner decides. When people from hierarchical cultures are forced to negotiate, because they are in a position of equal status or trade with foreigners, the negotiations often end in a game of power.

The higher ranked in hierarchical societies prefer top quality commodities to stress their position. They accept risk, because they do not expect the lower ranked to deceive them. The lower ranked on the other hand, avoid risk and protect themselves by settling for base quality commodities.

A trader from a culture with large power distance expects a lower ranked business partner to accept his conditions rapidly. If the lower ranked partner has the same cultural background, there is no problem and the rights of the higher ranked will be recognized and respected: the lower ranked will be modest and give in easily. However, a trader from an egalitarian culture will not give in to the pressure if his status is lower, but will either react furiously (e.g., break off negotiations) or simply ignore the pressure (make a counterproposal), in which case the opponent will be furious.

If a trader from a culture with large power distance negotiates with a foreigner and assumes the foreigner to have a higher status, he may give in more easily than the foreigner expected. In that case the foreigner may be happy, but his opponent will not have his fair share. If both are from hierarchical cultures but do not perceive one another's hierarchical position they may make misattributions resulting in one of them being dominated or stopping the negotiations.

Uncertainty Avoidance (Hofstede et al. 2008b)

Uncertainty avoiding traders have an emotional style of negotiation, making sure that the opponents understand their feelings. They will not adapt their behavior to their opponent's. They are quality-minded and avoid risk in business transactions, especially when dealing with strangers. For uncertainty avoiding traders, time is money. They want to go directly to their target, and are impatient. After a few unsuccessful iterations, the uncertainty avoiding trader will break off the negotiation.

Uncertainty tolerant traders on the other hand have a relaxed style of negotiation. They try to adapt their behavior to their counterparts, although they are not prepared to come to an agreement at all cost. They do not show their emotions and may be disconcerted if their opponents do. They are careful not to be more yielding than their counterparts are, not especially modest, and are ready to break off negotiations in case of insufficient progress.

Individualism and Collectivism (Hofstede et al. 2008a)

For a collectivistic trader negotiation has to be preceded by the formation of a relationship. If that goes wrong there will be no negotiation. During the negotiation, collectivist traders discriminate between in-group and out-group partners. They feel obliged to be more conceding to an in-group partner, are more hesitant to break off negotiations with in-group partners, and will try to maintain harmony as long as the opponent follows the in-group rules. Breaking the rules asks for a reaction. The style of that reaction may be furious, or they might never explicitly say anything, but just avoid the other from now on. The reply to a proposal from an in-group partner will be modest, but there is no need to be modest to an out-group partner. If an out-group partner replies with no or small concession, negotiation is likely to be broken off, where an in-group partner or an acquainted relation would get a second chance.

Responsibility for in-group welfare and compliance with in-group rules always play a prominent role in a collectivistic culture. A collectivist will accept benefits for his in-group rather than his personal advantage as a convincing argument.

Individualists have one thing in mind during negotiations: their own personal interest. Depending on their personality and incentives, this might be the material advantage of the deal in question, or the development of new long-term trusting relations with perspectives of future deals, or just the pleasant conversation during the negotiations, or the satisfaction of winning the game, but one thing stands for sure: individualists pursue private interests. So individualist traders are not very modest in their negotiations, nor will they give in for the purpose of maintaining harmony. If they are not aware of the cultural differences when trading with collectivists, they may be upset by the lack of explicit communication, or they may upset their opponents by being too explicit, or by talking business before the relationship has been established and acknowledged. They are not particularly patient or impatient negotiators, but behave patiently as long as it serves their interest.

Masculinity and Femininity (Hofstede et al. 2006)

The dimension of masculinity versus femininity can be interpreted as a preference for performance versus cooperation. A performance oriented trader (masculine culture) is interested in fast trades, with as many top quality goods as possible in one trade. This trader is rather impatient, and if bids are too far off from his profile, he will walk away quickly. The performance oriented sticks to the contract of the deal, deceive the trade partner to the limits of the contract without any compunction, and expects the partner to do so too. Each subsequent negotiation will be dealt with without taking past trustworthiness into account. Each new contract will be set up from scratch. The trader learns from mistakes to make sure that the contract will not lead to new and uncomfortable surprises on his side.

A cooperation oriented trader (feminine culture) is interested in the relationship with the trade partner; building trust is important. The amount of goods or quality level is not of the most interest, because the relationship built during negotiation might pay off in future negotiations. Given the interest in the relationship with the trade partner, a first negotiation with a trade partner will take time that is willingly spent by the trader. During such negotiations, the trader appreciates a negotiation process in which both partners show a willingness to accommodate the other over time. Past negotiations do play an important role in subsequent negotiations. The trader is perfectly willing to see the current negotiation as a kind of continuation of the previous one. If the trade is about the same kind of commodity, the trader will start the negotiation from the deal of the last one. If the other accepts, then the deal can be made in one round and in seconds, whereas the first deal might have taken a lot of rounds and lots of time.

Long- Versus Short-Term Orientation (Hofstede et al. 2008c)

Long term oriented negotiators are pragmatic and take the bigger picture. They tend to see one bargaining instance as a small step in a long process, and their decisions will be led by their estimation of the profitability or other success chances of that longer process. Long-term oriented traders show patience. They do not rapidly break off negotiations. They do not overcharge, but they do not rapidly give in.

Short term oriented negotiators, on the other hand, think in terms of moral principles and apply them to the situation that is before them here and now. They are very reliable when it comes to following standards of appropriateness of behavior, but this can make them disregard the ulterior consequences of their actions. They are conceding and patient with high-status partners and do not show them distrust. Otherwise they follow an opportunistic quality strategy.

Modeling Culture in ABMP

The model of the effects of culture on ABMP parameters and utility weight factors is based on the narrative descriptions in the preceding section. The descriptions indicate if a parameter is to be increased or decreased along each of Hofstede's dimensions. Table 1 summarizes the direction of the effects (increasing versus decreasing).

Some cultural dimensions have a direct effect on the parameter values, but in other cases the influence depends on the relationship with the partner:

- The societal status of an agent and that of its partner affect behavior in societies where power distance matters.
- Also in short-term oriented societies, partner's status is relevant.
- Members of uncertainty avoiding societies distrust strangers more than people they are familiar with.
- Common group membership and group distance are important in collectivistic societies.

In the model the agents are labeled with tags that indicate status and group membership. The tags are visible to other agents so that they can estimate status difference and group distance. The model combines effects of culture with effects of status and group membership.

Table 1. Influence of culture on utility weight factors and ABMP parameters (w_q: quality preference; w_r: risk aversion; γ: concession factor; β: negotiation speed; ω: acceptable utility gap; ι: impatience; + increased parameter value; - decreased; +! increased every negotiation round)

culture type	conditions	w_q	w_r	γ	β	ω	ι
large power distance	self status high	+					
	self status low	-					
	higher partner		+	+		+!	-
	lower partner		-				
small power distance							
uncertainty avoinding	similar partner	+	+		+		+
	different partner	+	++		+		+
uncertainty tolerant							
individualistic							
collectivistic	ingroup partner			+			-
	outgroup partner		+		-		
masculine		+	+		+		+
feminine		-			-		-
long-term oriented		-					-
short-term oriented	general	+					
	high partners	+	-	+			-

The effects on negotiation parameters and weight factors are modeled as follows.

(1) The Hofstede indices PDI, UAI, IDV, MAS, and LTO position national cultures on the five dimensions. They are known for many countries (see, e.g., Hofstede 2001). Let *H*, *A*, *I*, *M*, and *L*, respectively, represent the indices as real values scaled to [0,1], so that H=1 represent maximal power distance, (1-H)=1 represent maximal egalitarianism, etc. Thus, there are 10 cultural stereotypes.

(2) Status and group distance are represented as real values in [0,1]. Where status, status difference and group distance are relevant, the effect is conditional upon the value of a cultural index. For instance, the product (1-I)g represent the effect of group distance g in conjunction with collectivism (1-I); in a maximally individualistic society, 1-I=0 , so group distance g has no effect.

(3) As indicated in Table 1, some of the cultural stereotypes may have a positive, monotonously increasing, effect on a particular parameter value; other stereotypes may have a negative, monotonously decreasing, effect.

(4) For each parameter there may be a set of positive effects and a set of negative effects. The joint effect of a set of effects working with equal sign is weakly disjunctive, i.e. the joint effect equals the maximum of the effects of the individual dimensions[6] (e.g., if we model statement "*people from uncertainty avoiding or masculine societies prefer rapid negotiations*", then the joint effect is the maximum of the effects of uncertainty avoiding and masculinity).

(5) The resulting joint negative effects are assumed to compensate for joint positive effects, vice versa: the effect on parameter *x* is the difference of the joint positive and joint negative effects.

$$e_x = e_{x+} - e_{x-} \ .$$

One can, for instance, represent the effect "*in hierarchical societies parameter x is increased in case of status difference, unless the society is collectivistic or feminine*" as follows:

$$e_x = e_{x,H(s_i - s_j)}\lfloor H(s_i - s_j)\rfloor - \max\{e_{x,(1-I)g}\,[(1-I)g],\, e_{x,1-M}\,(1-M)\} \ ,$$

where $e_{x,D}$ represent a function that computes the effect of *D* on *x*. No actual evidence for the form or the range of the functions is available. In the current model we assume linear relations with range [0,1] for $e_{x,D}$, so the above example would reduce to

$$e_x = H(s_i - s_j) - \max[(1-I)g, 1-M] \ .$$

(6) Table 2 presents joint positive and joint negative effects deduced from Table 1.

6 Weak disjunction is taken as formalism to combine effects of cultural dimensions working in the same direction, because it takes only the stronger of the dimensions into account. This is to be preferred to, for instance, linear combinations, or (weighted) geometrical averaging, because in those cases a strong effect of a high value of one dimension would be conditional upon high values of the other dimensions. Weak disjunction is preferred to stronger forms of disjunction, because combination of moderate values of several dimensions must not have a strong joint effect.

Table 2. Formulas for the effects of culture on negotiation parameters; H, A, I, M, and L represent the scaled Hofstede indices; s_i represent the agent's societal status in [0, 1]; s_j partner's status; group distance g between the agent and partner is computed from agent labels, with 0 representing minimal distance, 1 maximal distance; ρ represent the round number in the current negotiation

x	increasing effect e_{x+} of culture on x	decreasing effect e_{x-} of culture
w_q'	$\max(Hs_i, A, M, 1-L)$	$\max(H(1-s_i), 1-M, L)$
w_r'	$\max\begin{pmatrix} H(s_j - s_i), A, \sqrt{Ag}, \\ (1-I)g, M \end{pmatrix}$ [7]	$\max(H(s_i - s_j), (1-L)s_j)$
γ	$\max\begin{pmatrix} H(s_j - s_i), (1-I)(1-g), \\ (1-L)s_j \end{pmatrix}$	
β	$\max(A, M, (1-L)s_j)$	$\max((1-I)g, 1-M)$
ω	$H(s_j - s_i)\rho$	
ι	$\max(A, M)$	$\max\begin{pmatrix} H(s_j - s_i), (1-I)(1-g), \\ (1-M), L, (1-L)s_j \end{pmatrix}$

(7) The actual value of x is assumed to be a function that maps x_T (the typical value of x) and the effect e_x to a range $[x_L, x_H]$, $x_L \le x_T \le x_H$. In the current model we take a simple approach and use linear interpolation:

$$x = x_T + \frac{e_x + |e_x|}{2}(x_H - x_T) + \frac{e_x - |e_x|}{2}(x_T - x_L) \ .$$

(8) The utility weights w_i, $i = v, q, r$, are to be normalized for proper functioning of ABMP. Culturally adjusted values of w_q', and w_r' (see Table 2) are relative to $w_v' = 1$, so:

$$w_i = \frac{w_i'}{1 + w_q' + w_r'} \ .$$

(9) The culturally adjusted parameter values and weight factors resulting from rules **(1)**…**(8)** are used in the ABMP evaluation of bids, in the decisions (to accept or not; to continue or not; see Hofstede et al. 2006), and in the planning of a new bid. In each round of the negotiation, the parameters are recomputed.

The next section presents results obtained from this model.

[7] An error that occurred in the original publication, has been corrected in this expression.

Test Runs

The models discussed in the previous sections, including the ABMP architecture, are implemented in a multi-agent simulation, where agents can select trade partners, negotiate business transactions with price, quality, and certification as attributes, deliver truthfully or opportunistically, have deliveries tested for quality, and update beliefs about partners according to experiences in negotiations and testing. The simulation environment is implemented in Cormas.[8]

The model was tested for correct implementation. The observed variables were:

- the number of successful negotiations (i.e. terminated with a contract) in runs of 200 time steps with a population of 8 supplier agents and 8 customers;
- the percentage of negotiations that failed, i.e. that were terminated by one of the agents before agreement was reached;
- the percentage of successful negotiations leading to top quality transactions, as a measure of willingness to accept risk.

In all test runs, the agents were set to be neutral with respect to trust, i.e. they had no information whether their partners were trustworthy or not (t=0.5). The option of certification was switched of, so that agents were forced to accept risk if they bought top quality products.

The following hypotheses about agents behavior in this environment are formulated on the basis of the narrative descriptions in this article's section on culture and bargaining.

H1: In hierarchical societies (large power distance), high-ranked agents buy top quality products; low-raked agents buy basic quality products to protect themselves from risk.

H2: In hierarchical societies, high-ranked agents are more successful trading with low-ranked than with equal-status partners, because lower-ranked yield.

H3: In uncertainty avoiding societies, high quality products are preferred, but agents are risk-avoiding and impatient. Therefore, trade proceeds less smooth in uncertainty avoiding than in uncertainty tolerant societies.

H4: In uncertainty avoiding societies, inter-group trade fails more often than in-group trade.

H5: In collectivistic societies, in-group trade runs smoother than inter-group trade.

H6: In masculine societies, agents deal rapidly but many negotiations fail, due to the combination of impatience and high quality ambitions.

H7: In feminine societies, negotiations proceed slowly, but with a low failure rate.

H8: In short-term oriented societies, agents prefer top quality.

H9: In short-term oriented societies, agents are more conceding toward high-status partners. This leads to rapid transactions and low failure rate if partner's status is high.

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[8] http://cormas.cirad.fr/indexeng.htm

To test the hypotheses, the model was run for each of the configurations of culture, status and group membership represented in table 1. To simulate a cultural stereotype, the value of one normalized index (*H*, *A*, *I*, *M*, or *L*) was set to 0.1 or 0.9, while the values of the other normalized indices were set to 0.5. In all runs, group distance between suppliers and customers was set to 1, except in the runs simulating uncertainty avoiding and collectivistic societies with in-group partners, where group distance was set to 0. Status was set to 0.5 for all agents, except in the runs where status difference mattered. In the latter case the status of either suppliers or customers was set to 0.1 and that of their counterparts to 0.9.

For each configuration, 10 runs (with different random generator seed) were made. Each run lasted 200 time steps with a population of 8 supplier agents and 8 customers. In 200 time steps 8 pairs can complete approximately 100 negotiations together, so for each configuration a total of approximately 1000 negotiations were completed (successfully or unsuccessfully).

Table 3 presents average results per run of simulated negotiations, using the parameter settings displayed in Table 4. In the following paragraphs the results are compared with the hypotheses.

Table 3. Average results of simulated negotiations for cultural stereotypes, with the value for the particular dimension set to either 0.1 or 0.9 and the values for the other dimensions set to 0.5 (8 suppliers; 8 customers; 10 runs of 200 time steps for each configuration; parameter values as in Table 4)

culture type	conditions	number of trans-actions	% failed negotiation s	% top quality
large power distance	self status high	44	57	97
	self status low	50	60	0
	higher partner	77	45	98
	lower partner	4	92	0
small power distance		72	49	2
uncertainty avoinding	similar partner	29	71	76
	different partner	27	73	87
uncertainty tolerant		49	58	1
individualistic		66	50	1
collectivistic	ingroup partner	117	13	61
	outgroup partner	39	65	0
masculine		36	71	80
feminine		61	45	0
long-term oriented		55	52	0
short-term oriented	general	24	72	95
	high partners	57	47	91

Table 4. Parameter values used in the simulation runs (w_q': quality preference; w_r': risk aversion; γ: concession factor; β: negotiation speed; ω: acceptable utility gap; ι: impatience)

Type of value	w_q'	w_r'	γ	β	ω	ι
typical value x_T	0.1	0.1	0.7	0.2	0.02	0.3
maximal value x_H	0.5	0.5	1	0.5	0.1	0.7
minimal value x_L	0	0	0	0	0	0.1

H1 is confirmed. In hierarchical societies, the higher-status agents buy top quality products and accept the associated risk. The lower-status agents buy basic quality products.

H2 is partly confirmed. In this simulation the higher-ranked agents succeed in enforcing transactions only in the consumer role. In the supplier role the higher-ranked supplier agents insist on selling top quality to lower-ranked agents and the lower-ranked keep asking for basic quality until the suppliers break-off.

H3 is confirmed. In uncertainty avoiding societies, top quality is dominantly traded and transaction success is lower than in uncertainty tolerant societies.

H4 is confirmed. In uncertainty avoiding agent societies, transactions with strangers mostly fail.

H5 is confirmed. In collectivistic societies, in-group trade runs smoothly and agents show trust in each other, trading top quality products. Collectivist inter-group trade is less efficient than in-group trade and also less efficient than trade in individualistic societies.

H6 is confirmed. Failure rate is high in the masculine society.

H7 is confirmed. Failure rate is low in the feminine society and negotiations proceed relatively slow.

H8 is confirmed. The agents in the short-term oriented societies dominantly trade top quality products.

H9 is confirmed. When trading with high-ranked customers, transaction rate is high and failure is low in short-term oriented societies.

These results comply with the expected behavior of the agents and verify the implementation. However, they do not validate that the implemented model generates believable culturally differentiated agent behavior.

For that purpose results produced by this model can be compared with results known from intercultural negotiation literature. For instance, Brett and Okumura (1998) report that joint gains in intercultural negotiations between Japanese and USA negotiators were lower than in either Japanese-Japanese or USA-USA negotiations. These situations are tested with the present model. All agents are assumed to have equal status. Japanese culture is more uncertainty avoiding and collectivistic then USA culture. Group distance experienced by the negotiators is expected to be very relevant in Japan. To verify this effect, tests are run with maximal group distance g=1 and reduced group distance g=0.5 for the intra-cultural negotiations. In human negotiations, the effect of group distance can be reduced by getting acquainted, but we assume that Japanese agents will still experience USA agents more as strangers than out-group Japanese agents. Therefore, intercultural tests are run with g=1 and g=0.7. For The hypotheses to be tested in this situation are:

H10: Japanese agent's negotiation results strongly depend on group distance.

H11: Intercultural negotiations between simulated USA and Japanese agents are less efficient than intra-cultural negotiations in those countries.

H12: Even if group distance is reduced, better results are obtained in a culturally homogeneous than in an intercultural setting.

The results presented in Table 5 confirm the hypotheses. USA agents are not very sensitive to group distance, but Japanese are. Under the assumption that Japanese agents experience larger group distance with USA than with other Japanese, H11 and H12 are confirmed. The difference in results with USA and Japan in customer versus supplier role is caused by differences in risk attitude.

Table 5. Average results of simulated negotiations between agents configured with cultural dimensions similar to Japan (H=0.5, A=0.9, I=0.4, M=0.9, L=0.8) and USA (H=0.4, A=0.5, I=0.9, M=0.6, L=0.3) (8 suppliers; 8 customers; 10 runs of 200 time steps; parameter values as in Table 4; status = 0.5 for all agents)

supplier / customer	group distance	number of transactions	% failed negotiations	% top quality
USA / USA	$g = 1$	31	70	70
Japan / Japan	$g = 1$	9	90	0
USA / USA	$g = 0.5$	32	70	69
Japan / Japan	$g = 0.5$	43	60	23
USA / Japan	$g = 1$	0	100	
Japan / USA	$g = 1$	19	81	37
USA / Japan	$g = 0.7$	7	93	0
Japan / USA	$g = 0.7$	22	79	38

The second example of results obtained with realistic cultural indices is based on results of human gaming simulations by Meijer et al. (2006). One of their findings is that Dutch buyers prefer to trust their suppliers with respect to agreements to deliver top quality products, while buyers from the USA prefer certification and third party testing. Simulations were run to test if the model could simulate this effect. For this test the following parameter settings were modified:

- quality preference w_Q' was raised to 0.2 (to stimulate to top quality trade);
- trust in each other agent was set to t=0.8 (to enable trusting behavior);
- the certification option was switched on, i.e. buyers had the opportunity to demand a certificate, which incurs extra cost on the suppliers (10% of the maximum price of top quality products) and thereby raises price.

All agents are equally configured, except for culture. The hypothesis is:

H13: Agents configured as Dutch buyers are more inclined to trust than USA agents; customer agents configured with USA culture are more inclined to pay for certified quality than Dutch agents.

The results presented in Table 6 confirm this hypothesis.

Table 6. Average results of simulated negotiations between agents configured with cultural dimensions similar to Dutch (*H*=0.4, *A*=0.5, *I*=0.8, *M*=0.1, *L*=0.4) and USA (*H*=0.4, *A*=0.5, *I*=0.9, *M*=0.6, *L*=0.3) (8 suppliers; 8 customers; 5 runs of 200 time steps; parameter values as in Table 4, except typical value of w_Q'=0.2)

supplier / customer	number of transactions	% failed negotiations	% top quality	% certified transactions
USA / USA	48	54	89	15
Dutch / Dutch	50	48	94	7
Dutch / USA	54	49	91	13
USA / Dutch	45	57	93	4

Conclusion

Negotiation can be approached as a rational process of collaborative decision making, as advocated by Raiffa et al. (2002). However, it is observed that negotiation outcomes differ across the world and that people from different countries differ with respect to the way they negotiate and the results they obtain (Gelfand and Brett 2004). As to all forms of negotiations, this applies to business negotiations and the bargaining about commercial transactions. There is abundant evidence that the result of decision making in business is influenced by the cultural background of the decision makers (e.g., Graham et al 1994; Adair et al. 2004; Metcalf et al. 2006) or institutional differences across countries (e.g., Kumar and Worm 2004), the development of which is also influenced by culture (Hofstede 2001). Therefore, agent-based simulations of international supply chains and networks should account for cultural differences.

De Rosis et al. (2004) suggested to explore the feasibility of Geert Hofstede's five-dimensional model (Hofstede 2001) to differentiate agents' behavior across cultures. The present paper shows how Hofstede's theory can be used for this purpose, in a multi-agent simulation of international trade.

In contrast with models that aim to optimize rational decision making, the model should in this case realistically simulate human negotiation behavior. The ABMP negotiation architecture (Jonker and Treur 2001) was validated to satisfy this requirement by Bosse et al. (2004). Therefore, the ABMP architecture is chosen as the basis for modeling cultural differences. A model has been developed for the joint effect of the dimensions of culture on ABMP parameters, based on earlier work that modeled the separate effects of individual dimensions (G.J. Hofstede et al. 2006; 2008a; b; c; 2009).

The model proposed in this paper has been tested on imaginary stereotypical cultures that differ on only one of the dimensions. Tendencies in the results along each of the dimensions comply with what is expected on the basis Geert Hofstede's theory. The tests with the stereotypical cultures confirm that the model is sensitive to variations of the cultural indices in the desired direction. Further testing with combinations of dimensions that are drawn from actual cultures should give evidence of the model's validity.

Two examples are given of simulations of results of negotiation research reported in business science literature. The simulations reproduce qualitative aspects of the cases reported in that literature, thus confirming that the model can reproduce actual cultural effects. However, this does not provide a full validation of the model. It is a test that confirms the model's sensitivity for relevant parameters. Validation and tuning of parameters require more simulations of actual cases from literature or experiments.

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12 A Cross-cultural Multi-agent Model of Opportunism in Trade

Abstract. According to transaction cost economics, contracts are always incomplete and offer opportunities to defect. Some level of trust is a sine qua non for trade. If the seller is better informed about product quality than the buyer, the buyer has to rely on information the seller provides or has to check the information by testing the product or tracing the supply chain processes, thus incurring extra transaction cost. An opportunistic seller who assumes the buyer to trust, may deliver a lower quality product than agreed upon. In human decisions to deceive and to show trust or distrust, issues like mutual expectations, shame, self-esteem, personality, and reputation are involved. These factors depend in part on traders' cultural background. This paper proposes an agent model of deceit and trust and describes a multi-agent simulation where trading agents are differentiated according to Hofstede's dimensions of national culture. Simulations of USA and Dutch trading situations are compared.

1 Introduction

A business transaction usually incurs cost on transaction partners, thus reducing the value of the transaction for the party bearing the cost. In transaction cost economics [1] opportunism and the incompleteness of contracts are central issues. Due to bounded rationality, contracts cannot specify solutions for all contingencies that may occur in transactions executed under the contracts. The incompleteness offers contract partners opportunities to defect. As Williamson [1] asserts, not every contract partner will take full advantage of every opportunity to defect. It is the uncertainty about a contract partner's opportunism that incurs transaction cost. *Ex ante* and *ex post* types of transaction cost can be distinguished. *Ex ante* are the cost of searching, bargaining, drafting, and safeguarding of contracts. *Ex post* are the cost of monitoring and enforcing task completion. Transaction cost economics is the basis for the process model of trading agents applied in this paper. The process model is depicted in Fig. 1.

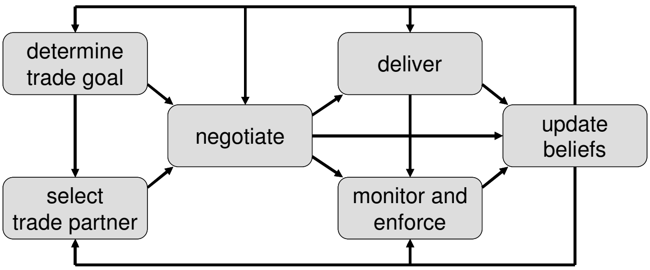

Fig. 1. Processes and internal information flows of trading agents

The outcome of successful negotiation is a contract. After that, it comes to delivery. An agent may deliver according to contract, or fail to do so intentionally (opportunism) or unintentionally (by incompetence or a flaw of its quality control system). At the same time, an agent may monitor the other party's delivery and either check if it is according to contract, or trust and accept without checking. Klein Woolthuis et al. [2] studied the relationship between trust and contracts. They concluded that trust can substitute or complement contracts: if trust is high, contracts can either be rather incomplete, because parties do not expect deceit, or more complete but not actively monitored and enforced, as a signal confirming the trusting relationship; if trust is low, a contract can either be rather complete as a safeguard against opportunism, or incomplete because of opportunistic intentions (so, contract incompleteness does not necessarily imply trust).

The trading situation of the simulation presented in this paper is based on the Trust And Tracing game [3]. In this game, players select trade partners and trade imaginary food products that have a value-adding quality attribute known by the supplier, but invisible to the customer, e.g. "organically grown". The customer can, at the cost of a fee, involve the Tracing Agency to test the actual quality. The Tracing Agency reports the test's outcome to both customer and supplier, and in case of untruthful delivery, punishes the supplier by a fine. Based on experience from negotiation and tracing results, agents update their beliefs about the market, potential partners, and the risks of opportunistic behavior. This paper focuses on the post-contract phase. The models for trust, deceit, and experience-based belief update are described in Section 2.

Human decisions to deceive and to trust are not strictly rational in the sense that is usual in neoclassical economics. Apart from financial benefits, human beings discount expectations of future deals and of social benefits that have to do with status and affiliation and can be succinctly described as 'reputation'. They do this for the simple reason that those of their ancestors who did it, or the groups and societies to which they belonged, have thrived and succeeded in reproducing [4]. The mechanisms that people use to guide their decisions to trust and deceive are largely unconscious. They include emotions [5] and intuition. Which emotions are felt in which circumstances, and which actions are taken as a result, depends on culture. As a result, the dynamics of trust and deceit depend on cultural background [6, 7]. G. Hofstede's five dimensions of national cultures [8] are widely used to identify cultural differences. G.J. Hofstede et al. described models for the influence of culture on trade processes, including deceit and trust, for each of the five dimensions separately [9, 10, 11, 12, 13]. However, the differentiation of human behavior cannot be described along a single one of these dimensions. The present paper's goal is to integrate G.J. Hofstede et al.'s individual dimension models, focusing on the decisions whether to deliver truthfully or untruthfully (*deceit*) and whether to trace the delivery or to accept it without tracing (*trust*), and on experience- based belief update about partner's trustworthiness and benevolence (i.e. its inclination to trust). Section 3 introduces Hofstede's five-dimensional model of culture and the dimensions' effects on deceit and trust. Section 4 presents the computational model of the effects of culture on deceit and trust. Section 5 describes experimental results from multi-agent simulations. Section 6 concludes the paper with a discussion of the results.

2 Modeling Deceit, Trust, and Experience-Based Belief

The simulation model represents the trade process of the Trust And Tracing game [3], where a group of 15-20 participants repeatedly trade commodities of different quality levels for an a priori unknown time. Suppliers are informed about the quality; customers are not informed. Participants are free to select a partner for each transaction, and negotiate about price, quality to be delivered, and conditions of the contract. Fig. 2 provides a graphical summary in the form of the 'Trader's Predicament' [14], a payoff matrix in the style of the Prisoner's Dilemma.

	Seller offers		
Buyer responds	Low Q	High Q, trustworthy	High Q, deceitful
a) accepts	No-risk deal		
b1) accepts, trusts		B, S: reward	B: sucker's payoff S: temptation
b1′) accepts, trace		B: reward minus cost of tracing S: reward B,S: possibly damaged relation (distrust)	B: confirmation of distrust S: punishment
b2) requires guarantee; no trace		B, S: reward B,S: possibly damaged relation (distrust)	B: sucker's payoff S: temptation
b2′) requires guarantee; trace		B: reward minus cost of tracing S: reward B,S: possibly damaged relation (distrust)	B: confirmation of distrust, money back S: punishment, return money
b3) requires certificate		B, S: no risk; reward minus certificate cost	B: no product S: withdrawal

Fig. 2. Payoff matrix for the version of the Trust & Tracing game modeled in this paper (Q: quality; S: seller's payoff; B: buyer's payoff)

Customers may (a) avoid deceit by buying low quality or (b) buy high quality and either (b1) accept vulnerability and trust the supplier to deliver according to contract, or (b2) protect themselves by negotiating a guarantee, for instance money back in case deceit would be revealed, or (b3) have the commodity traced in advance (certification). Option (a) is free of cost and risk, and a low price may be negotiated, but the customer has to accept low quality. Options (b1) and (b2) incur risk on the customer (as they offer the seller an opportunity to defect), and additional cost only if the customer decides to monitor (trace) the delivery. The certification option (b3) excludes risk, but always incurs additional cost.

Although trust is relevant for the processes of partner selection and negotiation, the present paper focuses on the post-contract phase of transactions. It describes the decision whether to deceive or not in the delivery process, the decision whether to trust or to trace in the monitoring and enforcing process, and the update of beliefs resulting from confirmed or violated trust. The remaining part of this section discusses relevant literature from the social sciences and introduces the agents' decision models applied in the simulation.

In experiments using a repetitive ultimatum game with asymmetric information, Boles et al. [5] found that most people do not choose deceptive strategies. However, deceit occurred in their experiments, in particular when stakes were high. So, for deceit to occur, at least two conditions have to be satisfied: motive (substantial advantage for the deceiver) and opportunity (lack of information on the part of the deceived).

As Boles et al. found, the conditions of motive and opportunity are not sufficient for deceit. The decision to deceive depended on interpersonal interactions and the player's satisfaction about the behavior of the other party. They report that "*the bargainers were little like those depicted by rational economic models*" [5] and that "*responders may react emotionally and reject profitable offers in the present when they realize that they have been deceived in the past*" [5].

Role-playing research into cheating on service guarantees by consumers reported by Wirtz and Kum [15] confirms that people are not inclined to seize any opportunity to cheat. Their research also confirms that potential material gain is a condition for cheating, but they found no evidence that people who cheat let their decision depend on the expected amount of payout or the ease of the opportunity to cheat. They report cheating to be related to personality of players (morality, Machiavellianism and self-monitoring). Two factors found to decrease cheating were satisfaction about the deal and the expectation of repeated dealing with the supplier in the future. Wirtz and Kum [15] suggest that a sense of loyalty and trust may reduce cheating. They also refer to Hwang and Burgers [16] who take an economics approach and argue that the high cost of the loss of a trusted partner is an inhibitor of opportunism. Both views indicate that a high-trust relation inhibits deceit.

In the research discussed above, four factors that influence deceit are found: opportunity, expected payout, player's personal traits and values, and player's trust relationship with their counterpart. Steinel and De Dreu [17] conclude on the basis of experiments with the Information Provision Game that, due to greed and maybe to fear of exploitation, individuals are less honest when they experience their counterpart to be competitive rather than cooperative, and that this tendency is stronger for prosocial than for selfish individuals. The importance of the relationship and the behavior of the counterpart is confirmed by Olekalns and Smith [18] who contrast two models of ethical decision making: *fair trade* (my counterpart trusts me, so I will cooperate) and *opportunistic betrayal* (my counterpart trusts me, so I can easily defect). In experiments with Australian undergraduate students they found strong support for *fair trade* as the prevailing model. However, Wirtz and Kum [15] found that individuals scoring high on Machiavellianism in the personality test, were more easily tempted to seize an opportunity to cheat and actually followed what Olekalns and Smith [18] called the *opportunistic betrayal* model.

A general conclusion of the work cited so far in this section is that deceit is less likely to occur when trade partners show trust in each other, even when rational strategies to win the game would suggest cheating. As the purpose of the multi-agent simulation reported in this paper is to represent actual human behavior rather than to apply deception as a strategy to win a game, we cannot employ rational models like the ones proposed by Castelfranchi et al. [19] and Ward and Hexmoor [20].

In the simulation a supplier's decision to deceive business partner *b* is modeled as a Bernoulli variable with probability of deceit

$$p(\text{deceit}) = q\,(1-c)\,m_b\,(1-d_b)\,, \tag{3}$$

where:

- q represents the quality agreed in the current contract (q=1 for high quality; q=0 for low quality or no opportunity);
- c=1 if certification has been agreed (no opportunity); c=0 otherwise;
- m_b represents the supplier's motive or rationale to deceive business partner *b*: m_b=1 if the supplier expects an extra profit from deceit; m_b=0 otherwise, for instance if the customer negotiated a guarantee and the supplier expects the customer to trace the delivery;
- d_b represents on the interval [0, 1] seller's threshold for deceit toward business partner *b*, where d_b=1 represents perfect truthfulness; d_b is influenced by seller's personal traits and values (like risk aversion and morality), power and group relations, and seller's estimate of customer's benevolence toward the seller, i.e., seller's trust that the customer will accept deliveries without tracing; details on d_b and the influence of cultural background are discussed in Section 3.

For the purpose of the simulation, Klein Woolthuis et al.'s [2] narrow definition of trust is adopted. A customer's trust in a particular supplier is defined as the customer's estimate of the probability that the supplier will cooperate and deliver according to contract, even if the supplier has the motive and the opportunity to defect. However, this does not imply that an agent's decision to have a delivery traced can be modeled as a Bernoulli variable with $p(\text{trace})=q(1–c)(1–t_b)$ where $q(1–c)$ represent opportunity as in equation (1) and t_b represents trust in business partner *b*. Additional factors like power and group relationships with the supplier and the agent's cultural background also have their effect on the decision to trace. The effects of relationships and cultural background on the tracing decision are discussed in Section 3.

Trust and distrust develop during social interactions. Visual and auditory contact is relevant to develop trust and detect deceit in human interactions [21]. The multi-agent simulation does not support these effects. The only sources of information that can be taken into account are negotiation outcomes and tracing reports, which are relevant in reality as well. Every successful negotiation resulting in a transaction will strengthen partners' trust in each other. The possibility that a supplier carries out a trace is disregarded here. Customers can decide to trace a delivery and this can have its effects on mutual trust. First, if the result of tracing reveals deceit, the customer's trust in the seller will be reduced. Second, to some extent the fine and the reputational damage resulting from revealed deceit will reinforce the supplier's honesty. However, reinforced honesty will decay to its original level in the course of time. Third, the supplier delivering truthfully may be offended by tracing and the relation may be damaged. For this reason, customers may exercise restraint to trace. Tracing by a customer will always reduce the supplier's belief about customer's benevolence. So, the following dynamics have to be modeled:

- development of trust and benevolence belief by successful negotiations;
- for customers: reduction of trust in case of revealed deceit;
- for suppliers: reinforcement of honesty in case of revealed deceit;
- for suppliers: decay of reinforced honesty to a base level;
- for suppliers: reduction of benevolence belief in case of tracing.

Formal models for representing the development of trust were analyzed by Jonker and Treur [22]. They distinguish six types of trust dynamics: blindly positive, blindly negative, slow positive – fast negative, balanced slow, balanced fast, and slow negative – fast positive. The most realistic type of dynamics for trust in trading situations is slow positive – fast negative: it takes a series of positive experiences to develop trust, but trust can be destroyed by a single betrayal (e.g., Boles et al. [5] report that deceit leads to emotional reactions and consequences beyond what is in their own interest; Steinel and De Dreu [17] refer to "*punitive sentiment*" towards deceivers).

The trust dynamics are modeled as follows. After the n'th experience a consumer's trust in business partner b is updated according to belief update factors u_+ and u_-:

$$\begin{aligned} t_{b,n} &= t_{b,n-1} + u_+ (1- t_{b,n-1}) && \text{if } n^{\text{th}} \text{ experience is positive ,} \\ t_{b,n} &= (1-u_-)\, t_{b,n-1} && \text{if } n^{\text{th}} \text{ experience is negative ,} \\ t_{b,n} &= t_{b,n-1} && \text{if } n^{\text{th}} \text{ experience is neither positive nor negative ,} \end{aligned} \qquad (\mathbf{2})$$

with $0 < u_+ < u_- < 1$, where $t_{b,n} = 1$ represents complete trust and $t_{b,n} = 0$ represents complete distrust in b; a successful negotiation counts as a positive experience; a tracing report revealing deceit counts as negative; all other experiences are considered neither negative nor positive with respect to trust.

A supplier's belief $v_{b',n}$ about a partner's benevolence is updated similarly:

$$\begin{aligned} v_{b',n} &= v_{b',n-1} + u_+ (1- v_{b',n-1}) && \text{if } n^{\text{th}} \text{ experience is positive ,} \\ v_{b',n} &= (1-u_-)\, v_{b',n-1} && \text{if } n^{\text{th}} \text{ experience is negative ,} \\ v_{b',n} &= v_{b',n-1} && \text{if } n^{\text{th}} \text{ experience is neither positive nor negative ,} \end{aligned} \qquad (\mathbf{3})$$

For the supplier a successful negotiation counts as a positive experience. However, tracing always counts as a negative experience for a supplier, whether it reveals deceit or not, because it is interpreted as distrust.

An effect of revealed deceit on the supplier's part is that supplier's current honesty h_k (a personal trait, representing the inclination to deliver truthfully) is reinforced to 1, representing maximal honesty in the supplier's cultural background. h_k will subsequently decay to a base value h' on each interaction, whether it is successful or not, with a decay factor f.

$$h_k = h' + f\,(h_{k-1} - h')\ , \ \text{with } 0 < h' < 1 \text{ and } 0 < f < 1\ . \qquad (\mathbf{4})$$

with $0 < h' < 1$ and $0 < f < 1$.

3 Deceit and Trust across Cultures

The preceding section introduced models for deceit, trust and belief update in a process of trade. The roles of deceit and trust are known to be different across cultures [6, 7]. Therefore, a multi-agent simulation of international trade that models the effects of deceit and trust should include the effects of culture. This section proposes an approach to model the effects of culture on the parameters and variables introduced in the previous section (deceit threshold, inclination to trace, and positive and negative trust update factors), based on G. Hofstede's dimensions of culture [8]. First culture and Hofstede's dimensions and their effects on deceit and tracing are discussed.

Hofstede describes culture as "*the collective programming of the mind that distinguishes the members of one group or category of people from another*" [8], p. 9. This implies that culture is not an attribute of individual people, unlike personality characteristics. It is an attribute of a group that manifests itself through the behaviors of its members. For a trading situation, culture of the trader will manifest itself in four ways. First, culture filters observation. It determines the salience of clues about the acceptability of trade partners and their proposals. Second, culture sets norms for what constitutes an appropriate partner or offer. Third, it sets expectations for the context of the transactions, e.g., the enforceability of regulations and the possible sanctions in case of breach of the rules. Fourth, it sets norms for the kind of action that is appropriate given the other three and, in particular, the difference between the actual situation and the desired situation.

Table 1. Hofstede's dimensions of culture [8]

Dimension	Definition
Power Distance	"*The extent to which the less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally*" [8], p. 98
Uncertainty Avoidance	"*The extent to which the members of a culture feel threatened by uncertain or unknown situations*" [8], p. 161
Individualism and Collectivism	"*Individualism stands for a society in which the ties between individuals are loose: Everyone is expected to look after him/herself and her/his immediate family only. Collectivism stands for a society in which people from birth onward are integrated into strong, cohesive in-groups, which throughout people's lifetime continue to protect them in exchange for unquestioning loyalty*" [8], p. 255
Masculinity and Femininity	"*Masculinity stands for a society in which social gender roles are clearly distinct: Men are assumed to be assertive, tough, and focused on material success; women are supposed to be more modest, tender and concerned with the quality of life. Femininity stands for a society in which gender roles overlap: Both men and women are supposed to be modest, tender and concerned with the quality of life.*" [8], p. 297
Long- Versus Short-Term Orientation	"*Long Term Orientation stands for the fostering of virtues oriented towards future rewards, in particular, perseverance and thrift. Its opposite pole, Short Term Orientation, stands for the fostering of virtues related to the past and the present, in particular, respect for tradition, preservation of 'face' and fulfilling social obligations*" [8], p. 359

G. Hofstede [8] identified five dimensions to compare national cultures (Table 1). For the dimensions, indices are available for many countries in the world. The indices are usually named PDI, UAI, IDV, MAS, and LTO. For the multi-agent model, we scale the indices to the interval [0, 1] and refer to the scaled indices as PDI^*, UAI^*, IDV^*, MAS^*, and LTO^*. E.g., IDV^* refers to the degree of individualism and 1-IDV^* to the degree of collectivism, both in the range [0, 1].

G.J. Hofstede et al. [9, 10, 11, 12, 13] modeled the influence on trade processes of each of the five dimensions separately. However, single dimensions do not fully represent the differentiation of human behavior. A realistic simulation must take the simultaneous effect of all dimensions into account. The purpose of the present paper is to develop a first version of integrated models for deceit, trust and belief update. The remaining part of this section summarizes the effects of individual dimensions as described in [9, 10, 11, 12, 13].

Power Distance. [9] On the dimension of power distance, egalitarian societies are on the one extreme (small power distance), hierarchical societies on the other (large power distance). In hierarchical societies, status and position in the societal hierarchy are the main issue in relations. Trust is only relevant among partners that have equal status. The lower ranked have no choice but to show trust in the higher ranked, whatever belief about their trustworthiness they may have. The higher ranked have no reason to distrust the lower ranked, because they assume that deceit of a higher ranked would not even be considered. With respect to deceit, the higher ranked do not have to fear for repercussions when trading with lower ranked, so the decision, whether to defect or not, merely depends on their morality. The lower ranked on the other hand will not easily consider to defect. They will usually cooperate when trading with higher ranked and will only defect if in need.

For egalitarian traders, decisions to deceive and to trust are not influenced by status difference. Trust is equally important in every relation, regardless of partner's status. However, showing distrust may be harmful to relations, so there may be other incentives for benevolent behavior.

Uncertainty Avoidance. [10] Uncertainty avoidance must not be confused with risk avoidance. People in uncertainty avoiding societies accept risks they are familiar with, but they fear the unknown. They are willing to take risks in order to reduce uncertainty about things they are not familiar with, or to eliminate them.

Uncertainty avoiding traders fear and distrust strangers. They follow the rules when dealing with familiar relations, but easily deceive strangers. A foreign partner will be distrusted until sufficient evidence for the contrary has been found. Once, in the course of repeated transactions, sufficient evidence for trustworthiness has been found through tracing of deliveries, and partners have become familiar, the uncertainty avoiding may finally come to trust their partners and expect them to follow the rules like they do themselves. After they have come to trust, any unexpected revelation of deceit provokes furious reactions from uncertainty avoiding traders. They will not easily deal again with a partner that abused their trust.

In this simulation it has been hypothesized that the tracing agency is always trusted. This is a deliberate simplification. In uncertainty avoiding societies, institutions in general and government in particular tend to be distrusted.

Individualism and Collectivism. [11] In individualistic societies, people have a personal identity and are responsible for their personal actions and view a business partner as an individual. In collectivistic societies, a person's identity is primarily given by group memberships (such as extended family, village, and clubs) and relations. People from collectivistic societies feel responsible for their in-group and prefer to trade with their in-group. Serious negotiations with out-group business partners must be preceded by some form of familiarization. In collectivistic societies harmony must be preserved, so the threshold for showing distrust by tracing is high. Tracing is also less likely because the idea of calling in outsiders to perform the tracing runs counter to a collectivistic way of thinking.

In collectivistic societies trust and deceit are based on group memberships and norms. People from collectivistic societies primarily trust in-group members and distrust out-group members. After a long-lasting relation, outsiders may be trusted as in-group members. Deceiving an out-group partner is acceptable if it serves in-group interests. In individualistic societies opportunistic behavior and trust are based on personal interests, personal values, and interpersonal relations.

Masculinity and Femininity. [12] On the masculine extreme of the dimension are competitive, performance-oriented societies; on the other are cooperation-oriented societies. A stereotypical trader with a feminine, cooperation-oriented cultural background is interested in the relationship. Building trust is important. In principle, the cooperation-oriented trader does not trace, since in his mind this would constitute ostentation of distrust. If conned, then the cooperation-oriented trader will avoid the conman if possible, or give him one more chance.

Trust is irrelevant in extremely performance-oriented, masculine societies. A performance-oriented trader sticks to the contract of the deal, and deceives the trade partner to the limits of the contract without any compunction. As a consequence, the performance- oriented trader sees no problems in dealing again with a trader that conned him in the past: "It's all in the game". The performance-oriented trader always traces the goods after buying, since he expects the possibility of deception. The trader learns from mistakes to make sure that new contracts will not lead to new and uncomfortable surprises on his side.

Long- Versus Short-Term Orientation. [13] Traders from long-term oriented societies value their relations. They value a deal not only by the financial pay off, but also by the relational gains. They are inclined to invest in relations by behaving truthfully and by trusting their partners. They value their business relations by the prospect of future business. They have no respect for others that put their relations at stake for some short-term profit. If they turn out to be deceived by a business partner they will not easily forgive the deceiver.

People from short-term oriented cultures find it hard to understand the sacrifice of the long-term oriented. The short-term oriented tend to grab a chance for an easy profit and are willing to put their relations at stake for it, especially if they are in need to fulfil other social obligations, like showing off for family members. They calculate the bottom line of the transaction. Their threshold to deceive or to distrust depends on the value they attach to the relation in their social life. They can understand that a business partner may be tempted to defect if a profitable opportunity occurs, and they have trouble understanding that people from long-term oriented cultures cannot.

4 Integrated Computational Model

Hofstede et al. [9, 10, 11, 12, 13] proposed formal models of the effects of each of the dimensions of culture on trade processes, including effects on deceit threshold, inclination to trace, and positive and negative trust update factors. The models are based on expert knowledge, gained with a classical knowledge acquisition approach. This section presents an approach to integrate the knowledge about individual dimensions into a model of the joint effect of the dimensions on deceit and trust.

The expert knowledge is formulated as "cultural factors" having an increasing or decreasing effect on the strength or occurrence of behaviors along one of the dimensions of culture. Apart from the dimensions of culture, the behaviors can be influenced by attributes of the relation with the business partner. Examples of such relational attributes are status differences and ingroup relations. This kind of relational attributes have different relevance in different cultures.

The expert knowledge about the effects of cultural factors is expressed as effects on parameters or variables of the agents' decision models. The dimensions of culture provide a linear ordering of cultures with respect to the strength or frequency of phenomena associated with the dimensions. Therefore, we model the effect of a cultural factor as either no effect at all or as strictly monotonic, i.e. increasing or decreasing. As long as no further evidence is available, we assume the most simple monotonic relation: a linear relation between a cultural factor and the effective value of a parameter or variable. Table 2 summarizes the effects of cultural factors that were identified as relevant for the present simulation. The effects are grouped by dimension. In some cases the effects of the cultural dimensions stand alone; in other cases the effects depend on attributes of the relation with the business partner.

The types of cultural factors in Table 2 are:

- a normalized index I^* of one of the dimensions, as a characterization of a culture;
- $(1–I^*)$, as the characterization of the opposite culture on that dimensions;
- an index I^* or $(1–I^*)$ multiplied with a relational characteristic, such as agent *a*'s group distance D_{ab} with business partner *b* or status difference $s_a–s_b$.

D_{ab} and s_a and s_b are reals on the interval [0, 1], as are the normalized dimension indices; so, the value of every cultural factor is a real on the interval [0, 1].

Table 2. Effects of Hofstede's dimensions of culture and relational characteristics on deceit and trust parameters (+ indicates increasing effect; - indicates decreasing effect)

Dim-ension index	Culture and relational characteristics	Cultural factor to be taken into account	Effect on			
			deceit thresh-old	inclin-ation to trace	negative update factor	positive update factor
PDI	Large power distance	PDI^*				
	- with higher ranked partn.	$\max\{0, PDI^*(s_b - s_a)\}$	+	–		
	- with lower ranked partn.	$\max\{0, PDI^*(s_a - s_b)\}$		–		
	Small power distance	$1 - PDI^*$				
UAI	Uncertainty avoiding	UAI^*			+	–
	- with stranger	$UAI^* \cdot D_{ab}$	–	+		
	Uncertainty tolerant	$1 - UAI^*$				
IDV	Individualistic	IDV^*				
	Collectivistic	$(1 - IDV^*)$			+	
	- with in-group partner	$(1 - IDV^*)(1 - D_{ab})$		–		
	- with out-group partner	$(1 - IDV^*)D_{ab}$	–			
MAS	Masculine (competitive)	MAS^*	–	+	–	
	Feminine (cooperative)	$1 - MAS^*$		–		
LTO	Long-term oriented	LTO^*	+	–	+	
	Short-term oriented	$(1 - LTO^*)$				
	- with well-respected part.	$(1 - LTO^*)s_b$	+	–		
	- with other partners	$(1 - LTO^*)(1 - s_b)$	–			

4.1 The Decision to Deceive on Delivery

In the preceding sections a model is developed of factors that influence the agents' decision to cooperate or to defect. In the agent model the decision whether to deceive or to deliver truthfully is modeled as a Bernoulli variable, taking the probability according to equation (1) into account.

$$p(\text{truthful delivery}) = 1 - p(\text{deceit}) \,. \qquad \textbf{(5)}$$

This decision is taken in the delivery phase of the transaction, after a contract has been negotiated.

The opportunity to deceive depends on contract attributes q (quality) and c (certification required). If q=0 or c=1, there is no opportunity to deceive and the agent delivers truthfully: $p(\text{deceit})=0$ and $p(\text{truthful delivery})=1$ if q=0 or c=1. Otherwise, the motive and the deceit threshold are relevant.

The motive to deceive is present if the value difference between high quality and low quality exceeds the cost of the estimated risk of deceit. The motive depends on:

- Δy , value difference between high and low quality,
- v_b , the agent's belief about the partner b's benevolence (interpreted as the subjective probability that b will not put the delivery to the test),
- r, the amount of the fine in case deceit would be revealed;
- $g \cdot y$, where g=1 if the contract entails a guarantee, g=0 if not, and y, the value to be restituted in case of a guarantee).

The motive to deceive b is computed as:

$$m_b = 1 \text{ if } \Delta y > (1 - v_b)(r + gy) \ ; \quad m_b = 0 \text{ otherwise} \ . \qquad \textbf{(6)}$$

It follows from (1) that p(deceit)=0 and p(truthful delivery)=1 if m_b=0. If motive and opportunity are present, the decision is affected by the agent's current honesty h_k and its belief about the quality relation with the customer b. We assume that the deceit threshold toward agent b has max(h_k, v_b) as a basis:

$$d_b' = \max(h_k, v_b) \qquad \textbf{(7)}$$

The actual deceit threshold equals basic value d_b' modified by increasing cultural effect $e^{d+}{}_b$ in the direction of 1; by decreasing effect $e^{d-}{}_b$ in the direction of 0:

$$d_b = d_b' + (1 - d_b')\, e^{d+}{}_b - d_b'\, e^{d-}{}_b \ , \qquad \textbf{(8)}$$

The joint increasing effect $e^{d+}{}_b$ is modeled as a weak disjunction of all increasing factors from Table 2; The joint decreasing effect $e^{d--}{}_b$ is modeled as a weak disjunction of all decreasing factors from Table 2:

$$e^{d+}{}_b = \max \{\text{PDI}^*(s_b - s_a),\ \text{LTO}^*,\ (1-\text{LTO}^*)s_b\} \ ; \qquad \textbf{(9a)}$$

$$e^{d-}{}_b = \max \{\text{UAI}^* D_{ab},\ (1-\text{IDV}^*)D_{ab},\ \text{MAS}^*,\ (1-\text{LTO}^*)(1-s_b)\} \ . \qquad \textbf{(9b)}$$

In the present model, if opportunity and motive for deceit are present, the probability that an agent acts truthfully equals the culturally adapted deceit threshold d_b according to equations (8) and (9); the probability that an agent defects under these conditions equals $1 - d_b$. If motive or opportunity are absent, the agents will always deliver truthfully.

4.2 The Decision to Trust or Trace Deliveries

According to Castelfranchi and Falcone [23] "*Trust is the mental counter-part of delegation*". The mental aspect of trust in the present agent model is the experience-based belief about a business partner b's trustworthiness t_b. The delegation aspect of trust is in the act of trusting: to delegate the responsibility to deliver high quality to b, without safeguard that b will actually do so.

Across cultures different norms exist for the showing of trust or distrust. The probability that an agent will show trust is not necessarily equal to its subjective, experience-based belief t_b about the probability that *b* will act truthfully. In the present model, believed trustworthiness is the basis for the act of trusting, but the actual act of trusting does not necessarily correspond with it.

The decision to trust a delivery from business partner *b* or to trace is based on the estimated trustworthiness t_b. An agent's belief t_b about *b*'s trustworthiness can be interpreted as a subjective probability that *b* will not deceive. $(1 - t_b)$ is the agent's distrust in *b*, or the subjective probability that *b* will defect. So, the basis for the inclination w_b' to trace b's delivery is:

$$w_b' = (1 - t_b) \, , \qquad \textbf{(10)}$$

which is adapted by culture, similar to equation (8):

$$w_b = w_b' + (1 - w_b')\, e^{w+}{}_b - w_b'\, e^{w-}{}_b \;\; , \qquad \textbf{(11)}$$

where

$$e^{w+}{}_b = \max\, \{\mathrm{UAI}^* D_{ab},\, \mathrm{MAS}^*\} \; ; \qquad \textbf{(12a)}$$

$$e^{w-}{}_b = \max\, \{\mathrm{PDI}^* |s_a - s_b|,\, (1-\mathrm{IDV}^*)(1-D_{ab}),\, 1-\mathrm{MAS}^*,\, \mathrm{LTO}^*,\, (1-\mathrm{LTO}^*) s_b\} \, . \qquad \textbf{(12b)}$$

The culture-dependent probabilities that agent *a* will trace or trust *b*'s delivery are:

$$p(\mathrm{trace}) = q\,(1 - c)\, w_b \;\; ; \qquad \textbf{(13a)}$$

$$p(\mathrm{trust}) = 1 - w_b \, . \qquad \textbf{(13b)}$$

4.3 Belief Update Factors

The values of the belief update factors to be applied in equations (2) and (3) for positive and negative experience, u_+ and u_-, respectively, are agent parameters that do not depend on the partner. They may be modeled as global parameters u_+' and u_-', respectively. In the latter case, the global values are culturally adapted as follows, in analogy with the preceding subsections.

u_+' is influenced by only a single factor according to Table 2. The value is reduced in societies with high uncertainty avoidance:

$$u_+ = u_+' \; - \; u_+'\, \mathrm{UAI}^* \, . \qquad \textbf{(14)}$$

u_-' is influenced by more factors, under the constraint that $u_- > u_+$:

$$u_{-} = u_{-}' + (1 - u_{-}')\, e^{u-+} - (u_{-}' - u_{+}')\, e^{u--}, \qquad \textbf{(15)}$$

where

$$e^{u-+} = \max\{\mathrm{UAI}^{*}, 1\text{-}\mathrm{IDV}^{*}, \mathrm{LTO}^{*}\}; \qquad \textbf{(16a)}$$

$$e^{u--} = \mathrm{MAS}^{*}. \qquad \textbf{(16b)}$$

5 Testing the implementation

The model described in the preceding sections is implemented in a multi-agent model in Cormas[9]. The decision functions and plans are implemented as methods in the software agents. The agents can communicate through the Cormas synchronized message system. They can exchange messages to communicate or to transfer the ownership of commodities. Each commodity has slots for

- real quality, not visible for the trading agents;
- stated quality, visible and modifiable by the agents; a commodity is initialized with stated equal to real quality, but may be modified during the simulation;
- traced quality, visible for the trading agents, but only modifiable by the tracing agent; it is initially empty.

In the simulation there is a tracing agent to which the trading agents may, at the cost of a fee, send a commodity for inspection (the stated quality slot may deceitfully be modified by a supplier). Upon request, the tracing agent sets traced equal to real quality, returns the commodity, informs the suppliers that their product has been traced, and, in case of deceit, traces deceivers to punish them with a fine. A product that has the traced value set, can be seen as certified. A supplier can have a product certified before selling it, to increase the value. The amount of the tracing fee increases with each transaction in the history of a commodity, so certification in advance is cheaper than tracing by the customer.

The agents have access to a central directory with references to all agents and the tracing agent. The agents have labels for status and group membership. Labels are visible for all other agents. In some cultures group distance and status difference with trade partners are very relevant. The agents use the label information to estimate these parameters. Experience gained while trading, using the update mechanism described by equations (2) and (3), results in beliefs about trustworthiness and benevolence for each partner. Agents propose to negotiate to potential partners and they may accept or ignore negotiation proposals.

Partner selection is based on the model of Weisbuch et al. [24]. This model is based on a nonlinear probability of selecting a particular partner according to experience of profitability of previous deals – which we call fairness belief – and an agent-specific

[9] http://cormas.cirad.fr/

loyalty parameter. The loyalty parameter determines the relevance of the fairness belief for partner selection. The fairness belief is updated through a mechanism like the ones describes by equations (2) and (3). The cultural adaptation of Weisbuch et al.'s model for the application in the simulation is described in [25].

In the process of negotiation, the agents exchange proposals with the following attributes:

- identifying attributes: sender; receiver; time; is it a first bid, reply to a previous bid or acceptance of a bid;
- price;
- quality;
- an indicator if is the commodity is to be certified in advance by the supplier;
- an indicator of a money-back guarantee in case deceit be revealed in future tracing.

The negotiation process is based on work by Jonker and Treur [26]. Their negotiation architecture is based on a multi-attribute utility function. In the present implementation the utility function is a linear combination of an economic value term, a quality preference term and a risk attitude term. The relative weights of quality preference and risk avoidance determine the agent's trade strategy and are culture-dependent. The other parameters modeled to depend on culture are the agents' willingness to make concessions, the step size of concessions, impatience, and the remaining utility gap that is acceptable between own and partners proposal. The agents' culturally adapted negotiation model is described in detail in [27].

A negotiation may end with a contract, or it may fail, because one of the agents quits. In the latter case the agents select a partner, to try and start new negotiations with. In case of a contract, the processes of trust and deceit modeled in the present paper come into effect.

To test the implementation of the model, simulations were run in the environment described above. Eight supplier agents and eight customer agents could trade repeatedly, approximately 30-40 times per run, resulting in approximately 240-320 deals per run. The negotiation process was limited to result in q=1, c=0, and g=0, so the agents were forced to decide on trust and deceit. They could only negotiate about price, and let negotiations fail in case of distrust.

A series of runs were made, with "synthetic" cultures: the culture dimensions were set to 0.5, except one dimension, which was set to 0.1 or 0.9 in order to represent a cultural extreme. For instance, in the first run, PDI^*=0.9, UAI^*=0.5, IDV^*=0.5, MAS^*=0.5, and LTO^*=0.5; in the second run, PDI^*=0.1, UAI^*=0.5, IDV^*=0.5, MAS^*=0.5, and LTO^*=0.5. In all runs, the agents were divided into two groups of four suppliers and four customers with equal labels, having group distance D_{ab}=0 in the ingroup and group distance $D_{ab'}$=1 with members of the other group. Status was mixed: four agents had status 0.1, four agents 0.4, four agents 0.6, and four agents status 0.9, divided equally over ingroups of suppliers and customers. A summary of the results is presented in Fig. 3.

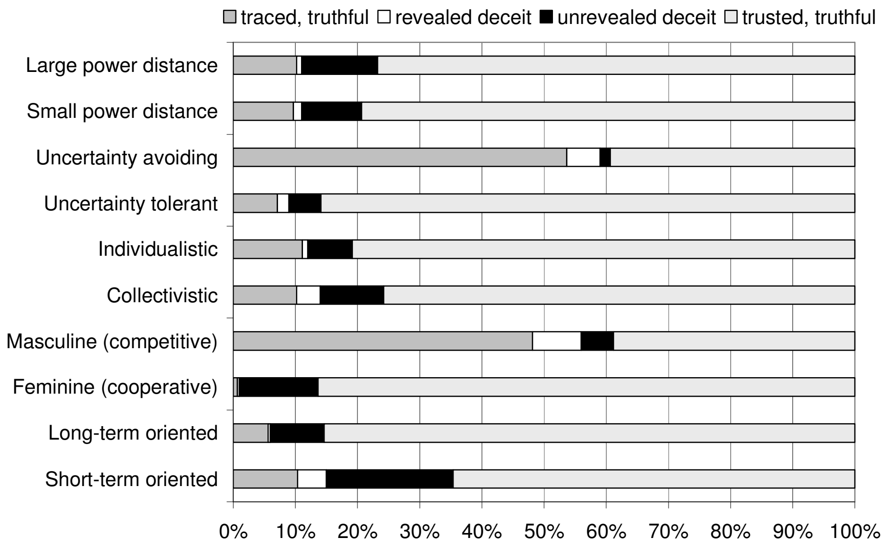

Fig 3. Results of simulations in societies with synthetic cultures; in the synthetic cultures all scaled cultural dimensions have index 0.5, except one, which has either 0.1 or 0.9

The first variable displayed in Fig. 3 displays the percentage of transactions that were traced and turned out to be truthful. Together with the second variable (traces that revealed deceit) it is a measure for the level of distrust that is shown. High values occur in the uncertainty avoiding and masculine societies. In the masculine society this results directly from the increased inclination to trace, equation (12), which reduces the relevance of the mental aspect of trust. In the uncertainty avoiding society, the high tracing ration results mainly from low trust: trust cannot develop because of the adapted positive belief update, equation (14). In addition, equation (12) has its effect on tracing frequency on deals with strangers.

The second variable in Fig. 3 indicates deceit revealed in traces, i.e. the confirmed distrust. There no obvious relation with the tracing frequency. In the societies where a considerable amount of the transactions is traced and distrust is frequently confirmed (the collectivistic and short-term oriented societies), this does not lead to even more tracing by the influence of equation (8), while the tracing ratio in the uncertainty avoiding society remains high, even if distrust is less frequently confirmed.

The third variable displays the frequency of unrevealed deceit. The high deceit frequency in the short-term oriented societies stems from the combination of the opportunity offered to higher ranked through equation (12b) - a low inclination to trace higher ranked – and the reduced deceit threshold toward lower ranked through equation (9b) – the opportunity is gratefully seized. This dimension is the only one where such a mutually reinforcing effect on deceit occurs in the equations. On the other dimensions, deceit frequency is lower and there is no obvious relation with the frequency of tracing (first column) across cultures. This is realistic.

In the masculine society the deceit frequency remains high while most of the deceit is revealed. This suggests that the competitive orientation is correctly implemented. In the feminine society, deceit is rarely revealed, but it does not occur more frequently than in the masculine society. This suggests that the cooperative orientation is also correctly implemented. In the short-term oriented society, the wrong partners are traced: the percentage revealed is lower than the actual percentage of deceit, in spite of the rather high tracing frequency.

The results presented in Fig. 3 give confidence that the model can differentiate trade behavior across the Hofstede's dimensions of culture in a way that is qualitatively realistic.

The remaining part of this section discusses an example on the basis of experiments with the Trust And Tracing game, the human gaming simulation that the present model represents. Meijer et al. [28] report, among others, gaming simulations with the Trust And Tracing game with business school students in The Netherlands and in the USA. They report that the American students showed more eager to win, traded higher quality, seized opportunities to cheat, and expected their opponents to do so too, so they traced more frequently. Furthermore they report that in the USA a greater fraction of high quality transactions was certified, i.e. traced up-front by the supplier, using the tracing report as a quality certificate. The reason for this is that in the game as it was played, the tracing fee for suppliers was lower than it was for customers. The players discovered that with a high tracing probability, it was efficient to have the suppliers trace in advance.

If the difference between USA and Dutch games may be attributed to culture, which seems plausible, they must be reproduced by the present multi-agent model. Fig. 4 represents the cultural indices for The Netherlands and the USA. The main difference is in the MAS index. The values of the indices are [8]:

- Netherlands: $PDI^*=0.38$, $IDV^*=0.80$, $MAS^*=0.14$, $UAI^*=0.53$, $LTO^*=0.44$;
- USA: $PDI^*=0.40$, $IDV^*=0.91$, $MAS^*=0.62$, $UAI^*=0.46$, $LTO^*=0.29$.

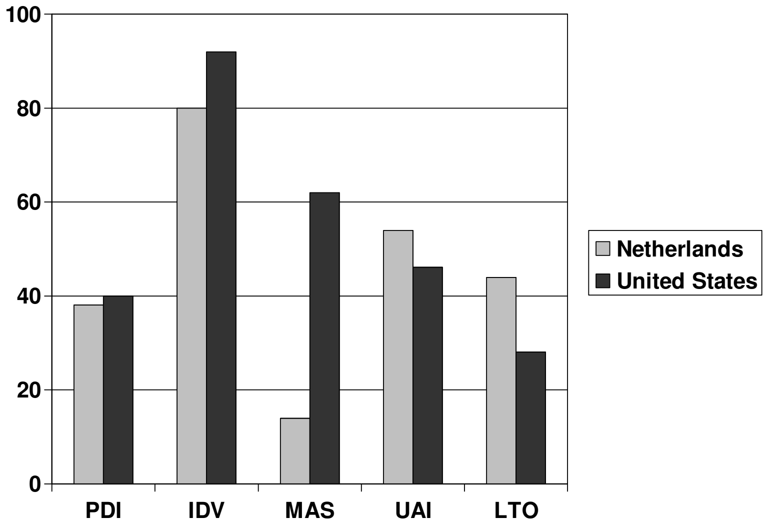

Fig. 4. The cultures of The Netherlands and the USA compared (data source: [8])

From the work of Meijer et al. [28] the following hypotheses can be formulated to be tested against simulation results:

1. The quality ratio (top quality transactions/all transactions) is higher in USA than in the Netherlands
2. The certification ratio (certified transactions/top quality transactions) is higher in USA than in the Netherlands
3. The defection ratio (untruthful deliveries/uncertified top quality transactions) is higher in USA than in the Netherlands
4. The tracing ratio (traces/uncertified top quality transactions) is higher in USA than in the Netherlands

For this purpose, simulations were run. As parameter values are unknown the following procedure was followed. For 1000 simulation runs, parameter sets were drawn at random from the joint space of parameters defined in the present paper (update factors u_+' and u_-', minimal honesty h_k, and honesty decay factor f, group distance D_{ab}, and status s_a and s_b) and parameters defined in the partner selection and negotiation models [25, 27]. All parameters were drawn independently from a uniform distribution on [0, 1], with some exceptions: u_+' was drawn from [0, u_-'], β (loyalty parameter in partner selection) from [0.5, 1.5], and the utility weight factors for quality and risk in the negotiation process were both drawn from [0, 0.2]. With these parameters agents were homogeneously configured, for a run where all agents had USA parameter settings and a run where all agents had Dutch parameter settings. So, in a single run, all agents had equal parameter settings, and for each setting, results for the USA and The Netherlands can be compared in pairs.

For each of the 1000 parameter sets, a simulation was run for each country. Each run had a length of 100 time steps, which practically limits the average number of transactions to a maximum about 20 per agent. To allow for partner selection, runs were configured for 8 suppliers and 8 customers, homogeneously parameterized. Negotiation was restricted to g=0 (no guarantees), with free choice between basic quality and top quality, and free choice of certification. Agents had the choice to deliver truthfully or untruthfully (equation 5) and to trust or to trace (equations 13).

Because of the wide range of parameters, many runs ended with zero or very few transactions. From the 1000 pairs of runs, the runs were selected that had a joint sum of at least 40 transactions per pair. Beneath this limit, many runs occur with zero transaction for one or both of the countries. The selection resulted in 317 run pairs.

Analysis of the results confirmed hypotheses 1, 3, and 4, but did not confirm hypothesis 2. The certification ratio as defined in hypothesis 2 was approximately equal for the USA and The Netherlands. According to the negotiation model reported in [27], customers do not take a differentiation of certification cost between themselves and suppliers into account. This difference was an important factor in the human gaming simulations in the USA. Therefore, the negotiation model from [27] was modified to take tracing fee difference and probability to trace into account. The original equation for customers' risk evaluation according to [27] was

$$r_c = (1 - c)(1 - t_b)q \; . \tag{17}$$

The modified equation is

$$r_c = (1 - c)(1 - t_b)q + p(\text{trace})\phi_c \; , \tag{18}$$

with *p*(trace) according to equation (13a) and ϕ_c representing customers' tracing fee.

This model adaptation is an example of the cyclic research approach proposed by Tykhonov et al. [3]. Their proposed approach entails stepwise refinement of models by alternating human gaming and multi-agent simulation.

The simulation was repeated after replacing equation (17) with equation (18) and setting the tracing fee equal to 0.2 for suppliers and 0.3 for customers. This resulted in 310 run pairs with a sum per pair of at least 40 transactions. Table 3 summarizes the results. Differences are significant for all variables, with $p < 0.001$ according to the Sign test. Histograms of differences are included in the Appendix.

Table 3. Test data for 310 run pairs for USA and NL with randomly generated parameter sets

Average of 310 runs	USA	NL	Test stat. [a]	Sample [a]	Probability [a]
Number of transactions	72	61	219	302	< 0.001
Quality ratio	0.37	0.15	277	285	< 0.001
Certification ratio	0.48	0.41	191	281	< 0.001
Defection ratio	0.25	0.13	128	154	< 0.001
Tracing ratio	0.40	0.07	169	177	< 0.001

[a] Test statistic, effective sample size, and two-sided probability level for Sign test

The simulation results confirm the hypotheses 1 through 4. However, some care must be taken. The hypotheses are formulated as stylized facts. The results reproduce these stylized facts, but cannot be interpreted to represent actual values for Dutch or American behaviors, as the model has not been tuned to actual data. Nevertheless, the tests give confidence that the model has been implemented correctly and can show cultural differentiation of deceit and trust in trade.

6 Conclusion

Culture is known to have its effects on honesty in trade, and on trust as a mechanism to compensate for the inevitable incompleteness of contracts. Occurrence of deceit, and mechanisms and institutions to reduce it, vary considerably across the world. For research into these mechanisms, multi-agent simulations can be a useful tool.

In intelligent agent research, much attention has been paid to trust. Little research has been published about the simulation of deceit. Publications such as [19] and [20] modeled deceit as a rational strategy to gain advantage in competitive situations. A strictly rational approach of deceit neglects the emotional impact that deceit has, not only on the deceived, but also on the deceivers. Feelings of guilt and shame result from deceiving [6]. The extent to which these feelings prevail is different across cultures [6]. People have emotional thresholds for deceit, that cannot be explained from rational evaluation of cost and benefit, but that are based on morality and cooperative attitudes [5, 15, 17]. Once deceived, people react to an extent that goes beyond rationality [5], especially when they are prosocial rather than selfish [17]. In human decision making a model based on *fair trade* prevails over a model of *opportunistic betrayal* [18]. In addition to psychological factors, evolutionary reasons [4] or rational economic motives [16] can be given for the human inclination to cooperative behavior.

This paper contributes by introducing an agent model of deceit and placing it in a cultural context. It takes human deceptive behavior as a point of departure. Building on the work of [9, 10, 11, 12, 13] that modeled single dimensions of culture, this paper proposes an integrated model of culture's effects on deceit and trust. Example results have been generated that verify the implementation and illustrate that cultural effects can be generated. However, for realistic experiments, the model has to be tuned to and calibrated by observations and results of experiments, for instance to simulate effects like the ones reported by Triandis et al. [6] from human experiments on deceit across cultures. Before such experiments can be performed, the integration of this model with culturally adapted models for partner selection and negotiation, based on [25] and [27], has to be tested and tuned in more detail. The integration task and experiments remain for future research.

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Appendix

Fig. 5 presents histograms of the (non-zero) differences reported in Table 3 between results of paired runs for simulated cultures of the USA and The Netherlands: in the top row the difference of the total number of successful transactions per run and the difference of the quality ratio; in the second row the certification ratio and the defection ratio; in the bottom row the tracing ratio.

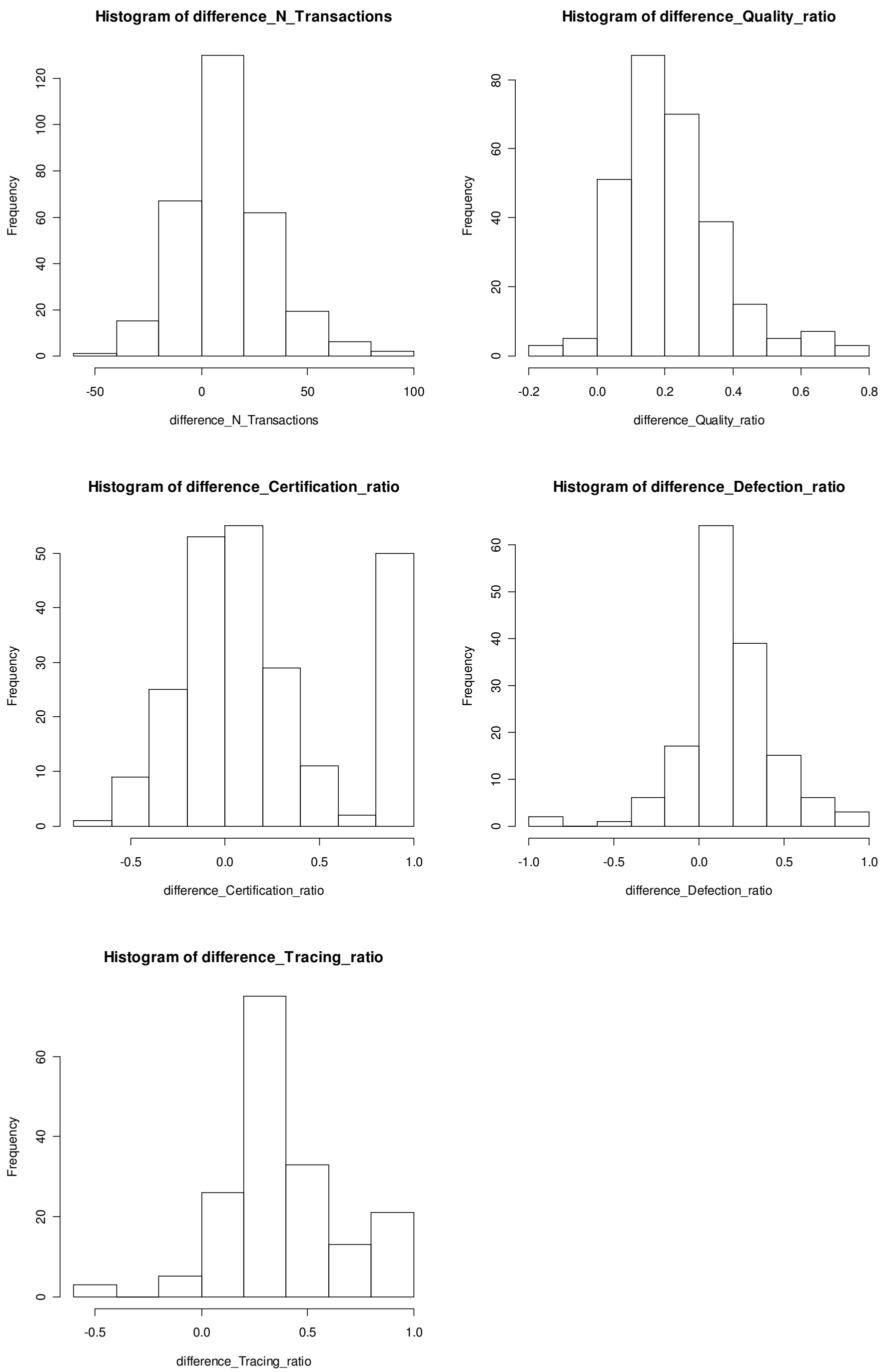

Fig. 5. Differences between tested variables of run pairs for the USA and The Netherlands.

Part V: Sensitivity Analysis and Validation

As Robert Sargent taught many simulation practitioners in his verification and validation tutorials at the annual Winter Simulation Conferences (e.g., Sargent 2008), validation of a simulation model is not just an operational validation in the positivistic sense, but it also requires a conceptual validation: a simulation should not only predict the behaviour of a system, its structure should explain the mechanisms that cause the behaviour. Some authors refer to the explanatory power of simulation models as structural validity (see, e.g., Troitzsch 2004).

For agent-based models in particular, with their unpredictable emergent behaviour, structural validity is of the essence. The main issue in structural validation is the link between theory and simulated system behaviour. Many authors refer to stakeholder involvement as a sine qua non for structural validation. In the research reported in this thesis, stakeholder involvement is guaranteed by the interdisciplinary approach. Nevertheless, it is just as hard for an expert to predict system behaviour of a complex adaptive system like an agent-based simulation is, as it is for a computer scientist. On the other hand, data generated by an agent-based simulated for a range of actual cases can be used for face validation of simulation results by an expert. For the model reported in this paper, such face validation has been performed on the data presented in the preceding chapters, and on a range of 62 countries for which the score on the Hofstede dimensions is known (Hofstede et al. 2011a).

Stakeholder validation of the decision rules that are applied in the model, and face validation of results for particular cases, may increase the confidence in the model, but in addition a more systematic approach is required. For agent-based models, sensitivity analysis is not just a check on the correct implementation. Nigel Gilbert (2008) advocates sensitivity analysis as the method to assess the link between theory and simulated system behaviour. It can help to explore the emergent system behaviour and, for instance, identify the opportunities for policy leverage (Brown et al. 2005).

Sensitivity analysis consists of a systematic exploration of parameter space. Several methods can be discerned, e.g. factorial design with analysis of variance, systematic traversal of parameter space with Fourier analysis of result, or Monte Carlo sampling with regression analysis (Ginot and Monod 2007, Saltelli et al. 2000).

For sensitivity analysis of the culturally differentiated model of the TRUST & TRACING game, the Monte Carlo method (Jansen et al. 1994) was applied for two reasons. First, the continuous nature of the parameters and the unpredictable behaviour of the simulation did not allow for the selection of representative values for a factorial design. Second, systematic traversal of parameter space would require an unfeasibly large number of simulation runs. The sensitivity analysis was performed as a joint work with Saskia Burgers, a statistician and sensitivity analysis expert. The results are reported in Chapter 13 and were originally presented in the 2010 Artificial Economics symposium (Burgers et al. 2010).

Notable conclusions from the sensitivity analysis are the following.

- Strong interactions of cultural and relational parameters with model parameters hinder straightforward global sensitivity analysis; sensitivity analysis is best performed for a particular cultural situation.
- For a multi-agent simulation, sensitivity analysis should be performed both at individual and at aggregated level.

While Nigel Gilbert (2008) advocates the performance of sensitivity analysis for the validation of agent-based models, he also stresses the importance of empirical validation. Chapter 14 discusses the use of the gaming simulations as a means to validate agent-based models. The work in Chapter 14 has been submitted as a contribution to a volume "Integrating Cultures: Formal Models and Agent-Based Simulations" edited by Virginia Dignum, Frank Dignum, Jacques Ferber, and Tiberiu Stratulat, to be published by Springer-Verlag.

13 Sensitivity Analysis of an Agent-Based Model of Culture's Consequences for Trade

Abstract. This paper describes the analysis of an agent-based model's sensitivity to changes in parameters that describe the agents' cultural background, relational parameters, and parameters of the decision functions. As agent-based models may be very sensitive to small changes in parameter values, it is of the essence to know for which changes the model is most sensitive. A long-standing metamodeling-based approach of sensitivity analysis is applied to the agent-based model. The analysis is differentiated for homogeneous and heterogeneous agent populations. Intrinsic stochastic effects of the agent-based model are taken into account. The paper describes how an appropriate regression model has been selected and analyses the parameter's variance contributions in general and in specific cultural settings.}

Introduction

Agent-based models are known to be very sensitive to parameter changes in some ranges of the parameter space. Small changes in parameter values may have dramatic consequences for the state of the system, while changes in other parts of the parameter space have little effect. This property of multi-agent systems is usually referred to as non-linearity. It is not just a property of agent-based models. It is a general property of complex systems such as ecosystems, climate, and the economy. Non-linearity may lead to abrupt changes in the state of systems, and this property invites to the application of agent-based models to simulate non-linear effects such as catastrophic events in evolution or economics [3, 12]. We may conclude that non-linearity is not a bad property of agent-based models. It is a general property of complex systems that complicates the work of modelers of such system.

In general it is considered good modeling practice to perform sensitivity analysis as a part of model verification [16]. In the case of agent-based models, two reasons urge to perform extensive sensitivity analysis: great uncertainty about actual values of model parameters and non-linearity. For instance, in the model discussed by [11], a tipping point between loyalty to trade partners and shopping behavior exists, depending on the value of the loyalty parameter β. If one wants to apply such a model in multi-agent models of markets, the agents have to be configured with actual values for β. For some range of low values of β, the value will not have an effect on the shopping behavior of a single agent. Around some critical value of β, there is an abrupt change, and there is a relatively small range of increasing loyalty. For a large range of higher values for β, the behavior is invariably loyal. As a result, depending on the actual distribution of β in the agent population, the efficiency of an artificial market may be very sensitive to small changes in the distribution of β, or may be rather insensitive to even larger changes. However, it is hard to predict the actual distribution of β for a particular context.

Because of the combination of non-linearity and uncertainty about parameter value distributions, extensive sensitivity analysis is a sine qua none for research with agent-based models. Before a conclusion can be drawn on the basis of an agent-based model, the modeler must search for the regions in parameter space where stable, maybe inactive, states of the system occur and where the model is insensitive to parameter changes, regions where tipping points occur and system behavior changes dramatically in case of small parameter changes, and regions where the system is more or less proportionally sensitive to parameter changes.

This paper presents the approach and results of extensive sensitivity analyses of a model of culture's effects on international trade. The multi-agent model is based on a model of a trade game that allows for experimental data collection on trust in supply chains with asymmetric quality information [9]. The model is based on transaction cost economics [19]. The agents' activities cover partner search, negotiation, and, if negotiation leads to a contract, truthful delivery or opportunism, taking advantage of the information asymmetry. Their counterparts may either trust the deliveries, or incur cost to monitor and enforce contract fulfillment. The agent model of Jonker et al. [9] has been refined and extended with differentiation of agent behavior according to cultural background [5, 6, 7]. For this purpose, rules were formulated for adaptation of default model parameters based on Hofstede's five dimensions of culture [4].

Sensitivity analysis is performed on the extended model. A systematic sensitivity analysis can serve several purposes: improve the understanding and reliability of model results; reveal effects of parameter variations; guide simplification and refinement of the model [15]. This paper focuses on the effects of parameter variation. The following are the main questions for the sensitivity analysis.

- Which areas in parameter space result in realistic behavior?
- In which areas of parameter space can tipping points occur?
- Which parameters have significant effects for which outputs?
- Which interactions between culture and other parameters are important?
- Are the answers different between aggregate and individual level?

Sensitivity analysis basically consists of a statistical analysis of the effect of input variations on model outputs. Richiardi et al. [15] identify types of variations of inputs. These types can be grouped into (I) variations of random seed and noise level, (II) variations of parameter values, (III) variations of the model, e.g. agent's decision functions, data aggregation, time scale and sample size. The present paper focuses on the first two groups of variation. It studies the effect of intrinsic variation caused by the stochastic nature of the model and the effect of external variation of model parameters and of culture.

The sensitivity analysis approach is based on Jansen et al. [8] and Saltelli et al. [17], applying two principles:

- meta modeling of results of parameter sets drawn at random from the joint distribution;
- analysis of contributions of Top Marginal Variance (TMV) and Bottom Marginal Variance (BMV) of individual parameters or groups of parameters to the variance explained by the meta model.

Trading Agents with Cultural Background

The model analyzed in this paper simulates trading agents operating in a game [9}. The agents may trade with each other, are free to select or refuse a partner, negotiate or quit negotiation if they do not expect a satisfactory conclusion, and, in case of successful negotiation, exchange a commodity. The special thing about the game is that commodities have high or low quality and that the seller is informed about the quality, which is invisible for the buyer. A buyer can either trust a delivery or (at the cost of a fee) offer it to the tracing agency that reveals the real quality and in case of deceit punishes the deceiver by a fine. Another option for the buyer is to have the seller trace the commodity in advance and add the tracing report as a quality certificate. The tracing fee for sellers is lower than it is for buyers. The strategies a buyer can chose are:

1. buy low quality (no risk),
2. trust,
3. require certification,
4. trace random samples, or,
5. in addition to random tracing, negotiate that some refund will be made in case quality turns out to be non-compliant.

Details of the models of the agents' activities and the effects of culture have been described in earlier papers [5, 6, 7]. For each of these activities, a model of the agents' decisions is selected from social sciences or artificial intelligence literature. For instance, for partner selection, the model of Weisbuch et al. [18] is used; for negotiation Jonker and Treur's ABMP architecture [10] is selected. The decision models' parameters included in the sensitivity analysis are listed in Table 1.

Table 1. Trading agent's activities and model parameters and variables that are adjusted according to an agents' cultural background [5, 6, 7]; the table also specifies the value range considered in the sensitivity analysis

Activity	Parameter or variable	Value range
Partner selection	Loyalty	0.5...1.5
	Learning	0.001...0.999
	Preference (initial value)	0.001...0.999
Negotiation	Concession factor	0.001...0.999
	Negotiation speed	0.001...0.999
	Impatience	0.001...0.999
	Quality preference	0.001...0.2
	Risk aversion	0.001...0.2
Deceit and trust	Minimal honesty	0.001...0.999
	Honesty decay factor	0.001...0.999
	Trust (initial value)	0.001...0.999
Belief update	Negative update factor	0.001...0.999
	Endowment factor	0.001...0.999

In the agent model the decision functions are influenced by a set of rules that take Hofstede's cultural dimensions and some culturally relevant relational characteristics into account [5, 6, 7].

The indices of the cultural dimensions are:

- PDI (power distance);
- UAI (uncertainty avoidance);
- IDV (individualism);
- MAS (masculinity);
- LTO (long-term orientation).

The relational characteristics taken into account are:

- group distance (i.e. absence of common group membership) and
- societal status of the agent and of its partner.

Cultural indices and relational characteristics are represented as real values in the range 0 ... 1. For the sensitivity analysis they are drawn from the range 0.001 ... 0.999.

Sensitivity Analysis Approach

The sensitivity analysis reported in this paper is regression-based: a meta model in terms of the input parameters is fitted to an output variable. The output is produced by simulation runs using input parameter sets generated by Monte Carlo sampling. Monte Carlo sampling of the parameter sets aims to cover the range of all parameters efficiently and to avoid multicollinearity.

The relative importance of individual input parameters on output variables is assessed by decomposition of the variance of the output variable. The key issue in this approach is to find a regression model that can serve as a basis for decomposition of variance. Any type of regression may be applied, e.g. linear regression including polynomial and interaction terms [14] or regression with smoothing splines [2} as a form of nonparametric regression, as long as it explains a great deal (preferably at least 90 %) of the output variance.

Jansen et al. [8] define the top marginal variance (TMV) of an input as the variance reduction that would occur if the input would become fully known. The bottom marginal variance (BMV) is the variance that the meta model can not explain without the input parameter. TMV and BMV of an input variable are equal if and only if that variable is not correlated with any other variable. Comparison of TMV and BMV can be used to check for multicollineairty unless interaction-terms are important. If interaction-terms are taken into account in the regression model, the BMV is defined as the variance that cannot be explained without the input parameter and all interaction terms including this parameter.

In this sensitivity analysis three sources of variance are studied:

- cultural and relational factors, used to adapt the decision making to culture,
- the default values of the parameters mentioned in Table 1,
- stochastic effects caused by variation of random seed.

The approach proposed by Jansen et al. [8] was developed for equation-based models, in which there is a single level of aggregation. When analyzing multi-agent systems, the unit of analysis has to be decided: system performance at aggregate level or individual agent performance. The present study observes ouputs at aggregated level for simulations with homogeneous agent populations and at individual agent level for simulations with heterogeneous populations.

Data generation proceeds as follows. The first step is to draw input parameters sets from the joint distribution of all model parameters. As the goal is to study the effects of parameter variation and there is no accurate information on actual parameter distributions, we draw values at random from uncorrelated uniform distributions, ranging as indicated in section~\ref{sec:trading}. The resulting parameters sets are used to initialize trading agents for simulation runs. In order to analyze intrinsic stochastic effects, model runs are repeated with equal parameter sets but different random seed.

The following outputs are observed:

- number of transactions;
- number of failed negotiations;
- average duration (number of rounds per negotiation)
- number of high quality transactions;
- number of deceitful transactions;
- number of traces requested;
- number of fines issued by the tracing agency;
- loyalty, measured as standard deviation of transactions per potential partner.

All statistical analyses were performed with GenStat 12th Edition (VSN International Ltd., Hemel Hempstead, Hertfortshire). Sensitivity analyses was performed with USAGE 2.0, a collection of GenStat algorithms for sensitivity and uncertainty analysis [1].

Results

This section presents results of the sensitivity analysis of simulations with the multi-agent model. All simulations were run with a population of 8 supplier agents and 8 customer agents. The agents were free to select or refuse a trade partner, negotiate and quit negotiations or accept an offer, and deliver truthfully or defect. The simulations ran for 100 time steps. The maximum number of transactions that can practically occur in such a run is between 160 and 180.

For the first series of simulations, parameters sets are drawn at random for configuration of homogeneous agents per run. Cultural indices, relational factors, and the default model parameters referred to in Table 1 are all drawn independently. For each parameter set the model was run 15 times with different random seed, in order to estimate the variance introduced by intrinsic stochastic effects. Statistics are collected at aggregate level. For 627 out of 1000 generated parameter sets the median of the number of transactions equaled zero over 15 replications.

Probability that transactions occur

A logistic regression model [13] was used to investigate which parameters or combination of parameters (interaction) were of significant influence on the probability whether or not transactions occurred (binary data: median equals zero or median greater than zero).

A first exploration revealed that concession factor γ is the most dominant parameter to predict the occurrence of tranaction: from 20% for low values of γ to 60% for high values.

Interactions between parameters appeared to play an important role. Starting from a logistic regression model containing all main effects, significant interactions ($p<0.05$) have been added by forward selection. Table 2 presents the coefficients for the main effects and the significant interactions in the model.

Table 2. Coefficients for main effects (left hand side) and interactions (right hand side) in the logistic regression model of the probility that transactions occur in a simulation run

Parameter	Symbol	Coefficient	Interaction	Coefficient
Power distance	PDI^*	0.566	$\|s_a-s_b\|\cdot\gamma$	-4.39
Uncertainty avoidance	UAI^*	-0.122	$S\cdot\gamma$	-4.43
Individualism	IDV^*	2.015	$MAS^*\cdot v$	-2.581
Masculinity	MAS^*	2.300	$LTO^*\cdot\gamma$	3.134
Long-term orientation	LTO^*	3.02	$LTO^*\cdot MAS^*$	-3.108
Group Distance	D	0.211	$S\cdot t_0$	-4.37
Mean status	S	7.29	$S\cdot LTO^*$	-3.38
Status difference	$\|s_a-s_b\|$	0.762	$\|s_a-s_b\|\cdot LTO^*$	2.69
Loyalty	B	0.276	$LTO^*\cdot w_q$	-14.18
Learning	C	-0.454	$IDV^*\cdot w_q$	-12.13
Initial preference	J_0	-1.948	$D\cdot LTO^*$	-2.426
Concession factor	γ	4.42	$\|s_a-s_b\|\cdot J_0$	2.99
Negotiation speed	v	1.015	$J_0\cdot w_q$	9.59
Impatience	ι	-0.509	$IDV^*\cdot h$	-1.884
Quality preference	w_q	3.27	$e\cdot f$	-2.934
Risk aversion	w_r	-3.22		
Minimal honesty	h	0.296		
Honesty decay factor	f	1.265		
Initial trust	t_0	2.919		
Negative update factor	u_-	-0.062		
Endowment factor	e	1.231		

The parameters that have significant effect without interactions are PDI, impatience, and risk avoidance. The probabilities that transactions occur are:

$$0.28 \text{ for } PDI^* = 0.01\,; \qquad 0.40 \text{ for } PDI^* = 0.99\,;$$
$$0.39 \text{ for } \iota = 0.01\$\,; \qquad 0.28 \text{ for } \iota = 0.99\,;$$
$$0.41 \text{ for } w_r = 0.01\,; \qquad 0.27 \text{ for } w_r = 0.20\,.$$

For parameters that have significant interactions, probabilities can only be predicted if the interactions are taken into account. For instance, the effect of MAS can be predicted in interaction with LTO and negotiation speed ν. Table 3 shows that the effect of MAS is great if LTO and negotiation speed are both high or both low.

Table 3. Prediction of the probability that transactions occur with different values of MAS in interaction with LTO and negotiation speed ν

LTO^*	MAS^*	$\nu = 0.01$	$\nu = 0.99$
0.01	0.01	0.19	0.38
	0.99	0.68	0.32
0.99	0.01	0.41	0.65
	0.99	0.24	0.07

From study of interaction tables like Table 3, it is concluded that transactions are unlikely to occur ($p < 0.20$ for extreme values of the parameters) if

- group distance and LTO are both high;
- status difference and concession factor are both low;
- MAS, LTO, and negotiation speed are all high or all low;
- status difference and intitial trust are both low;
- IDV, LTO, and quality preference are all high;
- status difference is low and initial partner preference is high;
- initial partner preference is low and quality preference is high;
- IDV and minimal honesty are both high;
- honesty decay factor and endowment factor are both high.

Sensitivity analysis

For analysis of the relations between parameters values and outputs a set of 1000 simulations with at least 16 successful transactions is generated. Parameter sets are randomly drawn and used for homogenous configuration of agents in simulation runs, until 1000 runs have produced at least 16 transactions. For each of the 1000 selected parameter sets 15 replications are run. The replications are used for analysis of the variance between parameter sets versus the variance caused by stochatic effects in the replications (Table 4). The percentages are small. the variation between simulations is dominantly caused by parameter variation.

Table 4. Mean variance in replications as percentage of total variance

observed output	% variance	observed output	% variance
number of transactions	1.60	number of deceitful transactions	8.63
number of failed negotiations	3.95	number of traces	7.71
average duration of negotiations	5.32	number of fines	13.75
number of high quality transactions	4.68	average loyalty	5.81

The mean values of outputs of 15 simulations per parameter set are used for analysis. As an example we treat the analysis of the number of transactions. Straighforward sensitivity analysis based on a smoothing spline with two degrees of freedom results in 61.3 % of the variance accounted for. For a few parameters the difference between the top and bottom marginal variance is substantial. This can only be due to correlations between parameters (caused by the selection proces). Correlation coefficients are small, see Table 5. Therefore, correlations are not further analyzed.

Table 5. Parameters having correlation coefficients of 0.10 or more

Parameter	Parameter	Correlation coefficient
Concession factor	Group distance	0.11
	Mean status	-0.14
	Quality preference	0.13
	IDV	0.11
	LTO	0.15
Mean status	LTO	-0.11
Negotiation speed	Quality preference	0.16

Since 39 % of the variation is not explained, several other models are tried, including smoothing splines with 5 degrees of freedom (63.1 %), polynomial models, models taking second and third level interactions into account, and log transformations on output and on both input and output. The models using log tranformations perform worse than models with polynomial and interaction terms (74.1 % and 44.4 %, respectively).

The best fit is obtained with a model including quadratic terms and 33 two and three factor interaction terms, that explained 80.7 % of the variation. For efficiency the sensitivity analysis is performed with a model with quadratic terms and two factor interactions that explains 79.5 %. All parameter combinations in the three factor interactions are also represented as two-factor interactions in the latter model.

For all variables and their interactions both linear and quadratic terms are taken into account (comparable to a smoothing spline with df=2). The result is a model with 30 two-factor, forwardly selected, interaction terms explaining 79.5\% of the variation. The interest is not in the model but in its use for gaining insight into the sensitivity of the multi-agent model. Based on this model the bottom marginal variance is calculated for each parameter by leaving this variable and all interaction-terms involving this variable, out of the model. Table 6 presents top and bottom marginal variances.

Variation in the number of transactions is for 32 % due to variation in negotion speed. Some other inputvariables interact with negotiation speed, resulting in a bottom marginal variance of 39 %. This means that without good information about negotiation speed 39 % of the variation in the number of transactions will remain.

The differences between TMV and BMV of culture and relational factors indicate that these parameters largely have their effect in interactions.

Table 6. Top Marginal Variance and Bottom Marginal variance of parameters as percentage of the total variance of the number of transactions

Parameter	TMV (%)	BMV (%)	Parameter	TMV (%)	BMV (%)
Index of culture			Loyalty parameter	0.0	0.0
-- PDI	0.0	0.6	Loyalty decay factor	0.0	0.1
-- IDV	0.2	5.3	Concession factor	9.1	25.0
-- UAI	0.8	3.4	Negotiation speed	31.8	39.3
-- LTO	0.7	6.8	Impatience	0.6	2.5
-- MAS	2.0	7.7	Quality preference	1.5	0.7
Group distance	2.7	6.8	Risk avoidance	0.0	3.0
Mean status	0.3	5.1	Negative update factor	0.9	0.3
Status difference	0.0	1.9	Endowment factor	0.1	0.0
Initial trust	2.7	6.3	Minimal honesty	0.0	0.0
Initial partner preference	1.2	3.0	Honesty decay factor	0.0	0.0

The model developed for the number of transactions cannot be applied for sensitivity analysis of the other output variables. The percentage of variation explained is unsatisfactory. Sensitivity analyses for other outputs have been carried out straightforwardly using smoothing splines (df=2), also resulting in unsatisfactory explanation of variation. The results indicate that modeling steps as applied for the number of transactions need to be followed for each output individually. The parameters contributing at least 10 % to output variation according to the sensitivity analysis with smoothing splines (df=2) are given below for each output variable.

- negotiation failure: negotiation speed, concession factor, impatience
- negotiation duration: negotiation speed, UAI, MAS
- quality: intitial trust, LTO, quality preference
- deceit: initial trust, MAS
- tracing: MAS
- fines: MAS
- loyalty: initial partner preference, negotiation speed

Differences between cultures

As found in the preceeding subsections there are many interactions between parameters. To further analyse the interaction with culture, sensitivity analyses are performed for 62 actual national cultures. 1000 simulations are run for each culture, each simulation with a ramdomly drawn parameter set that is used to configure a homogeneous agent population. Sensitivity analysis is performed on the simulations that result in at least one transaction. The purpose of this step is to focus sensitivity analysis on the parameters in Table~\ref{tab:params} and relational characteristics, and to find differences in sensitivity between cultures.

The number of simulations resulting in one or more transactions ranges from 228 through 490 across cultures, with mean 403. Taking only the runs with a positive number of transactions into account, three different models were fitted per culture (the minimum and maximum percentage of variation explained across cultures is given in parentheses):

- with all 16 parameters linear in the model (minimum 70.7 %, maximum 81.2 %),
- with all 16 parameters as a spline with 3 degrees of freedom in the model (minimum 73.3 %, maximum 83.4 %),
- with all 16 parameters and their first order interactions in the model (minimum 83.4 %, maximum 89.8 %).

No strong nonlinear effects seem to occur in the analyses per culture. Interactions between parameters are present. Table 7 presents some results from the analyses per culture. The sensitivity for parameter changes varies widely across cultures.

Table 12. Mean Top Marginal Variance values (of 62 countries) and data for the countries that have the maximum TMV score for a parameter}

national culture	group distance	mean status	initial trust	partner pref.	conces. factor	negot. speed	quality pref.	risk avoid.
mean (n=62)	4.1	1.0	3.4	1.8	24.8	30.2	0.5	1.6
Indonesia	16.9	0.1	0.2	0.0	11.6	40.9	0.0	0.0
Morocco	0.7	8.7	3.3	4.7	17.5	37.9	0.0	0.0
Hungary	0.0	0.0	11.5	1.9	37.6	1.4	2.4	11.5
Uruguay	4.9	1.7	8.5	5.5	23.4	24.1	0.0	0.0
Netherlands	0.7	0.0	1.6	0.3	46.2	28.8	0.0	2.1
Iran	1.3	3.1	0.9	0.4	10.3	56.2	0.6	0.0
Austria	0.0	0.0	3.8	2.6	27.1	11.5	4.8	6.9
Japan	0.5	0.0	8.3	1.6	30.8	0.9	0.1	15.8

Aggregate and individual level

To perform sensitivity analysis at agent level in heterogeneous agent populations, parameter sets for 4000 simulations are drawn. First 4000 sets of cultural indices, group distance, and status data are drawn. For each simulation run, all agents are configured with equal culture. This resticts partner selection to partners with equal cultural background. For each agent the other parameters are randomly drawn, resulting in a sample of 32000 suppliers and 32000 customers.

A sensitivity analysis could not be completed. Too low levels of explained variation were obtained: for the number of transaction the explained variation was for supplier agents 48.5 % with linear fit and with 51.3 % smoothing splines; for customer agents 37.6 % with linear fit and 38.6 % with smoothing splines. However, an interesting result was obtained. The pattern of marginal variance of suppliers matches the pattern found at aggregate level, with negotiation speed and concession factor as dominant parameters. The pattern of marginal variance of customers is very different, with relational characteristics explaining most of the variation. The information asymmetry explains this difference: trust is relevant only for customers.

Conclusion

Through sensitivity analysis insight can be gained into the properties of a model. For exploration of the regions where realistic behavior occurs, logistic regression can be used and probabilities of realistic behavior can be predicted with the model.

Parameters that have significant effects can be identified through metamodeling, even for complex systems. However, the analysis is not straightforward. The interactions between culture and other parameters are the main cause of the model's complexity. When keeping culture constant, straightforward methods for sensitivity analysis can be applied. Results differ considerably across cultures.

Sensitivity of individual agents can differ considerably from aggregate level sensitivity. However, a method for individual agents has to be further refined.

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14 Cross-validation of Gaming Simulation and Multi-agent Simulation with Cultural Differentiation

Abstract. For the study of complex social situations, both gaming simulation and agent-based simulation have been proposed as research methods. The combination of gaming and agent-based simulation has proved useful for the formulation of theories underlying trade network processes. However, validation remains a problematic issue in that type of research. Two important sources of difficulties are the sensitivity of gaming simulations to the participants' cultural background and the complexity of the agent model. The sensitivity to culture may be managed by incorporating it in the agent model. The complexity of the agent model may be managed by compositional process modeling. However, both solutions require additional validation. This chapter proposes a validation approach for a culturally adaptive, composed, process model.

Keywords: culture, trade networks, gaming, simulation, validation

1 Introduction

The operation of social networks such as trade networks is a phenomenon of great complexity, since variables at different levels of abstraction are involved: at the individual level, there are personalities and skills; at the group level there are cultures, and possibly group labels.

Gaming simulation is a technique that can be used to generate rich behavioral data by confronting subjects with realistic problem issues in complex social systems that provide ambiguous incentives [16]. Unlike, for instance, action research, gaming simulations abstract from reality and are set up to be repeatable and generalizable. Gaming simulations differ from other forms of experimentation in that they offer a social context in which group behavior and social networks can emerge. The question how realistic the gaming simulation results are, called the validation question, is not trivial. Gaming simulation professionals also notice the influence of group size, layout of physical space, time pressure, and other varied context factors.

Gaming simulation studies phenomena in a holistic way. Complementing it with computer simulation enriches the research by introducing an analytic approach. Gaming simulation is designed to test predictions based on a theory. Computer simulation can be used as a validation tool for theories about the mechanisms of social systems. A computer simulation is an implementation of a such a theory. Therefore, the validation of a simulation model, comparing the data it generates with the data observed in the system it simulates, contributes to the validation of the theory about the mechanisms [21]. Fig. 1 depicts how computer simulation enriches the gaming simulation.

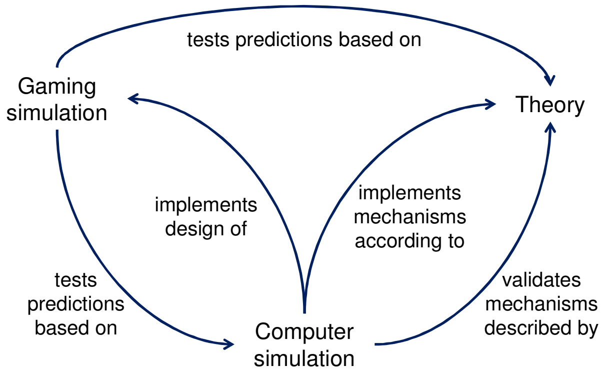

Fig. 1. Mechanism validation by computer simulation enriches gaming simulation

Agent-based simulations are a good candidate for mechanism validation in gaming simulations. An agent-based model simulates the behaviors and interactions of individuals in a social system and the aggregate system behavior emerging from these behaviors and interactions [4]. Developing an agent-based simulation requires explicit formulation of the knowledge and hypotheses about the behaviors and interactions of agents. Unlike equation-based simulations (for instance, based on system dynamics) agent-based models are not based on assumptions about aggregate level system behavior. The aggregate behavior emerges from the individual-level behaviors and interactions, similar to the way it emerges in gaming simulations. Agent-based simulations of social behaviors are beset with similar strengths and weaknesses as gaming simulations. Emergent system behaviors can be discovered through them, but validity is hard to establish. The important difference is that simulations can be run *ad libitum* while gaming simulations are much more time consuming to organize.

Agent-based simulation differs fundamentally from statistical (survey) research and qualitative approaches in that it allows for validation of both agent behavior and aggregate time series. Moss and Edmonds used the term cross-validation for an agent-based model validation approach that compares statistics of the agent-based simulation with statistics of the simulated system at aggregate level, and agent behavior at individual level with data from qualitative research [18].

An agent-based model can be validated at any level. The process model of an individual agent operating in a realistic social context is necessarily more comprehensive than a model of a single theoretical concept. The process model is best described as a composition of sub-processes, each of which implement theories of different aspects of agent behavior, e.g. negotiation, trust, and deceit. The validation of an agent model may suffer from under-determination: if a model explains the behavior of a system, it is not certain that it is the only model that can give an explanation [19]. This uncertainty is reduced if not only the composition as an entity, but also sub-process models at lower compositional levels are validated.

Having gaming simulation and agent-based simulation interact proved a useful research method to develop descriptive models (i.e., implemented theories) of processes in trade networks [16]. The gaming simulation and the agent-based simulation are designed as counterparts: together they enable efficient data gathering to develop and formulate more detailed theories of human behavior in trade. The functions of the agent-based simulation in the research method are:

1. Validation of models of behavior induced from observations in gaming simulations;
2. Testing of hypotheses about relations between aggregated outputs and individual agent parameters;
3. Selection of useful configurations for gaming simulations.

The first and second issues refer to what is called mechanism validation in Fig. 1; the third issue supports the testing of theory-based predictions by gaming simulation.

The validation that is an essential part of this research method is complicated by the fact that social situations are culture-sensitive, i.e., the processes running underneath the social situation play out differently with players having different cultural backgrounds. Validation should prove that the variations in system behavior in the gaming simulation between participants from different cultures correspond with the variations in outcomes of the agent-based simulation across those cultures.

This chapter introduces a cross-validation approach for a gaming simulation and its associated agent-based simulation for culture-sensitive processes. As a leading case study, we describe the validation of an agent-based simulation of a gaming simulation, called the Trust And Tracing Game in which negotiation and trade take place, involving the possibility of deceit and of checking on it. The activities modeled in the agent-based simulation are partner selection, negotiation about a possible transaction, the actual delivery after a deal has been closed, and maintaining beliefs about trade relations. The Trust And Tracing game has been used for data collection in social research into the role of trust in supply networks [15].

This chapter is organized as follows. Section 2 introduces the research project that serves as a case study for the work presented in this chapter: the Trust And Tracing game and the process model underlying the agent-based simulation. Section3 discusses related work that combines gaming simulation - or other experiments with human participants – with agent-based simulation. Section 4 discusses validation issues with respect to multi-agent simulation and introduces elements of the cross-validation approach: composition of validated models, expert validation of cultural adaptation, sensitivity analysis, statistical validation at aggregated level, agent behavior, and micro gaming simulations. Section 5 introduces culture sensitive validation of processes in agents that are modeled to have a cultural background. Section 6 presents an example of an experiment in the on-going process of model validation. Section 7 proposes the concept of micro gaming simulation to validate aspects of the agent model in isolation. Section 8 discusses the role of sensitivity analysis in the validation approach and the importance of performing sensitivity at both individual and aggregated level. Section 9 concludes the chapter.

2 Background

The Trust And Tracing game is a research tool for supply chain and network studies. This tool places the choice between relying on trust versus spending money on complete information in trade environments at the core of a social simulation game. The game is used both as a data gathering tool about the role of reputation and trust in various types of business networks, and as a tool to make participants reflect on their own daily experiences in their respective jobs.

The research follows the cycles depicted in Fig. 2. This figure illustrates that agent-based simulation is instrumental to gaming simulation in the research concept. Gaming simulation is the leading method, because the research focuses on data collection about trade processes in a rich social context.

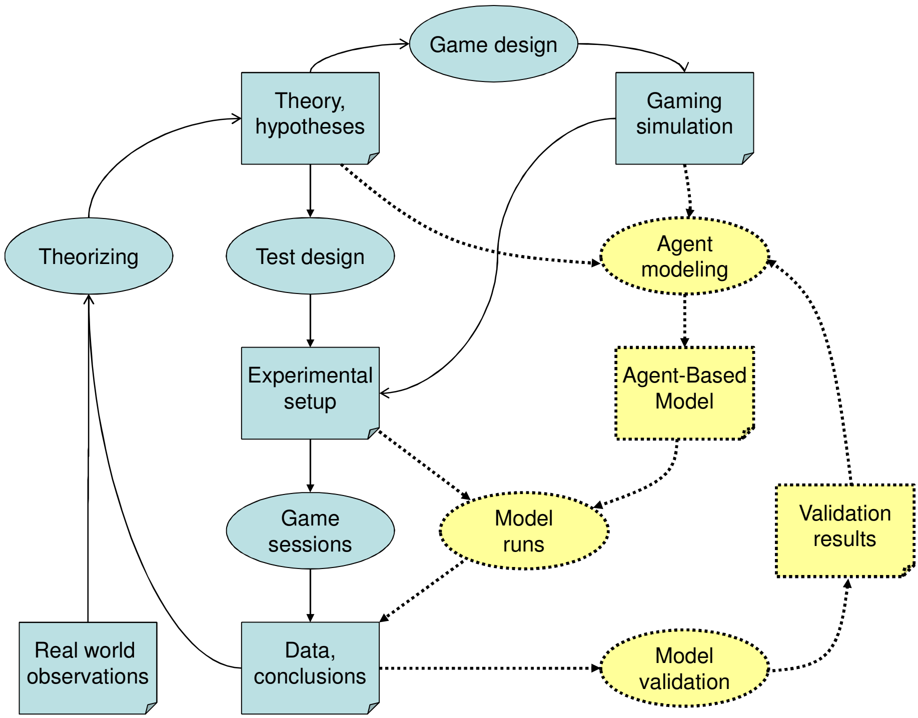

Fig. 2. Research cycle combining gaming and multi-agent simulation (after [22]).

The theory T formed on the basis of the literature and the gaming simulation G, has to be formalized in such a way that an implementation A can be constructed that underlies the agent-based simulation. This formalization step requires enriching the theory to the level of the individual. The agent-based simulation A must be validated to sufficiently reproduce outcomes of gaming simulation G, but at the same time it acts as a validation tool for the theory T, in the sense that mechanisms implemented in A should provide similar results as the gaming simulation G. Furthermore, the agent-based simulation A can be used to explore the space of possible experimental setups, which enables the identification of those setups that would most critically test the theory T when played in the gaming simulation G. These setups can be selected on the basis of a sensitivity analysis that identifies the circumstances under which the behavior of the A shows strong changes. These are the experimental setups for which gaming simulations can best be played for theory validation. The data and conclusions of these new gaming simulations might confirm the standing theory or might lead to revisions of the theory. Revisions of the theory lead to adaptations of the agent-based simulation (or the game design) and form the beginning of a new cycle.

A brief description of the Trust And Tracing game will be given here. An extensive description is available in [14]. In the game 12 to 25 participants play roles in a supply network. There are producers, middlemen, retailers and consumers (see Fig. 3). Sellers of a commodity have more information about the quality of the goods than buyers, since quality is invisible and only known by the producers. This leads to information asymmetry and the opportunity for deceit.

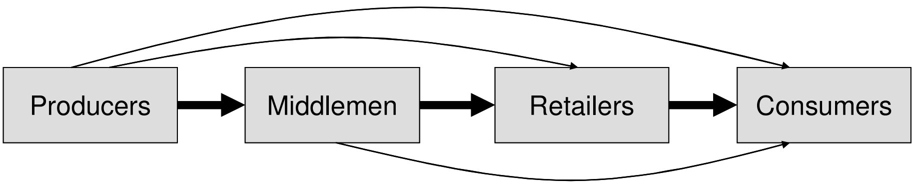

Fig. 3. Supply network configuration with commodity flows

Each player receives (artificial) money. The producers receive an initial amount of goods. The good traded is a sealed envelope that comes in 3 different types (colours) and each of the types in two qualities (high and low). A ticket covered in the envelope (so it is not visible) represents quality. Producers are informed which envelopes are high quality and which are low. The only person in the game allowed to open an envelope is the tracing agency. The game leader acts as a tracing agency and can, on request and at the cost of a fee, determine product quality.

The goal of producers and traders is to maximise profit. The consumers' goal is to maximise satisfaction. Table 1 specifies satisfaction values of each good for a consumer (utility).

Table 13. Consumer satisfaction value by type and quality of the commodity

Quality	Type		
	Blue	Red	Yellow
Low	1	2	3
High	2	6	12

An agent buying a high quality envelope takes a risk, as he cannot know the real quality. The buyer can check afterwards by doing a trace at the tracing agency, but this costs money. Tracing is cheaper early on in the network than for consumers. When consumers prefer traced goods (certified high quality) it would be economical to let a middleman do the trace and sell the traced product throughout the network along with the certificate. Successful deceit is beneficial for a seller as he receives an additional income. However, if the deceit is discovered the cheater has to pay a fine. Resellers of cheated products who did not check the quality themselves but acted in good faith have to pay a smaller "ignorance" fine.

The gaming simulations played with groups of participants from different cultural backgrounds produced different outcomes; for instance, patterns of deceit and trust differed considerably between Dutch and American business school students [14]. This implies that an agent-based simulation of the game must take culture into account.

The process model for trading agents acting in the agent-based simulation is given in Fig. 4. It is based on the sources of transaction cost according to transaction cost economics: searching, bargaining, and contract drafting in the pre-contract phase of transactions and, taking the risk of partners' opportunistic behavior with respect to delivery into account, monitoring and enforcing in the post-contract phase [23]. First, agents determine a short-term trade goal (e.g., to buy or to sell? what type of product? top quality or basic quality?). Next, agents search for acceptable trade partners with complementary needs that are willing to negotiate. After negotiating a contract, it comes to delivery, where an agent may deliver according to contract or defect. Partners have the choice to trust the other to comply with the contract, or to spend resources on monitoring and enforcing deliveries. Finally, after these trade interactions, the trading agents reflect upon the effectiveness of their trade, on the trustworthiness of their trade partners, and on their own decisions. On the basis of that reflection the agents update their beliefs.

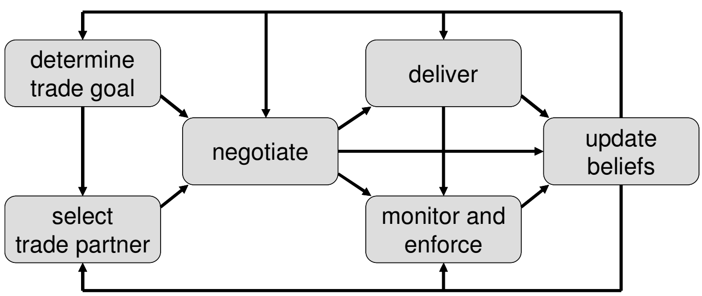

Fig. 4. Sub-processes and internal information flow of trading agents

The plans that the agents execute for fulfillment of the sub-processes are based on validated models taken from literature on social sciences and artificial intelligence. A problem with these models is that they have been validated locally in one particular culture, while the behavior in the game has been shown to be different across cultures.

Cultures can be characterized by multi-dimensional indices. The most widely used are Geert Hofstede's five dimensions of national cultures [7]. A method based on an expert systems approach was developed to adapt the sub-process models according to the five dimension indices [12]. The cultural adaptation is formulated as an adaptation of sub-process model parameters according to the values of the five indices. Application of this method resulted in cultural adaptations of the agent models of partner selection [9], negotiation [10], and deceit, trust, and belief updates [11].

It should be noted that by adapting only the sub-models to cultural differences, the overall process model depicted in Fig. 4 is assumed to be universal, i.e., trade is assumed to comprise these activities and no other activities in any culture. Only the way these activities are performed is assumed to depend on culture.

A validation method that supports the combined method of gaming- and agent-based simulation should address the validation of theory T, the validation of gaming construct G, and the validation of the implementation A. Note that the validation of G and A are instrumental, but not enough to validate T as a theory of the studied real-life social situations. As the agent-based simulation A is designed in interaction with the results of G and the theory T, there is a need for cross-validation of G and A.

The cross-validation of agent-based simulation A based on the process model composed of the adapted sub-process models, against the gaming simulation G, is the subject of the validation described in the present chapter. The agent-based model can be validated against the results of the Trust And Tracing game, played in various cultural settings. However, a risk of under-determination remains: although the sub-process behaviors are based on validated models, their cultural adaptations are not validated. Validation would be stronger if the adaptations at sub-process level could be validated in isolation. An approach for such multi-level validation is proposed in Section 7.

3 Related Work

The idea of combining gaming with agent-based simulation goes back to the work of Barreteau et al., who applied this combined approach to natural resource management in developing countries (see, e.g., [1]). Barreteau et al. discern the combined application of gaming and agent-based simulation for training purposes, for research purposes, and for decision support processes. For research purposes, they claim that agent-based simulation leads to the production and validation of theories, where validation relies upon finding a match between observed and simulated results as well as between modelled and real processes.

Barreteau et al. address two problematic issues with respect to validation. First, results to be validated are difficult to observe in the real process. Second, the capacity of the set of selected processes to display the same patterns of interactions must be tested. According to the authors, gaming appears, a priori, to offer an attractive solution. It is possible to record and partly control its progress in order to compare it with agent-based simulations and if players and/or observers are stakeholders in the real process, they provide a means to reflect on their behaviour in it in reality. The stakeholders' discussions contribute to the model validation.

To a great extent, our work is similar to that of Barreteau et al. However, it differs significantly in two respects. First, our work focuses on the influence of culture. The participants can reflect on their behaviour in the processes displayed in Fig. 4, but they are not cultural experts who can reflect on the influence of their cultural background on their behaviour. We need expertise on culture for process validation and face validation of results. Second, given that the social context is most relevant when doing cross-cultural research, in our approach the agent-based simulation is instrumental to the gaming simulation: it aims to simulate the game (the research tool), not the real world. Barreteau et al. aim to model the real world in the agent-based simulation and use the gaming simulation for validation of the agent-based model.

Guyot et al. and Heckbert both describe a method of experimental data collection where human subjects play a role in a multi-agent simulation [5, 6]. In these experiments, the gaming simulation environment and other players are computer-simulated. The experiments focus on the validation of particular aspects of the agent model. For research into trade networks where aspects like interpersonal trust and culture are relevant, the rich social context of human interaction is an essential element of the gaming simulation. It cannot be replaced by a computer simulation. However, for validation of the cultural adaptation of the sub-process models, experiments with human participants in an agent environment can be a valuable extension to the data collection toolbox [8].

4 Cross-validation

Boero and Squazzoni discuss empirical calibration and validation of three types of agent-based models, studying two examples from literature of calibration and validation for each of the three model types [2]. On one end of the continuum they identify *case-based* models that are specific for empirically circumscribed. For these models the micro-level data gathering strategy is the main issue. On the other end of the continuum are *theoretical abstractions*, which refer to general social mechanisms. Those models illustrate a theoretical concept, and data gathering and validation are an on-going process. In between the extremes are a third class of models: *typifications*, which intend to investigate theoretical properties of a particular class of phenomena. The model of the Trust and Tracing game classifies as a typification.

According to Boero and Squazzoni, typifications can be used to embed a case-based model into a wider theoretical reference, or vice-versa: a representative case can be used as an empirical test for a typification [2]. The latter is exactly what the role of gaming simulations is in the simulation of the Trust And Tracing game: data gathering in representative cases to test a theory and the agent model which implements that theory.

Gilbert refers to typifications as *middle range models* that "*aim to describe the characteristics of a particular social phenomenon, but in a sufficiently general way that their conclusions can be applied widely*" [4]. He explains that by the generic nature of these simulations their behaviour cannot be exactly compared with any observable instance, but that one must be satisfied with qualitative resemblance. For instance, for our simulation we would be satisfied with resemblance of *stylized facts* of the form "the tracing frequency in games with American business school students is higher than it is in games with Dutch business school students".

Resemblance of stylized facts at aggregate level is not a sufficient validation. Takadama et al. describe the validation of an agent model of the sequential bargaining game by means of experiments with human participants [20]. They compare the results of Q-learning agent types with different action selection mechanisms. At the macro-level, output distributions of all types converge to distributions found in human experiments. However, only the learning curve of one of the agent types (the type using a Boltzmann distribution for action selection) resembles the learning curve of human subjects.

The work of Takadama et al. stresses the relevance of process validation in multi-agent simulations, in order to reduce the under-determination problem. Janssen and Ostrom also argue that given empirical problems with data collection and the explicit inclusion of cognitive, institutional and social processes in agent-based modelling, statistical performance is not sufficient for validation [13]. Other criteria for validation of agent-based models they mention are:

- plausibility of the model, given the understanding of processes,
- understanding why a model performs well,
- better understanding of empirical observations gained through the model,
- stakeholder validation of model behaviour.

According to Gilbert, sensitivity analysis to acquire an understanding of model behaviour is an essential element of the validation of agent-based models [4]. Without the results of a thorough sensitivity analysis the issues raised by Janssen en Ostrom cannot be covered.

According to Moss and Edmonds, agent-based simulation differs fundamentally from statistical research and qualitative approaches in that it allows for validation of the representation of agent behaviour as well as characteristics of aggregate time series [18]. As a basis for validation Moss refers to data collection at individual level (interviews and surveys) to collect data about distributions of actions, their relations with demographics, and patterns of social interaction; an agent based simulation can be validated at any level of detail [17]. Further, that author refers to the application of validated concepts from social psychology and cognitive science and stakeholder participation as elements of model validation. Moss and Edmonds describe an approach where the model is based on data and assessments provided by domain experts and stakeholders, and cross-validated against statistical data at the macro level and qualitative research results at the micro level [18]. We take a similar cross-validation approach, with the following elements:

- apply validated results from social science to model sub-processes and culture; thus, only the top-level process model (i.e. the composition of the sub-processes) and the integration of culture in the sub-processes remain to be validated;
- perform expert validation of the integration of the model of culture with the sub-process models;
- perform sensitivity analysis to discover model behaviour under different parameter settings and compare the results with theory-based expectations (face validity);
- compare gaming and agent-based simulation statistics, such as the number of successful transactions, average quality level of traded commodities, frequency of failed negotiations;
- compare agent behavioural characteristics, such as loyalty, negotiation results, deceit, explicit distrust;
- design micro-level games to test the integration of culture in sub-process models, possibly applying human participation in multi-agent simulations.

It is important to note that this approach does not comprise a global calibration of the agent-based model to gaming results. First, like for most agent-based simulations, the high number of parameters would inevitably lead to over-fitting. We must rely on calibration using other data at the sub-process level. The results of the sensitivity analysis can be helpful in selecting actual parameter values, but these must be in a plausible range according to the social sciences results that are the basis of the sub-process models. Second, as Gilbert has pointed out, for a middle range model one must be satisfied with qualitative resemblance [4]. A middle range model cannot be expected to make accurate forecasts.

5 Culture-Sensitive Validation of a Process

The cross-validation method introduced in this chapter is an iterated approach, in which each iteration consists of three steps: first, validate the model irrespective of culture (i.e., in some cultural setting), then for a number of culturally homogeneous populations, and subsequently vary culture by comparing gaming simulations played with participants with different cultural background. The iteration is done for every compositional level of the process model. In this chapter we focus on the second step of each iteration in which culture plays are role.

Table 2. Hofstede's dimensions of culture [7]

Dimension	Definition
Power Distance	"*The extent to which the less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally*" [7], p. 98
Uncertainty Avoidance	"*The extent to which the members of a culture feel threatened by uncertain or unknown situations*" [7], p. 161
Individualism and Collectivism	"*Individualism stands for a society in which the ties between individuals are loose: Everyone is expected to look after him/herself and her/his immediate family only. Collectivism stands for a society in which people from birth onward are integrated into strong, cohesive in-groups, which throughout people's lifetime continue to protect them in exchange for unquestioning loyalty*" [7], p. 255
Masculinity and Femininity	"*Masculinity stands for a society in which social gender roles are clearly distinct: Men are assumed to be assertive, tough, and focused on material success; women are supposed to be more modest, tender and concerned with the quality of life. Femininity stands for a society in which gender roles overlap: Both men and women are supposed to be modest, tender and concerned with the quality of life.*" [7], p. 297
Long- Versus Short-Term Orientation	"*Long Term Orientation stands for the fostering of virtues oriented towards future rewards, in particular, perseverance and thrift. Its opposite pole, Short Term Orientation, stands for the fostering of virtues related to the past and the present, in particular, respect for tradition, preservation of 'face' and fulfilling social obligations*" [7], p. 359

In the multi-agent simulation, culture is modeled according Hofstede's model of culture. Hofstede classifies national cultures according to five indices on the dimensions presented in Table 2. National cultures can be compared on the dimensions. Fig. 5 displays the scores the Netherlands and the USA. The scores are rather similar, except for the dimension of masculinity versus femininity. If results from gaming and multi-agent simulations match for players with a cultural background in these countries, the confidence in the model to correctly represent the effects of that dimension, grows. Validation of middle range models is an on-going process. By successively conducting this kind of experiments for different cultural configurations, the validation level is increased.

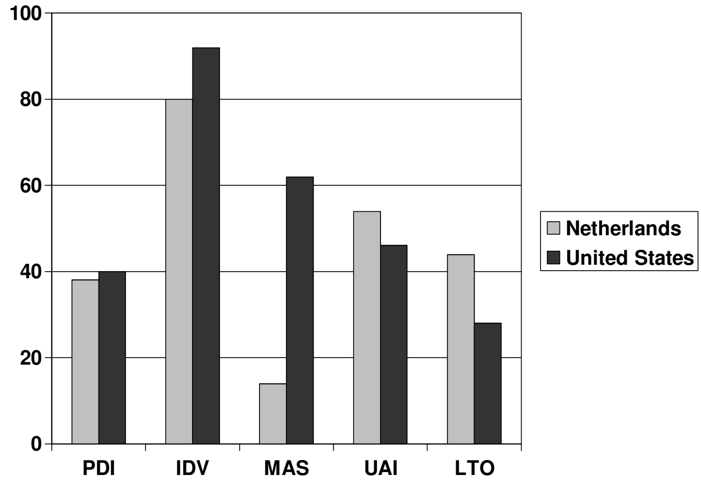

Fig. 5. The cultural indices of The Netherlands and the USA (data source: [7])

6 Example of Experimental Results

This section discusses an example on the basis of experiments with the Trust And Tracing game, reported by Meijer et al. [14]. In gaming simulations with the Trust And Tracing game with business school students in The Netherlands and in the USA, the American students showed more eager to win, traded higher quality, seized opportunities to cheat, and expected their opponents to do so too, so they traced more frequently. Also in the USA a greater fraction of high quality transactions was certified, i.e. traced up-front by the supplier. The reason for this is that the tracing fee for suppliers was lower than it was for customers. The players discovered that with a high tracing probability, it was efficient to have the suppliers trace in advance and use the tracing report as a quality certificate.. The following hypotheses can be formulated to be tested against simulation results:

1. The quality ratio (top quality transactions/all transactions) is higher in USA than in the Netherlands
2. The certification ratio (certified transactions/top quality transactions) is higher in USA than in the Netherlands
3. The defection ratio (untruthful deliveries/uncertified top quality transactions) is higher in USA than in the Netherlands
4. The tracing ratio (traces/uncertified top quality transactions) is higher in USA than in the Netherlands

Table 3 presents the results of the simulation runs. The simulation results confirm the hypotheses 1 through 4. However, some care must be taken. The hypotheses are formulated as stylized facts. The results reproduce these stylized facts, but cannot be interpreted to represent actual values for Dutch or American behaviors, as the model has not been tuned to actual data.

Table 3. Test data for 310 run pairs for USA and NL (source: [11])

Average of 310 runs	USA	NL	Test stat. [a]	Sample [a]	Probability [a]
Number of transactions	72	61	219	302	< 0.001
Quality ratio	0.37	0.15	277	285	< 0.001
Certification ratio	0.48	0.41	191	281	< 0.001
Defection ratio	0.25	0.13	128	154	< 0.001
Tracing ratio	0.40	0.07	169	177	< 0.001

[a] Test statistic, effective sample size, and two-sided probability level for Sign test

As discussed in section 3, these results increase the confidence that the model correctly represents the influence of the masculinity versus femininity dimension.

7 The Next Compositional Level: Micro Gaming Simulations

When playing the Trust And Tracing game in different cultural settings, it was observed that culture matters for the outcomes of the game [14]. What is the cause of these differences? The process model presented in Fig. 4 is universal. In order to trade, people need to find a partner, come to an agreement about the transactions, have the opportunity to defect and will consequently have to be prepared to monitor and enforce the delivery according to the contract. These activities are the essence of trade. The difference is in the way these activities are performed in different cultures.

As was formulated earlier in this paper, a sufficiently formalized implementation A of a theory T – formed on the basis of the literature and the gaming simulation G – underlies the agent-based simulation. Validation of G, A, and their interaction is no trivial matter, as the agent-based model underlying the implementation A combines a variation of models of theories that concern some aspect of the social situation, e.g., in trade we have to consider partner selection, negotiation, and delivery. Each of these sub-models has to be validated in separation as much as possible. Furthermore, the validated sub-models have to be validated in combination. First composing sub-models that have not yet been validated, and then trying to validate the composition may leads to under-determination. In the preceding sections the validation of the combination is considered.

Typically the sub-models in question have been developed in mono-cultural settings, whereas a social activity such as international trade is per definition a multi-cultural setting. This illustrates that validated sub models with respect to multi-cultural settings are not to be found. Of course, the problem of under-determination holds in general. To reduce this problem (in this example with respect to culture) the sub-models can be subjected to an additional validation process (in this example that would be testing it with humans of different cultures). We conclude that any compositional modeling approach for a complex system S runs into the problem of combining sub-models for subsystems that are underdetermined with respect to the modeling challenge of the whole system S.

In the agent model, the cultural differentiation is incorporated in the models of the sub-processes. The models applied in the sub-processes have been validated in experiments with human participants (this was a selection criterion for these models, a priori), but the adaption for culture has not. Cross-validation of statistics and behaviour in gaming versus multi-agent simulation increases our confidence in the correctness of the agent model and the integration of culture in the sub-process models. However, the risk of under-determination remains. That risk would be reduced if the sub-models could be tested in isolation. That is the purpose of the micro gaming simulations we propose in this section.

An additional feature of such a micro gaming simulation is that it gives a truth test of elements of the agent-based simulation with real people. Thus the system is tested at multiple levels: (1) the system behavior of the gaming simulation emerging from micro behaviors, (2) behaviors of individuals in the gaming simulation, and (3) elements of the individual's behaviors in isolation (see Fig. 6).

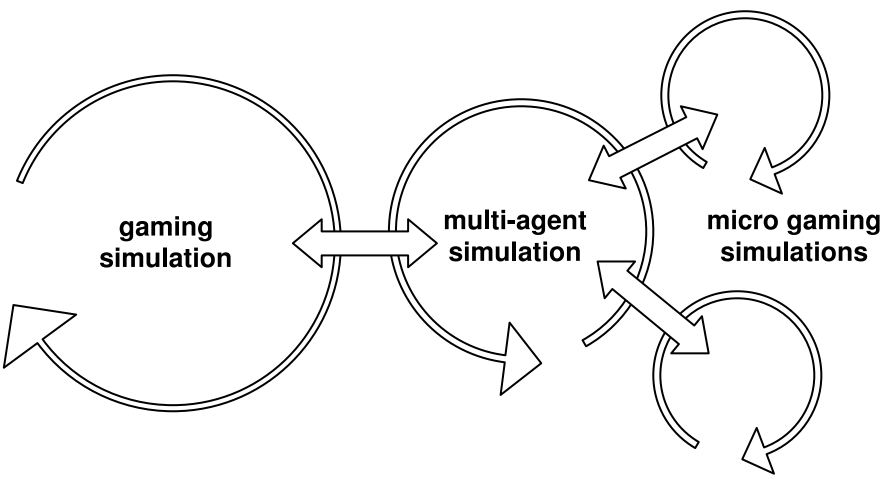

Fig. 6. Validation relations between gaming simulation, agent-based simulation, and micro gaming simulations

It is to be kept in mind that the long-term aim of the research for the case study is to develop a theory of human behavior in trading situations. The gaming simulation and the agent-based simulation are designed as counterparts: together they enable us to efficiently and effectively gather research data to develop and formulate more detailed theories of human behavior. The functions of the agent-based simulation in the research approach are:

1. Validation of models of behavior induced from observations in gaming simulations
2. Testing of hypotheses about relations between aggregated outputs and individual agent parameters
3. Selection of useful configurations for gaming simulations

The micro gaming simulations are designed to validate the decision models of the agent-based simulation. There is little experience with such an approach. A few conceptual papers have been published (e.g. [5, 6]), but no discipline has evolved. The context of the micro gaming is not as rich as that of the full gaming simulation, but since the essential element to be validated is the cultural adaptation of the sub-process models, some social context must be offered. Hofstede et al. have proposed a micro gaming simulation to test aspects of negotiation about the procurement of a second hand car (the Lemon Car game) [8]. This game is currently being further developed for application in secondary education. No results can now be reported on this work in progress. The concept of the game allows for data collection in live situations and through the internet.

8 Sensitivity Analysis in Agent-based Model Validation

The role of sensitivity analysis in agent-based simulation is to evaluate the fit between the theory and its implementation in the agent-based model [4]. In many types of simulation, sensitivity analysis is seen as a technical activity, aiming to improve the correctness of model implementation and the accuracy of forecasts made with the model. In the case of agent-based models, the relation between model formulation and output is hard to predict and sensitivity analysis also includes the discovery of emerging properties at the macro level. Therefore, sensitivity analysis must be performed at the agent level and at the macro level.

Burgers et al. have showed that for the Trust And Tracing game sensitivity at the macro level and at the individual level can differ considerably [3]. For instance, some parameter change may have little effect on the total number of transactions in the game, even if it greatly affects the performance of individual agents in different ways; other agents may step into the place of agents that do not perform well under the changed parameter settings. Sensitivity analysis at the individual level is complex. The behaviour of an agent does not depend solely on its own parameter settings. It is also influenced by the behaviours of the agents it interacts with. Burgers et al. conclude that methods for sensitivity analysis at the individual level have to be developed.

The multitude of parameters that are involved complicates the sensitivity analysis of agent-based simulations. In fact, every agent participating in the simulation has its individual parameter set. So, one has to work in a stylized way, using one or several groups of homogeneous agents, or generating the parameters from a distribution of which the parameters are taken as the input parameters to the simulation.

Sensitivity analysis at macro level can be performed by well-developed methods. However, in the case of culture-sensitive agents the analysis is far from straightforward - and time-consuming for the researcher. Strong interactions prevail between parameters of culture and other parameters. Burgers et al. conclude that straightforward sensitivity analysis of the Trust And Tracing multi-agent model can only be performed in a fixed cultural setting [3]. Thus, ideally, sensitivity analysis should be performed for every new cultural setting the model is applied in.

Although it is a laborious undertaking, sensitivity analysis pays off. It contributes to the validation criteria mentioned by Janssen and Ostrom [13]:

- it provides face validity of results, given the understanding of processes,
- sensitivity analysis contributes to understanding why a model performs well,
- results provide better understanding of observations gained through the model,
- the results of sensitivity analysis can be input to stakeholder validation.

Moreover, it identifies regions in parameter space where the model is particularly sensitive or insensitive to parameter changes. This information can be used in the experimental set-up of gaming simulations.

9 Discussion and conclusions

From trade process in the world to a gaming simulation is an abstraction that enables the researcher to execute repeatable experiments, i.e., a controlled setting with the essentials of trading in place, maintaining a social context in the experiments. As the required number of experiments with the gaming simulation, and the overhead of performing an experiment are prohibitive, an agent-based simulation is developed. However, this way another major abstraction is performed. This chapter shows a method with which it can be determined whether all important aspects of the gaming simulation are covered in a way that the behaviors seen in the gaming simulation also occur in the agent-based simulation and in a comparable way. Furthermore, our method determines whether the important sub-models of the agent-based model are valid with respect to real human behavior. This method is important as the agent-based simulation is intended to function as a way to:

1. Validate models of behavior induced from observations in gaming simulations;
2. Test hypotheses about dynamics of aggregated results in relation to parameter changes in individual behavior;
3. Select useful configurations for gaming simulations by performing sensitivity analysis on the agent-based analysis.

The approach we introduced for this purpose consists of :

- compositional agent modelling, using components based on validated results from social science, and a validated theory of culture, so that only the selection of components and their integration need to be validated;
- expert validation of the integration of the cultural theory into the components;
- sensitivity analysis to discover model behaviour under different parameter settings and compare the results with theory-based expectations (face validity);
- validation of agent-based simulation statistics against gaming statistics on aggregate level;
- validation of agents' behavioural characteristics with those observed in the gaming simulation;
- micro gaming simulations to test the integration of culture in sub-process models, possibly applying human participation in multi-agent simulations.

The micro gaming simulations have less context and focus on one or some aspects of one or some sub-processes. Thus, they contribute to structural validation of the mechanisms and reduce the under-determination of the full gaming simulation. Future research should develop micro gaming simulations for validation of aspects of the cultural adaptability of the Trust And Tracing agent model. For this purpose, computer-supported gaming simulations - like the one experimented with in the Lemon Car game - can be used. Guyot has called this approach participatory multi-agent simulation [5].

For a middle-range model like the culture-sensitive Trust And Tracing game simulation is, validation is an on-going process. It is infeasible to validate such a model for all possible configurations, but confidence in this type of models grows as they are validated in more and diverse situations. Future research should validate the model for other configurations than discussed in this paper.

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Part VI: Conclusion

In this dissertation a method to model cultural differentiation in artificial agents has been developed. The method has been applied to a multi-agent model by Tykhonov et al. (2008) of a gaming simulation to be played in different countries and different multicultural settings, called the TRUST & TRACING (T&T) game (Meijer 2006). A gaming simulation is a controlled environment where societal phenomena can be studied in a rich social context (Druckman 1994, Duke and Geurts 2004). It allows for the study of complex adaptive systems, such as supply networks, where system behaviour emerges from the behaviours and interactions of the participants. Gaming simulation shares this property with multi-agent simulation, so multi-agent systems are a natural candidate as a way to model gaming simulations.

Not only is the gaming simulation by itself a complex system when run. The rich context of a gaming simulation implies that both the process and the social relationships of the participants are complex. For the multi-agent simulation to be a useful research tool to understand and predict system behaviour, this complexity is to be reflected in the artificial agents. Complexity of agent structures can be managed by compositional design (Brazier et al. 2002). Such an approach is followed in this dissertation: the agent model is a composition of sub-models selected from social sciences and artificial intelligence literature. Only sub-models that are reported to have been validated in experiments with human subjects are selected, so only the composition and not the individual sub-models have to be validated. An approach to validate such a composition, using gaming simulation, has been proposed in Chapter 14.

Any professional who operates across cultures can confirm that negotiations differ across the world, and the area of cross-cultural consultancy is huge. Cross-cultural differences are also reflected in social psychological findings. Smith et al. (2006) performed an extensive review of social scientific experimental research across the world and found that all human social behaviour is sensitive to the cultural backgrounds of the participants. So are the outcomes of gaming simulations (Hofstede et al. 2010). This cultural differentiation is to be taken into account when modelling a gaming simulation that is to be played in different cultural settings. Culture by itself, in the sense of the collective pre-programming of the mind of a population, is also a complex phenomenon. In the social sciences it is studied either in a case-based fashion, or by a differential approach that aims to discover universally valid dimensions to classify cultures. Such dimensions reflect basic issues in the organization of society. It requires several dimensions to classify cultures, related to relational characteristics such as hierarchy, common group membership, aggression, anxiety, and morality.

The research questions for this dissertation have been put as follows:

1) Given a universal model of human behaviour in some domain, can the model of culture's effects be formulated, following an expert systems knowledge acquisition approach?

2) Having formulated the knowledge about the effects of culture on model parameters per dimension, how can a believable model of their joint effect be formulated?

3) How can the sensitivity of such a model be assessed for variation of cultural dimension indices, relational configurations regarding power and group membership, and universal model parameters?

4) Can such a model be applied to fulfil its function as a social sciences research instrument in combination with simulation gaming?

Using the dimensions to reduce complexity

Given a universal model of human behaviour in some domain, can the model of culture's effects be formulated, following an expert systems knowledge acquisition approach? The answer to this first research question is: "Yes, but only for specific cases or for one or two dimensions simultaneously". Culture is too complex a phenomenon to formalize the influence of culture on decision making in one go. In this thesis a dimension-by-dimension approach is followed in the knowledge acquisition to model the effects of culture.

Dimensional models of culture reduce the complexity of knowledge about cultures by identifying a set of measurable indices that can be related to the prevalence of broad classes of phenomena in a society, such as the salience of hierarchical relations and the trust in strangers. In this dissertation Hofstede's five-dimensional model of national cultures (Hofstede 2001) is applied to differentiate agent behaviour according to cultural background in the T&T game. It should be noted that following the same approach of knowledge engineering (literature study, expert consultation, process composition, and face validation), the method applied in this thesis could also be used to adapt other agent processes or to apply other dimensional models of culture. That would be an interesting additional test of the method's validity, but is not feasible in the framework of this thesis.

The method for cultural differentiation of agents proposed in this thesis takes advantage of the decomposition that is inherent in a dimensional model. An advantage of using Hofstede's model is that the concept of Synthetic Cultures as proposed by Hofstede and Pedersen (1999) can be applied for expert consultations and for face validation of the results. Synthetic cultures are imaginary cultures that are at the extreme of one of the dimensions and where the other dimensions have no effect. Thus, for five dimensions, there are 10 synthetic cultures (Hofstede et al. 2002). The synthetic cultures are at the basis of understanding the effects of the individual dimensions, and together with the material in Hofstede's work (Hofstede 2001, Hofstede and Hofstede 2005) and expert consultations, they provide a rich basis to model the effects of culture on agent decisions and agent behaviour dimension by dimension.

The way culture is modelled to influence agent decisions is that the score on the index of a dimension (normalized in the interval [0, 1]), or its opposite in the sense of synthetic cultures, modifies the values of parameters in the decision functions. The parameters have a global default value, as well as a maximal and a minimal value. The scores on each of the synthetic cultures, possibly moderated by relational factors, have an effect to increase the parameter value toward the maximum, or to decrease the parameter value toward the minimum, or have no effect.

Composing the joint effect of the dimensions

Having formulated the knowledge about the effects of culture on model parameters per dimension, how can a believable model of their joint effect be formulated? That is the second research question. The expert systems development approach for knowledge acquisition to model the influence of culture has showed fruitful in the modelling of individual dimensions. It has produced results that can stand face-validation against the synthetic cultures. All attempts to model the joint effect of dimensions following the expert systems approach have failed. It turns out to be too complex for both the expert and the modeller to formulate the integrated effects. So, criteria have to be drawn up for an integration formalism, and a formalism that satisfies the criteria has to be selected.

As described in Chapter 9, the joint effect should satisfy the following criteria:

- no interactions between individual dimensions,
- mutual compensation of increasing and decreasing effects on parameter values,
- effects in equal direction are disjunctive: one is sufficient,
- effects in equal direction do not reinforce each other: only the dominant effect counts.

Linear and probabilistic combinations, which are obvious candidates for integration of effects, do not satisfy the criteria. A simple formalism that does is to take the difference of the weak disjunction of all increasing effects with the weak disjunction of all decreasing effects. This formalism is applied to compute the joint effect.

To summarize: the influence of culture is modelled as the modification of model parameters, according to a joint effect of the dimensions. For each parameter, the joint effect is computed in a formal way from the effects of individual dimensions on that parameter. The effects of the individual dimensions are estimated using literature and expert knowledge. The formalism to combine the effects of individual dimensions is to take the difference of the weak disjunction of increasing effects and the weak disjunction of decreasing effects. This approach has been described in Chapter 9 and applied to the sub-models of the composed agent process model in Chapters 10 through 12. This answers the first and the second research question.

Sensitivity analysis

The third research question refers to sensitivity analysis: How can the sensitivity of such a model be assessed for variation of cultural dimension indices, relational configurations regarding power and group membership, and universal model parameters?

Sensitivity analysis is a sine qua non for the validation of an agent-based model (Gilbert 2008, Ginot and Monod 2007, Richardi et al. 2006). The complexity of an agent-based model makes it virtually unpredictable how the variation of agent parameters will influence agent behaviour and aggregate outputs.

First, aggregate system behaviour may be insensitive to parameters to which individual agent behaviour is sensitive. The latter is illustrated by the virtual insensitivity of aggregate outputs to large variations in the endowment effect parameter found in Chapter 3. The recently found explanation for this unexpected insensitivity of some aggregate outputs is that although individual traders are sensitive to the endowment effect parameter and will avoid partners that lumbered them up with a loss, other agents which did not have that experience will fill the space the disappointed agents leave.

Second, it is hard to predict agent behaviour because the agents are interacting and their behaviours may vary, depending on properties of the agents they interact with. Furthermore, the agents are learning, so their own pro-active behaviours as well as their behaviours in response to those of other agents are path-dependent. This implies that sensitivity analysis of an individual agent cannot be performed in isolation. It must be performed in multi-agent simulations where agents are allowed to interact with different partners, with equal or different initial parameter settings and interaction histories.

The results of the sensitivity analysis described in Chapter 13 confirm that it is useful to perform sensitivity analysis for both aggregate outputs and individual agent performance. That may be considered a main finding of this research. Sensitivity analysis is usually described and performed at the aggregate level. No literature has been found that explicitly stresses the importance of sensitivity analysis of individual agents. While methods for aggregate level sensitivity analysis are amply described in the literature and can be borrowed from other branches of modelling and simulation, methods for individual level sensitivity analysis in multi-agent simulations are lacking. This should be an issue for future research.

Sensitivity analysis at macro level can be performed by well-developed methods, but in the case of culture-sensitive agents the analysis is far from straightforward. Strong interactions that prevail between parameters of culture and other parameters complicate the sensitivity analysis.

Straightforward sensitivity analysis of the culture-sensitive multi-agent model can only be performed in a fixed cultural setting, and the sensitivity to input parameters is found to differ considerably across cultures, in that the most influential parameters of some cultures are not the most influential in other cultures. Thus, ideally, sensitivity analysis should be performed for every new cultural setting the model is applied in.

Although it is a laborious undertaking, sensitivity analysis pays off. It contributes to the validation criteria mentioned by Janssen and Ostrom (2006):

- it provides face validity of results, given the understanding of processes,
- sensitivity analysis contributes to understanding why a model performs well,
- results provide better understanding of observations gained through the model,
- the results of sensitivity analysis can be input to stakeholder validation.

By sensitivity analysis the regions in parameter space can be discovered where the simulation shows realistic behaviour. Moreover, it identifies regions where the model is particularly sensitive or insensitive to parameter changes. This information can be used in the experimental set-up of gaming simulations.

Twenty parameters are involved in the sensitivity analysis. This might suggest that a risk of over-fitting is present. However, the parameters are not calibrated to fit gaming outputs. The multi-agent purpose of the gaming simulation is not to make as exact forecasts as possible, but to predict a range of possible stylised facts that can be compared with the stylised facts observed in gaming simulations. For that purpose, parameters and initial values are calibrated to data available from other sources, such as Hofstede's indices of national culture and parameter values reported in literature.

Validity of the culture-sensitive T&T agent model

According to Sargent (2008) validation of a simulation model entails conceptual validation (also called structural validation by some authors) and operational validation. Moss (2008) stresses the importance of stakeholder involvement in formulation and validation of a model and asserts that evidence-based models are naturally validated. Since the work presented in this thesis is based on an expert systems knowledge acquisition approach on the one hand, interactively consulting the expert about the model structure and presenting the expert with simulation outputs for face validation, and on empirical results on the other hand (Hofstede's dimensions of culture and the models of the decision functions selected from literature), conceptual validation is built-in.

To validate an agent-based model, two areas need to be examined (Gilbert 2008). The first is the fit between the model and the theory, for which in addition to structural validation as described in the previous paragraph sensitivity analysis can be applied. The second is the empirical validation: the fit between the model and the system it represents. This is what Sargent has called operational validation. Operational validation implies in the case of the simulated T&T: the fit between multi-agent simulation outcomes and gaming simulation outcomes.

In Chapter 14 a cross-validation approach for gaming and multi-agent simulations has been proposed. It entails:

- compositional agent modelling, using components based on validated results from social science, and a validated theory of culture, so that only the selection of components and their integration need to be validated;
- expert validation of the integration of the cultural theory into the components;
- sensitivity analysis to discover model behaviour under different parameter settings and compare the results with theory-based expectations (face validity);
- validation of agent-based simulation statistics against gaming statistics on aggregate level;
- validation of agents' behavioural characteristics with those observed in the gaming simulation;
- micro gaming simulations to test the integration of culture in sub-process models, possibly applying human participation in multi-agent simulations.

According to the classification of Gilbert (2008) the culture-sensitive T&T game simulation is a middle-range model. It is infeasible to validate such a model for all possible configurations, but confidence in this type of models grows as they are validated in more and diverse situations. A limitation of this type of models is that they may be able to reproduce stylized facts in a qualitative way, but may not be relied upon to give an accurate prediction for every situation. However, through sensitivity analysis they may indicate a range of possible outcomes (Brown et al. 2005).

Validation of this type of models is an on-going process. Some examples of validation cases have been given in the previous chapters (face validation for synthetic cultures; the difference between Japan and the USA and between the Netherlands and the USA in Chapter 11). For now, the culture-sensitive T&T agent is valid as a first version to model relationships between trading partners Face validation can be continued by producing more simulation results (see, for instance, Hofstede et al. 2011a) and multi-agent simulation results can be cross-validated with gaming outcomes. As indicated in Fig. I in Part I, validation results can trigger the development of new versions of the model.

Under-determination (Sawyer et al. 1997) may be a problem in the validation of the model. The approach applying cross-validation of gaming and multi-agent simulation with micro-games would reduce this problem, but it has not yet been applied. Some preliminary experiments have been conducted with the LEMON CAR game (Hofstede et al. 2009d) and data collection with this game is subject of current research, and data collection is in progress, but conclusions cannot yet be drawn.

Validity of the method for cultural differentiation of intelligent agents

De Rosis et al. (2004) have suggested the application of Hofstede's framework to build culturally consistent agent characters. This thesis shows how that can be done, with the case of the T&T game as an example. It would be interesting to apply this method to other cases too, but this case offers a first validation.

The method could be applied using other dimensional theories of culture, such as Trompenaars' (1993) or Schwarz's (1994). However, the validity of an agent-based model depends on the validity of the empirical data it is calibrated on (Boero and Squazzoni 2005, Moss 2008). No other model today has shown such broad validity as Hofstede's (see the introduction section of Chapter 10).

The method for adapting agents to culture in this thesis has been applied to a single case. An advantage in this case has been that the expert on culture is also well-informed about gaming simulation and supply chain research. Is an expert in both culture and the domain of application available in all cases? Will the method also work if an expert on culture has to give clues on the effects of culture in a domain he or she is less familiar with?

Validity of the agent-based model as a useful research tool

The last research question is put as follows: Can such a model be applied to fulfil its function as a social sciences research instrument in combination with simulation gaming? This function comprises (Meijer and Verwaart 2005):

a) Validation of models of behaviour induced from game observations,
b) Testing of hypotheses about relations between aggregated outputs and individual agent parameters,
c) Test design: selection of useful configurations for games with humans.

With respect to model validation the multi-agent simulation has fulfilled its function in the research cycle depicted in Chapter I, Fig. I, in two ways.

First, the development of the culture-sensitive model by itself has been initiated by the observation that culture matters in the gaming simulations. Chapter 12 has closed the loop in that it shows that the multi-agent simulation reproduces the differences between behaviours of American and Dutch participants which motivated the development of the culture-sensitive agent model.

Secondly, the refinement of the negotiation model that is discussed in Chapter 12 – replacing equation (17) by equation (18) – underlines the usefulness of the multi-agent simulation for model improvement based on observed gaming results.

The usefulness of the multi-agent simulation to test hypotheses about system behaviour in response to individual parameter settings was already validated in Chapter 3 and has been reconfirmed in Chapters 10 through 11.

The multi-agent simulation has not yet been applied for test design in new rounds of gaming simulations. However, the results of the sensitivity analysis indicate that the model can be used to select the most informative out of a range of candidate gaming configurations, in an approach as described in Chapter 14.

Main contributions

The main contributions of the work presented in this dissertation are:

- an approach to model the influence of culture on decision functions in intelligent agents, applying expertise about a dimensional theory of culture dimension by dimension, and integrating the effects of the dimension by weak disjunction; such an approach can be applied in the development of research instruments (like the TRUST & TRACING game), educational and training applications to make people aware of cultural differences, and affective human-computer interfaces in a globalizing world;
- the finding that sensitivity of an agent-based simulation must be performed at both individual and aggregated level;
- the idea of the application of micro-games to validate individual components of the process model to reduce the under-determination problem in cross-validation of gaming and multi-agent simulation; however, the validation of this idea remains for future research.

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Summary

Agent-Based Modeling of Culture's Consequences for Trade

In this thesis, culture is interpreted as a property of a group of people who share the meaning they attach to symbols, have a common way of expressing their opinions and feelings, and share value systems to judge what is good or bad. The unwritten rules of a culture govern the interpretation of observations and emotions and how to react appropriately. The rules are embedded in an individuals' mind, form childhood on, by interactions with group members. People often are not aware of differences between their own unwritten rules and those of people having a different cultural background. This may result in unwarranted distrust or unwarranted trust, with serious consequences for the future of relationships.

Cultural differences are known to have their effects on trade. Signals that indicate benevolence and trustworthiness of a trade partner in one's own culture may be interpreted differently by people having a different cultural background. Hofstede (2001) has identified five dimensions of cultural differences:

- Given ingroup relation with relatives and community members may have a different impact on professional relationships in different cultures.
- The impact of hierarchical relationships on the freedom of action of trade partners may be different across cultures.
- Some cultures are oriented toward cooperation and care-taking; others are oriented toward performance and competition.
- Xenophobia is a wide-spread phenomenon in some cultures, while people in other cultures may be more open to the unknown.
- In some cultures people are anxious to keep up their status and display their societal success, while in other cultures thrift and perseverance are seen as virtues.

Cultural differences may have their effects in trade on the acceptability of potential partners, on progress and success of negotiations, and on the extent to which partners live up to the negotiated contracts. In a research project Meijer (2009) developed a gaming simulation to study the role of trust in supply networks of food products. The game is called the TRUST & TRACING game. In this game, the producers are informed about product quality. The other players either have to trust the suppliers on their quality statements, or they can have the products traced by an independent authority, but the latter will cost them a fee. In addition to the financial considerations, they must take into account that showing distrust may bring damage to their relationships. Experiments with human subjects in different cultures have shown that the considerations lead to different actions in different countries. It was also found that the inclination to grab an opportunity to defect was different across countries.

The subject of this thesis is a computer simulation of the TRUST & TRACING GAME. The purposes of the computer simulation are:

- Validation of theories about, implemented in models of, the players' behaviors
- testing of hypotheses about relations of rules of the game and parameters of individual players with aggregated game statistics,

– the design of useful game configurations to be played with human players.

In the computer simulation the players' rolls are realized by software agents. The questions which are answered in this thesis concern the modeling of culture's consequences for the decisions taken by the agents. Such an agent is a computer program which simulates the behavior of human players. In a multi-agent simulation a group of software agents is acting and interacting simultaneously. Autonomy is an important property of software agents. The agents decide what to do; there is no central computer program that imposes decisions on them.

Important functions of agents in the present simulation are to approach new potential trade partners, to negotiate about a transaction and to exchange proposals, and, when the negotiation has ended successfully, to exchange products, and to decide and request a trace to be performed. The agents' decision mechanisms are implemented according to models and data available from scientific literature. To model the influence of culture on the decision making, an expert systems approach is taken, using the Synthetic Cultures according to Hofstede en Pedersen (1999).

To develop an expert system, knowledge engineers represent knowledge about some domain of application as a set of rules that can be interpreted by a computer system. Since culture is considered as a set of rules, such an approach is a natural way to model it. The development of expert systems always is an interdisciplinary project. In this case the work of Geert Hofstede has been used and an expert on this work and on Synthetic Cultures has been involved in the formulation of the rules.

Synthetic Cultures are imaginary cultures in which the effects of a single dimension of culture are emphasized, isolated from the effects of the other dimensions. The purpose is to make the differences related to that dimension teachable. In reality the differences may be less pronounced and may be mixed with differences related with the other dimensions. In this thesis an approach has been elaborated to compute the simultaneous effect of several dimensions. The approach is based on the principle of weak disjunction, which implies that, if several dimensions have a similar effect, only the strongest effects counts. For instance, if dimension A would have an effect of 75% and dimension B would have an effect of 25%, then their simultaneous effect would be 75%.

Expert systems must at least have face validity. An expert in the domain of application mustaccept the decisions that the system produces and the reasoning that leads to these decisions, as being believable. For this purpose computations for specific cases can be made, of which the results are judged by the expert. Further, the results of sensitivity analysis can be judged by an expert. Sensitivity analysis of a model is performed by studying how model outputs vary in relation with systematic variation of input parameter.

In addition to face validity, the model must be tested empirically. To that end outputs from gaming simulations with human participants can be compared with outputs from multi-agent simulations. For example, Meijer et al. (2006) found different outcomes from the TRUST & TRACING game between games played in the United States and in the Netherlands. Compared with the Dutch, American players are found to be more eager to buy top quality products, have a stronger inclination to opportunism, anticipate to a greater extent on their partners to defect, and have a stronger preference for quality certification. These differences where reproduced by the multi-agent simulation.

The main question of this research is, whether an expert systems approach is feasible to develop a valid model of cultural differentiation in multi-agent simulations, to be applied in research with gaming simulations.

The conclusions are:

1. Effects of dimensions of culture can be modeled as an expert system based on Synthetic Cultures. Modeling the simultaneous effects of several dimensions as an expert system proved not feasible: the complexity exceeded the intellectual powers of both expert and modeler.
2. The simultaneous effect of several dimensions can be modeled by weak disjunction of effects. The results have face validity and have empirically been verified for a limited number of cases.
3. Sensitivity analysis of this model is a complex undertaking if both cultural parameters and other parameters are simultaneously varied, because of the strong interactions between these types of parameters. When only the culture parameters are varied (with a fixed setting of the other parameters), or only the other parameters are varied (in a fixed cultural setting), straightforward sensitivity analysis is feasible. Furthermore, it was found that the sensitivity of aggregate model outputs may greatly differ from sensitivity of individual level outputs: parameters that do not affect the aggregate system performance, may affect results of individual agents.
4. This thesis proves that multi-agent simulation is a potent instrument to be used in research with gaming simulations, in particular for the purpose of validation of behavioral models. A problematic issue is, that similarity of the outputs of gaming simulations and multi-agent simulations is no sound proof that the agent correctly implements the human decision making mechanism. This issue is known as under-determination. A validation method is proposed, which builds on the model's composed structure. Under-determination can be avoided by separate validation of the components in micro-games.

The results of this research contribute to the methodology of cultural adaptation of intelligent software agents. This is relevant for the development of research instruments (like the TRUST & TRACING game), educational and training applications to make people aware of cultural differences, and affective human-computer interfaces in a globalizing world.

Samenvatting

Multi-agentsimulatie van cultuurverschillen in handelsnetwerken

Cultuur wordt in dit proefschrift benaderd als een eigenschap van een groep mensen, die aan bepaalde symbolen een gemeenschappelijke betekenis hechten, die een gemeenschappelijke manier hebben om hun opvattingen en gevoelens te uiten en die gemeenschappelijke waarden hebben om te beoordelen wat goed en wat slecht is. Bij cultuur gaat het om ongeschreven regels voor interpretatie van waarnemingen en gevoelens en wat daarop gepaste reacties zijn. Door interacties in een groep worden de regels van jongs af aan verankerd in de geest van de groepsleden. Mensen zijn zich vaak niet bewust van verschillen tussen hun ongeschreven regels en die van andere groepen. Bij interculturele contacten kan dat leiden tot misplaatst wantrouwen of vertrouwen, met serieuze gevolgen voor de relaties.

Cultuurverschillen kunnen effect hebben op de handel. Signalen die in de eigen cultuur op betrouwbaarheid en welwillendheid van handelspartners duiden, kunnen in een andere cultuur een andere betekenis hebben. Hofstede (2001) onderscheidt vijf dimensies waarop culturen kunnen verschillen:

- Familie-, vriendschaps- en herkomstrelaties hebben in verschillende culturen vaak een verschillende betekenis voor professionele relaties.
- De betekenis van hiërarchische verhoudingen voor handelstransacties kan van cultuur tot cultuur verschillen.
- In sommige culturen is men vooral gericht op samenwerking, in andere meer op winnen.
- Er zijn culturen waar men vreemdelingen wantrouwt en culturen waar men open staat voor het onbekende.
- De mate waarin men vooral status wil ophouden of juist zuinigheid en volharding als deugden ziet, verschilt vaak tussen culturen.

Cultuurverschillen kunnen in het handelsverkeer effect hebben op de acceptatie van potentiële partners, op verloop en succes van onderhandelingen en op de mate waarin afspraken nagekomen worden. In een onderzoeksproject van Meijer (2009) is een spelsimulatie ontwikkeld, waarin vertrouwensrelaties in handelsketens een belangrijke rol spelen. De naam van dit spel is: “TRUST & TRACING game”. In dit spel hebben de producenten informatie over de productkwaliteit, die de andere spelers niet hebben. De andere spelers kunnen de kwaliteit vast laten stellen door een onafhankelijke autoriteit, maar dat kost geld. Ze moeten dus een afweging maken tussen vertrouwen, met het risico van bedrog, en de kosten van kwaliteitscontrole. Daarbij speelt mee dat het tonen van wantrouwen de relaties soms schaadt. Bij het spelen van het spel met deelnemers uit verschillende culturen bleek dat de afwegingen in verschillende culturen tot verschillende uitkomsten leiden. Ook de mate waarin men de gelegenheid tot bedrog aangreep, bleek te verschillen tussen culturen.

Het onderwerp van dit proefschrift is een computersimulatie van het TRUST & TRACING spel. De doelen van de computersimulatie zijn:

- het valideren van theorieën over en modellen van het gedrag van de spelers,

- het toetsen van hypothesen over relaties tussen spelregels en parameters van individuele agenten enerzijds en geaggregeerde statistieken van het spel anderzijds,
- het ontwerpen van effectieve spelconfiguraties om met mensen te spelen.

In het computermodel worden de rollen van de spelers vervuld door software-agenten. De vragen die in dit proefschrift beantwoord worden, hebben betrekking op het modelleren van de invloed van cultuur op de beslissingen van de agenten. Zo'n agent is een computerprogramma dat het gedrag van een menselijke speler simuleert. In een multi-agentsimulatie wordt het spel nagebootst door een groep software-agenten gelijktijdig te activeren en met elkaar te laten interacteren. Een kenmerk van een multi-agentsimulatie is dat de agenten autonoom zijn: alle beslissingen worden genomen door software in de agenten, niet door een centraal computerprogramma.

De belangrijkste functies van de agenten zijn het benaderen van potentiële handelspartners, het doen van voorstellen tijdens het onderhandelen over een transactie, het uitvoeren van de transacties en het daarbij eventueel laten uitvoeren van een kwaliteitscontrole. Voor het modelleren van de beslissingen over de uitvoering van deze functies is gebruik gemaakt van bestaande modellen en andere gegevens uit de wetenschappelijke literatuur. Met een expertsysteembenadering, gebaseerd op de *synthetic cultures* van Hofstede en Pedersen (1999), is de invloed van cultuur op de beslissingen gemodelleerd.

In een expertsysteembenadering leggen een of meer *knowledge engineers* de kennis over een bepaald vakgebied vast in regels die een computersysteem kan interpreteren. Omdat cultuur te beschouwen is als een stelsel van regels, is dit een voor de hand liggende aanpak voor het modelleren ervan. Ontwikkeling van een expertsysteem is altijd een interdisciplinair project. In dit geval zijn met gebruikmaking van het werk van Geert Hofstede en een expert op het gebied van *synthetic cultures* de regels geformuleerd.

Synthetic cultures zijn denkbeeldige culturen waarin het effect van één van de dimensies sterk wordt benadrukt, met weglating van de effecten van de andere dimensies. Daardoor worden de met die dimensie samenhangende verschillen bevattelijk. In een realistische situatie zijn de verschillen vaak minder groot en zijn ook de verschillen die met de andere dimensies samenhangen, van belang. In dit proefschrift is een methode beschreven om het gecombineerde effect van meerdere dimensies te berekenen. In de methode wordt het principe van *weak disjunction* toegepast. Het komt erop neer dat, als meerdere invloeden een vergelijkbaar effect hebben, alleen de sterkste invloed telt. Bijvoorbeeld: als dimensie A een effect van 75% zou hebben op een bepaald resultaat en dimensie B een effect van 25%, dan is hun gezamenlijke effect 75%.

Een belangrijke eis die aan een expertsysteem wordt gesteld is *face validity*: een expert op het vakgebied moet de beslissingen die het computersysteem neemt en de manier waarop het tot die beslissingen komt, geloofwaardig vinden. Dit kan door met het model te experimenteren en gevoeligheidsanalyses uit te voeren, en de resultaten door een expert te laten beoordelen. In een gevoeligheidsanalyse bestudeert men hoe de uitkomsten van een simulatie worden beïnvloed door systematische variatie van de modelparameters.

Naast *face validity* is het van belang om het model empirisch te toetsen, bijvoorbeeld door resultaten van spelsimulaties met computersimulaties te vergelijken. Een voorbeeld zijn de verschillen tussen Nederlandse en Amerikaanse spelers van het TRUST & TRACING spel, die in het onderzoek van Meijer et al. (2006) gevonden zijn. Amerikaanse spelers zijn meer belust op topkwaliteit, zijn meer geneigd afspraken over de kwaliteit niet na te komen als daar geen sancties op staan, anticiperen er meer op dat hun leveranciers geneigd kunnen zijn dit te proberen, en zijn sterker geneigd kwaliteitscertificatie toe te passen dan Nederlandse spelers. Deze verschillen konden met de multi-agentsimulatie worden gereproduceerd.

De hoofdvraag van dit onderzoek is, of het inderdaad mogelijk is om met een expertsysteembenadering een valide model voor culturele differentiatie in multi-agentsimulaties te formuleren, dat bruikbaar is in onderzoek met spelsimulaties.

De conclusies van het onderzoek zijn:

1. Het effect van de afzonderlijke dimensies kan met een expertsysteembenadering op basis van *synthetic cultures* worden gemodelleerd. Het direct modelleren van gezamenlijke effecten van meerdere dimensies met een expertsysteembenadering is te complex voor de expert en voor de modelleur.

2. Het berekenen van het gezamenlijke effect van de dimensies volgens het principe van *weak disjunction* van simultane effecten, zoals beschreven in dit proefschrift, levert een model op, dat op zijn minst *face validity* heeft en dat tot nu toe voor een beperkt aantal concrete situaties empirisch gevalideerd is.

3. Interacties tussen cultuur- en overige parameters zijn in dit model zo sterk, dat een gevoeligheidsanalyse zeer tijdrovend is wanneer beide typen parameters tegelijkertijd worden gevarieerd. Wanneer slechts de cultuurparameters (met een vaste instelling van de overige modelparameters) of alleen de overige modelparameters (voor een bepaalde culturele configuratie) worden gevarieerd, is een standaard gevoeligheidsanalyse wel goed uitvoerbaar. De daarbij gevonden gevoeligheid kan flink verschillen tussen spelstatistieken op geaggregeerd niveau en resultaten van individuele agenten: parameters die geen effect hebben op het functioneren van het systeem als geheel, kunnen wel de resultaten van individuele agenten beïnvloeden.

4. Dit proefschrift toont aan, dat multi-agentsimulatie een effectief hulpmiddel is bij het onderzoek met spelsimulatie, in het bijzonder voor de validatie van modellen van menselijk gedrag. Daarbij doet zich het probleem voor, dat overeenstemming van resultaten van spelsimulatie en multi-agentsimulatie geen sluitend bewijs is dat de agenten de beslissingen van de menselijke deelnemers correct representeren. Dit probleem is bekend als *under-determination*. In het proefschrift wordt een validatiemethode voorgesteld, die gebruik maakt van de opbouw van het model uit componenten. Door de deelmodellen afzonderlijk te valideren in *micro-games*, kan *under-determination* vermeden worden.

De resultaten van dit onderzoek dragen bij aan de kennis van methoden voor culurele aanpassing van intelligente software agenten. Deze kennis kan toegepast worden voor de ontwikkeling van onderzoeksinstrumenten (zoals het TRUST & TRACING spel), educatieve toepassingen en mens-machine interactie in intelligente software agenten in een globaliserende wereld.

Curriculum Vitae

Tim Verwaart is geboren op 20 april 1952 in Dordrecht.

Hij studeerde van 1970 tot 1978 milieuhygiëne aan de Landbouwhogeschool in Wageningen, met wiskunde en informatica als bijvakken.

Van 1980 tot 1983 werkte hij bij het computercentrum van het Nederlandse ministerie van volksgezondheid en milieuhygiëne aan informatiesystemen voor het milieubeleid (emissieregistratie en registraties van radioactieve stoffen en chemisch afval).

In 1983 kwam hij als hoofd van het computercentrum in dienst van het Landbouw-Economisch Instituut (LEI) in Den Haag. Daar heeft hij verschillende leidinggevende functies in de informatica vervuld. Sinds 2010 is hij coördinator voor modellen en infrastructuur van het LEI, dat nu onderdeel is van Wageningen UR.

Werkzaamheden voor het LEI betroffen in de afgelopen decennia vooral de verzameling en ontsluiting van databestanden voor wetenschappelijk onderzoek. Grote projecten waren, onder andere:

- ontsluiting van grote databases met internationale handelsgegevens,
- complexe databases met tijdreeksen en panelgegevens,
- servicegerichte inrichting van IT-dienstverlening,
- integratie van gegevens uit heterogene statistische bronnen,
- op BPM[11] gebaseerde verzameling van gegevens voor onderzoek,
- beheer van datamodellen in het onderzoek,
- implementatie van complexe administratieve systemen.

Het onderzoek waarvan in dit proefschrift verslag is gedaan, werd uitgevoerd in de periode van 2004 tot 2011, ten dele bij het LEI en ten dele als gast bij de TU Delft.

[11] BPM: business process management