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OPPORTUNISM, TRUST AND COOPERATION:

A GAME THEORETIC APPROACH WITH HETEROGENEOUS AGENTS

Abstract

Even when there is a potential danger of opportunism, economic agents often initiate contracts or engage in trust. Considering a world with two types of agents, opportunists and non-opportunists, interacting under incomplete information, this paper develops a simple two stage game theoretic model to show how trust and cooperation can emerge in a one-shot interaction, even in the absence of a supporting incentive mechanism. Two classic paradigms are considered: the prisoner's dilemma and the game of chicken. In the context of the prisoner's dilemma trust depends on the exogenous probability of having a non-opportunist partner; while in the game of chicken trust is purely a function of the payoffs. Contrary to intuition, a high ratio of non-opportunistic agents in the population does not favor contract initiation in the game of chicken and a strong presence of opportunists does not act as an impediment to respecting commitments.

KEY WORDS • Non-cooperative games • Incomplete Information • Trust • Cooperation.

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OPPORTUNISM, TRUST AND COOPERATION: A GAME THEORETIC APPROACH WITH HETEROGENEOUS AGENTS

Introduction

In real life, economic agents often initiate contracts even when there is a potential danger of opportunism, i.e. non-respect of commitments. A couple might decide to get married and promise each other to stay together for better or worse, though being aware that it might not turn out that way. Parents might hire a babysitter to play with their child, knowing well that the child might simply be seated in front of the television as soon as they are gone. Similarly, two political parties might form a coalition to win an election, taking the risk that once the election is won, they might not always support each other on state issues. Two firms might initiate an R&D consortium to share costs and information, even though after the initial investment is undertaken, one of the firms might not share the knowledge that is generated. The list can go on and on. The objective of this paper is thus to explore under which circumstances trust can emerge even when there is a risk of opportunism.

Most economic models attempting to find solutions to eliminate opportunism propose one of the following two methods: (i) a static approach involving contracts or (ii) a dynamic approach, with either contracts or some other type of incentive mechanism. There is an extensive literature on contract formulation that discusses how reward cum punishment schemes can be embedded within contracts, so as to make any opportunistic behavior yield a lower payoff than respecting the contract (For surveys see Salanié 1998; Tirole 1999). A vast literature also examines the ways to counter opportunism through implicit[1] or explicit systems of reprisal in the context of repeated games, involving termination of interaction, loss of reputation or loss of trust (Friedman 1971; Kreps and Wilson 1982; Kreps et al. 1982; Kreps 1990). A common feature of the above mentioned models is that all agents are assumed to be opportunists or equivalent to agents who will not respect their commitment unless it is in their interest to do so. In fact, even in the case of games with incomplete information, where cooperation emerges because each agent has a small doubt about whether or not his fellow player is an opportunist, all players are assumed to be opportunists.

If opportunism can be purged out as the above theory suggests, why are there such widespread manifestations of opportunism in the real world? There are three possible explanations. First, the opportunism observed could correspond to an equilibrium strategy of a repeated game, when it no longer pays to cooperate. Second, opportunism may emerge, when agents are forced to initiate contracts that are not optimally designed, due to institutional rigidities or agent specific constraints. Third, opportunism may arise, because the world is not made of homogeneous agents, but consists of a mix of opportunists and non-opportunists, so that under certain circumstances, it is not possible to formulate general conventions or optimal contracts.

The last explanation will be our starting point to account for the coexistence of opportunism alongside cooperation. In this paper we consider a world with two types of agents: *opportunists* or potential defectors and *non-opportunists* or cooperators. The actions of the non-opportunistic agents in the population are motivated by considerations other than opportunism (e.g. self-respect, altruism, moral values, ethical considerations etc…). They simply do not have the option to deviate on their commitments. The remaining agents are opportunists, who can defect whenever it is in their interest to do so.

In such a heterogeneous world, if there is incomplete information, i.e. if economic agents cannot distinguish the real nature of other agents, each agent makes his decision on the basis of an a priori belief on the type and strategic behavior of the other agent. Cooperation is ensured if a contract is initiated with either a non-opportunist or an opportunist who will respect his engagement.

In our paper, trust indicates the actors' decision to initiate a contract, where the term "contract" is used in a large sense including all explicit and implicit agreements. Two actors must decide whether or not to initiate cooperation with each other even when there is a potential danger of opportunism, or non-respect of a contract. In his comment on Williamson's article on "Calculativeness, Trust and Economic Organisation" (Williamson 1993), Craswell (1993) introduces a distinction between trust as a *explanans* and trust as a *explanandum*. Trust serves as *explanans* when it explains a certain type of behavior. On the other hand, trust is an *explanadum* when it just describes or refers to a specific behavior in a strategic interaction. We use the term "trust" in the *latter sense* to indicate the instigation of a formal or informal contractual relationship. Trust, that is to say the action of initiating a contract, is conditioned by the belief that one has about a potential cooperative behaviour on the part of the partner.

Adopting this approach, the present paper examines whether trust and cooperation can be sustained in a one-shot interaction without any form of incentive system to support it or induce it. According to the economics literature, this is anything but evident as a recent survey states "trust can be achieved in a roundabout way through institutional and other devices that give individuals an incentive to be trustworthy" (James 2002). While our presentation and use of trust as an *explanandum* is consistent with the standard interpretation in the economics literature, we show that there can be contract initiation and cooperation even without a carrot-and-stick mechanism. Indeed, the original contribution of the present model is to prove that trust and cooperation can emerge even in the *absence of an incentive system* in a one-shot interaction. The computations corresponding to the emergence of trust are shown to be based on the exogenously given probability of having a non-opportunist partner and the endogenously calculated strategy of an opportunist to respect the contract.

In the framework of repeated games with complete or incomplete information (and with a finite or infinite horizon), the emergence of cooperation with two types of agents who differ in their propensity for opportunism has been studied in some papers (Ghosh and Ray 1996; Watson 1999). These models identify the conditions under which trust and cooperation emerge provided that agents can initiate a contract and/or can interact *repeatedly*. Cooperation emerges because any manifestation of opportunism results in a penalty, such as the breakdown of trust, reputation and transactions. In other words, economic agents are motivated to trust and cooperate on the basis of calculations over time. This of course leads to the question, can trust and cooperation ever emerge in one shot interactions under incomplete information, when it is not possible to put in place an appropriate incentive mechanism to eliminate opportunism?

Contrary to what happens in the game theoretical models evoked earlier, in our model, trust cannot emerge on the basis of any "rewards cum punishments scheme", because it considers a one-shot sequential game, where there is no explicit or implicit social contractual arrangements to foster trust. It supports and is supported by experimental evidence that confirms the existence of trust and cooperation even in one-shot interactions (Berg et al. 1995; Guth et al., 1997). Such decisions could not have been deduced from an "incentive mechanism" in a one shot game, where players are sure to remain anonymous. On the contrary, according to the standard game theory, players should have chosen to *not initiate* cooperation in such games. Three kinds of explanations have been proposed. Certain individuals could be programmed genetically to have trust in others and cooperate (Ridley 1997). Cheating could engender psychological costs (Bolton and Ockenfels 2000). Players could have cognitive limits and have trouble adjusting rules of thumb developed from repeated games to one-shot games (Goeree and Holt 2001). Our model proposes yet another explanation, the heterogeneity of economic agents coupled with incomplete information, could under certain circumstances, lead to the realization of cooperation as an equilibrium phenomenon, even in the absence of a supporting incentive mechanism.

Starting with the two-fold assumption of heterogeneous players and incomplete information a simple two-player, two-stage Bayesian game is presented. Each player is either of the opportunistic type or of the non-opportunistic type. In the first stage of the game, each of the two players decides whether or not to initiate a contract. The contract is not initiated unless both of them want to do so. In the second stage, the opportunists decide whether or not to deviate. Opportunism and defection are synonymous with non-respect of contracts. Cooperation occurs whenever a contract is initiated and all type of players respect the contract, i.e. the opportunist respects the contract in the second stage, even when he has the option to deviate. The analysis is stopped here without going into the problem of optimal contract design, because various punishment cum reward schemes are possible to eliminate opportunism and render redundant the study of its relationship to trust.

The contribution of the present paper to the game theoretical literature on trust, opportunism and cooperation can be understood as follows.

First, it gives insight on the conditions of emergence of trust in a one-shot game. It shows that trust is mainly a function of an exogenous parameter: the structure of the population mix or the ratio of the opportunists and non-opportunists in the population. Any endogenous component of trust is actually determined by the structure of the population mix and the payoff configuration. Thus, the present paper provides a better understanding of the strategic foundations of trust.

Second, it identifies the conditions under which trust and cooperation transpire between rational agents in a *non-repeated context*, when no reward cum punishment scheme exists to eliminate opportunism. Two classic game configurations are studied: the “prisoner’s dilemma” and the “game of chicken”.

Under a “prisoner’s dilemma context”, trust depends on only one parameter, the structure of the given population mix, and more specifically, the probability of encountering a non-opportunist. Trust can emerge if and only if the ratio of non-opportunists is sufficiently high. Furthermore, vis-à-vis non-opportunist players, opportunists are willing to initiate contracts in populations containing a lower proportion of non-opportunists. There is respect of engagements only if two non-opportunists initiate a contract.

In contrast, in the “game of chicken”, trust does not depend on the structure of the population. Surprisingly, the ratio of the non-opportunists or the probability of not encountering an opportunist does not influence the decision to initiate a contract. Contract initiation is determined uniquely by the payoff configurations and is identical for both types of players. Here, cooperation can be realized even by opportunists, provided that the ratio of non-opportunists is sufficiently low. While the decision of an opportunist to respect a contract depends on the structure of the population mix and the payoff configuration, the proportion of opportunists in the population which chooses to respect the contract is independent of the initial population mix.

The above results lead us to reconsider some empirical truisms on trust and economic performance. For instance, in the game of chicken, a high ratio of non-opportunistic agents in the population does not favor contract initiation or trust. In the same non-intuitive vein, a strong presence of opportunists does not act as an impediment to respecting commitments.

In the following section, we describe the basic model of the two-stage, two-player Bayesian game. Then, we present the propositions concerning the relationship between opportunism, trust and cooperation, inferred from the behavior of the agents at equilibrium. Finally, we conclude.

The Model

Consider a two stage game, with two agents, *i* and *j*, who can be one of two types, opportunist or non-opportunist, indicated by $t_i = \{t_{i,o}, t_{i,n}\}$ and $t_j = \{t_{j,o}, t_{j,n}\}$. An opportunist is a player, who can defect, whenever it pays to do so. A non-opportunist is a player, who never defects on principle. The actions of the non-opportunistic agents in the population are motivated by considerations other than opportunism (e.g. self-respect, altruism, moral values, ethical considerations etc…). Their actions can be observed, but there is incomplete information about the type of each agent. Let $p \in (0,1)$ be the belief of each player that the other player is an opportunist. It is exogenously given and common knowledge to all players. The fraction *p* is also equivalent to the proportion of opportunist players in the population.

The game is symmetric with the payoff structures and the beliefs of the same type of players *i* and *j* being identical. The endogenous belief of each player that his fellow player will defect if he is an opportunist is given by the probability α and it lies in the interval (0,1). The beliefs of players *i* and *j* that they will not be cheated upon if they enter into a contract with each other is then given by the probability $(1 - p\alpha)$. Evidently, this is the probability of observing cooperation whenever a contract is initiated.

The game begins with nature, which chooses the types of players *i* and *j*. Given a type profile, the two players begin their game by deciding whether or not to initiate a contract. Trust emerges only if both players initiate a contract. If a contract is not initiated, the players *i* and *j* get *N*, where $N \in (0,1)$. If a contract is initiated or trust is manifested, the two players move on to a second stage, in which the contract is implemented. The simultaneous choice of actions in the first stage is revealed at the end of the period, and it leads to a revision of beliefs according to Baye's rule, with the standard assumption that posterior beliefs are independent and all types of player *i* and *j* have the same beliefs. Let $\hat{p}$ be the revised belief that the partner is an opportunist at the end of the first stage[2].

In the second stage, an opportunist has two possible actions to choose from. Either he can defect on the contract (*d*) or he can respect the contract (*r*). In the second stage, a non-opportunist has only one option and that is to respect the contract. In other words, the 'type' of the player determines his 'action space' in the second stage after the initiation of a contract[3].

The payoff function of player *i* in the second stage (and similarly for player *j*), is $\pi_i(.)$, a function of the actions chosen in the second stage by both players and constructed so as to exhibit the following standard properties:

- For any opportunist player, when the other is respecting the contract, defection yields a higher payoff than respecting the contract.
- If cheated upon, any kind of player get less than under non-cooperation or cooperation.
- Both players gain more if the contract is respected by all than when both defect.
- Initiation of the contract is of economic interest to both parties, i.e. if it is respected by all parties, it yields a higher payoff than non-cooperation.
- The payoff from respecting the contract is the same for all type profiles.

The payoff functions for the second stage of our symmetric game are normalized as follows. When both players defect in the second stage, the payoff to both players is 0. When both players respect the contract in the second stage, the payoff to both players is 1. If an opportunist defects, while his partner respects the contract, the former gets 1+ *H* (or a high payoff), where *H* is a positive real number.

Even when all the above properties of the payoff functions are satisfied, the game can be played under *two possible environments*. When an opportunist defects and the other player respects the contract in the second stage, the other player can get either less or more than when both players cheat. Thus, there are two possibilities:

- The prisoner's dilemma configuration, under which defection is a dominant strategy in the second stage for an opportunist. Here any player who is cheated upon gets $-L < 0$ and we have $1+H > 1 > N > 0 > -L$. Recall that N is the first stage payoff for non-initiation of contract and $0 < N < 1$.
- The game of chicken, in which defection is not a dominant strategy in the second stage for an opportunist. In this case, any player who is cheated upon gets $L > 0$, such that $1+H > 1 > N > L > 0$.

The game is illustrated in figure 1.

Figure 1: The trust game in the two contexts

Note: The first term in each cell of the matrix represents the payoff to player i, while the second term represents the payoff to player j. If a contract is not initiated, each player gets N (with *0*<L<N<*1*)

Prisoner's dilemma

player *i* \ player *j*	r	d
r	1 ; 1	-L ; 1+H
d	1+H ; -L	0 ; 0

Game of chicken

player *i* \ player *j*	r	d
r	1 ; 1	L ; 1+H
d	1+H ; L	0 ; 0

It is evident that our game is set in a prisoner's dilemma or chicken environment, depending upon whether the payoff from getting cheated upon is negative or positive. It is to be noted that both these contexts are classical game theoretic paradigms of social dilemmas, referring to situations in which rational individual behavior leads to an outcome in which everyone is worse off than they would have been otherwise. The leading game theoretic metaphor to characterize social dilemmas is the “prisoner’s dilemma”, where cooperative acts incur costs to the cooperators while yielding benefits to defectors. Standard texts abound with examples of real-life manifestations of the prisoner’s dilemma, such as in overinvestment on advertising, patent races, over depletion of natural resources etc. The “game of chicken” has been less studied, but it is an equally interesting context, where the benefits of cooperative acts not only accrue to others but also to the cooperator (also called a hawk-hove game). The game of chicken is often used to model social dilemmas where one of the players tries to influence the others to pursue a certain strategy through threats or brinkmanship, as it often happens in conflicts of all sorts, whether at a personal, institutional, market, national or international level (Witt and Wilke, 1992, Kollock, 1998).

Given the above structure of the game, a set of beliefs and strategies form a perfect Bayesian-Nash equilibrium if for every player, of every type, and every history in stage 1, (Fudenberg and Tirole, 1991, pp. 331-332)[4]:

- The Nash strategy maximizes the expected payoff in the second stage, under the revised beliefs and the observed outcomes of the first stage.
- The Nash strategy maximizes the expected payoff in the first stage given the initial beliefs.

The identification of these equilibria permits the formulation of the propositions given in the next section.

Results and Discussion

We now present the propositions that examine the relations between trust, initiation and respect of contracts. The two environments: “prisoner’s dilemma” and “chicken” are treated separately[5].

The prisoner’s dilemma context

We will begin by showing that for any configuration of beliefs, under the prisoner’s dilemma paradigm, the only sustainable belief about second stage behavior by opportunists, α , is that opportunists will always defect in the second stage or $\alpha = 1$.

For any player *i*, of any type and any belief $\hat{p}$ and α, where $\hat{p}$ is the revised belief about the partner being an opportunist, and α is the belief that such an opportunist will defect in the second stage, the expected payoff from respecting the contract in the second stage is:

$$E[\pi_i(r,.,.)\,|\,\hat{p},\alpha] \;=\; \hat{p}(1-\alpha)-\hat{p}\alpha L+(1-\hat{p})=1-\hat{p}\alpha(1+L)$$

The above equation indicates that if any player initiates and respects a contract, there are three possibilities: the partner can be an opportunist, who chooses not to defect, or he can be an opportunist who chooses to defect, or he can be a non-opportunist. The probabilities of these three events are $\hat{p}(1-\alpha)$, $\hat{p}\alpha$ and $1-\hat{p}$ respectively, with the corresponding payoffs of 1, $-L$ and 1. The expected payoff from contract initiation is then obtained by multiplying the probability of an event with the payoffs associated with the same event and adding such products of all possible events.

Similarly, if a player weighs the expected payoff from defecting on the contract in the second stage, he faces the same three possibilities, this time with the payoffs $1+H$ if his partner is an opportunist who respects the contract, 0 if his partner defects and $1+H$ again if his partner is a non-opportunist. Formally, the expected payoff for an opportunist from defection in the second stage can be written as:

$$E[\pi_i(c,.,t_{i,o})\,|\,\hat{p},\alpha] \;=\; \hat{p}(1-\alpha)(1+H)+(1-\hat{p})(1+H) = \;(1-\hat{p}\alpha)(1+H)$$

Thus, an opportunist will always cheat if:

$$1-\hat{p}\alpha(1+L) \;<\; (1-\hat{p}\alpha)(1+H) \Leftrightarrow H > \hat{p}\alpha(H-L).$$

If $L < H$ then the above equation holds since $\dfrac{H}{(H-L)} > 1 > \hat{p}\alpha$.

If $L > H$, when we divide by a negative entity *(H-L)* the signs change and again the equation always holds since $\dfrac{H}{(H-L)} < 0 < \hat{p}\alpha$.

Therefore for any configuration of revised beliefs, it is always better for an opportunist to defect in the prisoner's dilemma payoff configuration, and the only belief about α that can be sustained at equilibrium is that α =1.

Now the interesting question to ask is: does systematic defection on contracts by opportunists in the second stage necessarily eliminate the possibility for contract initiation in the first stage?

Any agent will initiate a contract, only if the expected returns are greater than or equal to the payoff from non-initiation. Recall that in the first stage, the initial belief that a fellow player will be an opportunist is p and decisions about contract initiation are therefore made with the beliefs p and α =1. Now, suppose player i is a non-opportunist. If he initiates a contract, he can either meet an opportunist, be cheated upon and gain $-L$ or he can play with a non-opportunist and gain 1. He will initiate a contract and exhibit trust only if contract initiation yields a higher pay-off than non-initiation i.e. :

$$p(-L)+(1-p)\geq N\,;$$

$$\Leftrightarrow (1-p)\geq \frac{N+L}{1+L}=T_n\,.$$

Clearly, since N lies between 0 and 1, T_n is positive and less than 1.

Now, suppose player i is an opportunist with the beliefs p and α =1. If he initiates a contract, with an opportunist, he will be cheated upon and gain 0 and with a non-opportunist he will obtain $(1+H)$. In this case, he will initiate a contract, and show trust if:

$$(1-p)(1+H)\geq N \;\Leftrightarrow\; (1-p) \;\geq\; \frac{N}{(1+H)} = T_o\,.$$

Again T_o is positive and less than 1.

We have thus determined the conditions for the emergence of trust for both types of players. A non-opportunist initiates a contract whenever the ratio of non-opportunist or the probability of encountering a non-opportunist is greater than T_n and an opportunist follows suit if it is above T_o. This in turn leads to another question: *for which type of agent is it easier to engage in trust ?*

Recall that under the prisoner’s dilemma, there is a minimum necessary ratio of non-opportunists for contract initiation for both types of players. For an opportunist, this limit is T_o, which is always lower than T_n, the limit for a non-opportunist. The difference arises from the fact that encountering an opportunist in the second stage always yields a lower payoff for a non-opportunist as compared to an opportunist. Suppose $H>L$, then by simple examination of T_n and T_o, we can conclude that $T_o<T_n$. Suppose $H<L$, by cross multiplying and bringing all terms to one side we have $T_o<T_n \Leftrightarrow NH+HL+L(1-N)>0$, which is always true since $N<1$.

Given that the ratio of non-opportunists necessary to induce trust is lower for an opportunist relative to an non-opportunist, both types of agents will exhibit the same behavior in the first stage whenever $(1-p)\geq T_n$ or $(1-p)<T_o$. In the former, in view of the fact that

the conditions for contract initiation are satisfied for both types, all will opt for contract initiation, and in the latter, since the trust requirements are not satisfied for any type of player, both types will opt for non-initiation of contract. In these two cases, no further inference can be made on the type of the players at the end of the first stage.

However, when the ratio of non-opportunist is between T_o and T_n, opportunists will initiate the contract in the first stage, while non-opportunists will not. This means that player type can be inferred at the end of the first stage. There will be contract initiation only if both players are opportunist, but at this point, the revelation of the type of the player has no impact on the second stage outcome.

The above reasoning then permits us to describe the outcome of the trust game in the prisoner's dilemma environment as below.

The perfect Bayesian Nash equilibrium in the prisoner's dilemma context is such that:

- *When* $(1-p)\geq T_n$, *every type of player initiates a contract in the first stage; revised beliefs are the same as initial beliefs and opportunists cheat in the second stage.*
- *When* $(1-p)<T_o$, *no type of player initiates a contract in the first stage and revised beliefs are the same as initial beliefs.*
- *When* $\{T_n>(1-p)>T_o\}$, *opportunists initiate the contract in the first stage, non-opportunists do not initiate the contract in the first stage. The revised beliefs are such that any player who initiates the contract is revealed to be an opportunist and any player who does not initiate the contract is revealed to be a non-opportunist at the end of the first stage.*

This result highlights two interesting features of contract initiation when it is common knowledge that cooperation is not possible or that opportunists will always deviate in the second stage.

First, if $(1-p)$ is interpreted as the proportion of agents in a population who are non-opportunist, then a minimum proportion of non-opportunists $(1-p)>T_o$ is required in an economy for contract initiation. Here, trust is based on the evaluation of the probability of falling upon a non-opportunist or $(1-p)$. Agents initiate a contract, only if they believe that the likelihood of meeting an opportunist is sufficiently low, so as to justify the risk of initiating a contract. This is tantamount to stating that the trust in the system is an increasing function of the proportion of non-opportunists in the population.

Second, opportunists can exhibit trust in populations with a higher ratio of opportunists as compared to non-opportunists. All that opportunists require is a minimum level of "suckers" to exploit, in order to exhibit trust. On the contrary, non-opportunists tend to be more wary and need to be insured of a higher level of non-opportunists to initiate contracts.

The game of chicken

In the context of a game of chicken, there are multiple equilibria and since defection is not a dominant strategy, it is possible that at least in some equilibria there is cooperation. Indeed, depending on initial payoff configurations four types of equilibrium outcomes are possible:

- Both types of players initiate a contract in the first stage and opportunists respect the contract with a positive probability $\left(1-\alpha\right)>0$ in the second stage.
- Both types of players initiate a contract in the first stage and opportunists defect in the second stage, making it similar to the prisoner's dilemma paradigm.
- No player initiates a contract in the first stage given that the equilibrium strategy of opportunists is to defect in the second stage.
- No player initiates a contract in the first stage given that the equilibrium strategy of opportunists is to respect the contract in the second stage with a positive probability $\left(1-\alpha\right)>0$.

In order to avoid a plethora of proofs, we focus only on the first type of outcome where cooperation can be observed as opportunists respect their commitments with a positive probability $\left(1-\alpha\right)>0$ in the second stage[6].

Whenever a contract is initiated, in the second stage of the game, for an opportunist, with the revised belief $\hat{p}$ that his partner is an opportunist, the expected payoff from respecting the contract is greater than or equal to that from defection on the contract if:

$$\left[\hat{p}[(1-\alpha)+\alpha L]\right]+(1-\hat{p})\geq\left[\hat{p}(1-\alpha)(1+H)\right]+(1-\hat{p})(1+H)$$

Both the left hand and the right hand sides of the above equation take into account the three possibilities after contract initiation: either the partner can be an opportunist, who respects the contract, or he can be an opportunist who defects, or he can be a non-opportunist. The probabilities of these three events are $\hat{p}(1-\alpha)$, $\hat{p}\alpha$ and $1-\hat{p}$ respectively with the corresponding payoffs being 1, L and 1 in the case of respect and $(1+H)$, 0 and 1 in the case of defection by the player (and not the partner) concerned.

The terms can be rearranged so that the above equation becomes:

$$(1-\hat{p}\alpha) \leq T = \frac{L}{H+L}$$

This reveals two interesting features of cooperation.

First, cooperation is possible but never certain in a chicken game. In other words, any perfect Bayesian-Nash equilibrium must involve completely mixed strategies for an opportunist, whereby in the second stage, the opportunist respects the commitment with a positive probability, i.e. $0 < 1-\alpha < 1$. Given that *T* lies strictly between 0 and 1, α cannot be equal to zero. Neither can α equal 1 for then it means that an opportunist will always defect in the second stage, and this is not possible since we are in the context, where the expected payoff from respecting the contract is greater than that from defection upon the contract. In fact, it can be shown that the exact probability with which an opportunist will respect the contract, when the expected returns to respecting the commitment are greater than that from defection at the second stage is $(1-\alpha) = 1 - \frac{1-T}{\hat{p}}$. The proof is detailed in the appendix.

Second, a necessary condition for cooperation is that the probability of non-defection is not too high. When the probability that a partner respects a contract, $(1-\hat{p}\alpha)$, is above a value *T*, it is always optimal for an opportunist to deviate in the second stage. The intuition behind this is clear when we look again at the payoff structure of the chicken game (see figure 1). The two pure strategies that form the equilibrium are those where it is optimal for a player to respect the contract if he anticipates that his partner is going to defect.

Let us turn to contract initiation in the first stage now.

Consider a situation where the initial belief is the same as the revised one; i.e. $p = \hat{p}$. In other words, suppose both players choose the same action in the first stage of the game so that no further information is revealed about the type of the player. Can this be an equilibrium outcome?

In the first stage, a non-opportunist player, with first stage beliefs p and α, expects to meet an opportunist who will respect the contract with probability $p(1-\alpha)$ or who will defect on the contract with probability $p\alpha$ or play with a non-opportunist with probability $(1-p)$. Given that the above options lead to gains of 1, L and 1 respectively, he will opt for contract initiation, if the returns are greater than from non-initiation:

$$p\left[(1-\alpha)+\alpha L\right]+(1-p)\geq N .$$

Re-writing the above equation, it can be shown that a non-opportunist will initiate a contract, if:

$$(1- p\ \alpha) \geq T_n^{'} = \frac{N-L}{1-L}.$$

Then substituting for $\alpha = \frac{(1-T)}{\hat{p}} = \frac{(1-T)}{p}$, the optimal probability of an opportunist to defect, and $T = \frac{L}{H+L}$ in the above equation, we get that a non-opportunist will opt for contract initiation and he will always respect the contract in the second stage if the following condition holds:

$$\frac{L(1+H)}{H+L} \geq N \Leftrightarrow T > T_o$$

Let us now turn to the opportunist. An opportunist with the first stage beliefs, p and α, will initiate a contract, if the expected returns from contract initiation are greater than from non-cooperation, i.e. if:

$$p\left[\left(1-\alpha\right)^2+\left(L+H+1\right)\alpha\left(1-\alpha\right)\right]+\left(1-p\right)\left[(1-\alpha)+(1+H)\alpha\right]\geq N \ .$$

The above equation is obtained by the same logic as in the preceding cases. The left hand side gives the reward from non-initiation namely N. The right hand side indicates the payoff to the opportunist from contract initiation. In the chicken game, an opportunist can enter into one of four possible states:

- Play with another opportunist, with both of them respecting the contract. The probability of this event is $p(1-\alpha)^2$ and the associated gain is 1.
- Play with another opportunist, with one of them defecting on the contract. This can occur with a probability $p\alpha(1-\alpha)$. When the player concerned defects while his

partner respects the contract, his payoff is $(1+H)$. When the player is cheated upon while respecting the contract, he gets L.

- Play with a non-opportunist, and respect the contract, the likelihood of which is $(1-p)(1-\alpha)$. In this case, the agent gets 1.
- Play with a non-opportunist and defect. The odds on this last type of event are $(1-p)\alpha$, in which case he obtains $(1+H)$.

Again substituting for the optimal value of α as $\frac{(1-T)}{p}$ and the value of T, we get that a contract will be initiated by an opportunist whenever $T > T_o$.

Thus, the condition for contract initiation by an opportunist and by a non-opportunist is the same. Both of them will initiate a contract if $\frac{L(1+H)}{H+L} \geq N$; otherwise not. This implies that the starting assumption of $\hat{p} = p$ is validated, since both types of players choose the same action in the first stage and subsequent Bayesian updating does not yield any further information.

The above results then enable us to describe a perfect Bayesian Nash equilibrium for the chicken environment as follows.

Under the chicken configuration, whenever $(1-p) < T$ and $T > T_o$, *at the symmetric perfect Bayesian Nash equilibrium:*

- *The belief structure is* $\alpha = \frac{(1-T)}{p}$ and $p = \hat{p}$.
- *A non-opportunist initiates a contract and respects it thereafter.*
- *An opportunist initiates a contract and respects it thereafter with a probability* $(1-\alpha)$.

Whenever the proportion of non-opportunists is below an upper limit dictated by the payoff configuration, i.e. $(1-p) < T$, an opportunist cannot defect with certainty as the inequality implies that returns from defection yield less than from respecting the contract. Then the resolution of equilibrium in the game of chicken indicates that an opportunist will respect the contract in the second stage with a positive probability $(1-\alpha)$ that is a function of both the ratio of player types and the payoff configuration. The actions of both types of players in the first stage, or their capacity to engage in trust is however dictated only by the payoff structure occurring whenever $T > T_o$.

The analysis of the game of chicken permits us to make a number of inferences on the emergence of trust and cooperation.

- *Partner " type" is not taken into account at all in the decision making on contract initiation or trust engagement.* Generally speaking, a higher probability of encountering a non-opportunist is held to favor contract initiation between agents, as it represents a kind of insurance against free-riding. However, the equilibrium reveals that once the plausibility of cooperation is ensured by a minimal level of non-opportunists in the population, it plays no role in the initiation of contract for both types of players. Trust depends only on the payoff configuration.

- *An opportunist has a greater incentive to respect a contract when the proportion of opportunists in the population is higher (or (1-p) is lower).* Since $\alpha = \frac{(1-T)}{p}$, for a given value of *T*, higher the value of *p*, or higher the probability of encountering an opportunist, lower the value of α, or the probability with which an opportunist will defect in the second stage. It is as if there is an implicit sanction embedded in the form of the possibility of reprisal from a like-minded agent, which leads the opportunist to respect the contract. This is also paradoxical, because such a supposition is at loggerheads with the widely held notion that a high proportion of opportunistic agents leads to the failure cooperation.

- *The proportion of opportunists who defect is independent of the initial population mix, depending only on the payoff configuration.* Interestingly, lower the proportion of opportunists in the population, *p*, greater the incentives for the opportunist to defect, or higher the value of α. However, at the same time, as *p* decreases, the proportion of non-opportunists, $(1-p)$, increases and this compensates for the increase in incentives for defection, so that the *actual* proportion of opportunistic agents defection at equilibrium is solely determined by the payoff configuration in the form of *T* rather than the initial population mix. In other words, the fraction of agents who defect in the economy is given by $p\alpha$ and since $p\alpha = 1 - T$ and T is determined by the payoff structure, we have the result. Thus, a greater or smaller level of non-opportunists does not alter the proportion of agents who actually "defect".

- *High returns to defection, H, decreases the chances of contract initiation, while high returns to being cheated upon, L, increases the chances of contract initiation.* Finally, only the parameters H and L influence the choice to cooperate. When cooperation is plausible, contracts are initiated or trust is manifested, when the returns, $\frac{L(1+H)}{H+L}$, are bigger than that from non-initiation, N. The former is clearly a decreasing function of H and an increasing function of L. Clearly when an opportunist contemplates cooperation, if the payoffs to defection are very high for his partner, it implies that he is more likely to defect and the contract itself becomes less profitable. At the same time, if the opportunity costs of being cheated upon are reduced, any player is more willing to enter into a contract.

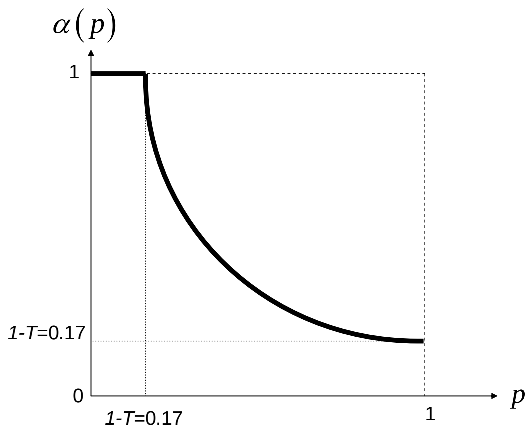
Here, we illustrate the results that have been derived with a simple example that also allows us to highlight some interesting behavioral patterns at equilibrium. Consider the following structure of payoffs for the second stage of the game as given in table 1, which conforms to the chicken configuration. Let N = 0.6 be the payoff from non-initiation in the first stage. For the above example, $T = \frac{L}{H+L}$ = 0.83; $T_o = \frac{N}{1+H}$ = 0.54; $T_n^{'} = \frac{N-L}{1-L}$ = 0.2.

Table 1: Payoffs in the second stage

		Player j	
		Respect	Defect
Player i	Respect	1,1	0.5,1.1
	Defect	1.1,0.5	0,0

We can therefore distinguish two situations.

- A population with a high proportion of non-opportunists, or where players believe that the probability of encountering an opportunist is low, as when $(1-p) > T$ or $p \in (0, 0.17)$. Here following the preceding analysis, both types of players will initiate contracts, but opportunists will choose to defect in the second stage given their strong belief that their partner is a non-opportunist.
- A population with a low proportion of non-opportunists, or where it is common knowledge that the probability of encountering an opportunist is high, as when $(1-p) < T$ or $p \in (0.17,1)$. Here, all players will initiate contracts because $\frac{L(1+H)}{H+L} \geq N$ and even if two opportunists are picked out by nature, they will both respect the contract with a positive probability $(1-\alpha(p)) = 1 - \frac{1-T}{p} = 1 - \frac{0.17}{p}$. The probability of defection $\alpha(p)$ can be represented as a function of the proportion of opportunists, *p*, as in figure 2.
- Finally, in the second type of situation, the proportion of the agents who defect in the second stage will remain stable for any value of *p* at $(1-T)$ = 0.17 or 17%. The ratio of those who defect depends only on the payoff configuration $(1-T)$ and not on beliefs.



Discussion on applications

The application of our model can throw light on the emergence of trust and cooperation in situations that mime a prisoner's dilemma or a game of chicken. Here we give a few examples.

An established result in the game theoretic literature on R&D cooperation is that a high degree of knowledge spillovers promotes R&D cooperation (d'Aspremont and Jacquemin 1988). However, this proposition is not confirmed by reality where there is a lack of wide-spread inter-firm cooperation even in knowledge intensive sectors (e.g. biotechnology) exhibiting high spillovers. Introducing heterogeneity of players and incomplete information in the standard model of R&D cooperation, Cabon-Dhersin and Ramani (2004) show that it corresponds to a prisoner's dilemma and they explain that a lack of extensive cooperation could be due to an insufficient number of non-opportunistic firms. Conditions for trust engagement also vary according to the type of the firm: higher knowledge spillovers between firms facilitate the emergence of trust among opportunists, while it impedes trust among non-opportunists.

There are many international agreements that are supported by a large number of countries to deal with environmental problems, such as global warming and depletion of the ozone layer. The game which captures the strategic play in this context is not a prisoner's dilemma but a game of chicken with two groups of players: signatories and defectors. In the literature that models international environmental agreements as coalitions in a non-cooperative game the predicted size of a stable coalition is just between 2 to 4 countries, again contradicting reality (Carraro and Siniscalco 1993; Barrett 1994). By introducing the heterogeneity of countries and incomplete information, our model permits the identification of trust-payoff configurations under which a global coalition may be supported, while ensuring that global welfare is maximized.

As may be recalled from the introduction, our model also serves to explain experimental evidence that confirms the existence of trust and cooperation even in one-shot interactions

Lastly, the present model also has implications for some of the ongoing debates on trust and inter-firm cooperation at a regional level. For instance, there have been a number of studies comparing inter-firm cooperation in the U.S.A., Europe and Japan. They indicate that American firms are more hesitant to initiate cooperation than their Japanese counterparts

(Casson, 1991; Dunning 1995; Sako and Helper, 1998). Hagan et Choe (1998) put forward the notion that trust in Japan is simply a social norm that emerges given the system of sanctions and punishments associated with deviation on commitments. With respect to the above literature, the present article points out that irrespective of the kinds of social norms generated, trust and cooperation could emerge if there is an appropriate population mix of non-opportunist and opportunist firms and the payoff structure satisfies certain conditions. Furthermore, a greater number of non-opportunistic firms need not always imply more trust or cooperation.

According to our analysis, if a region or sector is noted for a high level of contract initiation or trust there are two possible explanations. First, the payoffs could correspond to a prisoner's dilemma context with a high ratio of non-opportunistic agents. Here, non-opportunists are willing to trust as the likelihood of being cheated upon is low, while opportunists are tempted by the high potential for opportunism. Second, the situation could be a game of chicken where the payoffs satisfy the required condition for contract initiation. In this case, additionally, trust occurs with cooperation or respect of commitments, whenever the proportion of opportunistic agents is sufficiently high.

Conclusion

In a world where no agent is an opportunist, there is no room for suspicion, and no need to speculate on trust. In a world where all agents are opportunists, there is no room for trust. Thus, trust becomes an issue, only when the following three conditions hold: (i) the population is composed of heterogeneous agents that include both opportunists and non-opportunists; (ii) there is incomplete information on the types of agents and (iii) opportunism cannot be eliminated through any "screening", "incentive mechanism" or any "punishment scheme".

In game theory the initiation of contracts and the building up of cooperation in the context of renegotiation and repeated interaction has been extensively studied. Our focus is on the less-studied situation of non-repeated interactions, where exchanges have to be initiated under incomplete contracts, under tacit understanding, without the possibility of verification of actions. The question that we ask is: how can the emergence of trust and cooperation be explained in a static or one shot interaction context, when the potential partners are confronted by the risk of opportunism? A model in the form of a two-person, two-stage game with incomplete information about the other agent's type (opportunist or non-opportunist) permits the answer. While confirming some known results in the literature, it gives new insight on the factors influencing trust and cooperation.

There are two payoff configurations that correspond to our initial assumptions: the “prisoner’s dilemma” and the “game of chicken” environments. Equilibrium outcomes are identified for each of these contexts as a function of the initial payoff configurations. In the first, trust depends only on the proportion of non-opportunist agents in the population. Under the second, trust doesn’t depend on the probability of encountering a non-opportunist. All types of players decide on whether or not to initiate contracts as a function of the payoff configurations. However, it is the proportion of opportunists that determines the probability with which an opportunist respects the contract in the second stage.

The model also yields some counter intuitive results. The social sciences literature mainly supports the proposition that a strong presence of opportunists acts against the initiation of contracts and the respect of commitments. The present paper refines this hypothesis by demonstrating that while a minimum level of non-opportunists is necessary for contract initiation, whenever cooperation is plausible (as in the game of chicken) a minimum level of opportunists is also necessary to observe cooperation.

The simplicity of the present model is such that it can be applied to various concrete situations of strategic interaction between agents studied in any of the social sciences such as sociology, economics, or political science, permitting a better understanding of the determinants of trust in such contexts.

The model also had its own limitations. A straightforward model has been considered, just to examine whether any interesting inferences can be made even at this level of simplicity. This in turn indicates that many theoretical refinements can be tried out in extensions of the present model. For instance, the proportion of opportunists in an economy was assumed to be exogenously given. These could be endogenized through an evolutionary mechanism. The chicken property, which is necessary for cooperation, could be generalized to situations with continuous action spaces. New payoff structures can be considered. Other behavioral patterns such as altruism can also be introduced.

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NOTES

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1. Many models incorporate implicit social sanctions in order to eliminate opportunistic behavior, but these models also require that the interactions among participants be repeated or long term (Kandori, 1992, Spagnolo, 1999).

2.We now recall the standard definition. Let a_i^1 be the action taken by player *i* in stage 1 and let $a_{i,o}^1$ be the action taken by player *i*, of opportunist type in the first stage. Similarly for player *j* and any non-opportunist player of any type. The revised belief at the end of stage 1 of player *i*, about the type of player *j*, is then given by $\hat{p}_i(t_j \mid t_i, a_i^1, a_j^2)$ i.e. it depends both on the history and the type of player *i*. A behavior strategy σ_i of player *i* maps the set of possible histories and types of player *i* into the action spaces. In other words, $\sigma_i = (\sigma_i(a_i^1 \mid t_i), \sigma_i(a_i^2 \mid t_i, a_i^1, a_j^1))$ indicates the probability with which player *i* is going to play each possible action in stages 1 and 2. The behavior strategy of player *j* can be similarly defined. Then according to Baye's rule, player *i*'s revised belief about the type of player *j* at the end of the first stage is given by:

$$\hat{p}_i(t_{j,o} \mid t_i, a_i^1, a_j^1) = \frac{p\sigma_j(a_j^1 \mid t_{j,o}, a_i^1)}{p\sigma_j(a_j^1 \mid t_{j,o}, a_i^1) + (1-p)\sigma_j(a_j^1 \mid t_{j,n}, a_i^1)} = \hat{p}\ ;$$

$$\hat{p}_i(t_{j,n} \mid t_i, a_i^1, a_j^1) = 1 - \hat{p}_i(t_{j,o} \mid t_i, a_i^1, a_j^1) = (1-\hat{p})\ .$$

Similarly for player *j*.

3. This is equivalent to defection being a dominated strategy for non-opportunists.

4. A set of beliefs and behavior strategies (*p*, $\hat{p}_i(t_j \mid t_i, h^1)$, $\hat{p}_j(t_i \mid t_j, h^1)$, σ_i, σ_j) forms a perfect Bayesian equilibrium if it gives rise to a Bayesian equilibrium for the game starting at the first stage and for the game starting in the second stage (Fudenberg and Tirole, 1991, pp. 331-332). For each player *i*, type t_i, player *i*'s alternative strategy $\sigma_i^{'}$ and history in stage 1 :

- The Nash strategy maximizes the expected payoff in the second stage:

$$E\pi_i(\sigma_i(a_i^2 \mid t_i, a_i^1, a_j^1), p, p'(.)) \geq E\pi_i(\sigma'_i(a_i^2 \mid t_i, a_i^1, a_j^1), p, p'(.))$$

- The Nash strategy maximizes the expected payoff in the first stage:

$$E\pi_i(\sigma_i \mid t_i, p) \geq E\pi_i(\sigma'_i \mid t_i, p)$$

[5] The symmetric perfect Bayesian-Nash equilibrium of the game is resolved by the usual method of backward induction, by identifying the optimal strategies in the second stage for every possible outcome of the first stage, and then identifying the optimal strategies in the first stage.

[6] The justification for the other types of equilibrium can be obtained on request from the authors.

APPENDIX

When the expected returns to respecting the commitment are greater than that from defection at the second stage, opportunists will respect the commitment with a probability

$\left(1-\alpha\right)=1-\frac{1-T}{\hat{p}}$.

Proof: Let $\hat{\alpha}$ be the probability of defection that player *i* wants to optimize over expected returns. If an agreement is initiated, the expected returns for an opportunist *i*, $E\pi_{i,o}$, at the beginning of the second stage, under the revised beliefs $\hat{p}$ are:

$$\hat{p}\left[1\left(1-\alpha\right)(1-\hat{\alpha})+\left(L\alpha\left(1-\hat{\alpha}\right)\right)+\left((1+H)\hat{\alpha}\left(1-\alpha\right)\right)\right]+\left(1-\hat{p}\right)\left[1(1-\hat{\alpha})+(1+H)\hat{\alpha}\right].$$

Then the optimal value of $\hat{\alpha}$ is determined by differentiating the above with respect to $\hat{\alpha}$. Since we are in the situation where expected returns to respecting the commitment are greater than that from defection, i.e. $\alpha\hat{p}(H+L)>H$, it is clear that:

$$\frac{\partial E\pi_{i,o}}{\partial\alpha}=H-\hat{p}\alpha(H+L)<0$$

Given that $E\pi_{i,o}$ is decreasing in α, the probability of defection α will be fixed at the lowest level such that $(1-\hat{p}\alpha)\leq T$ or $\alpha=\frac{1-T}{\hat{p}}$. Similar reasoning holds for the other player and by symmetry $\alpha=\hat{\alpha}=\frac{1-T}{\hat{p}}$ at equilibrium.

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