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Modelling and Simulation of Selling and Deceit for the Trust and Tracing Game

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Abstract. Deceit is commonplace in trade. Understanding deceit is vital for detecting deceit, and for the design of governance mechanisms in trading to discourage deceit. This paper presents a number of observed regularities related to trust that are gained from human simulation games in supply networks. These regularities form the basis of models for deceit and sellers capable of cheating as presented in this paper. The models were used to simulate the game. Analysis of the simulation results show the same regularities as observed in the human game results.

1. Introduction

Deceit is commonplace in trade, thus also in supply chains and networks. 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. [4] 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? Understanding deceit is vital for detecting deceit, and to design governance mechanisms in trading to discourage deceit, thus safeguarding food for consumers.

In the field of New Institutional Economics, the concept of Transaction Costs [14] tries to incorporate social interactions around searching, bargaining, monitoring and enforcing of contracts in economic models. The possibility of deceit causes the need for monitoring and enforcing of contracts. An empirically validated model of sellers behavior with regard to deceit will be of value to this field of economics.

This paper contributes to the understanding of deceit by proposing models for deceit and sellers capable of cheating. A time-honored 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, the problem of the real world is its complexity. Therefore, it is better to first study the phenomenon (in this case cheating) in a limited setting. The models presented in this paper are based on insights gained from the Trust and Tracing game: a human simulation game in supply networks.

The Trust and Tracing game is a research tool for supply chain and network studies [7]. 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 the buyers, as quality is invisible and only known by the producers. This leads to information asymmetry and the opportunity for deceit. Meijer and Hofstede [7] describe the dilemma similar to the well-known Prisoners Dilemma in the so-called Trader's Predicament.

Conducting and analyzing human simulation games is a time-consuming activity (see [3]). For the Trust and Tracing game testing one configuration variation takes approximately one week. Playing the game over forty sessions in a few selected configurations led to the hypotheses and models presented in this paper.

The cheating model is incorporated in a seller model, which in turn is used in multi-agent simulations of the Trust and Tracing game. Other essential elements of the multi-agent system are, e.g., a trust model, a model for reputation damage, a buyer model, and a negotiation model. Depending on the role that the agent plays in the game, the agent contains only a seller, only a buyer or both seller and buyer models. Those other models, the corresponding hypotheses, and the obtained simulation results are presented in other papers and are not discussed in this paper.

The focus of this paper is on behavior of sellers in negotiations and the opportunity for deceit that their information advantage offers them. Section 2 briefly describes the Trust and Tracing game. The models we implemented for seller behavior and deceit are described and explained in Section 3. Sections 5 and 6 contain some experimental results. Section 6 compares our work to that of others and offers a conclusion.

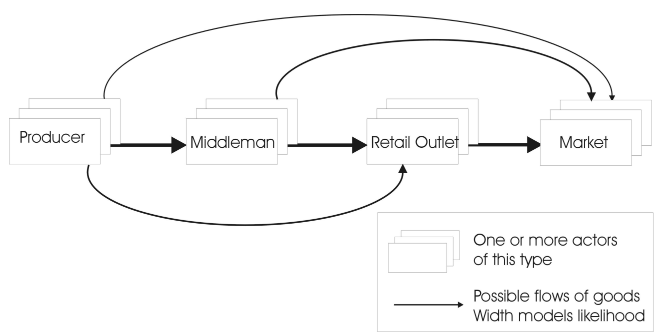

Fig. 1. Supply network configuration

2. The Trust and Tracing Game

In the human Trust and Tracing game 12 to 25 participants play roles in a supply network. There are three types of roles: traders (producers, middlemen, retailers), consumers (see Figure 1) and the tracing agency. The traders have the goal to make as much money as possible. Consumers have to collect as many points as possible, gained with goods bought. The tracing agency is played by a game leader.

Table 1. Consumer satisfaction value by product type and quality

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

The typical setup consists of 3 to 4 players of every trader role, 6 to 9 consumers and one tracing agency. This setup is chosen based on the typical size of a trade network. The three steps in the trade chain are needed to represent the interdependencies on companies that you don't do business with directly.

Producers receive an initial amount of goods. The good traded is a sealed envelope that comes in 3 different types (colors) 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), represented in points.

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 as more steps need to be checked later on. 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 high and low-quality products) However, if the deception is discovered, the seller has to pay a fine. Resellers of cheated products who did not check the quality themselves have to pay a smaller "ignorance" fine.

3. Models of Seller's Behavior and Deceit

The Trust and Tracing game models trade with hidden attributes that provide the opportunity to gain extra profit by deceit. The quality of products in the game is invisible, so sellers have the opportunity to deliver low quality commodities where high quality was agreed. In real world supply chains avoiding such opportunistic behavior is an issue, for instance in case of food safety, see [9].

Sellers bargain with potential buyers about multiple attributes: type of product, quality, price, and guarantees for the quality. 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. Producers cannot trace, to force the environment to use at least one transaction with an unchecked product.

A buyer intending to resell the product to another person might request such an extra assurance because of the chance of delivering a low quality product when a high quality product was agreed upon. Following economics literature [14; 2], a seller in the Trust and Tracing game (and therefore, also in the model presented here) has three economic incentives not to cheat:

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

The model presented in this paper offers possibilities to experiment with the 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 amount of the fine depends on whether or not the agent you bought from cheated you. The damaged reputation depends on the socio-cultural system the agents come from, which influences their opinions on the importance of trust and honesty and their reaction on being deceived. The variable *Δhonesty* reflects a simple approach to incorporating agent's response on being caught (or not being caught) in deception in the agent's utility function.

The utility-based multi-attribute negotiation algorithm of Jonker and Treur [9] is used to model the bargaining process. 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 or not is discussed in subsection 3.2.

3.1 Seller's Utility Function

In structural design of the seller's model we used multi-criteria problem solving approach by constructing seller's utility function as generalized criterion of price and risk [8].

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

$$u_{seller}(bid) == w_1 f_{price}\left(price_{effective}\right) + w_2 f_{risk}\left(risk_{seller}\right) \quad \textbf{(1)}$$

The functions f_{price} and f_{risk} present the effective price and seller's risk in the interval [0; 1]. The weight factors add up to one and represent seller's strategy with respect to the risk she 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, while w_1>w_2 models risk-taking behavior.

Effective price represents the seller's benefit:

$$price_{effective}(bid) = price_{purchase}(bid) - price_{sell,\min} - cost_{transaction} - cost_{certification} \quad \textbf{(2)}$$

where $price_{sell,min}$ represents seller's belief about the minimal price he may receive (Agents update their price beliefs based on negotiation experiences); $cost_{transaction}$ represents cost of making a transaction with the given partner (transaction costs are defined by the game leader in the form of a matrix like the one shown in Table 2); $cost_{certification}$ represents the fee a player has to pay the tracing agency for tracing the commodity and providing a certificate, if needed.

Table 2. Example of a transaction cost matrix

Buyer	Seller			
	Pro.	Mid.	Ret.	Con.
Producer	10	100	100	100
Middleman	2	10	100	100
Retailer	4	2	10	100
Consumer	8	4	2	10

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

$$risk_{seller} = p_{neg.trace} \cdot cost_{neg.trace} \tag{3}$$

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):

$$p_{neg.trace} = \left[1 - \prod_{seller_i \in S} trust_{honest}(seller_i)\right] \cdot \left[1 - trust_{tracing}(buyer)\right] \cdot q(bid) \cdot \left[1 - c(bid)\right] \tag{4}$$

where S is the set of agents upstream in the supply chain of this particular lot; $q(bid)$=1 if quality is high, 0 if quality is low; $c(bid)$=1 if a certificate is present or to be provided, 0 otherwise.

Each agent in the Trust and Tracing game simulation maintains for every other agent in the game the level of trust it has in that agent, modeled according to the trust dynamics model proposed by Jonker and Treur [5]. The trust update mechanism and the models for trust from the buyer's viewpoint are described in more detail in [15].

'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.

$$cost_{neg.trace}(bid) = fine_{good\ faith} + rep.damage + g(bid) \cdot \left[rep.damage.garantee + money\_back(bid)\right] \tag{5}$$

where $g(bid)$=1 if the bids entails 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 formal way 'money back' can be considered as the following expression:

$$money\_back(bid) = price_{purchase}(bid) \cdot [1 - satisfaction\_ratio(bid)] \quad (6)$$

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.

3.2 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. [4] As said before, we incorporate reputation and trust in our agents. Figure 2 represents the structure of the model discussed in the remaining part of this subsection.

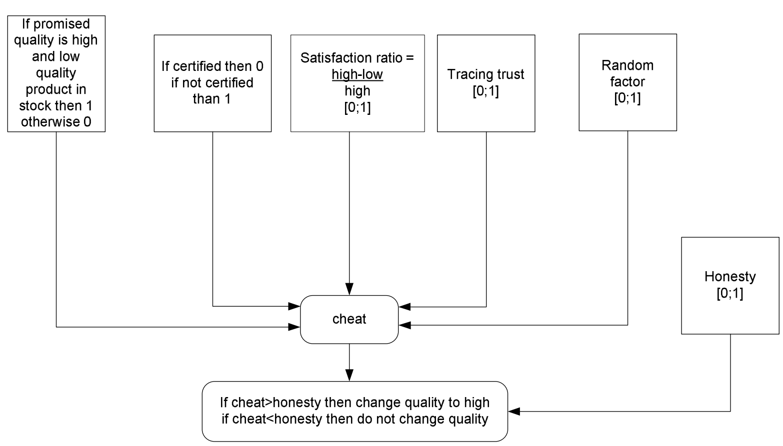

Fig. 2. Deceit model

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 counterforce to the opportunistic behavior, 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 modeled as an incentive not to deceive friends, but only as an asset that enhances market position [7]. Selling agents maintain trust in each individual buyer according to the trust update mechanism from [5]:

$$updated\_trust_{tracing}(buyer) = \Delta trust \cdot evt + (1 - \Delta trust) trust_{tracing}(buyer) \qquad \textbf{(7)}$$

where experience value *evt* is set to 0.75 for positive and 0.1 for negative experience.

In the reality other factors may influence the cheating 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 scarcely 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.

All factors are normalized on [0, 1]. The following equation expresses temptation to deceive:

$$\begin{aligned} & cheating\_level(bid) = q(bid) \cdot [1 - c(bid)] \cdot s[type(bid), low] \cdot \\ & \{(1 - rtw) \cdot [1 - satisfaction\_ratio(bid)] \cdot trust_{tracing}(buyer) + rtw \cdot rnd\} \end{aligned} \qquad \textbf{(8)}$$

where *cheating_level*(*bid*) represents temptation with a real number in interval [0, 1]; *rtw* is the weight of the random term, set in the interval [0, 1] by the game leader to regulate the influence of the random term; *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.

Each agent has an honesty parameter that represents the agent's threshold for cheating, udated similar to the trust update after each transaction:

$$updated\_honesty = \Delta honesty \cdot evh + (1 - \Delta honesty) honesty \qquad \textbf{(9)}$$

where *evh* is set to 1 for negative experience (fine) and 0.2 if no consequences occur.

Comparison of the cheating_level with the agent's honesty leads to the decision:

$$\begin{aligned} & if\ cheating\_level > honesty\ then\ cheat; \\ & if\ cheating\_level \leq honesty\ then\ do\ not\ cheat \end{aligned} \qquad \textbf{(10)}$$

where *cheat* stands for: deliver low quality where high quality has been agreed.

4. Human Experiments with the Trust and Tracing Game

Some forty sessions with human players from a range of cultural backgrounds have been played so far. Twelve of the sessions have been played with participants from real trade networks. The rest have been played with students. The number of sessions is too little to draw statistical conclusions about the influence of parameters like honesty and risk-attitude on game statistics like frequency of cheating and frequency of deceit, especially considering the developments made to the game over the sessions. However, playing the game resulted in qualitative insights in the relations between variables.

Insights gained from these sessions are partially presented in [7] and partially unpublished. Three most applicable to mention here are:

1 Cheating among people who know each other is not done. The reputation damage (implicit cost) is high, especially among people from uncertainty avoiding cultures.

2 When only a few traces are done, opportunistic behavior occurs rapidly especially with people from uncertainty tolerant cultures.

3 When a cheat is found it is most likely to be followed by many traces and again cheats found.

Based on these insights the qualitative systems dynamics model presented in figure 3 could be formulated, using the method described by Vennix [11]. This qualitative model was used to formulate hypotheses about the expected system behavior in order to verify the implementation of the models in the agents. The results of the experiments presented in the next section of this paper do not represent realistic simulations of real human game simulations. They are a test of the plausibility of the implementation. Further tuning in realistic situations is required. Special notice should be given to the test with different levels of initial honesty: it indicates if the system is stable in the sense that it reaches equal equilibrium regardless of the cheating frequency in the beginning of the game.

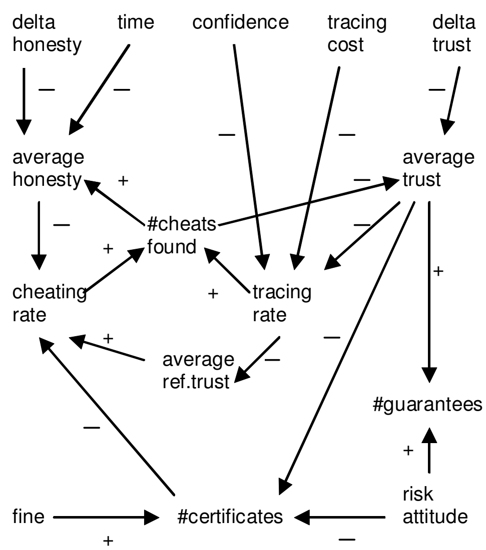

Fig. 3. System dynamics model

4.1 Hypotheses

Initial honesty

1. Initial honesty does not influence game output because players are capable of adjusting honesty to the game conditions.

Δhonesty

2. A high value of delta honesty increases the number of cheats because it makes honesty degrade rapidly after successful deceit without punishment.
3. A high level of delta honesty increases the amount of cheating (see hyp. 2); it also increases the number of traces through the trust mechanism: many negative traces as a consequence of deceit decreases average trust. A low level of trust increases the number of traces.
4. A high delta honesty value decreases average trust (see hypothesis 3). This leads to an increase of the buyer's preference to buy products with a guarantee or a certificate. Risk-avoiding agents will prefer a certificate; risk-seeking agents prefer a guarantee.

Fine

5. High fines for deceit increase the number of traces. More severe punishment leads to high seller's risk and makes selling certified products more attractive.
6. High fine decreases the amount of cheating. This is because high fines increase the number of traces (see hypothesis 5) and the number of traces has an inverse relation with the amount of cheating through the times cheating was discovered and cheating trust.
7. High fines for deceit increase the number of certificates. The higher risk of the seller makes untraced products less preferable and pushes him to provide certificates when selling them.
8. High fine for cheating decreases the number of guarantees provided by sellers. Because high fine makes providing a guarantee more risky seller would prefer to trace and provide a certificate.

5. Simulated Experiments with the Trust and Tracing Game

This section describes the results of experiments with agent populations of various risk-taking attitudes. All experiments have been conducted across agent populations of various risk-taking attitudes: no increased-risk-takers (denoted as "neutral" on the X-axis of the charts on figures 5,6,7), 1 out of 3 risk-takers (denoted as "2:1"), 2 out of 3 risk-takers (denoted as "1:2"), and all risk-takers respectively (denoted as "high"). Results will be discussed here for different values of *initial honesty*, *Δhonesty*, and *fine*. In the beginning each producer has 20 products of each type: 10 products of high quality and 10 products of low quality. (Sixty in total) The game session continues until the moment when at least one of the producers runs out of stock. This termination criterion has been chosen to avoid end-of-game effects.

Game sessions are performed in continuous real-time and depend only on the performance of the computer. Agents can be involved in only one transaction a time. This organization allows (future) combining of artificial and human agents in one game session. Values of free parameters were selected uniformly from their definition intervals to confirm the models capability to reproduce desired input-output relationships and explore their sensitivities.

Initial Honesty

Figure 4 presents results of experiments performed for two levels of initial honesty 0.1 and 0.9. Y-axis is normalized by number of transactions that took place in the game session. Similar to hypothesis no. 1, the initial value of honesty does not significantly influence the game output statistics. This means that the system is capable of self-adjusting through the trust and honesty update mechanisms.

The influence of risk-taking attitude usually outweighs the influence of other parameters and results in the typical increasing deceit ratio with increasing risk-taking, and the preference for the more risky guarantee instead of the more costly certificate

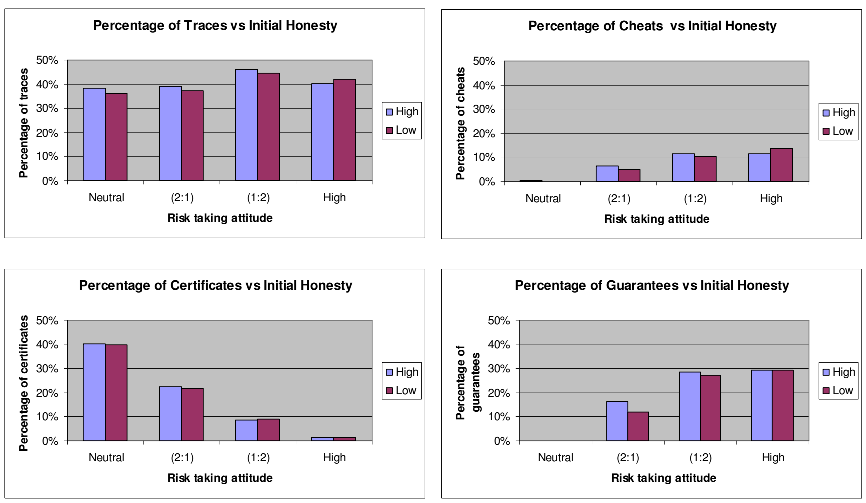

Fig. 4. Results for different levels of initial honesty (“high”=0.9; “low”=0.1)

Δhonesty

Figure 5 presents the results of experiments performed for two values of *Δhonesty*: 0.1 and 0.9. The number of cheats is significantly higher for high values of *Δhonesty*. This supports hypothesis no 2. However, for the experiment with neutral risk taking players more deceptions were observed for the low value of *Δhonesty*. This can be partly explained by the high *Δhonesty* pushing risk-avoiding sellers to a situation where it is more preferable to sell products with certificate. The increase number of certificates means a decrease in the number of situations where cheating is possible.

There is hardly any effect on the number of traces, although a slight increase in three out of four configurations may be interpreted not to reject hypothesis no 3.

The number of guarantees increases for high *Δhonesty* in games for mixed players populations. This partly confirms hypothesis no. 4. As guarantees may substitute certificates and vice versa the opposite relationship can be observed for the number of certificates.

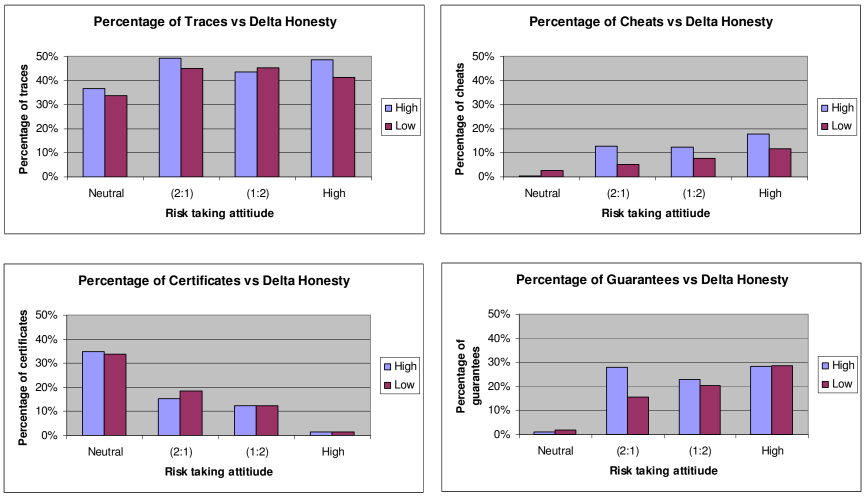

Fig. 5. Results for different levels of delta honesty ("high"=0.9; "low"=0.1)

Fine

The number of traces is higher for games with higher fines for all risk-taking player game configurations, see Figure 6. This confirms hypothesis no. 5. The same relationship in hypothesis no. 7 for the number of certificates is also confirmed by all experiments in the set.

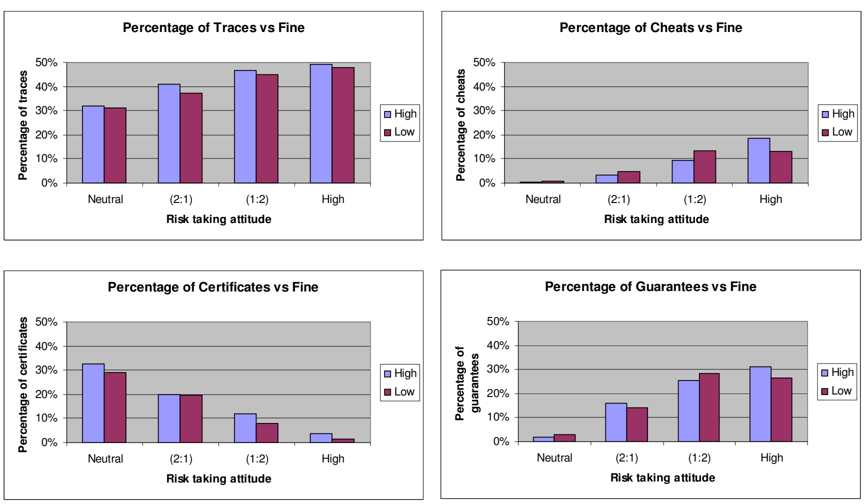

Fig. 6. Results for with different levels of punishment ("high"=20; "low"=5)

Hypothesis no. 8 is only confirmed in two cases out of four. Further human simulation is needed to clarify this point.

6. Conclusion

This paper contributes to the research of cognitive and economic concepts underlying trade in supply chain networks by presenting hypotheses that are based on human experiments in the Trust and Tracing Game, a model for cheating, and a model for sellers for the Trust and Tracing game that incorporates the cheating model. The hypotheses identify the influence of initial honesty, the change in honesty, and fines on the cheating behavior of sellers. The hypotheses were used to validate the outcome of computer simulations of the models presented here.

Our work acknowledges the work of Williamson [14] 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 to frailty of its motive. This stresses the broad application of transaction cost economics, as opportunism is possible in transactions where both traders have honest motives. The importance of opportunistic behavior is further supported by Diederen and Jonkers [2] who mention that production quality and quality assurance is an issue of chain and networks research to keep fast-switching consumers as a client.

Our model balances motivations to deceive on the one hand and forces that keep agents from deceiving on the other hand. We hypothesize that two factors influence what may be experienced as deceit in the Trust and Tracing game: (1) opportunistic behavior caused by asymmetric information between buyer and seller, and (2) failure of quality control in supply chains.

Our approach differs from that of Castelfranchi *et al.* [1] and de Rosis *et al.* [10] 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 behavior including their moral thresholds for deceit. Furthermore, our model does not simulate the art of deception as for instance the model of de Rosis *et al.* [10] does.

Ward and Hexmoor [13] 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.

The models proposed in this paper are based on the assumption of rationality during negotiations - where risk and reputation are assigned some financial value - versus the assumption of socio-psychological motivations to deceive during product delivery, based on the balance of temptation and honesty. However, the negotiation model is not strictly rational in the financial sense, as preference to avoid or take risk is taken into account. On the other hand, there is some rationality in the deception decision, as a high value ratio of high versus low quality products enforces temptation. Furthermore, the motivation to deceive or to be honest is a very complex phenomenon, which is not completely covered by the proposed models. However, the current multi-agent system offers an environment to study the effect of extended models.

Some interesting simulation activities in the research on trust (for instance [12, 16]) are carried out in environments such as the Internet, and P2P networks, where information can be unreliable, and untrustworthy. These domains suffer from the problem of uncontrolled parameters. This makes results of the experiments hard to interpret. The Trust and Tracing Game is an environment having pre-defined parameters, thus allowing a comparison between simulated results and the results of human experiments. The models of cheating and selling presented here can be used to simulate game configurations based on limited economic rationality through concepts like fine, honesty, and risk.

Future work includes the mutual benefit of human and simulated experiments. For example, computer simulation can be used to determine interesting variations of the Trust and Tracing game to be played by humans. The results of the thus selected human simulations will be compared to the results of the computer simulations. This process will gain us further insight into the cognitive behavior of human traders and the economics of supply chain networks, which undoubtedly will lead to more detailed models of, among others, cheating and sellers.

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