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# USING INSTITUTIONS TO BRIDGE THE TRUST-GAP IN UTILITY COMPUTING MARKETS – AN EXTENDED “TRUST-GAME”

Tina Balke, Torsten Eymann<sup>1</sup>

## **Abstract**

*With the ongoing evolution of the Internet as a trading platform and the corresponding paradigm change from small non-anonymous markets to their large anonymous utility computing pendants, new challenges arise. One of them is the promotion of trust in these new markets as it is an essential prerequisite for bilateral economic exchange [2]. This work tries to meet this challenge by using an evolutionary game-theoretic approach in combination with institutions. Starting from a basic trust game it will show that the introduction of institutions will lead to the crowding in of trustworthy behavior, even if no special detection capabilities are available.*

## **1. Motivation**

In the last years, the vision of utility computing (UtiC) has gained significant interest and has become a popular buzzword. The word “utility” is used to draw an analogy to the provision of other services, such as electrical power, the telephone, gas or water, in which the service providers seek to meet fluctuating customer needs, and charge for the resources based on usage rather than on a flat-rate basis. Examples of such IT-services are storage space, server capacity, bandwidth or computer processing time, hence interchangeable IT commodities that can easily be offered by a large number of suppliers. UtiC envisions that, in contrast to traditional models of web hosting where the web site owner purchases or leases a single server or space on a shared server and is charged a fixed fee, the fixed costs are substituted by variable costs and he is charged upon how much he actually uses over a given period of time. The business idea behind this vision is that if a company has to pay only for what it is using it can adapt its cost structure and will be able to economise, while the company offering utility computing services can benefit from economies of scale by using the same infrastructure to service multiple clients [6]. Thereby, due to the commodity nature of the products sold, UtiC envisions no oligopoly-like structures with a small number of large sellers, but ubiquitous infrastructures that are open and non-discriminating with regard to the users wanting to join. Hence anybody can participate in such an infrastructure. However, keeping this ubiquitous vision of UtiC markets in mind, several questions occur: Bilateral economic exchange envisioned in UtiC markets often involves risks, such as risks resulting from strategic- and parametric uncertainties [16]. Whereas the latter ones refer to environmental uncertainties that cannot (or only with a disproportionate effort) be reduced by the

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## 2. The Basic Trust Game with Parametric Uncertainty

The standard game theory often analyzes the strategic interaction of two players in the view of what individual players know and how they perceive their own situation and act according to these parameters, assuming rational agents [9]. This concept can be applied to the UtiC market problems by using the basic trust game that can be seen in figure 2.

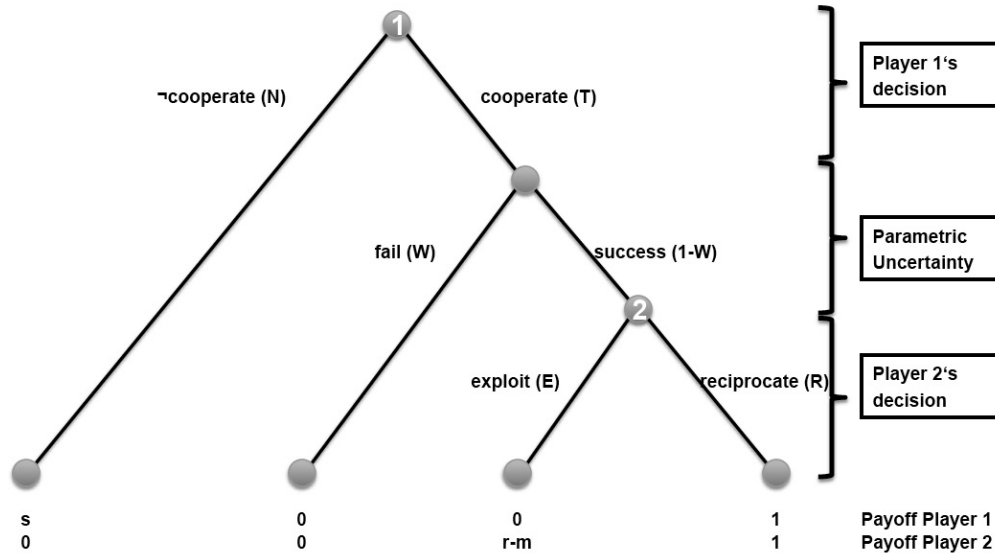


Figure 2: Basic Trust Games with Parametric Uncertainty<sup>2</sup>

Figure 2 shows the interaction of two market participants<sup>3</sup>, which make their decisions consecutively. Thus, when being offered a transaction with player 2 (i.e. for using player 2's hard disk space against payment), player 1 can decide whether to trust him and cooperate with him by making an advance investment  $s$ <sup>4</sup>, or whether to choose the outside option  $N$  and refrain from trading with player 2. In case player 1 decides to cooperate with player 2, the parametric uncertainty comes into play. It is independent from both players, occurs with a probability of  $W$  and can cause transactions to fail through external, non-strategic effects. For instance, it might happen that the network in which player 1 and player 2 interact breaks down, and as a result player 2 cannot fulfill his part of the transaction (i.e. provide the disk space), even if he wants to.<sup>5</sup> If this happens, player 1 loses his investment  $s$  and player 2 receives zero payoffs.

In case no parametric failure occurs and therefore compliance is possible, it is player 2's turn to decide whether to exploit player 1's trust by cheating on him (E) (i.e. by rejecting requests or by not answering any request until their timeout occurs) or whether to reciprocate it by complying with what has been agreed upon (R). If trust is rewarded, player 1's investment yields the positive net return of 1 and player 2 receives a net payoff 1. If player 2 exploits the trust however, player 1 receives nothing, whereas player 2 receives a material payoff of  $r$  with  $r > 1$ . The second payoff

<sup>2</sup> In the trust game the following restrictive assumptions about the parameters and probabilities are made for limiting the number of sub-cases to be considered by the theoretical analysis:  $s, w \in ]0; 0.5[$ .

<sup>3</sup> As this paper uses games theoretic analysis for its argumentation, the two market participants will be called "players" in the further course of this paper.

<sup>4</sup> The game uses positive payoffs. That is why  $s$  is treated like an economized disbursement in case player 1 decides against trading with player 2.

<sup>5</sup> For reasons of simplicity, it is assumed that a parametric failure means that player 2 cannot fulfill his part of the transaction at all. Partial fulfillments are therefore not considered.

parameter of player 2 after exploiting –  $m^6$  – is a non-pecuniary utility component which measures his morality, i.e. it specifies player 2’s bias of acting in accordance with what has been agreed on. It thus indirectly determines the population shares in the model, by determining which group an individual player belongs to. If  $m$  is assumed to be zero, the result of the game is straightforward as player 2 will always defect due to  $r > 1$ . If however, the intrinsic motivation to be trustworthy is present, the following picture can be drawn: player 2 will reciprocate in case the non-pecuniary payoff component  $m > r - 1$  (R-branch in figure 2) and he will exploit trust in the opposite case (E-branch in figure 2). If it is possible for player 1 to observe the  $m$  type of player 2 he can perfectly discriminate between non-trustworthy and trustworthy players and only trade with the latter ones. However, this detection is bound to fail in UtiC markets with infrequent interaction and a high level of anonymity where the  $m$  type is a private information of player 2. Even in the case that the relation of trustworthy against untrustworthy players (in the total society)  $p$ , i.e. the  $m$ -type-proportion, is known to all players, this does not help the game. In this case player 1 would always cooperate if  $p(1-w) > s$ . As in the second step untrustworthy player 2’s are always better off than their trustworthy counterpart (due to higher profits), they are edged over in the evolutionary process and consequently the population share  $p$  of trustworthy players decreases up to the point where no player 1 will choose to trust its co-players because the share of trustworthy players is too small [10].

### 3. The Court Game

A first approach to solve this problem with the help of institutions was proposed by Güth and Ockenfels. They expanded the basic trust game explained above with an arbitration board as shown in figure 3 and called the new game “court game” [11]. This court game assumes that whenever player 1 does not receive what he has paid for (i.e. every time he has a total payoff of zero) he appeals to an impartial rational belief forming institution: the arbitration board in figure 3.

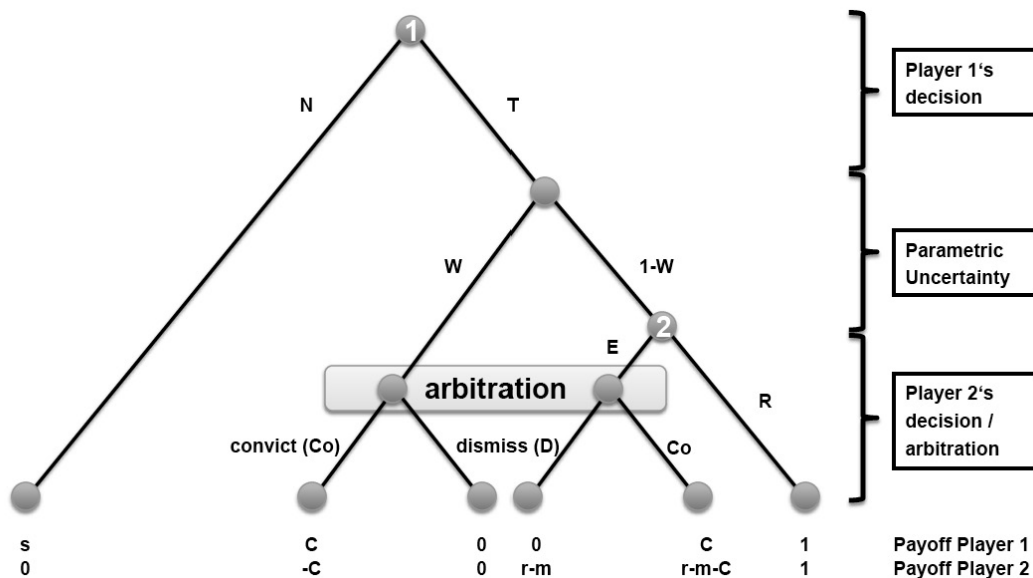


Figure 3: The Court Game

This arbitration board can either convict player 2 (the Co-move in figure 3) and impose the penalty  $C$  on him or dismiss the case (mode D in figure 3). In the model, the arbitration board is a rational belief forming instance, without any own interests that holds the party responsible whose guilt is most likely [13]. Hence, in order to reach its decision, the arbitration board itself uses the following

<sup>6</sup> The parameter  $m$  can take values in the interval  $[0;1]$ .

simple verdict rule for determining the probability  $q$  of conviction as well as the constant compensation payment  $C$  that player 2 has to pay player 1 in case of the conviction:

$$v = (C, q(E)); \text{ with } C \geq 0 \text{ and } q(E) \in [0;1]$$

In contrast to many existing models (see [5] for example), it is assumed that the arbitration board does not have any special detection capabilities and as all other UtiC market participants, does only know  $p$ , the share of trustworthy against untrustworthy players and can assess  $W$ , the exogenous probability that the transaction failed through external, non-strategic effects (this assessment of  $W$  can be based on historical data about the average network breakdowns, etc.).

Hence, the only indicators, the arbitration board can use in order to come to its verdict about the (conditional) probability  $E$  that the loss of player 1 was due to a fraud by player number 2 are the  $p$  and  $W$ , whereas  $E$  is calculated as follows using Bayesian rules:

$$E(W, p) = \frac{(1 - W)(1 - p)}{W + (1 + W)(1 - p)}$$

If, according to  $E$ , the arbitration board considers it to be more likely that player 2 decided for the exploit-path ( $E(W, p) > 0,5$ ), it convicts player 2 and enforces it to make a compensation payment, and otherwise ( $E(W, p) \leq 0,5$ ) it dismisses the case. Güth and Ockenfels [9] show that if the compensation payment  $C$  is chosen correctly and does not treat preferentially one group or the other, a stable market equilibrium can be achieved<sup>7</sup>. In brief, if  $p$  is small, and thus the conviction case is likely, even untrustworthy players are induced to behave trustworthy (i.e. choose the  $R$ -path) in order to avoid a conviction and hence the payment of  $C$ , whereas if  $p$  is large, non-delivery is likely to be caused by unintentional damage and consequently conviction is very unlikely. Whereas the first case results in an increase of  $p$ , the second case causes the opposite and hence an evolutionary stable bimorphism evolves, which however does cultivate trustworthy behavior in general, but fosters strategic behavior by all players.

These problems, as well as the fact that in reality more than two institutions (namely the arbitration board and trust) exist, compete and co-evolve at the same time [15], has been accounted for by a further evolution of the model which is discussed in chapter 4.

#### 4. An Extended Court Game With Legal Insurances

After having analyzed the basic trust game as well as the court game, the final model-evolution that is needed for reducing strategic uncertainties and promoting trust in UtiC markets shall now be presented. As shown in figure 4, as the court game, it includes an arbitration board that acts as independent rational belief forming institution which can convict player 2 and impose a penalty  $C$  on him or dismiss the case. As before, the arbitration board as well as the two players are anonymous, hence it is impossible to assess player 2's  $m$ -type, but Bayesian beliefs need to be used instead. Nevertheless, compared to the court game two fundamental things are different.

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<sup>7</sup> The basic parameter range of  $C$  is:  $\max\{\frac{1}{2}, r-m-1\} < C < 1$ . Hence  $C$  is larger than  $s$  what makes it profitable for player 1 to trade even if successful litigation is required. It is furthermore larger than the amount player 2 can gain from exploiting player 1's trust, however it is smaller than 1 to – in the case of successful litigation – make player 1 not better off than in the case, player 2 cooperated. For a detailed discussion about the appropriate amount of  $C$  see [11] or [9].

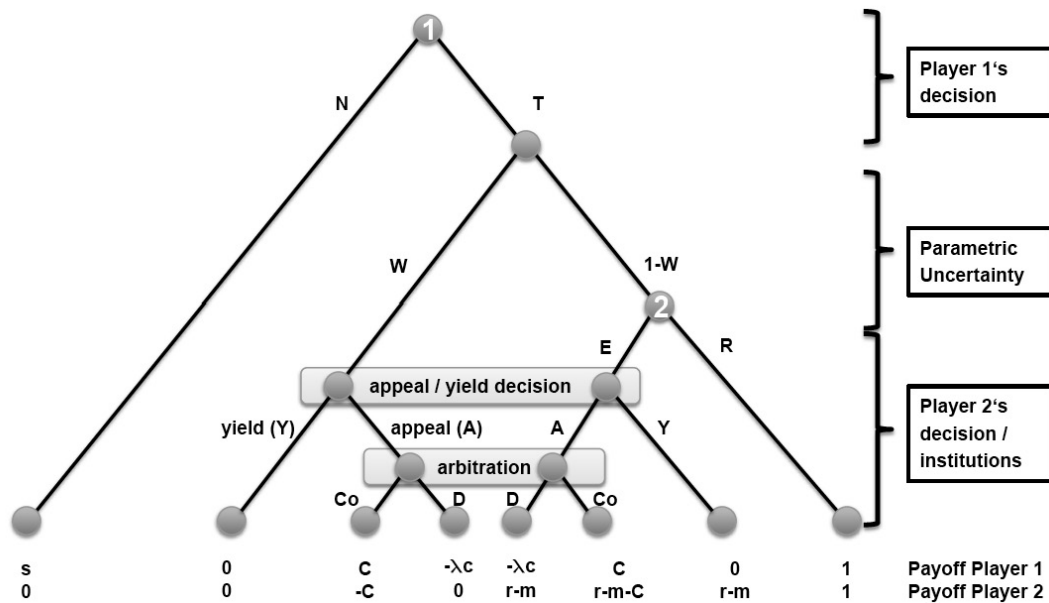


Figure 4: The Court Game With Legal Insurances

Firstly, player 1 is not obliged to call the arbitration board in case he does not receive what has been promised by player 2, but can decide to yield instead, inducing the same outcome as in the basic trust game. If he decides to appeal to the arbitration board and the board convicts player 2 everything works as in the “normal” court game. If however, the arbitration board dismisses the case, player 1 has to pay the court fees  $c^8$ . At this point the second difference comes into play: legal insurance that every player can obtain<sup>9</sup>. If insured ( $\lambda=0$ ), player 1 first of all can obtain (better) legal advice and furthermore does not need to pay  $c$ , but his insurance takes it over, otherwise it is 1’s turn to pay. However insurance is not for free, but is assumed to accumulate as costs  $K$  that are subtracted from the insured player’s payoff [13].

Summing up, in total the model includes the following parameters:

- $W$ , the probability that the transaction failed due to external effect, with  $0 < W < \frac{1}{2}$
- $m$ , the non-pecuniary utility component which measures the morality of player 2, with  $m \in \mathfrak{R}$
- $p$ , the  $m$ -type-proportion in the society
- $\lambda$ , the parameter for the legal insurance; with  $\lambda = \begin{cases} 0 & \text{if player 1 is legally insured} \\ 1 & \text{if player 1 is not insured} \end{cases}$
- $C$ , the compensation payment in case of conviction with  $\frac{1}{2} < C < 1$
- $s$ , the advance payment of player 1 with  $0 < s < \frac{1}{2}$
- $r$ , the exploitation payoff of player 2 with  $1 + C > r > 1$
- $c$ , the legal costs when the case is dismissed by the arbitration board with  $0 < c < 1$
- $K$ , the costs of legal insurance that are subtracted from player 1’s gains, with  $0 < K < c$ .

<sup>8</sup> It has to be noted that the court fees  $c$  (small letter  $c$ ) that are to be paid by player 1 in case of the dismissal of the case are not the same as the compensation payments  $C$  (capital letter  $C$ ) that player 2 has to pay in case of conviction.  $c$  is an element of the interval  $[0;1]$ . The upper border needs to be 1 as unsuccessful litigation should not be more costly than the potential gain from the transaction.

<sup>9</sup> Being insured is assumed to be an inherent trait that is determined by evolutionary forces. Hence the players do not decide rationally about insurance in advance, but evolutionary forces determine the success of insurances and thus the evolutionary success of insured players, making insurance an evolutionary evolving behavioral trait.

Let now  $z$  be the probability that player 2 chooses  $R$ , and  $x$  and  $y$  be the probabilities that player 1 chooses  $T$  and  $A$  respectively. In that case, for  $xy > 0$  the arbitration board's posterior probability that player has exploited player 1 can be obtained by applying Bayesian rules:

$$E(z) = \frac{xy(1-W)(1-z)}{[W + (1+W)(1-z)]xy} = \frac{(1-W)(1-z)}{W + (1-W)(1-z)}$$

Since the arbitration board uses the basic verdict rule explained above, it will convict an uninsured player 2 in case an intentional non-delivery is more likely than an unintentional damage based on parametric effects, hence if  $E(z) > 1/2$ , or

$$W < \frac{1-z}{2-z} =: f(z).^{10}$$

Finally, it is assumed, that in case player 1 is insured, he gets better legal advice and consequently his odds for winning the arbitration decision are improved. This means that if player 1 is insured, player 2 will be convicted even when  $E(z) > 1/2$ , more specifically whenever  $E(z) > \underline{E}$  with  $0 < \underline{E} < 1/2$ .

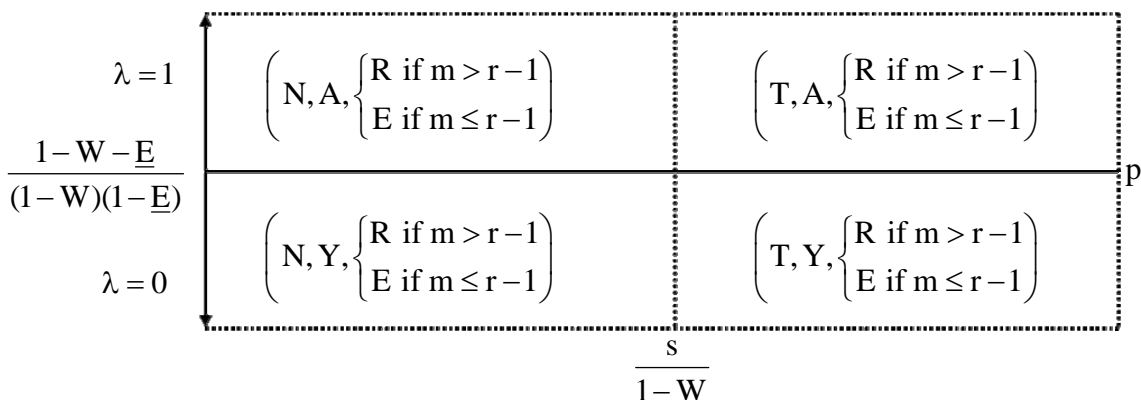
Now that the decision making process of the extended court game with legal insurance concerning the two  $\lambda$ -types has been described in detail, the paper will address and mathematically analyze the game for all constellations of  $\lambda$ - and  $m$ -types and show the effectiveness of the institutional components for reducing uncertainty and promoting trust in UtiC markets. It has to be noted that since different  $m$ -types rely on different choice probabilities to which the arbitration board reacts and since the arbitration board reacts differently towards  $\lambda=1$  and  $\lambda=0$  types<sup>11</sup>, the arbitration board's decision making is influenced by the evolution of the  $m$ - and  $\lambda$ -types and hence trustworthiness, morality as well as institutions (in the form of court decisions and insurances) co-evolve as projected in the introduction. From an analytical point of view it is consequently easiest to start the analysis of the model by looking at one of the coevolving components. In this paper this shall be the arbitration board, whose rulings and therefore influence on the total population depends on three cases, namely case (i) in which the probability that player 2 exploited player 1's trust ( $E(z)$ ) is smaller than the conviction threshold in case player 1 was insured ( $\underline{E}$ ), case (ii) in which  $E(z)$  is above the threshold  $\underline{E}$ , but below  $1/2$  (i.e. the conviction threshold in case player 1 was not insured) and case (iii) in which  $E(z)$  is above  $1/2$  [13].

Assuming that neither player 1 or the arbitration board can recognize player 2's  $m$ -type nor player 2 player 1's  $\lambda$ -type and the beliefs concerning  $m$  and  $\lambda$  are determined by the true population decision and keeping in mind the previous behavioural analysis, the following pictures can be drawn (see figure 5):

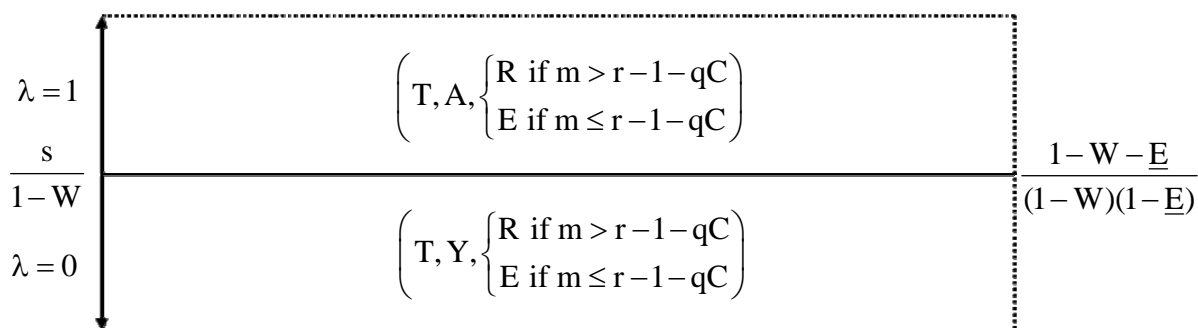
<sup>10</sup> It has to be noted that for all elements of  $z \in [0;1]$ , the functional values can never exceed  $W \geq 1/2$  (as  $f(0) = 1/2$ ,  $f(1) = 0$ ,  $f'(z) < 0$ ). This explains why the probability for an unintentional damage based on parametric effects  $W$  was restricted to the range  $[0;1]$ .

<sup>11</sup> It has to be noted that the arbitration instance only is able to identify player 1's  $\lambda$ -type when player 1 appeals to it, but not before that point. Consequently it has no superior detection capabilities.

case (i):



case (ii):



**Figure 5: Solutions Depending on Arbitration Board Rulings**

For both case (i) and case (ii), in figure 5, the ordinate indicates player 1's  $\lambda$ -type, whereas on the abscissa all composition parameters that are in line with the basic assumptions of the two cases are plotted, to indicate how behaviour depends on  $p$  in general as well as the specific  $m$ -type. Hence, the abscissa in case (ii) applies for  $p > s/(1-W)$ , whereas in case (i) the initial assumption  $E(z) < \underline{E}$ , which can be expressed as follows, needs to be kept in mind:

$$p > 1 - \frac{W\underline{E}}{(1-W)(1-\underline{E})} = \frac{1-W-\underline{E}}{(1-W)(1-\underline{E})}$$

In case (iii), due to  $E(z) > 1$ , player 1 will always appeal and player 2 always reward as otherwise he will be convicted. Due to this simplicity case (iii) is omitted in figure 5. With these results in mind, the co-evolution of the population composition  $p$ , the conviction probability  $q$  and the arbitration board rulings can be analyzed:

In case (i) both player 1  $\lambda$ -types choose  $N$  if the potential gains are lower than  $s$  (i.e.  $p(1-W) < s$ , a detailed explanation for this  $N$ -choice was given in chapter 2), and cooperate above this level. However only the  $\lambda=0$ -type would appeal to the court if he does not receive the promised output. As however, the arbitration board will always dismiss the cases since  $E(z) < \underline{E}$  and consequently  $q \rightarrow 0$ , in the long run the uninsured players will be evolutionary more successful, as they are not burdened with the insurance cost  $K$ , but achieve the same outcome as insured players in the game. Looking at the player 2s, a similar unilateral picture can be drawn: as defecting players earn more in the long run ( $r$ , instead of 1),  $p$  will decline, until it leaves the interval of case (i) and moves to case (ii), i.e.:



$$p = p(q \rightarrow 0) \rightarrow \frac{1 - W - \underline{E}}{(1 - W)(1 - \underline{E})}$$

In case (ii) both player 1 types choose  $T$ . In case of non-delivery, the insured ones appeal and win the case, whereas the uninsured ones yield. Thus the net outcome for the  $\lambda = 0$  types is  $p(1 - W) + (pW + 1 - p)C - K$ , whereas the  $\lambda = 1$  types earn  $p(1 - W)$ . For

$$\frac{C - K}{C(1 - W)} < p$$

this leads to  $q \rightarrow 0$  and therefore  $p$  decreases till the range of (ii) is left. In the opposite case, however,  $q$  would approach 1 and  $p$  would increase until it leaves the range of (ii):

$$p = p(q \rightarrow 1) \rightarrow \frac{1 - W - \underline{E}}{(1 - W)(1 - \underline{E})} \text{ for } \frac{C - K}{C(1 - W)} > p \left( > \max \left\{ \frac{s}{1 - W}; \frac{1 - 2W}{1 - W} \right\} \right)$$

Last but not least, if case (iii) is reached,  $p$  and  $q$  will decrease again, leaving the evolutionary dynamics to come to an interior rest point at  $(1 - W - \underline{E}) / ((1 - W)(1 - \underline{E}))$  as shown in figure 6.

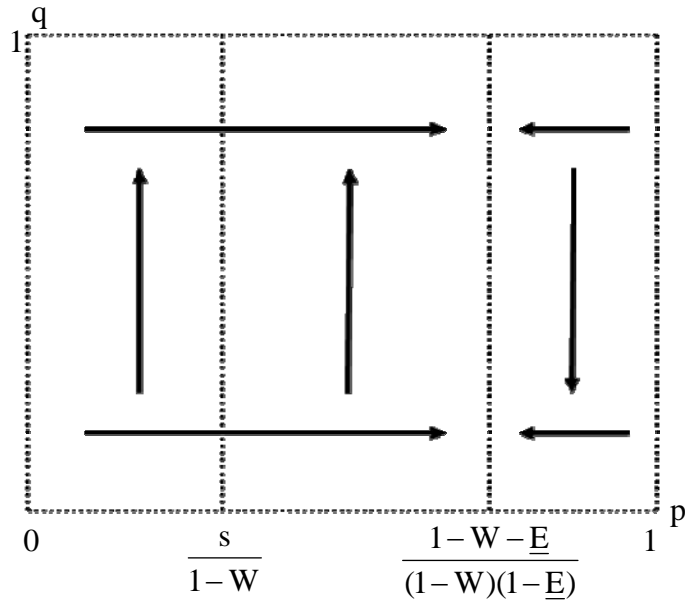


Figure 6: Evolutionary Dynamics of the Court Game with Legal Insurances

By reaching this rest point, the institutions have helped the system to come to an equilibrium besides the ones described in chapter two and three. However, in contrast to the equilibria shown before the institutions do not foster strategic behavior (or lead to undesired market outcomes), but cultivate cooperation and trustworthiness in an UtiC market where no type detection capabilities are at hand and where the institutions cannot rely on any superior knowledge about the individual players.

## 5. Conclusion

As shown in this paper, with the help of institutions such as court rulings and legal insurances, it is possible to increase trust and reduce strategic uncertainty in open environments such as UtiC markets, where type-detection mechanisms are not feasible. Thus, even when not being equipped with superior type detection capabilities, arbitration boards may crowd in reliability and together

with legal insurances lead to long-term market states with a strictly positive share  $p$  of trustworthy players, where cooperation is rewarded.

As however, the assumptions of the model are slightly restrictive with regard to the “real world” and due to the parameter-dependent limitation of sub-cases for the mathematical analysis in a next step the model shall be expanded even further. Thus, in the future work a step-wise expansion of the parameter space in combination with a reduction of the restrictive assumption is planned which then shall be analyzed with the help of simulation. Furthermore, it might be fruitful to not exclude reputation mechanisms completely from the model, but analyze their impact on as well as potential trust-enhancing contribution in combination with the model presented in this paper.

Putting everything in a nutshell, this paper presented a model for fostering trust and cooperation in UtiC markets, which, despite its parameter- and restriction-caused limitations, tackles a problem whose solution is essential for the future development of this promising area of UtiC markets.

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